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Stakeholder interaction and learning using an example of push-pull technology in Ethiopia

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Table of Contents

List of Figures and Boxes

Boxes

List of Tables

List of Appendices

List of Abbreviations

AATF	African Agricultural Technology Foundation
ADLI	Agriculture Development-Led Industrialization
ADPLAC	Agricultural Development Partners' Linkages Advisory Council
AIS	Agriculture Information Systems
AKIS	Agricultural Knowledge and Information Systems
ATA	Ethiopian Agricultural Transformation Agency
BMBF	Federal Ministry of Education and Research of Germany
CADU	Chillalo Agricultural Development Unit
CIMMYT	International Center of Maize and Wheat Improvement Center
CPA	Comprehensive Package Approach
CSA	Central Statistical Agency of Ethiopia
ECFF	Environment Coffee Forest Forum
EEA	Ethiopian Economic Association
EEPRI	Ethiopian Economic Policy Research Institute
EIAR	Ethiopian Institute of Agricultural Research
EMTP	Extension Management Training Plots
EPID	Extension Planning and Implementation Department
EPRDF	Ethiopian Peoples' Revolutionary Democratic Front
EU SCAR	European Union Standing Committee on Agricultural Research
FAO	Food Agriculture Organization
FGDs	Focus Group Discussions
FSR	Farming Systems Research
FTC	Farmer Training Centers
FTI	Follow The Innovation
GDP	Gross Domestic Product
GIS	Geographical Information Systems
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IITA	International Institute of Tropical Agriculture
IECAMA	Imperial Ethiopian College of Agriculture and Mechanical Arts

KALRO	Kenya Agriculture and Livestock Research Organization
KI	Key Informant
MLN	Maize Lethal Necrosis
MoA	Ministry of Agriculture
MOARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MOU	Memorandum of Understanding
MPA	Minimum Package Approach
MPP-II	Minimum Package Programme II
MPP-I	Minimum Package Project I
NEPAD	New Partnership for Africa's Development
NGOs	Non-Governmental Organizations
OECD	Organization for Economic Cooperation and Development
PADEP	Peasant Agricultural Development and Extension Project
PADETES	Participatory Demonstration and Training Extension System
PPT	Push-Pull Technology
SET	Stakeholder Engagement Team
SG 2000	Sasakawa Global 2000
SIDA	Swedish International Development Authority
SNNP	Southern Nations Nationalities and Peoples
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
T&V	Training and Visit
TAHADU	Tach Adiabo and Hadekti Agricultural Development Unit
TDR	Trans-Disciplinary Research
TVETs	Agricultural Technical and Vocational Education and Training centers
UNDP	United Nations Development Programme
US	United States of America
WADU	Wolaita Agricultural Development Unit
WB	World Bank
ZEF	Center for Development Research

Abstract

Maize is an important cereal crop for food security in Ethiopia. However, its productivity is low with average grain yields of less than 1 ton/ha which is below its potential of over 4 ton/ha. This is attributed to a variety of biophysical as well as socio-economic and institutional factors including weak linkages between research and practice. Despite high investments and the existence of technologies to improve smallholder maize productivity, there are low rates of adoption and even rejection. This is partly attributed to the non-participatory nature and linear structure of agricultural extension delivery systems which is not tailored to the potentials of different agro-ecological zones and the needs of the farmers.

An analysis based on an innovation systems approach was considered in this study as a possible strategy to explore how researchers and other stakeholders can work together during technology planning and implementation. The Push-pull technology (PPT) was used as a boundary object to provide an opportunity for collaboration, interaction and learning among the stakeholders. The PPT is a biological based strategy for stemborer pest control in maize. In this strategy, maize crop is intercropped with a fodder legume, Desmodium (the push), together with an attractant trap plant, Napier/Brachiaria grass (the pull), planted around maize-legume intercrop. Using a transdisciplinary action research process, the study was implemented in Bako, Jimma Arjo and Yayu *Woredas* in the Oromia region of Ethiopia. Qualitative research methods were used in data collection: 37 key informant interviews, 20 Focus Group discussions, 2 stakeholder workshops, on-farm practical demonstrations and participant observations. The study lasted 8 months from August 2014 to April 2015. The qualitative data were manually transcribed into themes and analyzed using content analysis and interpreted in relation with research objectives, concepts and theories used in this study.

The findings show that the PPT implementation involving participation of all the stakeholders from planning to evaluation stand a better chance of adaptation than rejection. The existence of a real-life stemborer pest problem which previously had not received any promising solution is a strong motivation for the stakeholders' collaboration, knowledge sharing and learning about PPT. The use of farmers own fields for practical implementation creates an opportunity which enable critical assessment and relaxed learning about PPT. The technology is science based, applicable by farmers and also provides opportunities for researchers, extension staff, private sector players to learn new knowledge and linkages. The mutual trust among stakeholders plays a significant role in enabling the fruitful interaction and learning. However, uncertainty, doubts, spread of negative rumors about local fit of PPT, jealousy and interpersonal conflicts among stakeholders could be observed in the incidences showing some resistance and portraying it negatively. The long term nature of PPT implementation provides opportunity for continuous interaction and learning to either overcome these suspicions or confirm them. There is need for a follow-up and a long term study to ascertain these facts.

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My interest and journey to join Centre for Development Research (ZEF) was ignited in the year 2003 when I started receiving post mail subscriptions for the ZEF working paper series. I was encouraged by its diverse research and topical focus on developmental matters related to the developing countries' context. I came closer to the reality when I participated in a BiomassWeb project workshop on improving food security in Africa through increased system productivity of biomass-based value webs. The workshop was organized by the University of Hohenheim and Centre for Development Research (ZEF), and hosted by Forum for Agricultural Research in Africa (FARA) in Accra, Ghana (April, 2012). During the workshop, I was inspired by the senior researcher, Dr. Detlef Virchow from ZEF who encouraged me to apply to join as a program student under Work package 7.2 focusing on introducing complex innovations: creating strategic linkages for increased production and wider application of Push-pull technology in Ethiopia. Since then, I have focused on the success of this journey.

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Deutsche Zusammenfassung

Mais ist eine wichtige Getreidepflanze zur Ernährungssicherung in Äthiopien. Die Produktivität ist jedoch mit durchschnittlichen Getreideerträgen von weniger als 1 t/ha niedrig und liegt unter dem Potential von über 4 t/ha. Dies wird auf eine Vielzahl von biophysikalischen, sozioökonomischen und institutionellen Faktoren zurückgeführt, sowie einer schwachen Verknüpfung zwischen Forschung und Praxis. Trotz hoher Investitionen und existierender Technologien zur Verbesserung der kleinbäuerlichen Maisproduktivität, gibt es nur geringe Akzeptanz- und sogar Ablehnungseffekte. Dies ist teilweise auf den nicht partizipatorischen Charakter und die lineare Struktur landwirtschaftlicher Systeme zurückzuführen. Sie sind nicht auf die Potenziale verschiedener agrarökologischer Zonen und die Bedürfnisse der Landwirte zugeschnitten.

Eine Analyse basierend auf einem Innovationssystemansatz wurde in dieser Studie als mögliche Strategie betrachtet, um zu untersuchen, wie Forscher und andere Interessengruppen bei der Technologieplanung und -umsetzung zusammenarbeiten können. Die Push-Pull-Technologie (PPT) wurde als ein Grenzobjekt verwendet, um eine Möglichkeit für Zusammenarbeit, Interaktion und Lernen zwischen den beteiligten Akteuren zu schaffen. In diesem Fall ist PPT eine biologische Strategie zur Schädlingsbekämpfung für Mais. Hierbei wird Mais vermischt mit einer Futterleguminose, Desmodium (pull), und einer Lockstofffallenpflanze, Napier/Brachiaria-Gras (push), die um den Mais-Hülsenfrucht-Zwischenfruchtanbau gepflanzt ist.

Die Studie erfolgte mit transdisziplinärer Aktionsforschung in Bako, Jimma Arjo und Yayu Woredas in der Region Oromia in Äthiopien. Bei der Datenerhebung wurden qualitative Forschungsmethoden eingesetzt, die durch eine Fragebogenerhebung ergänzt wurden: 37 Experteninterviews, 20 Gruppengespräche, zwei Stakeholder-Workshops eine praktische Demonstrationen vor Ort und Teilnehmerbeobachtungen. Die Studie dauerte 8 Monate von August 2014 bis April 2015. Die qualitativen Daten wurden manuell transkribiert und mittels einer Inhaltsanalyse ausgewertet, um sie in Bezug auf Forschungsziele, Konzepte und Theorien, die in dieser Studie verwendet wurden, zu interpretieren.

Die Ergebnisse zeigen, dass die PPT-Implementierung, an der alle Beteiligten von der Planung bis zur Evaluierung beteiligt sind, eher Anpassung als Ablehnung erfährt. Die Erscheinung eines echten Stößelkrankheitsproblems, für das es zuvor keine erfolgversprechende Lösung gab, ist ein starker Antrieb für die Zusammenarbeit, den Wissensaustausch und das Lernen von Akteuren über PPT. Die Nutzung von Feldern der Landwirte für die praktische Umsetzung, ermöglicht eine kritische Bewertung und leichtes Lernen von PPT. Die Technologie basiert auf wissenschaftlichen Erkenntnissen, ist für Landwirte anwendbar und bietet auch Forschern, ländlichen Beratern und Akteuren des privaten Sektors die Möglichkeit, neue Kenntnisse und Netzwerke zu erwirken. Das gegenseitige Vertrauen zwischen den Beteiligten spielt eine wichtige Rolle für die erfolgreiche Interaktion und das Lernen. Ungewissheit, Zweifel, negative Gerüchte über die Eignung von PPT, Neid und zwischenmenschliche Konflikte zwischen Akteuren lassen es jedoch negativ erscheinen. Die langfristige Natur der PPT-Implementierung ermöglicht kontinuierliche Interaktion und Lernen, um diese negativen Aspekte zu überwinden oder zu bestätigen. Es bedarf einer Folge- und einer Langzeitstudie, um dies zu ermitteln.

Chapter 1:
Agricultural Innovation Systems in the Context of Change

1.1 Background

According to the United Nations, Department of Economic and Social Affairs reports (2007; 2010), by 2030, the world's population is expected to reach 8.2 billion. Almost all the growth will occur in less developed regions that are home to significant numbers of people who are faced with food insecurity, malnutrition, resource scarcity and environmental degradation (Godfray et al., 2010). Alongside the population increase, food demand especially cereals, dairy products and animal protein is on the rise (Delgado et al., 1999; Regmi and Meade, 2013). The agricultural land is under pressure as a result of human population and urbanization growth. To feed these people, the farmers must produce more food while at the same time maintaining resource base and preserving the global environment for future generations (Beddington et al., 2012; Vitousek et al., 2009). In order to meet the food, fiber and fuel demands, the future increases in agricultural production must come mainly from higher productivity and cropping intensity per unit of land (Connor et al., 2011; Swaminathan & Borlaug, 2010). Increasing and sustaining food production without compromising the environment is a challenging task (FAO, 2001; Tilman et al., 2001). Thus the need for improved agricultural productivity to address such demands and with minimal possible increases in land, water, fossil fuels, and the minimal use of external inputs such as pesticides and fertilizers (Sayer & Cassman, 2013). This view is supported by Swaminathan & Borlaug (2010, p. 560) who state:

> "We don't need to increase the area under cultivation to increase food production, rather, increase productivity per unit area by investing in research for high yielding crop varieties….the ecological necessity for improving production through higher productivity rather than through area expansion is obvious".

However, the increased productivity will not take place without addressing or responding to the challenges linked to distribution and access to agricultural information and farming inputs. At the same time, the human population is confronted with environmental challenges as a result of effects of climate change from the reduced or less regular rainfall, increased incidences of pests and invasive weeds; rising food prices etc. This is requiring development of new relationships, skills, roles and concepts in order to succeed under these new, highly uncertain and changing conditions (Archer & Cameron, 2009; Crosby & Bryson, 2005; Linden, 2002). Such challenges cannot be resolved by individuals or one community or a country alone because they cut across agency, professional and regional boundaries. Addressing them therefore, require joint efforts from multiple disciplines, organizations to groups or communities (Atkinson et al., 2007; Bililign, 2013). It requires a constellation of approaches and tools, joint working by crossing disciplinary or cultural-practice boundaries, as well as collaborations and effective communication among the various stakeholders involved (Gibbons et al., 1994; Klein et al., 2001). The cooperation and collaboration of such diverse actors who would normally not work together to address a common problem has a transdisciplinary outlook. The transdisciplinary approaches have been hailed as learning and problem solving through involving the society and the academia or researchers to solve the real-life societal and environmental challenges (Fuqua, et al., 2004; Hornidge et al., 2011;Rosenfield, 1992; Singh, et al., 2012; Ul-Hassan et al., 2011). This is because the results from such engagements are achieved when people of different world views work together. This change in approach to research and working together is influenced by the new thinking that the success of the process relies on the participation and involvement of the stakeholders (Allen et al., 2014).

The international and national governmental research agencies are constantly engaged in the production of new agricultural knowledge and technologies aimed at improving human wellbeing (IAASTD & McIntyre, 2009). These efforts have so far contributed to increased agricultural yield levels and lowered costs of production. During the last 40 years, the global cereal yield production has doubled from greater input of fertilizer, water and pesticides, new crop varieties, and new technologies (FAO, 2000). This has increased the global per capita food production and supply, reducing hunger, improving nutrition and sparing natural ecosystems from conversion to agricultural land (Tilman et al., 2002). However, these successes have been disproportionally felt across the globe. For example, Sub-Saharan Africa (SSA) is the only region since 1990 which had an annual decline of at least 3% per capita food production whereas other regions such as East Asia and Pacific, and Latin America experienced 30% and 20% increase respectively (World Bank, 2008). These low yields are attributed to a combination of factors from low-yielding varieties, sub-optimal agronomic practices, multiple a biotic and biotic constraints, and climate change to lack of extension services (Fischer et al., 2005; International Center of Maize and Wheat Improvement Center [CIMMYT], 2001. At the center of this are those most vulnerable and food insecure, and likely to be the first to be affected by the risks which come with crop failure, invasive pests and diseases to collapsed infrastructure leading to a lack of appropriate agricultural inputs and extension services (FAO, 2008; Miyan, 2015).

The SSA agriculture requires a constellation of evolutions that differ both in nature and extent among many different types of farming systems, socio-economic environments and institutions rather than a single solution (InterAcademy Council, 2004). Yet to date few approaches to understand constraints and explore options for change, have tackled this bewildering complexity of African farming systems (Giller et al., 2011). In view of this, it is important to rethink the role of agricultural research not only in the development of new agricultural knowledge, science and technology, but also exploring on working together with the smallholders and paying attention to their diverse agroecosystems and needs

(Fischer et al., 2005). Based on the report of the World Development Report (2008), smallholder agricultural growth integrated with the development of rural non-farm sector and markets will lead to significant reduction of poverty and improve the living conditions of the poor households. The report further shows that it is in the staple cereal food crops i.e. maize, sorghum, millet, and tef, where significant gains can be made.

Ethiopia is one of SSA countries with a large geographical area of 1.1 million km^2 and an estimated population of over 90 million (Central Statistical Agency, 2012). Agriculture is the main stay of the country's economy with over 50% of Gross Domestic Product (GDP), 90% export earnings and employer of 85% of total labor force (Prabhakrar and Alemu, 2013). Although the agriculture sector's share of GDP has been declining over the past decade, it still continued to form the backbone of the Ethiopian economy (World Bank, 2015) and receiving heavy investments of over 15% of the total annual budget. This is supposed to support programs such as the Agriculture Development-Led Industrialization (ADLI) and participatory agricultural extension delivery (Chanyalew *et al.*, 2010; MoFED, 2002). However, the setback to such efforts is that the extension training, management and delivery services are unimodal, state controlled and not tailored to the potential and constraints of different agro-ecological zones and the specific needs of smallholder farmers (Egziabher et al., 2013; Gebremedhin et al. 2006). This may be partly attributable to organizational cultures, particularly among public sector providers of extension services that are hierarchical, averse to change, and persistently focused on linear approach of science (Davis et al., 2007). Despite the investments and new technologies developed by research and extension activities, the productivity of cereal crops in particular is low, resulting recurrent food shortfalls and national food insecurity (Abate et al., 2011; Belay & Abebaw, 2004). The environmental factors such as *Striga* weed, stemborers and low soil fertility and the smallholder farmers' socio economic conditions have also been the attributed to this (Degaga, et al., 2001; Khan, et al., 2008b; Massawe et al., 2001; Rodenburg et al., 2005; Vissoh et al., 2004; Welsh & Mohamed, 2011).

1.1 Study Justification and Problem Statement

Considerable efforts are required to shift and put in place research and extension services which are action based and implemented beyond participatory rhetoric (Abate et al., 2011). The shift should focus on joint development of innovations which are adapted to agro-ecological zones and best fit solutions through a combination of scientific and practice knowledges (Davies et al., 2010; Kassa, 2005). The actors engaged in the process should exploit and work in an agricultural research and extension system that supports innovation for production and growth of the sector (Spielman, 2008). This is bearing in mind that the agricultural sector is characterized by a host of new technologies, policies, actors, and relationships which have influence on the smallholders' access and application of new information and knowledge (ibid).

Thus prompting the need to have a locally embedded extension system approach which is matched to various agro-ecological zones and responding to the needs and demands of the smallholder farmers (Abate et al., 2007). Despite that, little is known about how those opportunities can be harnessed and operationalized and made to work in the promotion of pro-poor processes for rural innovation (ibid). Moreover, the role of communicative intervention in the innovation process is mostly weak and in some cases non-existent (Leeuwis, 2010; Spielman et al. 2008).

There is a weak culture of coordination, integration, and cooperation among key actors in Ethiopia's agricultural innovation system (Spielman et al., 2007). This has not been achieved presently due to institutional obstacles to the diffusion and adoption of the innovations that could solve these problems. This is also coupled by the lack of empowerment of smallholder to learn, adapt and uptake new and useful knowledge (Sayer & Cassman, 2013). Although, recently, it has been shown by Abate et al. (2011) during the promotion of high-value and market-oriented grain legumes (common beans, chick peas and lentils), that, a strong partnership arrangement between national research and extension systems with regional administrations, cooperative unions, private sector and farmers is workable, but this has not been widely practiced in the country. Such successes demonstrate the viability of joint efforts aimed at facilitating cooperation among diverse actors and strengthening innovation networks.

With the diversity of farming systems and challenges faced by the smallholder agricultural sector in Ethiopia, there is a need to explore how the joint stakeholder processes can be used to harness the potential of agricultural innovation and new technologies to improve productivity. Boundary work has emerged as a growing field of study that supports to understand and address the societal boundaries for stakeholder collaboration (Dörendahl, 2015; Carlile, 2002; Hornidge et al., 2011; 2015; Pohl et al., 2008; Mollinga, 2008; 2010; Star and Griesemer, 1989). It embodies innovative efforts to link science, other sources of knowledge, and the worlds of action (Clark et al., 2011). It is on this basis that, this study is formulated to establish how research scientists and other stakeholders with different disciplinary interests, experiences and expectations can interact and learn together to address a common problem of cereal stemborer pests in maize using the Push-pull Technology (PPT). In this case the PPT is used as a boundary object (Star and Griesemer, 1989).

An analysis based on an innovation systems approach is considered in this study as a possible strategy to explore how different actors can work together during the PPT implementation, overcome research-practice boundaries by sharing and integrating their knowledge perspectives and experiences through joint learning. The approach draws attention to the multiple actors who contribute to agricultural technology development by focusing on their roles and responsibilities, actions and interactions that contribute to their behaviors and practices (World Bank, 2006). This is in contrast with the traditional view of agricultural technology transfer which has been a linear process (Knickel et al., 2009; Leeuwis, 2004). The age old notion of linearity where science is an active knowledge producer and society is a passive recipient, need to be replaced with the processes of co-design and co-creation in order to make research findings socially relevant and locally adaptable (Knickel et al., 2009, Mauser et al., 2013). Thus calling for holistic, interactive and integrated efforts linking all actors in the agricultural sector collaborate and work together in the development and implementation of agricultural innovations (Amankwah *et al*., 2015; Hornidge & Ul-Hassan, 2010; Tilman et al., 2002). Nonetheless, this is not normally an easy undertaking due to inherently different disciplinary training, knowledge bases or perspectives and experiences of the researchers and different stakeholders involved in the agricultural sector (Abate et al., 2011). These are the same structures which have constrained transdisciplinary interactions leading to linear relationships and development of agricultural technologies which are not adaptable to local conditions or not transferable, resulting to adoption rates to as low as 10% (NEPAD, 2002). In most cases, different stakeholders try to address these problems independently without even considering the smallholder farmers diverse needs, farming systems and ecological dimensions (Bacon et al., 2012).

1.2 Objectives of the Study

The overall objective of the study is to understand how the interactions and joint learning among researchers and other stakeholders in a transdisciplinary and participatory process is contributing to the strengthening and increasing the local adaptability and productivity of PPT in Ethiopia. Specifically the study seeks to:

1 To understand how the researchers and other stakeholders organize themselves to achieve effective learning and innovation during PPT implementation in the study sites.

2 To assess how the science and practice cultures and settings of researchers and other stakeholders influence their collaboration, cross-boundary interaction and learning for joint production of new practices and concepts on PPT.

3 To evaluate how PPT can be effectively used as boundary object for empowerment and enhancing science-practice interaction in agricultural innovation development.

1.3 Organization of the Thesis

This section provides an overview of the structure of this thesis outlining the main points covered under each chapter. The chapters one to five is setting the context of the study. Chapter one gives the background and an overview of the agricultural innovations system in the context of changing agricultural, environmental and market demands with specific reference to Ethiopia. It also covers the section of the problem statement and objectives of the study. Chapter two presents an overview of the historical development of the agricultural extension system and generally the smallholder agricultural farming during the last 5 decades. It covers on how successive government regimes have tried to develop the agriculture extension system using different approaches in response to and addressing the agricultural sector challenges and demands over time. The role and contributions of the informal institutions in the agricultural extension services and smallholder agriculture in Ethiopia is also presented. Chapter three gives the outline of the research methodology and approach, the description of the study area and its limitations. Chapter 4 introduces the concept of innovation systems approach and analytical framework applied in the study. Chapter 5 provides an overview of the Push-pull technology, its scientific development, the contributions of farmers and other stakeholders towards its working and dissemination. The PPT is used as a boundary object to support interaction and participatory learning among the stakeholders generate new ideas, concepts or strategies which can be in turn used to support research and extension practices. It is used foster knowledge transfer and sharing. Thus its activity implementation forms the basis for the empirical chapters.

The empirical chapters are covered from chapter six to nine. Chapter six presents the findings on the organization of the process of stakeholder mobilization and engagement during the planning and implementation of PPT. Chapter seven presents the findings on the stakeholder interaction and learning based on the transdisciplinary action research and practical PPT implementation. This chapter covers how different stakeholders' viewpoints based on their research, professional and experiences played out during PPT implementation and how this contributed to learning and the empowerment of the stakeholders involved with regard to stemborer pest control and other existing or emerging farming challenges. This chapter provides an overview on how the stakeholder interaction and collaboration played an instrumental role to ensure that the stakeholders worked together and focused on the PPT practical activities during the TDR process. Chapter eight highlights on how PPT enhances the transdisciplinary leadership, empowerment and democratizing of the knowledge production process. It points out how the researchers, extension officials and farmers jointly worked together as a team during all the activity stages of the PPT implementation process. The chapter highlights on how the collaborative leadership was enhanced among the stakeholders especially the smallholder farmers and contributed to their empowerment through learning, creation of new linkages and relationships towards the sustainability of the PPT. Chapter nine provides an analysis on adoption and non-adoption challenges of the PPT. This is based on the critical assessment of different stakeholders' perceptions on the performance and non-performance of the PPT. Finally chapter 10 presents the conclusion and recommendations outlining the key outcomes of the study and its contributions to extension services and research in Ethiopia and in further development of the PPT.

Chapter 2:

Overview of the Agricultural Extension Service System and Smallholder Agriculture

2.1 Introduction

From the 1950s, the successive political regimes in Ethiopia have been promoting hierarchical, top-down, non-participatory and supply-driven approaches to agricultural extension (Berhanu & Poulton, 2014; Belay, 2003; Gebremedhin et al., 2006). The extension system has gone through radical policy shifts during this period, from feudalism to socialism to the current free market system where extension is mostly provided by the public sector, operating in a decentralized manner and implemented at the *Woreda* level (Dejene, 2003; Kassa, 2005; 2008). In this system, the smallholder farmers are the main targets of extension messages which are identified by either researchers or extension service providers towards improving agricultural production to meet food and industrial raw material needs for the country. Despite the efforts of the different regimes and gains of such an elaborate and expansive agricultural extension system, the country and agricultural sector in particular, is faced with the challenges of productivity, recurrent episodes of drought, famine, sporadic interstate conflicts and a fast growing population (Belay, 2003). This is also coupled with the absence of adequate institutional structures, capacity and forums for implementing agricultural policies (Dejene, 2003).

Based on the history of the country and challenges of the agricultural sector, the current regime, in particular has made extension service provision a priority area of intervention. Although faced with a myriad of constraints, the attempts are meant to create strong linkages, coordination and collaboration between research, extension and farmers for the efficient delivery of goods and services (Deneke and Gulti, 2016) and promoting a decentralized and broad based agricultural growth strategy (Agricultural Research Task Force, 1996; Davis et al., 2010; Task Force on Agricultural Extension, 1994). Despite such efforts and investments, the extension system has not reached its full potential of enabling the agricultural sector to achieving sufficiency in food production and reducing poverty. Partly, the reason which is attributed to this is that, the smallholder farmers who are the intended beneficiaries are generally reluctant to take up and make use of high yield- and quality-improving agricultural technologies generated by research (Yirga and Alemu, 2016). The research and extension programs or projects are formulated and implemented without due consideration to the smallholder farmers' needs, opinions and perspectives anchored on their local knowledge and practice systems (Kassa, 2005). At the same time, most of the smallholder farmers are not organized into strong community based organizations to effectively serve their interests and that are without political clout (Adem, 2012; Berhanu & Poulton, 2014; Sanginga, 2009). The farmers are mainly depended on the decisions which are made and passed linearly to them by the research-extension system or on their own traditional farming practices. The linear linkage is seen to purposely serve the political interests of the ruling elite and also to gain total control over the populace and cling to power (Berhanu & Poulton, 2014). According to Davis et al. (2009), there is limited support or engagement of the private sector and NGOs in the provision of extension services in the country. Such a hierarchical approach with strong state control is contrary to the spirit of pluralism in extension service delivery which is supposed to be demand-driven, collaborative and participatory in approach. The public extension service providers' claim on participatory engagement is just a mere rhetoric. This has generated concern and calls for a collaborative effort to engage the stakeholders in the agricultural sector in decision-making during the planning, development and implementation of agricultural innovations (Davis et al., 2009; World Bank 2006). This will contribute to meeting the particular needs of the farmers and the demands of the country in terms of productivity improvement.

2.2 The Evolution of the Agricultural Extension System in Ethiopia

A booming smallholder agricultural sector in Ethiopia is an important factor for reducing poverty, ensuring food security and providing raw materials for industrial uses. That means, the farmers should have access to appropriate agriculture technology, improved skills and knowledge on a timely basis to effectively achieve this. The successive regimes over a period of past 5 decades have tried using different agricultural extension programs to reach the smallholder farmers with new and improved agriculture production technologies (Fig. 1).

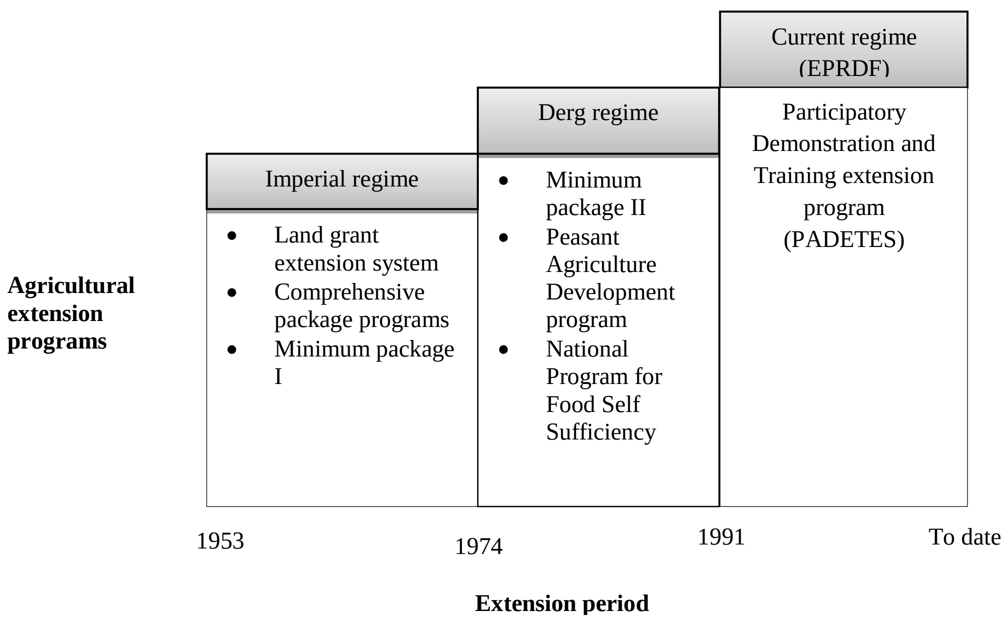

Figure 1: The evolution of Agricultural Extension programs over a period of five decades in Ethiopia

Source: Authors' elaboration

2.2.1 Extension before 1974 under the Ethiopian Imperial Regime

The agricultural extension services began in Ethiopia in 1931 with the establishment of the Ambo Agricultural School offering student training in general agriculture for the first time (Belay, 2003). The school mainly focused on training students and demonstrating on best agricultural practices and performance of improved crop varieties to the nearby farmers. In 1953, Imperial Ethiopian College of Agriculture and Mechanical Arts (IECAMA-now Haramaya University) started full time extension program. This was done on a joint basis when the imperial Ethiopian government entered an agreement with the United States of America (US) and the program was modeled on land grant university system (Oklahoma state university) with a tripartite objectives of education, research and extension services (Belay, 2003; Deneke & Gulti, 2016; Gebre Medhin et al., 2006). The extension program was later included as part of the mandate for the college in extending the research outputs to farmers and also importing new farming technologies. The farmers were taught on the application of the new technologies as adult learners (Davis et al., 2009). For example, school youth clubs were established by the extension agents in poultry and gardening in the hope that after learning the improved practices, the students would pass on the knowledge to their parents. This was the starting point of the diffusion model of extension in the country (Belay, 2003). As forerunner model, it laid the foundation for the provision of extension services to the smallholders during the imperial Ethiopian government.

The coverage of extension services in the country during the imperial regime was limited to a small extent comparing size of the country and the number of farmers who needed these services. This limitation was linked to factors such as; lack of institutions to provide complimentary support such as farming inputs and credit, low manpower deployment to undertake the extension activities and limited resource allocation to the agriculture sector, and the development of the peasant agriculture was still poor. For example, the development plans of the periods 1957-1961 and 1963-1967, the agriculture sector, despite its importance to the economy received low budget allocations and was skewed towards large scale farmers whose interests was mainly on cash crops for export (Aredo, 1990). In an effort to address such concerns, the Ministry of Agriculture (MoA) was established in 1963 and mandated with the task of providing extension services to cover whole the country using its structured departments at the national and provincial levels (Abate 2007). With the MoA in place, in the 1967-1973 development plan and with the pressure from international partners, the government made attempts to improve the smallholder agriculture by initiating the comprehensive package approach (CPA) and the Minimum Package Approach (MPA) (Gebre Medhin et al., 2006). These programs were supported by donor funds mainly from the Swedish International Development Authority (SIDA) and it involved the removal of barriers to production by concentrating efforts in strategically-selected areas in which results could easily be seen

(Belay, 2003). It was believed that the progress made in the selected sites would have multiplier effects on the surrounding areas through autonomous adoption and spread of new production enhancing technologies and practices. Several such community level efforts were initiated by local governors in different regions of the country.

The first Comprehensive Package Approach (CPA) was the Chillalo Agricultural Development Unit (CADU) which was established in 1967. Apart from extension services, CADU provided a wide range of productive and social services aimed at achieving socio-economic development of the smallholder farmers. For example, marketing and credit support programs were initiated with the aim purchasing and storing of grains for seasonal stabilization of prices to assure the farmers with price incentives and ability to purchase inputs and other services. The CADU was also involved in technological packages and development programs such as, soil and water conservation, rural health, women extension and rural road construction (Ketsela, 2006). The CPA program used the model farmers and demonstration plots to train other farmers who were organized mainly through various field days. Using the knowledge and experience gained from CADU, other comprehensive package projects with varying objectives and approaches were initiated e.g. Wolaita Agricultural Development Unit (WADU) and the Tach Adiabo and Hadekti Agricultural Development unit (TAHADU). These projects were initiated to facilitate the promotion and use of technological packages such as improved seeds, fertilizer and credit, and to assist in the development of both human capacity and physical infrastructure in soil and water conservation (Berhanu & Poulton, 2014; Ketsela, 2006).

The Minimum Package Project I (MPP-I) was introduced during period 1971–1979 was the first nationwide extension program meant to provide individual smallholder farmers with extension and input supply services. The MPP-I based on the experiences of CADU, used demonstration plots and model farmers as extension approaches (Gebremedhin et al. 2006; Davis et al., 2010). The annual target was cover 10 minimum package areas each addressing 10 thousand smallholder farmer households along the 10km radius of all-weather roads (Aredo, 1990). The MPP-I established 55 minimum package areas with 346 development centers in 280 districts out of the total 580 districts in the country. It was a very ambitious initiative, however, during its evaluation, the findings showed that, it had failed to achieve smallholder agricultural improvement it was intended. The failure was attributed to the land tenancy system which was under tenant-landlord relationship (Kassa, 2003). The system excluded smallholder peasants from active participation and benefiting from implementation of programme and having access to technology and credit facilities. At the same time, Ethiopia is a vast country, that means not all the areas were under coverage and majority of farmers were out of reach and the packages were biased on crop based farming while neglecting a significant livestock sector. The initiative was also too expensive to scale out in terms of fiscal and human resources (Gebremedhin et al., 2006).

2.2.2 The Extension from 1974-1991 under Derg Regime

After toppling King Haile Selassie in September 1974, the derg military regime began taking some drastic measures on the agriculture sector development. According to Baye (2013) and Kebede (2008), the major drastic reform was a revolutionary Land Reform Promulgation in 1975 which abolished private land ownership and prohibited the transfer of land by sale, exchange or mortgage. The proclamation limited the maximum farm size of farmers to not more than 10 hectares and initiated the establishment of Peasant Association comprised of about 250 households in an estimated area of 80 hectares. These reforms were implemented by the decentralized Extension Planning and Implementation Department (EPID). The main extension programs during this period were the Minimum Package Programme II (MPP II) and the Peasant Agricultural Development and Extension project (PADEP) with financial support from the international donors (Berhanu & Poulton, 2014). The MPP II was launched in 1981 with an ambition of covering the whole country by establishing farmers' organizations and improving crop and livestock productivity and general rural infrastructure in 440 districts (Kassa, 2008). The MPP II was placed under commodity based departments such as crop production, crop protection, livestock production, and forestry in the newly reorganized MoA. This reorganization resulted in the fragmentation and proliferation of efforts, and confusion in the administration of extension activities (ibid.). These changes affected performance of the agricultural extension staffs who were over stretched to cover vast areas of the country with limited budget support and also required to perform other non-extension related assignments such as tax collection, following up loan repayments and promotion of farmer cooperatives (Kassa, 2003). MPP-II was phased out in 1986 and replaced by PADEP.

The PADEP was implemented in high potential (surplus producing) areas of the country with the objective of increasing self-sufficiency in food production, creating employment opportunities through production of cash crops for export and raw materials for local industrial production. This was done by laying emphasis on strong research-extension linkages under liaison committees which were coordinated at national and zonal levels. However, during this period the government passed a legislation to organize smallholder farmers into cooperatives which were based on socialist ideological orientation. The then existing approach of working with model farmers was replaced with service and producer cooperatives as the focal points for introducing and disseminating agricultural innovations and with more emphasis laid on implementing the Land Reform Proclamation (Davis et al., 2009; Kassa, 2003). Under this program, the extension agents were also required to perform a number of other tasks which were unrelated to agricultural extension, such as delivering extension messages with political objectives. The overall extension planning was highly centralized and less flexible. The contribution of agricultural extension to agricultural development was seriously undermined by giving priority to state and collective farms at the expense of smallholder individual farmers (Davis et al., 2009).

The National Program for Food Self Sufficiency and the Modified Training and Visit (T&V) approach was introduced in the mid-1980s as a follow up of MPP II to be implemented in surplus producing districts, in lowland areas and on livestock development. This was aimed at increasing productivity and incomes of the peasant sector (Abate, 2007; World Bank, 1997). However, due factors such as the increased incident of droughts, unstable political and institutional environment, government policy of total control of the extension processes, dislocation of rural communities through hurried resettlement and the conscription of youths for the military service, led to retarded agricultural development (Tilahun, 1999). Despite these efforts, the overall trends show that up to this point the smallholder agricultural sector was still faced with growth challenges to meet the food and income security of the smallholder farmers.

2.2.3 Extension Efforts after 1991: The Current Agricultural Extension Approaches

The period after 1991, the regime of Ethiopian Peoples' Revolutionary Democratic Front (EPRDF) is considered as a new beginning in the history of agricultural extension delivery services in Ethiopia in terms of institutional pluralism and decentralization (Berhanu & Poulton, 2014). During the period 1991-1995, the country underwent to regionalization as part of the decentralization cum devolution process which ended up with the creation of 10 regions largely along the ethnic lines (Alemu, 2010; Berhanu & Poulton, 2014). Thus with regionalization, the role of the MoA extension division changed accordingly whereby the extension service provision became the responsibility of the regional bureaus of agriculture, whereas at the federal level the mandate was to coordinate and advice inter-regional extension work, provide policy directions in extension management and administration. This period also marked the beginning of the involvement of private sector and Non-Governmental Organizations (NGOs) in on-farm research and extension processes. The notable example is Sasakawa Global 2000 (SG 2000) which among other NGOs became actively involved in the provision of extension services.

In Ethiopia, SG 2000 target was increasing agricultural food production at the level of the smallholder farmers and stimulating their links with research and extension services (Takele, 1997). After making the inventory of available technologies with the support of the national agricultural research and extension system, SG 2000 initiated an extension support in 1993. This initiative served as a precursor to the Participatory Demonstration and Training Extension System (PADETES). The PADETES program started with 160 model farmers who were growing maize and wheat using EMTP (Extension

Management Training plots) approach. The EMTPs were started as on-farm technology demonstration established and managed by the model farmers in the Oromia and Southern Nations, Nationalities and Peoples (SNNP) regional states (Habtemariam, 1997). One year later Tigray and Amhara regions were included with additional technologies of teff and sorghum which were demonstrated to 1600 farmers. The EMTP strategy consisted of a package of; improved seeds with recommended fertilizer usage (e.g. type, rate, time and method of application) with appropriate agronomic practices (e.g. recommended seeding rate, proper planting rates and methods, timely weed control and proper crop protection measures). The model farmers were provided with 25% down payments credit to cover the cost of inputs and the Development Agents (DAs) provided extension support with close monitoring and supervision. The yields improved 2-3 times more than what was obtained from traditionally managed plots. Such a good performance impressed the stakeholders in the sector, especially the government officials and the political class who felt that self-sufficiency in food production could be easily achieved by adopting the SG 2000 extension approach. Consequently, the government launched the Participatory Demonstration and Training Extension System (PADETES) as national extension intervention program 1994/95 using the SG2000 approach (Ashworth, 2005; Gebre Medhin et al., 2006; Keeley and Scoones, 2000; Takele, 1997). The PADETES became a major extension management system in all regional states and the number of farmers that participated in it and had increased from 35000 in 1995 to 3.6 million in 2001 (Berhanu & Poulton, 2014).

The PADETES approach is being implemented since 1995 and is focused on improving production and productivity of the agriculture sector with major focus on staple crops and livestock in Ethiopia. This is aimed to achieve food security, boosting farmers' incomes and agriculture development led industrialization. To effectively achieve this, it's required that the approach is extended to cover many areas of the country as possible and reach many farmers adopting the best agricultural practices. However, it was realized that, there was insufficient manpower for deployment to cover the whole country. As a strategy to overcome this challenge, the government and with donor support, from the year 2004 has heavily invested in the establishment of the Agricultural Technical and Vocational Education and Training centers (TVETs) to train and deploy additional DAs and the establishment of Farmer Training Centers (FTCs) as focal points for extension and research support in the *Kebele* levels (Davies et al. 2009; Spielman et al., 2006; 2008). As seen during the previous regimes extension programs, the shortcoming of such heavy investments which are dependent on donor funding, may not be sustainable if the government doesn't provide its own funds sustain the programs.

The current Ethiopian extension system is focused on developing and undertaking various technological packages covering different types of crops, livestock and natural resource management practices that are suited to both smallholder and large scale farmers in the different agro-ecological zones including arid and semi-arid areas (Rahmato, 2008). These technological packages are aimed at increasing productivity and also ensuring that areas that were previously neglected are also included in agricultural transformation agenda. For example, the agro-pastoralist extension package is focused in the provision of water, feed, animal health care and livestock marketing services (EEA/EEPRI, 2006; MOARD, 2001). The establishment of the Ethiopian Agricultural Transformation Agency (ATA) in 2010 is a catalyst and as a sign of commitment by the current government to rapidly transform and support the country's agriculture by using existing structures under MoA and also embracing private sector and other non-governmental organizations as key actors in the sector.

2.3 Provision of Agricultural Extension Services in Ethiopia

There are variety of actors who are engaged in agricultural extension and advisory services delivery in Ethiopia. The major categories of actors are primarily the public extension service providers, which include MoA and Regional Agricultural Bureaus with their subsidiary institutions. The federal and regional agricultural research institutes, private enterprises, agro-industries, NGOs and farmers' organizations and cooperatives are the other actors involved in the delivery of agricultural advisory services (Table 1 below).

The pre- and post-1974 regimes in Ethiopia adopted different approaches to the agricultural extension service delivery systems. As opined by Berhanu & Poulton (2014) the Ethiopian extension system was not only used as a key factor for agriculture and economic growth, but also for political control. The state control was tight and deviation was not readily welcome by political authorities during the last 5 decades history of the county. This trend is not likely to change even with the current administration. As pointed out by Davies et al. (2009), in their review of agricultural extension systems in Ethiopia, the involvement of NGOs and private sector was limited. This is because, the extension system is largely state funded and managed. Such an institutional context has great influence on the manner in which the extension services are procured and delivered (Minh et al., 2010). According to (Klerkx, et al., 2017), different institutions either at formal or informal levels interact and create country-specific histories and path-dependencies, which lead to different degrees of propensity and preparedness, and hence different starting positions for participatory extension approaches and actors involved. The agriculture extension services provision in Ethiopia is mainly undertaken under the MoA and is clearly organized from federal, regional, zonal to *Woreda* levels. The MoA at federal level is charged with regulatory functions and oversees national level agricultural policy directions and coordination of the regional bureaus of agriculture. The bulk of coordination and implementation of agriculture extension services are undertaken by the regional bureaus of agriculture and the *Woreda* levels respectively. In this regard, the regional administrative councils are mandated to modify some of the federal level government policies based on and to suit specific local conditions and needs. Zonal level of administration is responsible for the overall coordination of the agriculture and other development activities in the zone and as a link between the regional and *Woreda* levels of administrations. The *Woreda* level administration is responsible for the overall agriculture and development activities of the *Woreda* at the *Kebele* levels. The operational extension activities are undertaken by crop and livestock production, Natural Resources Management (NRM), and agricultural extension team with technical support from the zonal bureaus of agriculture (Gebre Medhin *et al.*, 2006). The *Kebele* offices of agriculture and Farmer Training Centers (FTC) are responsible in the frontline extension delivery through advisory and training services with technical support from the *Woreda* Office of Agriculture.

The agricultural research in the country is undertaken mainly by the federal and regional research institutes whose centers are distributed throughout the country in different agro-ecological zones. The universities with well-developed agriculture department such as Haramaya, Jimma and Hawassa are engaged in research and extension programs. Based on their respective research activities, these institutes and departments generate new technologies which they promote through demonstrations and training of farmers and the frontline extension staffs. This undertaking is part of their mandate to test newly generated technologies and also in building the capacities of the farmers and MoA extension staff as a strategy to strengthen extension services.

The private sector actors have an important role to play in extension service provision, however, their participation and contribution is rather limited in Ethiopia. That means, the public-private linkage in the extension service is weak, which otherwise has potential to provide complimentary and additional services to support the bulk of the smallholder farmers who are in need of the services. The dominance of the public sector extension service provision in the agricultural sector has in some ways contributed to low level participation of the private sector. Such strong public sector presence is linked to the history of the extension system and agriculture development in the country. The public officials control funds and decisions on the programs which are directed to the agricultural sector. The public agricultural extension support system, however elaborate, it cannot effectively meet the wide ranging information needs of farmers in different agro-ecologies, to organizing markets and supplying of farming inputs. This is requiring the need for collaboration and linkage between the sectors to harnesses their technical and knowledge capacities for investment in agriculture. In most of the instances, the private sector investments come along with capital, contractual arrangement on marketing and extension support packages. Although, such in initiatives are new in Ethiopia, lessons can be drawn from them. For example, in sugarcane production and processing, the private sector is engaging the farmers residing around where the sugar factories are located as out growers in cane production under contractual arrangements with extension and marketing support packages.

The NGOs involvement in extension in Ethiopia is limited to areas which are not reached by the public sector. The humanitarian assistance to these vulnerable groups and regions is helpful in the development of agriculture and related enterprises as coping mechanisms. Notable examples of NGOs such as SG-2000, Oxfam (International) and World Vision are actively involved in improving food and income security through better access to production technology and training, providing information on sustainable markets for the smallholder farmers in the hardship regions. Farmers associations or cooperatives, although have no full-fledged extension service provision to their members, they offer services such as distribution of farming inputs, grain marketing, and some in some cases training members on paraprofessional skills to provide services in animal health, commercial seed production and distribution. However, there are exceptional cases in such as coffee sector, where the farmer cooperatives are well established and they are able to provide full processing and marketing services for their members.

The church and the historical developments in Ethiopia is closely related and particularly that of the Orthodox Church. Its involvement cuts across the social development programs, ecumenical roles as well as the custodian of Ethiopian cultural heritages and ancient agricultural practices (Loubser, 2002). The church performs these functions with a strong link and ideological support from the state (Baye, 2017). This commitment is shown from the presence of large number of priests in the community and widespread orthodox schools in the country. There is a large following and engagement among the peasant farmers in the traditional eco-friendly agricultural practices which they are preached, socially approved and linked to those prescribed in the Bible (Larebo, 1987). This places church as an important actor not only in the social, historical and cultural lifestyle of the Ethiopian people, but also on custodian of agricultural practices. The church is an important actor in the short and long term planning and implementation of agricultural linked development programs. It is more of an ally than an obstacle (Loubser, 2002). For example, it has been shown by Berhanu et al. (2006), that in most instances, agricultural extension messages are effectively transmitted during church linked or related platforms. That means any reforms in the agricultural sector such as the introduction of new technologies which require strong public participation will definitely need the support from church as an institution or the membership. Informal associations such as the *Maheber and Senbete* are the examples not only involved with strong religion and church afflation but also with agricultural related activities (GebreMichael, 2006).

Table 1: Actors in the Agricultural Extension services in Ethiopia

Actors in extension services provision		**Role and contribution**
Public	Ministry of agriculture	Policy and technical support to the regional bureaus of agriculture: improve their production capacity and productivity for food security, export and raw materials production for local agro- industries.
	Regional agricultural bureaus	Tailor national policies to regional specific needs; provide technical support of the *Woreda* agricultural offices in the implementation of programs.
	Zonal agricultural offices	Provide link between the regional and *Wored*a levels of administration through facilitated communication, monitoring and evaluation of agricultural extension program implementation.
	Woreda agricultural offices	Prepare and implement extension services to the farmers.
	Kebele farmer training centers (FTC)	Implement extension services directly to the farmers through advisory and training.
	Federal and regional research Institutes	Conduct research and generate new knowledge, capacity building and promotion on the application and use of new agricultural technologies.
	Universities and Agricultural training centers	Conduct research and generate agricultural technologies, capacity building through training of manpower in the agricultural sector.
Private sector	Private enterprises (small scale and large scale enterprises)	Supply farm inputs and equipment such seeds, pesticides and information on the use of their products.
	Farmers' organizations	Facilitate delivery of farming inputs to members and provide other logistical support services such as micro finance, transport and storage of agricultural inputs and products.
Non-governmental organizations (NGOs) and civil society organizations	NGOs	Piloting best practices and testing methods and approaches to agricultural extension and facilitate access to technologies and markets.
	International research institutes (CGIAR centers)	Research and capacity building on new technologies which are relevant and applicable in Ethiopia.

Source: Compiled by Authors and inputs from (Kassa & Alemu, 2016; MOARD, 2001; Davis et al., 2009)

2.4 Informal Institutions and Agricultural Extension

Informal institutions in Ethiopia play an important role as sources of and pillar of innovation. They complement and bond with formal institutions through a web of personal relations and attributes (Lauth, 2000; World Bank, 2012). These informal institutions include *Iddir* (funeral association), *Iqup* (Savings and credit associations), *Debo* (pooling community labor for support or sharing), *Maheber and Senbete* (religious associations*)*. They are composed of voluntary membership and are used to perform different purposes and functions for the social economic wellbeing and development of the people. Although they lack formal structures, they possess all the other features such as shared cultures and communication codes, governance structures, incentives and routines which are associated with formal institutions (Lauth, 2000).

The *Iddir* are traditional burial associations which primarily provide financial, social and psychological support to the affected family members, and may include insurance against misfortunes such as fire, death of livestock or any social challenges and calamities (Decron et al. 2004; Pankhurst and Mariam, 2000; Stellmacher, 2007). They also serve as a social platform for community development through working closely and in complementarity with other formal institutions of government or Non-governmental organizations (NGOs). For example during national campaigns on soil and water conservation, the *Iddir* membership are called upon and are engaged in tree planting, construction of gabions, terraces etc.

The *Debo* is indigenous form of voluntary association through which rural communities cooperate with each other in pooling labor for agricultural tasks whereby the person or family hosting the *Debo* receives labor and is only required to provide food and local drinks such as beer, coffee and tea (Gebremichael, 2006). This commonly happens mostly during agricultural activities such as ploughing, weeding or harvesting of crops. Such a cooperative effort and support from the community members enables a household to accomplice a piece of farm work that they would have not managed in a very short period of time or at minimal expenditure. *Debo* enables the household to easily meet various social and economic needs which otherwise they could not on individual basis. For example through *Debo,* the physical handicapped or socially disadvantaged such as the sick, widowed and aged members of the community are voluntary assisted to meet their physical labor needs.

The *Iqub* is a voluntary association established for the purposes of making informal financial savings whereby the members contributes an agreed amount of money at regular intervals to the common pool and when each of their turn comes, they are able to receive a lump sum (Gebremichael, 2006). This is a saving scheme where there is high level discipline and their obligation must be met without defaulting such as postpone saving from one month to another (Pankhurst and Endreas, 1958). Many people prefer *iqub* to the formal financial services sector because of the strong social connection, transparent and friendship tied within the group membership and also which serves as an assurance against unlikely event of defaulting when issued with loan from the savings (Dejene, 2003).

The *Maheber and Senbete* are religious associations (GebreMichael, 2006). The members come together as a form of social self-help group. They are able to assist each other during social occasions such as weddings which are logistically demanding or require allocation of relatively large amount of financial resources. They also provide a forum for the community to meet and discuss issues affecting them and create and strengthen ties between them.

Nikinake is an informal public mobilization and engagement process for the purposes of building local capacities for collective action and learning (Leta et al. 2018). The practice was initially implemented in Tigray region during the 1990s and later emulated and adopted by other regional states as a way of promoting agricultural extension (Jabbar et al., 2000). The mobilization of the public is done on a voluntary basis and sometimes forced. The public who are mobilized are required to participate in implementing the commonly identified project such soil erosion control, tree planting etc. Unlike other informal approaches, the *Nikinake* draws support from political establishment right from the federal, regional, to the local administrations and mainly focused on promoting (Leta et al. 2018).

The extension services in Ethiopia in general are decentralized to the *Woreda* level. Although the MoA places more emphasis on the formal institutions, the context under which the agricultural activities are undertaken, is at the grassroots level where these informal institutions have influence on the daily activities of the farmers or on the social organization of members of the community in general. Contrary to this, successive regimes in Ethiopia have tried to assume and in most cases to replace or surpass the role and importance of the informal or local social institutions with intrusive state power. The central political administration tend see the informal institutions as rivals to the power structures (Berhanu & Poulton, 2014). At best they are exploited in terms of provision of labor to undertake state activities. Instead, these informal institutions should be used serve as complements to the formal extension institutions rather than seen as rivals. They can serve as alternative channels of information dissemination to the areas where the formal extension services are not accessible or in the worst case scenario, to extend the political interests of the power elite. For example during *Debo* the participants are fellow smallholder farmers who have skills or experiences on farming activities or new farming technologies such as weeding, planting, spacing, new seed varieties etc. These skills are shared through *Debo* and they could be either from the formal extension sources or local experiences. These forums are also serving as informal learning platforms for empowerment of the participants and also the channels for information and knowledge dissemination. The *Debo* provides an ideal platform for learning and communicating agriculture extension related messages and is more influential were extension activities are limited.

2.5 Summary of Findings

Ethiopia has implemented a number of agricultural extension approaches under different regimes from the imperial period to the current under EPRDF. Despite these approaches having growth and agricultural productivity objectives, their impacts were limited in terms of productivity, area coverage and stakeholder engagements. For example, during the imperial regime, the land tenure system was unfavorable for the smallholder's farmers who were mainly tenants. During this period, the smallholder farmers had no incentives to participate or implement extension recommendations meant to improve productivity because the land belonged to landlords. The subsequent *Derg* and the EPRDF regimes centralized administrations did not improve the situation either. The institutional atmosphere for a truly participatory stakeholder engagement to take place is still lacking. Although, there are claims from MoA of being ‘participatory’ and geared towards pluralistic in respect to extension service provision, this is not see practice. The participatory rhetoric is contradicted by nature of the planning, management and implementation of the extension services which are centralized and communicated on a top down hierarchy from federal to regional, zonal, *Woreda* and *Kebele* levels. However, there are examples on a limited scale, which have shown some ‘participatory’ aspects and involvement of NGOs and the private sector in extension services delivery. This is in parts of the country where the public extension services may not be reaching the farmers such as moisture deficit areas. Overally, the agriculture extension in Ethiopia is under state control and it is treated as purely as a public good. The role and contribution of the informal institutions and the private sector, despite their immense potentials, they are not given prominence they deserve in extension services provision. They are most cases viewed as intrusive to state power and threat to the monopoly of thought held by the ruling elite.

In order for a truly participatory innovation development and implementation to take place in the agriculture sector in Ethiopia, the user oriented research, extension and training services should institutionalized under the auspices of multi-stakeholder platforms. These efforts should fully embrace public-private actors in research and extension linkages (Wennink, 2006; Kassa & Alemu, 2016). The role and contribution of the informal institutions and private sector should be also recognized as important learning platforms and source of social networks and much needed capital for investment. For example, the mutual trust inherent within the informal institutions can be used as entry to the community and providing a link between research and other stakeholders engaged in the agriculture extension sector. The fusion of the different perspectives, ideas and knowledges of different stakeholders taking up new roles in the extension sector will likely bring out new perspective in the agricultural research and extension systems. This is in the relation with the changing demands on the agricultural sector Ethiopia either from the effects of crop pests, diseases, climate change, population increase, new markets or industrial needs.

In this study, the introduction of the PPT implementation using a participatory action research process is used as an example to illustrate how the interaction between researchers and other stakeholders can be facilitated and their joint action strategies used as opportunities for learning to inform both research and practice.

Chapter 3:
Research Approach and Methodology

3.1 A Transdisciplinary Action Research Process

The implementation of this study was based on a transdisciplinary action research (TDR) process (Siarta *et al.,* 2012) by drawing on practical experiences such as the Follow the Innovation (FTI) which was developed by the Center for Development Research [ZEF] in the context of Uzbekistan's agriculture (Djanibekov et. al, 2012; Hornidge et al., 2009; Hornidge et al., 2011; Ul-Hassan et al., 2011; Lamers 2014) and the continual stakeholder engagement model developed by Reid et al. (2016). The choice of the approach was based on the fact that, in real life situations and as humanity we are faced with multiple challenges which are complex in nature from climate change, poverty, conflicts etc. and cannot be easily addressed at once or by single approaches or disciplines. At the same time the society is multi-faceted and highly fragmented with heterogeneity of actors with diverse interests, knowledge bases, experiences, perspectives and different cultures (Becker and Jahn 1999). Although it is acknowledged that disciplines provide essential methods and tools required, it is also pointed out that, they lack the capability to handle such complex problems that require collaboration with other disciplinary approaches (Mauser et al. 2013) and other societal players in general. With such complexity, there is a need to integrate the views and knowledge from different stakeholders' perspectives in order to find practical solutions (Renner et al., 2013). This perspective makes the bringing together of scientific knowledge and practice a central theme of transdisciplinary research (Lang et al., 2012; Reid et al., 2016; Siebenhüner, 2004). The integration process essentially involves combining scientific knowledge from different disciplinary perspectives as well as knowledge types from the realm of practice (Bergman et al., 2005). It involves experiential learning, and linking it with the development of cognitive-epistemic competencies, social and organizational, communicative and technical skills (Chakravarthy, 2015). This rises and in respect to the different expectations, legitimacy concerns of researchers and heterogeneity of participants from scientific research and practice (Bergman et al., 2005).

A transdisciplinary research approach requires that different scientists with their discipline-specific theories, concepts and methods find ways to work together with other societal players to solve a real-life problem (Hirsch Hardon et al., 2008; Pohl and Hirsch Hardon, 2007). The approach is seen as a way of legitimizing and increasing the intellectual potential and effectiveness of scientific research and disciplines (Frydman, et al., 2000; Stokols et al. 2003). The process requires participatory interaction and mutual learning for exchange, integration and generation of new knowledge across the realm of scientific and societal practices (Klein et al., 2001). According to Siebenhüner (2004), the participation of societal stakeholders is seen as a means for empowerment, learning and increasing legitimacy of the research process and engagement in the production of new knowledge and its practical implementation to address societal problems. The prospects for success of such an engagement can be built on the organization of the process and nature of interaction of the participating stakeholders (Renner et al., 2013). During this process attention should be paid to ensure that the participants are socially integrated and act jointly (Kates et al., 2001), i.e. there is a continuous process of interaction and learning among the stakeholders during innovation development and its implementation (Reid et al.,2016). To achieve the social learning and innovation in such environment, the different actors have to align their diverse attitudes, motivations and values into a shared pool of knowledge and collective action (Tisenkopfs et al., 2015). According to Reed et al. (2010), for a process to be considered social learning, it must demonstrate that a change in understanding of the complexity of problem at hand has taken place within an individual and then become situated within wider society. Bandura (1977) pointed out that, although social learning may occur through imitation and under the influence of norms and social context, multi-stakeholder negotiation and interaction has an important contribution to the learning process (Scholz et al., 2014; Röling, 2010). This is because it brings in new relational capacities between the stakeholders, including improved collaboration and a novel understanding of each other's capacities and roles (Pahl-Wostl et al. 2009).

In the recent past, the transdisciplinary approach to research has gained prominence as a potential means to address contemporary social and environmental challenges which cut across the boundaries between orthodox disciplinary knowledge and practice (Fuqua, et al., 2004; Horlick-Jones & Sime, 2004; Singh, *et al.*, 2012). The approach has been influenced by the new thinking that, the participation and continual interaction of different disciplines and stakeholders can effectively contribute to addressing the societal problems (Allen et al., 2014). During this process, researchers work jointly as a team with other stakeholders to develop and use a shared conceptual framework drawn from their discipline-specific approaches and experiences to address a common problem (Stokols et al., 2003). Indeed as pointed by Reid et al. (2016) there is no doubt that continual engagement of researchers and other stakeholders' produces science and practice knowledge that is relevant to the society's needs. But, the process requires time and patience to truly understand the language of all relevant disciplines and practices, in order to integrate their perspectives to a shared problem definition and solution (Rosenfield, 1992). That means, the process doesn't work easily as described or seems. It may sound very positive, but has its potential challenges or barriers which may hinder effective implementation or even became a cause of misunderstandings and conflicts. For example intrapersonal factors such as values, career expectations, goals, and experiences of individual team members may be causes of internal team conflicts (Stokols, 1999). This arises from the fact that the teams are unable to bridge power differences, misunderstanding and disagreements on individual methodological approaches, different institutional settings and reward systems etc. The success of the transdisciplinary research process may also become elusive due to lack of common problem definition or understanding. The process skills such as decision making, problem solving, and conflict resolution and boundary management become very crucial at this point (Gray, 2008). Thus, effective facilitation and collaboration helps in redressing the asymmetries in power relation among the team members and ensures their continual engagement to address the societal-life challenges.

Apart from research, transdisciplinarity as a concept has been applied in many other forms of human engagement such as in critical citizenship education, democratic learning processes and natural resources management. Transdisciplinary approach to politics embraces participant inclusion in decision making. It has been to shown to provide a framework of active, participatory and inclusive expressions of the citizens in the decision making processes and citizenship pedagogy in teaching and learning democratic practices as an alternative to neo-liberal models (Mitchell & Moore, 2012). The approach eliminates any form of authoritarianism and embraces politics of inclusion, creates awareness that academics do not have a monopoly on knowledge or wisdom and be seen as an alternative model for citizenship education (ibid.) Transdisciplinary approach offers different stakeholders an opportunity to appreciate and embrace mutual dialogue to engage and to challenge the traditional top down or linear power relations which tend to sustain inequality in the society. According to the 20th century Brazilian educator Paulo Freire, participatory principles underlying the democratic citizenship make education to become both a political and moral practice providing students with requisite knowledge, skills and social relations to explore on their own what it means to be active and engaged citizens (as cited in Mitchell & Moore, 2012, p 8). Thereby showing that, schools and teachers make a significant contribution to democracy. This is exemplified by findings from innovative case study by Ye Wangbei (2012), where she looked into the role of Chinese schools and teachers on citizenship education. Based on the case study under a tight Chinese Communist Party's (CCP) political control and government's deep involvement in citizenship education, she evaluated school-based curriculum development, from planning to implementation. Her findings showed that; school practices and teachers have emancipatory potential to advance democratic citizenship education by de-politicization and decentralizing curriculum decisions, and democratizing school culture to meet the citizens' needs without necessarily eliminating the state political values and central control.

In another related case study by Moore and Mitchell (2012), this focused on events associated active child and youth citizenship in Ontario University, Canada. Their findings showed of an emerging global assemblage of childhood citizenship who yearns to see their participation in civil society translate into action. The authors concluded that, transdisciplinarity has an inherently important role to play in addressing the status quo in any specific discourse or type of research, and could be used address young people's citizenship in the context of globalization (ibid).

Drawing on these examples, boundary crossing comes in as a central metaphor and in leveling the differences of power among the stakeholder groups (Klein, 1996; Reid et al., 2016). Boundaries are seen as the sociocultural differences between stakeholder practices leading to discontinuities in action or interaction (Akkerman and Bakker, 2011). These boundaries which are either between local, national and global levels of participation, children citizenship and adult power, scientific research and practice etc. are historically embedded in different epistemic cultures which adhere to different ways of thinking by the actors (Akkerman, et al., 2013). Thus becoming useful resources for learning, as they compel different actors to reconsider their previous assumptions in order to jointly address a common problem and come up with actionable outcomes.

3.2 Transdisciplinarity in the Research Process

In this study the researchers and other stakeholders who represented different scientific research disciplines and practice levels came together to jointly address challenge of stemborer pests in cereal crops, with attention on with maize crop. The problem of stemborer affects the productivity maize which is a staple food crop for most of the smallholder farmers in the study area (Fig. 6 below). The researchers and extension service providers usually recommend chemicals based control methods which are often not effective, unaffordable by the farmers and with negative effects to the environment. The search for sustainable and alternative solution to the use of pesticides in the control of stemborers is a common challenge and an ongoing undertaking by both researchers and other stakeholders. Among the initiatives to address the problem, the participatory introduction and implementation of PPT was identified as an alternative to the use of pesticides to address the stemborer problem. The study adopted the TDR approach during PPT implementation whereby the researchers and other stakeholders jointly worked, not only to solve the stemborer problem, but also as a mutual learning process (Allen et al., 2014). The TDR approach is participatory and supports transdisciplinary reflective learning, communication and co-operation between researchers and other practitioners as stakeholders. The implementation of PPT technology in this case, was used as boundary object (Mollinga, 2008) and a means to enhance TDR process. The field study was conducted for a period of 8 months (August 2014 to April 2015) following the TDR action research cycle (Fig. 4); from joint planning and design, on farm practical PPT implementation and learning to evaluation (Bortz & Döring, 2003; Kemmis & McTaggart, 2005).

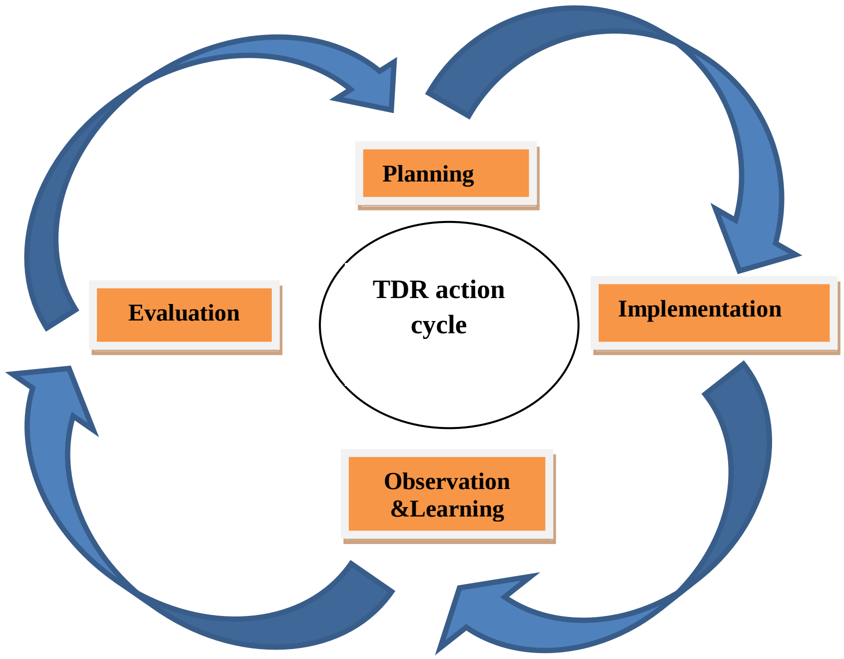

Figure 2: The Transdisciplinary Action Research Cycle.

Source: Authors' illustration

3.3 Research Design

3.3.1 Joint Planning and Design

The research process started with stakeholder identification and organizing the planning workshops at the regional and *Woreda* levels. The identified stakeholders were drawn from MoA, Jimma University, researchers from the Ethiopian Institute of Agricultural Research (EIAR), smallholder farmer representatives engaged in maize crop farming and journalists/reporters from Oromia TV/Radio. The regional workshop was conducted in the first week (2^{nd} -4^{th}) of October 2014 at Bedele town in the Oromia region (Fig. 3). This workshop was aimed to; introduce the concept of the PPT, research objectives and TDR approach, have a common understanding of the research problem and stakeholder engagement in the joint learning and addressing stemborer pest problem. The stakeholders who formed the research team were represented by an entomologist, chemical ecologist, weed scientist, agricultural extensionists, social scientists, agricultural sector administrators (local, regional and federal), journalists and smallholder farmers. During the workshop, the discussions were centered on how the use of the PPT as an innovation can be used to address the problem of stemborer pests and also as an opportunity for collaboration and joint learning through interactive exploitation of the technical expertise, knowledge and the experiences from the stakeholders (research, farmers and extension service providers).

Figure 3: The first regional stakeholders planning and team building workshop

Workshop photo: Nyang'au I.M.

The follow up planning workshops took place at the *Woreda* and at farm levels in Bako Tibe, Jimma Arjo and Yayu. The workshops were meant to introduce to the *Woreda* level stakeholders and seek their views and if possible for their support and commitment in the implementation of the activities which were discussed and planned at the regional level workshop. Despite the fact that the research approach was participatory, the hierarchy of information flow followed the laid out administrative channels. Before initiating any farming or development related activities at the farmer level, *Woreda* level administration should be aware and consented to it. At the farmer level the workshops and discussions (Fig. 4) mainly focused on practical and day to day PPT farming activities such as the dates for planting maize, source and supply of inputs (Desmodium, Brachiaria, Maize and fertilize), and farmers knowledge of the stemborer challenge and how they have addressed it before, the their perceptions on joint stakeholders implementation, and other related activities such as livestock feeding, fodder supply or availability during dry seasons, soil and water conservation practices etc. The activity planning and information flow followed the laid down structures by extension system. The stemborer pest in maize and other cereal crops was an existing problem and this was confirmed during the stakeholders' workshops.

3.3.2 On-farm Push-pull Technology Implementation

The PPT practical implementation, field observations and joint learning took place at farm level (Fig. 5) and it involved participatory engagement of the research team in undertaking the activities which were in discussed during the previous planning meetings (regional, *Woreda* and farm levels). During this stage, joint discussions and observations were based on the PPT practical on farm activities starting from land preparation, laying and planting (maize, Brachiaria and Desmodium), weeding, gapping, thinning, identification of symptoms and sources of stemborer, harvesting of Brachiaria and Desmodium for fodder, harvesting maize (green or cereals) and maintaining PPT plot for the subsequent cropping seasons. Further discussions on these topics included; how the new the PPT management practices were different or similar with conventional practices, new practices and knowledge gained as well as the challenges faced with the introduction of the new technology.

Figure 4: Farmer level planning and discussion meetings

Field photo: Nyang'au I.M.

Figure 5: Farmer sharing his knowledge on maize crop growth with DAs

Field photo: Nyang'au I.M.

At this point it should be noted that, the facilitation of the process by the researcher played an important role of ensuring that there was a balanced participation during the workshops discussions and on-farm activities. It was aimed at managing potentials biases or conflicts which could arise. It also ensured that knowledge and concerns of all the stakeholders were consolidated during and implementation of the research. The facilitation took into consideration the consent to participate and confidentiality of the information shared by the stakeholders. The study was implemented and evaluated within 8 months. This period was short to make complete overview of the learning process. However, the transdisciplinary action research approach ensures that stakeholder interaction takes place on a continuous basis. Additionally, the implementation process of the PPT is perennial in nature, meaning that the companion crops still remain in the farm over several cropping seasons, thereby providing the stakeholders opportunities to continue learning. As opined by Scholz et al. (2014), such interactions play an important role in social learning and in enhancing the capacities of the stakeholders either as researchers or practitioners.

3.4 The Study Area

The study was implemented in three *Woredas* in Oromia Region in Western Ethiopia, namely Bako Tibe, Jimma arjo and Yayu (Table 2). These sites were identified in Ethiopia using a GIS based 'hot-spot' approach by African and German partners of the BiomassWeb project[1]. However, due to logistical challenges, follow ups in Jimma arjo were severely constrained. The *Woredas* are located in the western parts of Oromia (Fig. 6). and were selected as the potential 'maize growing basket' of Ethiopia (Abate et al., 2015; Abdissa et al., 2001) in which the "livelihood of local communities […] traditionally stands on household-based subsistence agriculture, extensive use of forests and cultivation on considerably small plots of agricultural land with an average of one hectare of cropland mainly for the cultivation of staple cereals such as maize, *teff* and wheat*"* (Stellmacher and Grote, 2011: P, 10). The soils in the areas are either severely degraded due to nutrient depletion, and/or poor in organic matter from continuous mono-cropping and unsustainable farming practices. Insect pests, principally stemborers, are major cereal production constraints (Assefa, 1998; Belay & Foster, 2010; Getu et al., 2001). According to Hurni (1998), the area is characterized mainly by mono-modal rainfall, with short rains in March and April, and long rains from June-October, with a distinct dry season extending usually from November to February. The dominant soil types are Nitosols with fertile alluvial soils in valley bottoms and depressions. Major crops, in order of importance, are maize, *teff*, pepper, sorghum, millet and pulses. In Yayu, coffee is an important cash crop. The farming system is mixed crop-livestock based.

[1] http://www.zef.de/2141.html

Table 2: The study area and location of the PPT demonstration plots

Study area and Location of the PPT demonstration plots							
Zone	*Woreda*	*Kebele*	AEZ	Location of the plots	Altitude	Longitude (N)	Latitude (E)
West Shawa	Bako Tibe	Dembi Gobu	Mid-land	Gibe river	1660	09°09.173'	037°02.131'
		Seden Kite	Mid-land	Leku river	1648	09°05.331'	037°09.847'
East Wollega	Jima Arjo	Wayu Kumba	High land	Nageso river	1990	08°46.442'	036°31.616'
		Wayu Kumba	High land	Nageso river	1986	08°46.582'	036°32.554'
Ilu-Ababora	Yayu	Jame Shono	High land	Sky-sky	1904	08°21.353'	035°36.584'
		Jame Shono	High land	Jame-Bone	1870	08°21.351'	035°57.736'

Source: Authors compilation

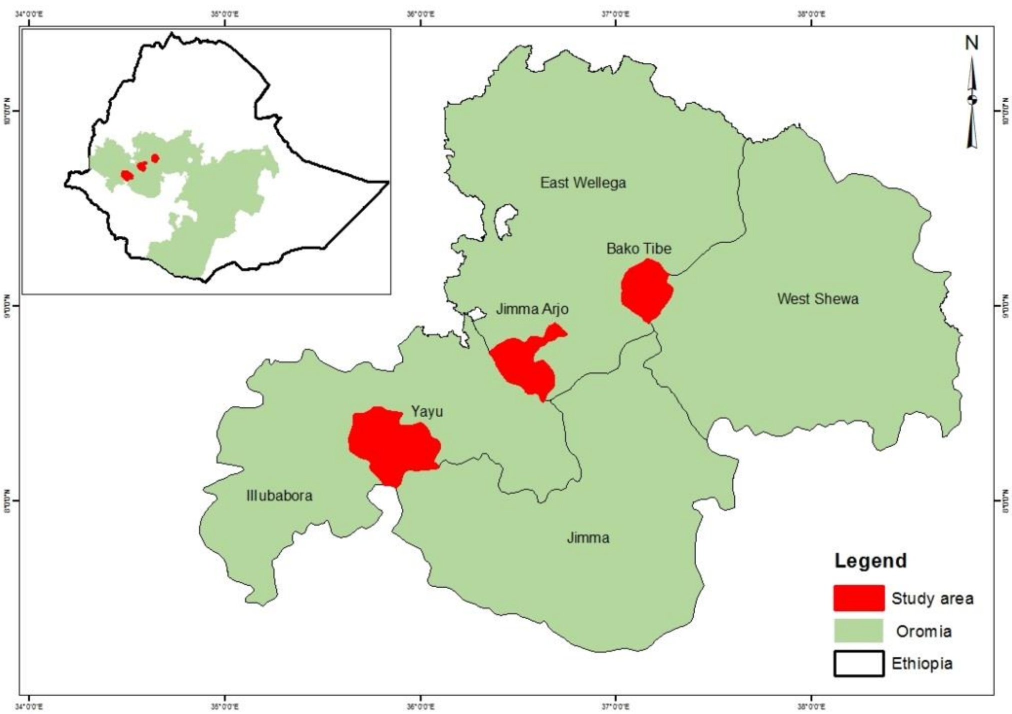

Figure 6: Map of the study area in Western Oromia, Ethiopia

Source: ZEF GIS expert

3.5 Data Collection and Analysis

The data collection process involved a triangulation of methods mainly qualitative methods. The data collection process engaged 37 key informant interviews, 20 Focus Group discussions, two stakeholder workshops, on-farm practical demonstrations and participant observations. The study lasted 8 months from August 2014 to April 2015 (See Appendices 1-3). Key informant interviewees were researchers, extension and administration officers from the ministries and the PPT lead farmers. Focus group discussions participants were the DAs and farmers. The qualitative data was manually transcribed into themes which were analyzed and interpreted in relation with research objectives, concepts and theories used in this study.

3.5.1 Semi-Structured Key Informant Interviews

The semi-structured key informant interviews were an ideal method for me as a researcher to collect data on participants' experiences regarding PPT and other related topics. This is because the method allows the interviewer to use a written topic guide to ensure that all questions areas are covered during the research process, while at the same time allowing the informant to discuss their thoughts freely (Barker et al., 2005). The key informants who participated during the interviews were; the researchers drawn from *icipe*, Bako and Jimma agricultural research centers and Jimma University, the extension officers from the ministries of agriculture, livestock, cooperative and plant health clinic. The other key informants were opinion leaders; farmer leaders, women leaders, youth leaders, local administrators at district and *Kebale* levels, journalist/information officers from information bureau at Bako Woreda, agriculture college tutors, and agro-dealers as private sector stakeholders.

The interview schedules and venues were arranged and agreed through personal visits either to their offices, business locations or on their farms/PPT plots. Almost all the requests were granted. There was an exception of three cases where the officers were busy at the time of the interviews and later they were engaged in training for voter registration exercise in preparation for the national election which were forthcoming. Overally, those who granted permission for interviews had interest due to the fact that they were; involved in the planning and implementing PPT, affected by the stemborer pest problem and interested to find a lasting solution, had a first-hand experience on PPT and its performance and were interested to continue to participate and learn more about it. The interviews were conducted in English with services of a translator to Oromifya language for the respondents who couldn't speak English.

The key informant interviews were in form of open ended and semi-structured questions and covered a wide range of topics from; their knowledge and experiences on the challenges of stemborer pest problem in the study area, the current methods and practices used dealing with the stemborer problem, their experiences, roles and contribution as stakeholders in ensuring that there is mutual and interactive learning between researchers and practitioners during the PPT activities. Other topics discussed during the interviews included; their opinion regarding the kind of incentives, policies or frameworks to be put in place to ensure sustainability of the PPT as an innovation, the socio-economic or contextual factors which may hinder the implementation and utilization of research results/new knowledge generated and how to be resolved. How other groups such as the private sector, women and youths can be engaged in the planning and implementation of the PPT as an innovation. The interviews also covered on their opinions, the key lessons learnt and way forward regarding the PPT implementation using TDR approach.

3.5.2 Focus Group Discussions (FGDs)

The FGD were facilitated by me as the researcher with assistance of the Oromifya language translator. I explained to the participants (DAs and farmers) on objective of the FGDs, the benefit of participation in the PPT implementation and research processes. From the initial stages, the participants were encouraged to contribute freely, their opinion was highly valued and there are no wrong answers to the questions and topics discussed. The discussions lasted about 2-4 hours. However in some instances when the discussions lasted longer than this, we had lunch/snack together and thereafter the participants were free leave. There were no direct monetary gains and the participants had right to refuse or withdraw their participation. It was completely voluntary, but it was made clear to them, that being engaged in the process was a learning experience that was even more rewarding. The FGDs were divided into two stages. The initial sets were conducted during planning stage and th**e** subsequent sets were conducted during the PPT implementation stage. In each session of the FGD, the process started with opening remarks by either the host DA or the farmer and welcome was extended to the researcher and other participants. This was followed by introduction of each participant by their name. The attendance ranged between 6-20 farmers and 4-8 DAs/*Kebele* administrators during the meetings.

The initial (i.e. planning) FGDs were based on background information topics such as; the farmers past experiences on stemborers pest problem in cereal crops mainly maize and sorghum and effect on cereal yields, type of control measures they were applying and whether they are working or not (Fig. 7) and alternative stemborer control measures.

At this stage, the concept of PPT was an alternative strategy was introduced to the participants and implementation details were discussed. This information was meant to enable them to have an understanding how PPT works in controlling stemborer pests. The purpose of establishing demonstration plots was to provide an opportunity for the researchers and other stakeholders interact and learn together on the performance of the PPT. The participants' opinions, suggestions, fears and concerns were documented during the discussions. A total of 9 FGD meetings were conducted in 9 different villages during the planning stage. The PPT implementation process started with the establishment of the demonstration sites in 6 villages (Table 2 above). The other three villages were willing to participate, but due to logistical challenges, they were dropped.

Figure 7: Focus Group Discussion during baseline data collection

Field photo: Nyang'au I.M.

The subsequent FGDs were follow ups and discussion topics were based on-farm practical experiences but not limited to; practical PPT implementation stages and its management practices covering; land preparation, laying and planting (Maize, Brachiaria and Desmodium), weeding using hand and hoe, gapping, thinning, sources of stemborers in the area, identification of stemborers and symptoms, harvesting of Brachiaria and Desmodium for fodder, harvesting maize (green or cereals) and maintaining the PPT plot for the subsequent cropping seasons. The discussions also covered on; how PPT management practices were different from usual practices, challenges faced and suggestions on what; needs to be improved to make PPT more effective from research, extension and to the farmer level, incentives to be put in place for the sustainability of the PPT to attract other players such as private sector, the youth and women farmer to participate. A total of 11 focus group discussions were conducted during on farm PPT implementation.

3.5.3 Participant Observation

The researcher adopted participant observation as part of qualitative data collection. With this method, the researcher was able to connect and discover through immersion and participation, and experience first-hand how people behave in a particular context and be able to understand the social world from the respondent's point-of-view (Angrosino & Mays de Perez, 2000). This method enables the researcher to learn about the activities of the people under study in the natural environment through observing and participating in their day to day activities (Barbara, 2005). I applied this method to document observations on the attitudes, behaviors and actions of the researchers, farmers, and extension staffs towards each other and take note on how new ideas or issues learnt during workshops and on farm PPT activities were perceived. I had informal chats, took photos and notes to capture on how the different stakeholders were working hand in hand to overcome some of their 'fears', concerns, cultures and practice boundaries. I was able to reflect on some of these observations and raise questions later on with participants during key informant interview and FGD. This was helpful strategy to minimize bias that may be associated with such observations especially from the point of view of being an outsider from the community.

On weekly basis, the researcher visited the farmers in their fields and households (Fig. 8) to make observations and have informal discussions on what they were observing and how they were managing their new PPT plots from land preparation, planting, to harvesting and utilization of the harvested products (maize and fodder). Through this period, I was able to take note on their day to day interactions and learning experiences on PPT performance, what their thoughts were; regarding the joint efforts by both researchers and extension staffs in the implementation process and the farmer to farmer based learning. During the informal discussions I was able to draw insights regarding the new practices farmers learnt and challenges they faced on day to day farm activities and decisions taken regarding the introduction of PPT. Other general observations and discussions covered issues such as; farmers' perceptions or attitudes on towards PPT in terms of technical details such as plot measurements or markings/labelling, spacing and intercropping, weeding, labor demand, stemborer pests infestation in their plots, sharing information on new knowledge on stemborer control using Desmodium and Brachiaria, the fodder provision and improving soil fertility and soil erosion control.

Figure 8: During family visit and field demonstration on Desmodium weeding

Field photo: Nyang'au I.M.

In some instances, some of the externally generated agricultural technologies and later introduced for farmers uptake, have been reported to constrain the family labor. To witness or experience whether PPT is an additional burden or was fitting their other day to day activities, I chose to spend 3 full days with two farmer families in April 2015 in two separate villages (Dembi gobbu and Sedani Kite). This was meant to make some observations and be able to piece together how other farm and household activities were either linked or in conflict with the introduction of PPT and lessons drawn. The selected farm families were the hosts of the PPT demonstration and learning plots. The initial plans were to spend nights in these families. However, my language interpreter was not willing to stay overnight, I decided to arrive very early in the morning and leave late in the evening. This enabled me to observe and participate in the farm related activities and other cultural activities which took place during the day time. The normal day in each family on average start as early as 5.30am for women who start preparing breakfast for family and school going children. I met these families at between 7.00am-6.00pm.

3.6 Research Ethics

Any form of research involving human subjects, their voluntary consent to participate is an important requirement. Qualitative research requires respondents to answer or provide information on various topics and sometimes on sensitive and personal issues, researchers have an obligation to seek their consent before engaging them in an interview (Bray, 2008). The researchers, we have responsibility to safeguard their privacy or anonymity without exploiting their vulnerability while at the same time ensuring that they are able to respond to the research questions accurately and truthfully. The respondents were made aware by the researcher that they have liberty to choose to participate in the interview or withdraw at any time whenever they felt uncomfortable to continue.

As part of University of Bonn policy on research ethics, and as a junior researcher, it is a mandatory requirement to sign and submit ethical clearance and informed consent before travelling for the field research. Using these guidelines, I ensured that before engaging the participants during Focus Group Discussions, key informant interviews, and workshops deliberations, they understood the purpose of the study and sought their consent to participate in the interviews, discussions, taking notes, photographs or recording their conversations. I informed them that, their participation in the research process was part of finding a lasting solution to the problem of stemborer pests and other related farming challenges such as fodder for livestock, soil and water conservation. Their cooperation in providing relevant and accurate information was important contribution to this. I assured then that any information or views provided or shared will be used for research purposes only and no names shall be mentioned on the published data. The documentation and reports by various interviews was properly referenced and no names of participating researchers or stakeholders were recorded with exception of their actual designations. This was for confidentiality of the information and anonymity of the respondents.

3.7 The Limitations of the Study

During interviews, I noted that, being a person from another country, sharing confidential information was not coming out freely at the initial stages. However, with time and my presence in the community over a longer time, the respondents opened up and were free to be engaged in the study. This trend was equally noted with the way the respondents viewed PPT. Initially they took it like any other agricultural intervention introduced by extension staff and researchers for the sake of their employment. In some of the instances, the farmers and extension expected to receive some 'goodies', however, I explained to them, that it will be more useful to focus for the longer term benefits of learning and implementing PPT.

The major challenge at this stage of research implementation was low rainfall season. The establishment of the crops depended on irrigation with sporadic rainfall. That means, study was implemented on the sites which had access to furrow irrigation. This was a limitation not only to the number of respondents, but also the size of plots established and in different locations and *Kebeles.* That means travelling and sharing experiences among the farmers was limited by distances. Despite these challenges, it was interesting to observe that, the participant stakeholders did not show any fatigue and were keen to learn and discover what other benefits which may come with the technology apart from what it was designed for. What was most striking during interviews was that; there few women attending activity planning but their number increased during activity implementation (Fig. 9 below). This is linked to the patriarchal nature of the society where women roles are limited to providing farm labor and support to the household welfare while men roles are technical oriented and supervisory in nature.

Figure 9: Men and Women farmers' attendance during the PPT activity planning and implementation

Field Photo: Nyang'au I.M.

Chapter 4:
Innovation Systems Approach: Conceptual and Analytical Framework

4.1 Introduction

The formal agricultural research and extension programs in Ethiopia date back to the imperial era, which reflected among other things, centralized and hierarchical linear traditions of engaging and communicating with smallholder farmers. Such engagements have disproportionately not taken into consideration the farmers' knowledge, experiences, decisions and expectations during key stages of planning, implementation and evaluation of the extension programs. At the same time, the complexity of the challenges faced by the smallholder farmers especially with regard to interaction with the environment and new market demands is continuously growing, making it a necessity for new modes of knowledge production (Gilbert, 1998) and working closely among the stakeholders. That means, knowledge production is no longer a domain of experts (Edelenbos, et al., 2011) or problems are not confined within academic disciplinary territories or boundaries (Choi & Anita, 2008). As opined by Knorr-Cetina (1999), knowledge production is a social construction process whereby the experts and other stakeholders come together and work towards addressing or solving a societal problem. However, it is a not a straight forward process as it may sound; it has its unique challenges as well as opportunities. The process encompasses a system level of interaction and relations where the machineries of knowledge production belong to different epistemic cultures at different scale levels specialization and networks that are beyond the immediate work contexts even to the most interpersonally competent research scientists (Gray, 2008; Mørk, et al., 2008).

When dealing with such complexity it is necessary for research focus to shift from mono-disciplinary to interdisciplinary and transdisciplinary concepts or approaches (Lawrence, 2010). The terms; disciplinarity, multidisciplinarity, interdisciplinarity, and transdisciplinarity are used as integrative research concepts meant to describe the contribution of disciplines towards generation of new knowledge, methods or theories to solve societal problems (Fig 10). Disciplinarity represents researchers working within one academic discipline without cooperation with other disciplines to address a problem. Multidisciplinarity represents researchers from different disciplines working independently on their own disciplinary-specific perspective to address a common problem. Interdisciplinarity involves cooperation between disciplines resulting in reciprocal interactions that overlap disciplinary boundaries to solve a common problem. Transdisciplinarity is the advanced level which transcends the disciplinary boundaries incorporating research scientists and non-academic scientists as societal players in the development of integrated knowledge and theory among science and society (Choi and Pak, 2006; Fuqua, et al., 2004; Rosenfield, 1992; Tress et al., 2005).

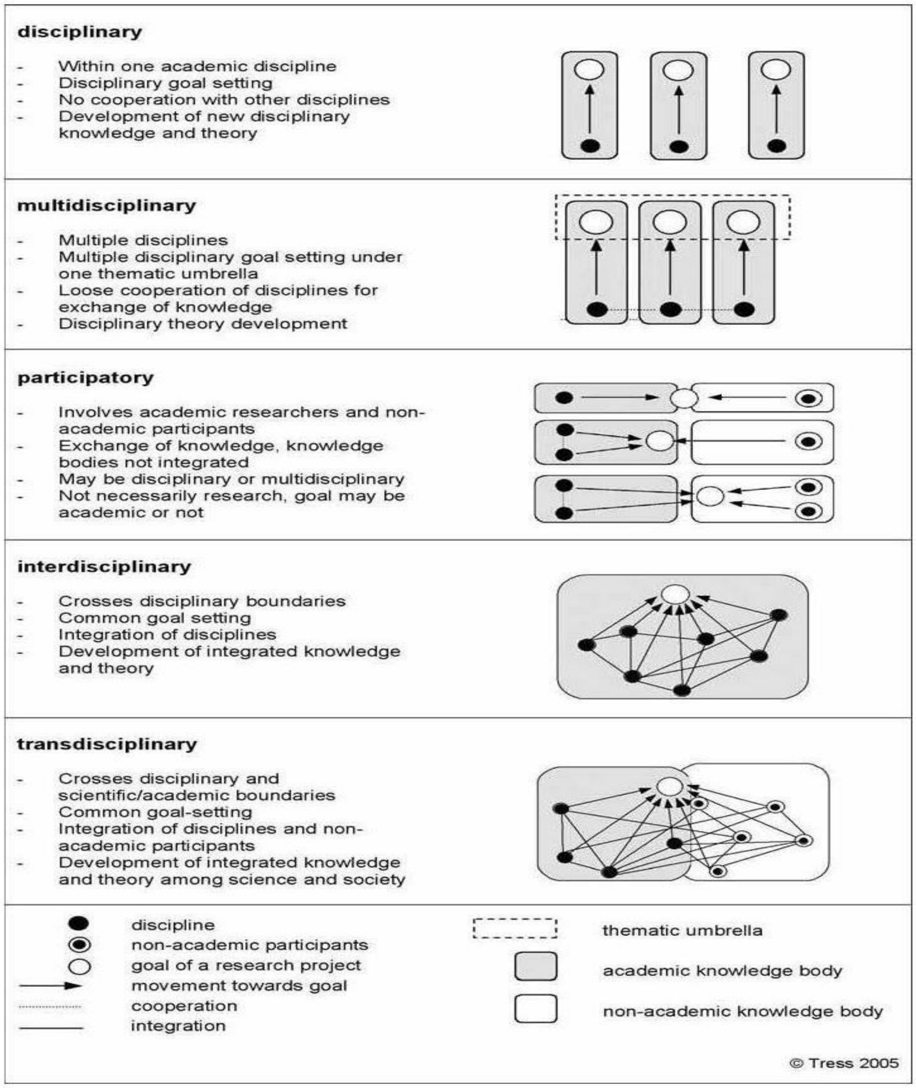

Figure 10: An overview of concepts: Disciplinary, Multidisciplinary, Interdisciplinary and Transdisciplinary
Source: Tress, Tress, & Fry (2005, p. 16)

Disciplinary collaboration among the researchers and other stakeholders plays an important role towards generation new information, knowledge or methodology to address societal problems. According to Rosenfield (1992), transdisciplinary research is the strongest form of cross-disciplinary collaboration because it involves integrating two or more disciplines to come up with an integrated hybrid of ideas, theories, and methods which transcend the individual disciplinary perspectives of the contributing actors. Over the last 3 decades, a number of efforts by teams of researchers from local to global levels in trying to see how close the gap between scientific disciplines and practice by integrating knowledge across these boundaries. According to Reid et al. (2016), the boundary spanning model has effectively progressed by linking researchers and other stakeholders using boundary spanning agents, teams, and organizations. Based on their experiences of integrating social and ecological science of pastoralism in East Africa over three decades, Reid came up with model linking knowledge with action (Fig. 11). The model is a practical manifestation on how the linkage between knowledge and action has evolved over the decades.

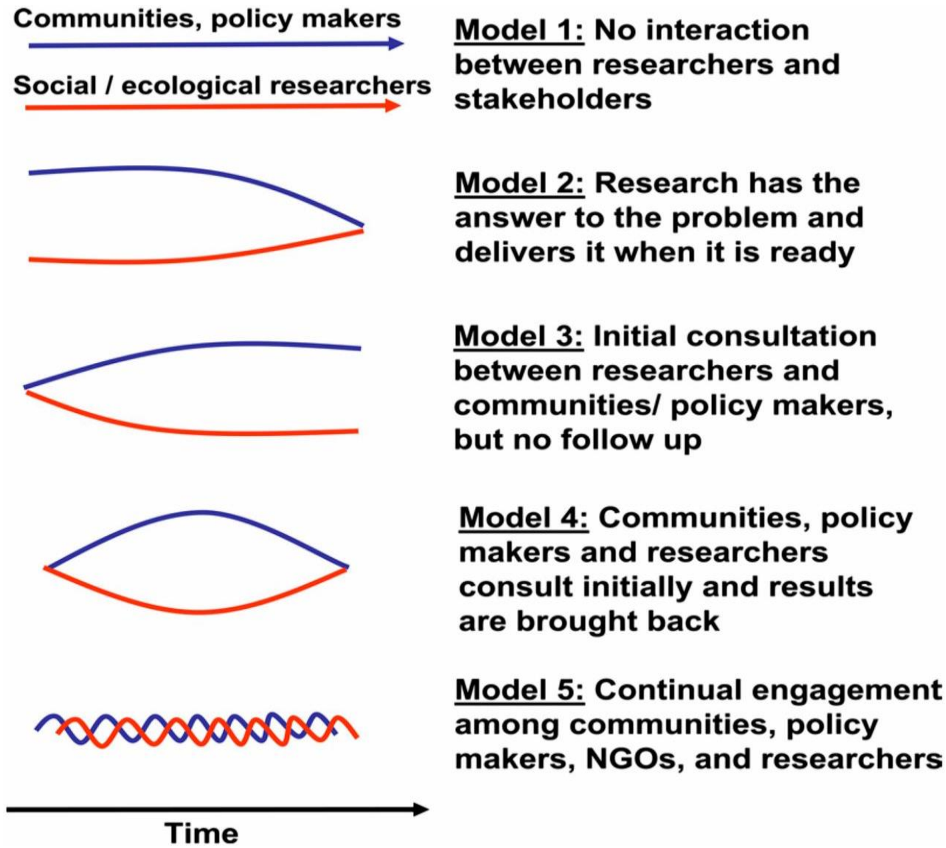

Figure 11: Evolution of models linking knowledge with action in pastoral systems of East Africa
Source: Adopted from Reid et al. (2016, p. 4581)

Drawing on the experiences on the nature of interaction between social-ecological researchers, policy makers and the pastoral communities in East Africa during the last decades, shows that the process has evolved from research that is disciplinarily planned and implemented where the stakeholders and research partners are research objects to a model where there is continual stakeholder engagement from planning to implementation as shown in figure 11 above.

Over two decades ago, research teams used Model 1 whereby there was no interaction between researchers and other stakeholders. During this stage, the research process was purely an academic exercise and driven to collect data from the pastoral communities. Being the norm during that time, the information was willingly shared by the communities despite the fact that their participation was reduced to mere field guides and respondents. As time went by, the members of these teams realized, the solutions to the problems were held by research. This evolved to model 2, whereby the research team members became actively involved with policy makers and the pastoral communities to create scientific information that is meeting their needs. At this stage, they directed their research on issues which they felt were of concern to the policy makers and the pastoral community in particular. So far these models seemed not to work. This shifted to some sort of participation where there were initial consultation between the researchers and other stakeholders on the research problem. However, at the end of the research project, there were no follow ups as shown in Model 3. In the 1990s, the researchers moved a step further by bringing back the research results to the community after initial consultations. This was done so that the research findings are interpreted and validated together with the community (Model 4). Along these stages of progression, there was continual improvement in terms of relationship among the stakeholders on mutual trust, facilitation and understanding on what was not working. This shows that, it is important, that the researchers and other stakeholders should always find ways to work as a team with mutual respect of the multiple cultural and knowledge perspectives. This not only ensures effective collaboration, but will also enable integration of knowledge and experiences. This is what is culminated in Model 5 where there is continual engagement among the researchers and other stakeholders through facilitation and full integration of their knowledge bases. Model 5 is built on the continuous conversation with a shared language, perceptions and understanding of different disciplines to bridge cultural differences and support cooperation across core spectrum of disciplinary, multi-, inter- and trans-disciplinary research approaches (Botha et al., 2014; Reid et al., 2016). One notable outcome of Model 5 was the generation of new knowledge which was jointly generated by economists and pastoral families in Kitengela town where an information system on household returns to different kinds of land use was created and is currently used to determine fair payments to pastoral families with incentives to avoid fencing their land for free livestock and wildlife movement (Nkedianye et al., 2009 cited in Reid et al., 2016).

Based on the example on the evolution of models discussed above, transdisciplinary research approach and model 5 has the potential to effectively address increasingly complex societal problems which cut across the boundaries between science and societal realms and generate new knowledge (Horlick-Jones & Sime, 2004). This can take place despite challenges involved such a political collisions, epistemic-cultural conflicts, mistrust between the stakeholders etc., This approach has changed the way scientific knowledge is produced with an increase in collaborative research where multiple disciplines cooperate within and across boundaries to develop integrated knowledge and theory (Mollinga 2010). This study applied this methodological approach in the implementation of the PPT to enhance stakeholder interaction and learning across research-practice levels by sharing knowledge on stemborer pest control and other integrated agricultural practices which can be used to inform further research and improvement of extension practice (Fig. 12). The conceptual framework of analysis is based on the innovation systems approach. This is aimed to explore how different actors in agricultural research and extension in Ethiopia can work together during technology planning and implementation to overcome research-practice boundaries. They are able to do this through integrating and sharing their respective knowledge bases, practices and experiences through interactive joint learning. The analysis draws further insights from Knorr-Cetina's theory (1999; 2007) on epistemic cultures and Mollinga's boundary crossing framework (Mollinga, 2008; 2010).

4.2 The Innovation Systems Approach

The concept of innovation system was introduced by Lundvall (1985) and has been defined and used by different authors (Freeman 1987; Lundvall 1992; Nelson 1993; Edquist 1997), largely based on the national developments of the industrial economies. Edquist (1997: 14) defined a system of innovation as "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations". The continuous processes of innovation that emerged from these settings were seen as central to the economic success of the industrial countries. This was fostered by the interaction and learning between scientific and private sectors in response to changing economic and technical conditions (OECD, 1997; World Bank, 2006). Correspondingly, the innovation systems perspectives on agricultural research and technological change are becoming a popular approach to the study of how society generates, disseminates, and utilizes knowledge (Spielman, 2005). Although this may be true, the traditional view of innovation in agriculture has been a linear process where research scientists generate technologies that are transferred by extension agencies to end users (Leeuwis & Van den Ban, 2004; Knickel *et al*., 2009). This view has been criticized for neglecting other societal actors as contributors to innovation, and for considering science as the only one source of legitimate knowledge (Leeuwis & Van den Ban, 2004). As a result of these criticisms, the linear view is being replaced by systems approaches where thinking has shifted towards other players in the agricultural sector as important actors in knowledge generation. While this stereotypical view may still be applicable, however under critical analysis, it has been shown that the process of knowledge generation and application does not take place in isolation (World Bank, 2006; Diebolt, et al., 2016).

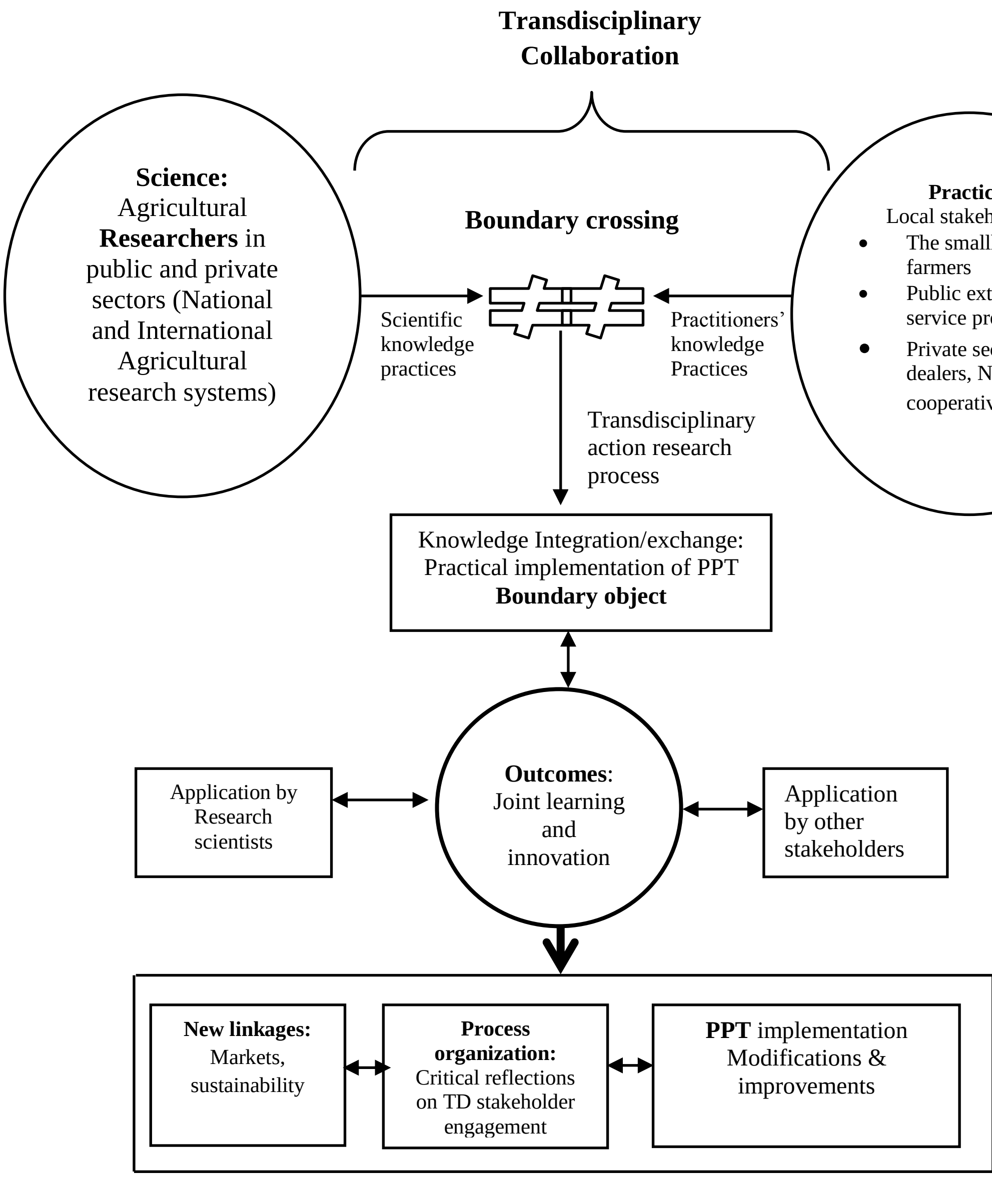

Figure 12: The Conceptual and Analytical Framework
Source: Authors' compilation 2016

As noted by Lundvall (1987), even the most conspicuous single innovation has its roots in accumulated knowledge and experience of different players and stakeholders. In response to such challenges, alternative approaches began to emerge and have gained momentum since, with the aim of achieving sustainable agriculture in collaboration with other players in sector and active participation of the smallholder farmers (Klerkx, et al., 2009). These approaches increasingly recognized integration of local indigenous or technical knowledge and practices with modern scientific knowledge to enhance technology generation and dissemination. These include various types of farmer participatory research in technology and innovation development (Belay & Abebaw, 2004). The table 3 below shows a summary on the evolution of agricultural knowledge, technology development and transfer models.

The introduction of participatory approaches in technology development during the 1980s, for example was seen as a paradigm shift away from the conventional linear approaches (Chambers and Jiggins, 1987). Lately, Agriculture Information Systems (AIS) in the year 2000s era came with a mental mode of co-innovation development in collaboration based on transdisciplinary, holistic systems perspectives (Klerkx et al., 2012; Reid et al., 2016). The intended outcome of these developments is the broader institutional change and developing the capacities to co-innovate and joint learning among different players i.e. the stakeholders in the agricultural sector.

The innovation systems approach lays its emphasis on bringing and working together all the relevant stakeholders encompassing the components of generation, dissemination, adaptation and adoption of new knowledge or putting into use the existing knowledge (Gevorgyan *et al.,* 2015; Caraça, et al., 2009). When these players are brought together they presumably complement each other's knowledge and capacities, aligning their practices, interests and commitment to solving common problems (Sanginga, (2009). The approach emphasizes the linkages between different stakeholder and interactive learning processes (Wennink, 2006) and provides framework on how different types of disciplinary and practice knowledge can be brought and work together (Sanginga, 2009) making it an important analytical tool for understanding the processes of production and distribution of knowledge (Edquist, 1997).

This study was implemented in Ethiopia, a country with a history of agriculture extension dating over 5 decades ago and has undergone several transformations in terms of approaches under different political regimes. This is done supposedly in search of better and improved services provided to the farmers for improved productivity. However, it has its share of challenges from lack of stakeholder involvement and participation in the generation and implementation of new agricultural technologies to linear processes of information communication. Thus, making it an interesting case to analyze. The country's historical and institutional context in extension services delivery has a contribution to the current status and performance of the sector. For example, the role of pluralistic extension service providers (the private sector and NGOs) is not fully recognized, but more of emphasis is placed on current regimes' political agenda which is ingrained in the agricultural extension system. An important promise of the innovation systems approach is that it is able to reflect on these institutional issues and also in embracing the researchers and local stakeholders as players in the agricultural sector to come and work together and regarding each other's knowledge as complementary to generate new and locally relevant knowledge or practices (Hornidge et al, 2009). Integrating knowledge across different communities of practice and sectors is an important milestone to address the complex nature of problems faced by humans. However, this neither is not straight forward affair nor guaranteed. The interaction between the researchers and other stakeholders is a bound to be faced by challenges such as mistrusts and conflicts arising out of different disciplinary specializations, experiences and expectations. We have used Knorr-Cetina theory on knowledge cultures and settings and Peter Mollinga boundary crossing framework to further reflect on the approach and make a deeper analysis into these perspectives. To achieve this, the PPT implementation is used as a practical example to show how the existing knowledge and practices among the stakeholders can be used in addressing the problem of stemborer pests in maize crop and how their interaction can contribute to learning to inform further research and improving practice.

Table 3: The Evolution of Agriculture Technology-Knowledge Transfer Models

Characteristics of the perspective	Type of perspective			
	Diffusion and adoption	**Farming systems research (FSR)**	**Agricultural Knowledge and information Systems (AKIS)**	**Agricultural Innovation Systems (AIS)**
Era	1950s and1960's	1970's and 1980's	1990's	2000's
Mental mode	Supply technologies through pipeline	Learn farmers constraints through surveys	Collaborate in research and extension	Co-develop innovation in partnerships
Knowledge and disciplines	Single discipline driven (e.g. breeding)	Multi-disciplinary (agronomy and economics)	Interdisciplinary (plus sociology and farmers)	Transdisciplinary, holistic Systems perspective
Drivers	Supply push from research	Diagnose farmers' constraints and needs	Demand-pull from farmers	Responsiveness to changing contexts and patterns of interaction
Relation with policy environment	Science is independent Institutional factors as External conditioners of adoption	Science is independent institutional factors as external conditioners of adoption	Science and technology develop in a historically defined context	Science and technology develop in a historically defined context
Role of science	Innovators	Experts	Collaborators	Partners, one of many responding to demands
Role of farmers	Adopters/ laggards	Sources of information	Experimenters	Partners, entrepreneurs, Innovators exerting demands
Innovators	Scientists	Scientists and extensionists	Farmers, scientists and extensionists	Multiple actors, innovation platforms/networks
Key changes sought	Farmer's behavior change	Removing farmers' constraints	Empowering farmers	Broader institutional change, creating innovation capacity
Intended outcomes	Technology adoption/ uptake and increased productivity	Farming system fit and removing the socio-economic constraints to adoption of new technologies	Co-evolved technologies better fitted to livelihood systems	Enhancing of local capacities to co-innovate, learn and change

Source: Adapted from Klerkx et al. (2012, pp.460-461).

4.3 Knorr-Cetina's Work on Epistemic Cultures

Production of innovations, application of new knowledge and use of information will be decisive for the society's success or failure in dealing with complexity from a local to a globalized economy (Pfister, 2009; Evers & Gerke, 2004; Evers, 2000). In particular, during this century, knowledge production and information dissemination is playing a pivotal role in the global economic and social development. This process rests as much on social interaction, life-world experience and culture (Evers, 2000). Knorr-Cetina (1999; 2007) argues that, the transition of contemporary societies to knowledge societies implies the growing importance of knowledge related cultures, specifically of epistemic cultures and knowledge cultures. "Epistemic cultures are the cultures of knowledge settings, and these appear to be a structural feature of knowledge societies" (ibid, 1999: p, 8). She argues that, the notion of disciplines and scientific specialties historically has been captured in a delineated environment in which knowledge was constructed and under which it became disseminated and applied. "But this concept proved less felicitous in capturing the strategies and policies of knowing that are not codified in text books but to inform expert practice''(ibid, p.3). She thus uses the concept of epistemic cultures to "amplify the knowledge machineries of contemporary sciences until they display the smear of technical, social, symbolic dimensions of intricate expert systems" (Ibid, p. 3). Culture here she refers to as "the aggregate patterns and dynamics that are on display in expert practice and that vary in different settings of expertise" (Ibid, p. 8). "She gradually shifted attention from the construction of knowledge to the preconditions of such construction, to the construction of environments, tools, infrastructures, that enable construction and dissemination of knowledge" (Van Assche *et al.,* 2013). She captures these under the notion of epistemic cultures and defines them as "those amalgams of arrangements and mechanisms, bonded through affinity, necessity and historical coincidence, which in a given field, make up how we know what we know" (Knorr-Cetina, 1999).

Knorr-Cetina (2007) demonstrates that it is not always possible to distinguish between production, dissemination and application, as they might be dependent on the same infrastructure or as parts of these infrastructures that might influence the quality of the epistemic activity in seemingly remote domains. Epistemic cultures are not entirely closed environments, they are linked to many factors ranging from policies to organizations, objects, methods, machines and concepts and even the society as a whole (Van Assche *et al.*, 2013). These linking elements are both enabling dissemination of understanding and the continuous transformation of this knowledge (Knorr-Cetina, 2007). Institutional and disciplinary structures crucially influence the development of epistemic and knowledge cultures and continue to be geographically bounded (Van Assche et al., 2013) between global knowledge and its expert cultures and those areas of practice and mentality which remain local (Knorr-Cetina, 1999; 2007). This implies that local knowledge and scientific knowledge cannot be clearly separated and their epistemic cultures are always locally embedded (Van Assche et al., 2013). This is from the point of view that, their efforts are meant to solve a common problem. However, the challenge has been how we bring these two to start to work together to co-create new knowledge to address common society problems. Research scientists and experts have an orientation to focus on the scientific rather than practical application of knowledge generated. This concurs with Knorr-Cetina (2007) where science and expertise are obvious candidates for cultural divisions, as they are pursued by specialists separated off from other specialists by long training periods, intense division of labor and distinctive technological tools. However, because of different epistemic cultures involved, each one with specialized professional language, unique objectives and individual understanding of technology, collaboration is likely to suffer from cultural impediments to interdisciplinarity. That means, epistemic unity becomes casualty of the cultural approach to knowledge production because each stakeholder fosters own unique epistemic culture (Knorr-Cetina, 2007; 2009). Due to the complexity of the nature of problems addressed by scientific research, transdisciplinary collaboration (Hirsch Hardon et al., 2008) is critical to achieve this in terms of integrating knowledge across different communities of practice. Although this may come with costs such as collisions from disciplinary misunderstanding and conflicts, the integration of scientific knowledge with local practice is worthwhile course to engage in. Indeed, despite the so called epistemic causalities, mutual learning among the researchers and others stakeholders is robust enough to spur innovation.

Based on Knorr-Cetina theory, drawing on the knowledge cultures and settings of stakeholders with different disciplinary specialization and practice was important during planning and implementation of the research process. In addition, to better understand and facilitate learning and innovation in situations of knowledge sharing or linkages, it is very important to examine the mechanisms that allow joint endeavors and connections between their diverse epistemic cultures (Tisenkopfs et al., 2015). According to Wenger (1998), an established practice not only creates boundaries, but also develops opportunities to interact with other practices. Thus, boundary objects help bridge different communities of practice and boundary work helps to understand and manage the disciplinary and practice demarcations inherent in the participating actors. This study applied PPT as boundary object in order to bring different stakeholders together to integrate their knowledge in order to address the stemborer pest problem. It is also used as a tool to support interaction and participatory learning among the stakeholders to generate new ideas, concepts or strategies which can be in turn used to support research and extension practices. In addition, the PPT was being extended to new sites in Ethiopia and involving multiple stakeholders who had not worked transdisciplinary teams. It is an opportunity used foster knowledge transfer and sharing.

4.3 Mollinga's Boundary-Crossing Framework

In the process of innovation development, not only different perceptions but also different interests of researchers and others stakeholders should be understood and taken into consideration. This is arising from the fact that, human societies have developed into multi-faceted, highly fragmented and diverse entities with a broad array of differing interests, views, knowledge structures, perspectives, norms and values (Becker and Jahn 1999). Therefore, understanding and addressing complex societal problems such as stemborer pests in the smallholder maize crop farming systems, extends beyond the scope of a single discipline, profession or approach. This requires integration of diverse knowledge cultures in analyzing, understanding and addressing such problems. Similarly, the problems facing the society are interlinked in terms of societal and ecological processes, and the scientists and non-scientists need to learn and understand such complexity to be able to develop practical and relevant innovations (Popa *et al.,* 2015). To enable effective and fruitful collaboration among scientists and non-scientists, instruments for effective boundary crossing have to be developed and put into practice (Evans, 2005; Gieryn 1983). Science-practice integration is a form of boundary crossing (Mollinga, 2010). However, it does not happen automatically, it requires a concerted effort. The Mollinga in his framework raises these concerns regarding the kind of gates, bridges, and other cross-over devices and procedures which should exist at the boundaries to make the integration to take place and more effective. Equally, Akkerman and Bakker (2011) and Lundvall (1992) found out that, innovation is a consequence of different learning mechanisms taking place in the situations of boundary crossing by different kinds of actors and agents involved. As has been pointed out by Van Assche et al. (2013), these actors are linked by many factors which can either be methods, objects, machines etc., meaning that they don't work in closed environments.

The implementation of PPT was not only meant to enhance integration of the different stakeholders, but also enable them to learn during the interaction process. The implementation of different PPT activities was an opportunity for stakeholder interaction and learning in a stepwise process. According to Akkerman and Bakker (2011), the learning mechanisms involves; *first,* identification, whereby the integrating cultures or disciplines are discussed and defined in the light of one another i.e. how they are delineated and how possibly they can co-exist; *second,* coordination of among the researchers and others stakeholders to allow diverse practices to cooperate efficiently in distributed work and through dialogue; *third,* reflection process, referring to mutually defining the different perspectives that each intersecting culture or discipline brings, and openness to take up others' perspectives and knowledges, and to look at one's own practice; and *fourth,* transformation process, whereby shared problem space is defined, on the basis of which the intersecting cultures are integrated by combining different perspectives and methods. However, as pointed by Knorr-Cetina (2007; 2009), achieving epistemic unity of common understanding from a diverse knowledge base and cultures is not automatically guaranteed. This is because each of the stakeholders has own and unique epistemic culture, knowledge and even interests which in one way or another they are not willing to let go or diluted. Equally important is the fact that, the history of agricultural extension in the country and ruling regime's tight political control of extension activities and the limited role of private sector has important institutional ramifications on the integration and learning processes.

Scientific knowledge is sometimes put in such a dilemma when required for decision making in situations structurally characterized by incomplete information, uncertainty, non-linearity or unpredictability (Mollinga, 2008). The boundary objects and participation are drawn upon both to understand the multiplicity of knowledge systems and to suggest possible approaches to the creation of effective solutions (Puri, 2007). Using Star and Griesemer (1989), definition, boundary objects are referred to as objects which are,

> […] both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds (p, 393).

According to Bowker and Star (1999) and Fischer and Reeves (1995), boundary objects are objects that both inhabit several communities-of-practice and satisfy informational and multiple requirements of each of them simultaneously and are used as a means of coordinating and aligning differing perspectives across social and geographical boundaries. On-farm implementation of PPT was used as a boundary object and platform to initiate and enable dialogue, interaction, and learning amongst the researchers and other stakeholders to address the problem of stemborers in maize crop production and other related farming challenges.

Chapter 5:
The Push-pull Technology

5.1 Scientific Developments of Push-pull Technology, Design and how it Works

In Ethiopia maize accounts for 28 percent of the total cereal production compared to sorghum (22%), and *teff* (20%) (CSA, 2010/2011; Demeke, 2012: p, 6). Smallholder farmers accounts for more than 90 percent of the total agricultural production and 95% of total maize area cultivation. The average yield is about 2.5 t/ha (Abate et al., 2015; CSA, 2011). This is below the potential average of 5 t/ha (Cairns et al., 2013, Smale et al., 2013: p, 27). Higher productivity in the maize sector has potential to propel Ethiopia's food production and reduce the national food deficit and to keep pace with the growing population. However, maize production is severely constrained by stemborer pests and parasitic weeds, particularly *Striga*, and low soil fertility (Mantel & Van Engelen, 1999; Oswald, 2005). Among these, stemborer is the most important and it can result in significant yield losses ranging from 10 to 80% of the total maize yield, depending on pest population density and phenological stage of the crop at infestation (Ampofo, 1986; Kfir et al., 2002; Khan and Pickett, 2004). Stemborer control is, however, difficult, largely as a result of the cryptic and nocturnal habits of moths, and protection provided by host stem for immature pest stages (Midega et al., 2015). The pest infestation seriously limits the potential of the maize crop throughout its growth from seedling stage to maturity (Khan and Pickett, 2004). Controlling of these pests is very important to the smallholder farmers who are affected directly due to the yield loses incurred. The control measures mostly advised by extension services to smallholder farmers are based on the use of pesticides, which is not only harmful to the environment and humans but also expensive for smallholder farmers (Midega et al., 2013; Tende et al., 2010) and even the emergence of pesticide resistance (Khan and Pickett, 2004).

The researchers and other stakeholders in the agricultural are challenged to devise alternative control measures to the use of pesticides which are cost effective, easy to apply and environmentally friendly. Such measures should also be able to put stemborer pest control within the reach of the smallholder farmers and tailored to the diversity of their farming systems (Pickett et al., 2008). Based on this considerations, the International Centre of Insect Physiology and Ecology (*icipe)* researchers, Rothamsted Research in the UK in the early 1990s commenced studies on the ecology of stembores pests with a view to come up with and a develop an integrated pest management (IPM) approach. Their efforts together with farmers, national research and extension partners culminated to the development of the Push pull technology (PPT) as an ecological approach for pest management based on a combined use of inter-and trap cropping systems where stemborers are driven away from maize crops by push plants (Push) and attracted by trap plants (Pull).

The concept 'Push-pull' as a strategy was originally documented by Pyke et al. (1987) as a potential method in the management of cotton pest, *Heliothis sp.* The method involved the use of an attractant trap crop and a chemical feeding deterrent to control the pest. A few years later Miller and Cowles (1990) refined and formalized the 'Push-pull' concept as 'stimulo-deterrent diversion' strategy and used the system for protection of onion crop from the onion fly infestation. Common to these initiatives was the use of a chemical deterrent or toxin to repel or kill the insect pests. However, none of these methods exploited natural means (Khan et al., 2003). To contribute to this knowledge gap, the *icipe* researchers and partners moved a step further by exploring how a cereal based cropping system can exploit natural insect–plant interactions and relationships in the management and control of stemborer pests (Khan et al 1997). These efforts, together with the researchers' knowledge drawn from earlier research initiatives and experiences (e.g. pest control in cotton and onion crops), effects of pesticides use during the Asian green revolution (Pyke et al., 1987; Miller and Cowles, 1990; Forget, 1993) bore fruit in the development of the PPT. Over 25 years, a close working relationships and the joint efforts by researchers from *icipe*, Rothamsted and other partners from the national agricultural research institutes from Kenya (KALRO), Uganda (NARO), Ethiopia (EIAR), and Tanzania (LZARDI) has continued with the smallholder farmers and extension support staffs in furthering the development of the PPT as an innovation.

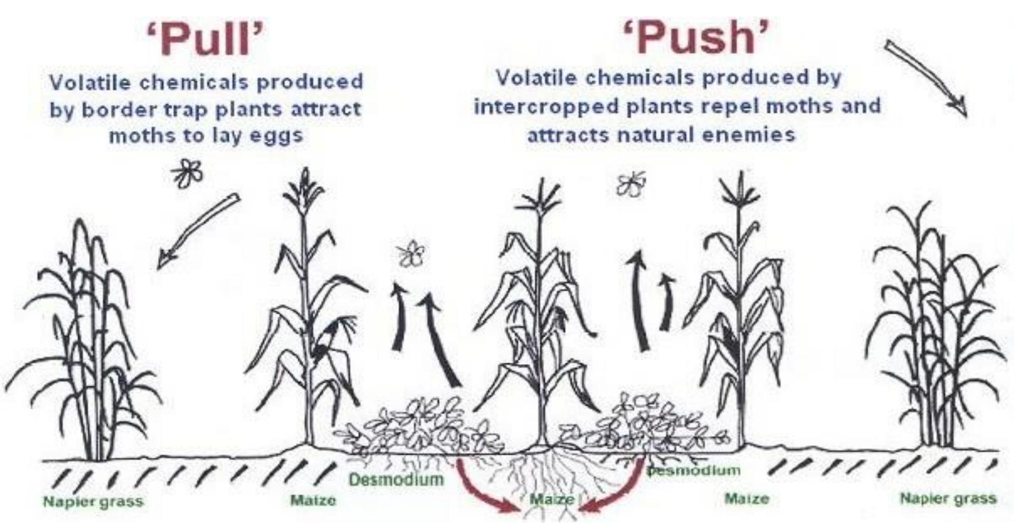

Figure 13: How the Push-pull Technology works

Source: Khan et al. (2014, p.5)

The PPT has been dubbed as a multi-functional innovation strategy that addresses concurrently maize production constraints of stemborers, *Striga* weed, low soil fertility and low soil moisture retention (Khan et al., 2006; 2014). In this strategy, maize is intercropped with a fodder legume, Desmodium (the push), together with an attractant trap plant, Napier/Brachiaria grass (the pull), planted around maize-legume intercrop as shown in figure 13 above. The chemical volatiles produced by Desmodium repel stemborer moths while those produced by the trap grasses attract them (Chamberlain et al., 2006). In addition, Napier grass or Brachiaria grass does not support all stemborer larvae to develop fully and hence the majority of them die before reaching maturity (Khan et al., 2007). Besides stemborer control, Desmodium also suppresses and eliminates *Striga,* leading to significantly enhanced maize grain and biomass yields (Khan et al., 2006) through allelopathic effect(Khan et al., 2000; 2002; Tsanuo, et al., 2003). Desmodium roots produce a blend of chemical compounds, some of which stimulate *Striga* seeds to germinate while others inhibit lateral growth of *Striga* roots, thereby hindering their attachment to maize roots. The *Striga* emergence is thus suppressed, with an *in situ* reduction of soil seed bank (Khan et al., 2002). Research and practice developments on PPT, has shown that it supports other integrative components of human nutritional and sustainable livelihoods such as animal husbandry and dairy farming through fodder provision, soil improvement, agro-ecosystems resilience through crop intensification, income generation and meeting food security demands of smallholder farmers (Khan, et al., 2008).

The developments of the PPT have been undertaken using a holistic and concerted approach among the researchers and other stakeholders by exploiting their vast knowledge and experiences from chemical ecology to agro-biodiversity in the management of the stemborer pests. The companion crops which were introduced to the cereal crop farming systems were selected from their natural environments based on studies conducted from 1994-1995 in the coastal and western regions of Kenya (Khan et al., 1997). These studies were aimed to expand knowledge on a range of natural hosts and crop plants of cereal stemborer, and to assess on host suitability for insect development and oviposition. Out of the recorded of over 500 grasses, only about 30 species of grasses were identified as preferred hosts of cereal stemborers. It was observed that oviposition was heavy on these grasses, but only on a few was able to complete their life cycle to maturity. This was an indication that the grasses acted as trap plants for the stemborers and could potentially be used as a natural method to reduce their populations. Out of this pool of candidate trap plants, Napier grass (*Pennisetum purpureum*) and Sudan grass (*Sorghum sudanense*) ranked best. When these grasses were planted on the border rows of the maize crops, the stemborers were attracted to lay their eggs on them rather than on the maize. They were effective in providing a ‘pull’ effect but also had own protective mechanisms against stemborer attack. For example, under the Napier grass, when the larvae bore into its stem, it secretes a sticky gum which traps the stemborers thus preventing most larvae from completing their life cycle. Whereas, Sudan grass provided a natural habitat and reservoir for stemborer predators such as African parasitic wasp (*Cotesia sesamiae*), ants, spiders and cockroaches (Khan et al., 1997).

The on-station research and demonstrations showed that cereal crops planted with the grasses can co-exist in the same farmland and easily control the stemborers. However, convincing the smallholder farmers to introduce them on their small farms for pest control was a big challenge for the researchers. It required a lot of dialogue and working together. The researchers, with their scientific discoveries at hand, embarked on-farm research trials to evaluate these candidate grasses together with farmers and extension service staffs from the ministries of agriculture and livestock development. Despite the joint experimentation, the research was led by the scientists. In addition to stemborer control, other benefits of introducing the PPT on-farm were also evaluated such as source of livestock fodder for the smallholder farmers, soil and water conservation measure. Out of other candidate grasses, Napier grass (Bana variety) was selected by the farmers due to its smooth, broad leaves which provide bulk biomass for perennial livestock fodder. Combined with its preference by the stemborer moths for oviposition and minimal survival of the larvae (Khan et al., 2006; Khan et al., 2007) as shown in Fig.14 below, it emerged the best 'pull crop'. The molasses grass as a 'push crop' has a strong repellent effect on stemborer moths and attractive to the natural predators which feed on the eggs of stemborer (Khan et al., 1997). The farmers preferred molasses grass and an intercrop. It also provided additional fodder for their livestock.

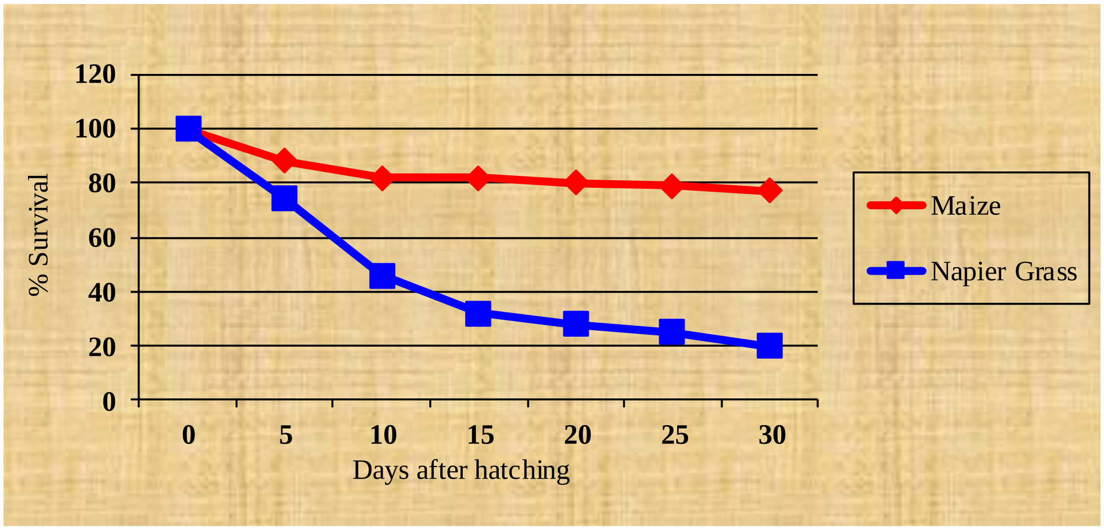

Figure 14: Survival of stemborer larvae (*Chilo partellus*) in maize and Napier grass

Source: Khan et al. (2006, p. 207)

At this stage of research process, the two grasses i.e. Molasses grass and Napier grass with 'push' and 'pull' effects on stemborers and suitable fodder crops were selected as best candidates. However, convincing the smallholder farmers who are constrained with land in terms of acreage and ownership, to start growing two additional grasses together cereal crop for stemborer pest control was difficult. This again prompted the researchers together with smallholder farmers to search for other crops to be incorporated into the ‘push-pull’ system as alternatives to these grasses. Traditionally, under the smallholder farming systems, farmers plant legumes as intercrops with cereal crops as a diversification strategy in case of crop failure. The additional crop serves as insurance. This age old farming practice drew the attention of the researchers on the use legumes as an alternative intercropping strategy with ‘push’ effect. The suitability tests and potential of various legumes (common bean, Desmodium, green grams and cow peas) were conducted at the on-station experiments. Out of this pool, Desmodium *(Desmodium uncinatum)* emerged as the best and promising candidate (Khan et al., 2007). Additionally, as other legumes, it has capacity improve soil fertility through nitrogen fixation, provide additional source of fodder for livestock. The final selection stage of the best candidates, the smallholder farmers were convinced and selected silver leaf Desmodium and Napier grass as the best push and pull plants respectively.

The dissemination of Push–pull technology as package of began in 1997 and the number of adopter farmers began to grow steadily to an estimated of over 100,000 farmers in the eastern African region (Midega et al., 2014). The growth in terms of number of practicing farmers, the area covered and the research publication has been steadily rising over the years. The dissemination was in itself not the end of the research engagement process, but the beginning of a second generation research period when new questions and challenges emerged. These once again engaged the researchers and other stakeholders on further studies and trials both in the laboratory and on-farm experiments. Such challenges include; the adaptation of the ‘push and ‘pull’ plants to climate change, emergence of previously unrecognized pest problem of blister beetles, the napier stunting disease, the sustainability of Desmodium seed supply for new PPT farmers among others. This was borne in mind that the long term sustainability of PPT is depended on the durability and effective performance of the companion cropping.

5.2 The ‘Push’ and ‘Pull’ Challenges and the New Research

5.2.1 Climate Change Effect

The performance and sustainability of the PPT under changing climatic conditions was a second generation research and development concern for the researchers and other stakeholders. Conventionally, effective performance of the PPT utilizes the silver leaf Desmodium as repellent intercrop and Napier grass as trap crop. However, changes due to environmental factors such as drought and rainfall have effect on its performance regarding plant-insect interactions (Khan et al., 2014). In order for PPT to perform in or to be extended to drought prone areas, identification of drought tolerant trap and intercrop plants was an important and necessary step (Khan et al., 2014; Pickett at al., 2014). In order to understand and address this challenge, the *icipe* researchers initiated a study to investigate the impact of water stress on the 'push-pull' crops and other grasses on the oviposition preference of the stemborer moths, larval feeding and development on these grasses (Chidawanyika et al., 2014). The study was conducted with the aim of selecting plants that exhibit desirable traits compatible with the 'push-pull' companion cropping system even under drought stress conditions. In this study, five host grass species (Maize crop, Napier grass, Signal grass, Brachiaria cv. 'Mulato', and Molasses grass) were tested. The results showed that stemborer moth responses to drought-stressed plants varied with grass species. One notable observation made was that of Napier grass under drought stress conditions may not be effective to be used as a trap crop to divert stemborer moth oviposition from the maize crop (ibid). This is an indication that drought stress can change host preference and acceptance. An evaluation study on Desmodium intercrops involving the use of 17 different Desmodium species, the Greenleaf Desmodium (*Desmodium intortum*) showed its ability as a 'push crop' to control stemborers, tolerant to higher temperatures and at the same time able to fix nitrogen in the soil (Khan et al., 2005). Based on these studies, Brachiaria cv Mulato grass (trap crop) and Greenleaf Desmodium (intercrop) were identified to tolerate long droughts and can be used as candidate crops to extend PPT to drier areas (Midega et al, 2015). On-farm field trials and evaluation have shown that using these two companion crops under the adapted Push–pull technology(i.e. climate-smart PPT) provides effective control of stemborers resulting in significant grain yield increases (Murage et al., 2015).

5.1.1 Napier Grass Stunting Disease

As the name depicts, Napier grass stunt disease affects Napier grass, an important companion crop in the PPT strategy. Although the disease was reported previously in the eastern African region in the years 1997 in Kenya, 2001 in Uganda and 2004 in Ethiopia (Orodho, 2006; Jones et al., 2004, 2007; Nielsen et al., 2007), its mode of transmission was unknown. The *icipe* researchers together with other stakeholders later on discovered that, the disease is transmitted by a leafhopper (sap-sucking insect) called *Maiestas banda* (Obura et al., 2011*)*. After infection, the disease rapidly infects the whole plant causing an extensive damage and the stunting symptoms are manifested in re-growth after cutting or grazing (Orodho, 2006; Khan et al., 2014b). This means that, the Napier grass may look health but infected. The disease is spread over long distances by farmers unknowingly by use of infected canes or root splits which they share as vegetative planting materials. But over short distance between plants within a farm, it is spread by a vector (Bové and Garnier, 2002). Apart from the disease effect on PPT expansion, it has a devastating effect on dairy industry which is heavily depended on Napier grass fodder. Based on the survey conducted (Khan et al., 2014b; Asudi et al., 2015), it was shown that over 80% of the farmers, had their Napier grass was already affected by the disease and did not have effective management approaches. The measures which they were using were either rogueing or planting alternative fodder grasses. But the effective management option was to develop resistant Napier grass cultivars (Asudi et al., 2015). This challenge further engaged the researchers in search for alternative measures. The research is in progress.

5.1.2 Blister Beetles

As discussed above, the 'pull' and 'push' components are responsible for the effective performance of the PPT. The 'push' is provided mainly by Desmodium intercrop. The supply of Desmodium in sufficient quantities to meet the demands for expansion of PPT is dictated by the production of enough quantity of seeds. The Desmodium seed production can be met by farmers either individually or in groups under commercial production arrangements. However, this is seriously faced with the challenge of pdest infestation by blister beetles which feed on its flowers (Lebesa et al., 2011). This has a direct negative effect on the quantity of seeds produced and eventually available in the market for the establishment and expansion of the PPT. A study by Lebesa et al. (2012) in western Kenya on farmers' knowledge and perception on the pest status showed that, the effects of the blister beetles were experienced by the farmers who were engaged in commercial seed production. The farmers who established Desmodium farms as pure stand or monocrops experienced higher pest infestations and low seed yields as compared with those on the Push–pull plots. The explanation given by the researchers on the observed differences on infestation was linked to less efficient location of Desmodium by the blister beetles in a 'polyculture' system and the pests' ability to alternate between the two hosts i.e. maize crop and Desmodium to obtain different food resources to balance nutritional requirements (Lebesa et al., 2012; Altieri et al., 1993). That means without any management or control measures, large scale production of Desmodium seeds can be severely constrained by the blister beetles. At the same time, small scale production under PPT plots cannot produce sufficient quantities of Desmodium seeds required in the 'PPT generated market'.

5.3 Farmer Practices in the Development of the Push-pull Technology

The smallholder farmers are the targeted beneficiaries of an effective and easy to establish PPT. That means their participation during research and development process of the PPT plays an important role in terms of legitimizing the findings and operationalization as an innovation. This was shown by number of farmer led research initiatives e.g. integrating common beans in an established PPT plot, contribution of research materials for Napier stunt on farm research and the use of Desmodium vines as alternative to seeds in the establishment of the PPT.

5.3.1 *Integration of Edible Beans*

Traditionally the smallholder farming systems are characterized by mixed cropping patterns as an intensification strategy to increase production per unit area and also increase chances of harvesting at least some crop in case of failure. This strategy is equally useful for pest management (Altieri et al., 1993). For example, under normal maize crop farming systems, farmers intercrop the main crop with edible legumes such as common beans as source of supplementary plant protein in their diets. Under PPT, the introduction of Desmodium which is not edible by humans is used as an intercrop in the place of common beans. The new intercrop greatly put strain on farmers who value beans above other alternative crops or the potential PPT benefits. This new development among others, discussed above, brings another twist in the promotion of PPT and its acceptability among the farming households who value and depended on edible beans as sources of proteins. Although the researchers knew they were replacing the beans with Desmodium during the design of PPT plot, their major focus was on the control of the stemborer pests and *Striga* weeds. Drawing on their disciplinary competencies and career expertise, there was an assumption that the farmers concerns were important in the promotion and dissemination of the PPT. Faced with the twin challenges i.e. cereal pests and replacement of beans, the farmers went ahead on their own intuition and introduced beans in their PPT plots by planting them in between and in the same hole with maize plants. Between the rows of maize, the Desmodium line was maintained as originally designed by PPT. This new intervention and development attracted the attention of the researchers who initiated a survey to assess overally farmers' practice and perceptions on intercropping and willingness to integrate beans in their PPT plots. The survey findings showed an overwhelming majority (92%) were willing to integrate beans in their PPT plots (Khan et al., 2009). This was followed by the on- station experiments to further evaluate on the effects of integration of beans in the PPT with maize–Desmodium intercrops. The on-station evaluation as well on-farm findings showed that, planting arrangement did not compromise stemborer control, instead, there was a guarantee of additional beans to supplement household source of proteins (ibid).

5.3.2 *Farmers' Experimentations*

The conventional linear or top down approach by research and extension, is designed such that, the smallholder farmers who are the intended beneficiaries, are expected to accept the researchers' driven experiments, generated technologies and findings. With such a relationship, the farmers' initiatives are not recognized or undocumented. The researchers working under PPT have tried to overcome this stereotype of relationship on a number of occasions. For example, scientists who are engaged in Napier stunt disease research have incorporated the farmers in terms of their perceptions, experiences and knowledge on the effects of the disease. It was discovered from the survey conducted by Khan et al., (2014), that some farmers were growing Napier grass variety that had not been affected by the disease. This was an indication of a possibility of resistant or tolerant Napier grass varieties that were available. The laboratory process of selection, screening and identification of resistant Napier varieties started from a point of knowledge of existence of resistant or tolerant varieties. This background information had been provided by the farmers and researchers acknowledged it as an important starting point.

The Blister beetles infestation, as discussed above, pose a serious challenge in the production of Desmodium seeds input for the expansion of PPT. Farmers who are faced with this challenge directly, cannot wait for researchers to come up with a working alternative. This will take them a long time. As an alternative to this challenge, the farmers devised a stop-gap measure in case Desmodium seed production is completely wiped by the pests. Thus, they started using vines or cuttings as vegetative means of propagation. Meanwhile, the control measures which were recommended by the extension service providers such as use of chemicals, handpicking of the blister beetles and crushing them and the application of ash were either expensive, laborious and time consuming. The researchers' recommended the use of simple traps developed from a combination of visual and olfactory cues as the potential control or alternative strategy (Labesa et al., 2011; 2012). The production of these traps has not been finalized and the problem has to be addressed. The use of Desmodium vines by the farmers was based on their practical knowledge on planting other crops such as sweet potatoes. They did an experiment with mature Desmodium vines and they found it working. Between the rows of maize crop, they make furrows and plant the vines by ensuring that the hair roots are buried in the soil in a continuous line. This has to be done when there is sufficient moisture in the soil for faster establishment. The farmers shared these findings with researchers and were found to be effective during on-station trials.

These two examples is a proof of a changing trend where the input of the end users is used as basis for conducting research and experiments. As pointed by Reid et al. (2016), initially, most of the researchers developed their careers by extractive model of taking information willingly or unwillingly from their subjects. However, there is the realization, that real world problems cannot be solved by individual approaches, but require continual engagement among the researchers from planning to implementation of research with other stakeholders. The design of the second and third generation PPT research projects should be driven by transdisciplinarity approach in the scope of design and implementation.

5.4 Dissemination and Economic Analysis of the Push-pull Technology

Access to and exchange information and knowledge regarding PPT plays a key role to enable learning and stakeholder interaction to take place (Murage et al., 2012). Farmer based information sourcing and dissemination has a strong contribution towards achieving this. This is attributed to fact, such pathway of communication emphasize on practical farmer to farmer learning (Erbaugh, 2007; Wambugu, 2006). The use of farmers as extension agents is seeking to contribute to overcoming barriers related to access, utilization of information, understanding farmers' information needs, and designing effective dissemination pathways (Amudavi et al., 2009). However, the dissemination of knowledge intensive technology such as PPT (Khan et al., 2007) requires more than a single dissemination pathway. This is partly attributed to the constellation of actors involved in the PPT, specific nature of pests and crops involved and diversity of farm and farming systems. Different pathways have specific emphasis on what aspect of PPT is promoted from awareness creation to practical training and learning. Additionally, dissemination pathways on new farming technologies such as the PPT are resource driven and this has an implication on the promoter's capacity to invest in a specific pathway that is feasible and can be able to reach critical mass of targeted beneficiaries and achieve economies of scale (Murage et al., 2012). The same applies to the resource constrained smallholder farmers who may not be willing to incur costs in search for new information although they may need it (ibid.). This shows that the choice of dissemination pathway has effect on farmers' decision making on the adoption or adaptation of new technologies being promoted (Doss, 2006).

Based on these considerations, the *icipe* researchers initiated studies to evaluate the effectiveness of the different pathways in the dissemination of the PPT. Several channels have been applied in the dissemination of the PPT ranging from interpersonal communication to the use of mass media such as the use of Radio and Television programs, print materials (fliers, manuals and comic books) and participatory videos (farmer led and expert directed and produced). These studies were undertaken mainly in Kenya, Uganda and Tanzania (Amudavi et al., 2008; 2009; Murage et al., 2011; Ouma et al., 2014). The findings show that, exposure to different dissemination pathways significantly influenced likelihood of PPT awareness and adoption among different categories of farmers. For example, Murage et al. (2011a) found out that the different pathways had different levels of effectiveness depending on the farmer category. The farmers who were less educated preferred the field days, while those with small parcels of land preferred farmer teachers, the farmers belonging to groups preferred Farmer field schools (FFS) while the young and educated preferred printed materials. The same study established that field days had the highest effect on the speed of PPT uptake followed by the farmer teachers. Understanding such different effects of pathways is useful to help the extension delivery stakeholders to target different groups of farmers with different pathways of knowledge transfer based on their preferences and also which allow for effective interaction in information sharing and learning (Murage et al., 2011b). The study by Amudavi et al. (2008) which assessed the effectiveness of field days (FD) in PPT dissemination, established that through the FDs farmers were able to overcome information and learning-related constraints to stemborer pest control, and enhanced their ability to plant and manage maize using PPT. Also in another a related study by Amudavi et al. (2009), on the effectiveness of farmer teachers, they found out that on average, one farmer teacher influenced about 17 other fellow farmers in adopting PPT while these fellow farmers influenced other two farmers within the 3–4 year period.

Several studies were initiated by either economists or agronomists from different international and national institutions (IITA, AATF, CIMMYT, KALRO, Kenya seed company) evaluated the economic benefits the PPT (Khan et al., 2008b; De Groote et al., 2010a; 2010b; Khan et al., 2011; Khan et al. 2014). Uniquely, these researchers were promoting alternative technologies on the control of *Striga* and stemborer. The different technologies include; the PPT, resistant hybrid maize, conventional herbicide application, seed varieties coated with herbicides, Germination stimulants etc. The working together of these researchers and stakeholders from such diverse institutional and organizational set up did not take place without some form of mistrust and conflicts. The study experiments were not about their disciplinary approaches or business interests but to have a favorable rating of their 'own' as alternative and effective technology. In their comparisons with conventional maize mono cropping or maize rotated with food legumes or using herbicides, they established that productivity of maize under PPT cropping system is higher and profitable than the other systems under smallholder farmer production conditions. They noted that, although PPT requires slightly higher investment cost at establishment stages, it is still profitable (De Groote et al., 2010a). Thus making PPT is a viable option for the farmers who are depended on limited land resource on one hand and cannot afford high costs of inputs for pesticide application in the control of stemborer pests and fertilizers for improving soil fertility on the other hand.

5.5 The Development of the Push-pull Technology as a Social Innovation

There is sufficient evidence during the last 20 years or so showing that *icipe* and partners have made considerable effort in research and development of the PPT as an innovation. The development of the PPT since its discovery has been mainly through interaction of researchers and other stakeholders through various research activities and contributions from the end users, especially the smallholder farmer. The researchers are mainly drawn from international and national research centers, while other stakeholders from national extension systems, Non-governmental organizations, farmers groups and individual farmers. The interaction processes either at institutional or individual levels, has evolved from the research topic in the hands of research scientists to an innovation in the hands of farmers. As it was pointed by Khan et al. (2007) and De Groote et al. (2010a), the PPT is knowledge intensive technology and profitable, but requires slightly higher investment cost at establishment stages in terms of inputs and labor. That means, after establishment, the remaining activities such as thinning, trimming and weeding of Desmodium, harvesting the crops etc. are easy to manage. Its multipurpose nature in terms of use and benefits is an incentive which attracts other stakeholders on board. The PPT established and development is seed based and driven (Desmodium, maize, Brachiaria, other legumes such as beans). This is attractive to the stakeholders with commercial interest from the private sectors who are dealing with agricultural inputs. They can invest in seed production and distribution. That means, the PPT is potentially contributing to the development and strengthening of the private sector.

The evolution and developments of the PPT up to date, has been able to allow additional modifications without compromising it performance. From this point of view, it has shown that it can effectively be applied as a boundary objects (Star, 1989). Its adaptability and fit into smallholder farming systems in different agro-ecological zones has enabled it to be accepted and implemented in different locations by different stakeholders in the eastern African region and even beyond. The on-farm introductions and practical demonstrations of the PPT have shown that, in situations where it has faced challenges, the participation of farmers has introduced new ideas which the researchers had not known nor considered before. This is one of the contributing factors which have kept the research and development of the PPT interesting and sustained. The Napier grass stunt disease research, edible bean integration in PPT and use of vegetative vines in the establishing Desmodium are some of the examples. According to Diebolt et al. (2016), innovation cannot take place in isolation. Such developments in the PPT are as a result of the contributions from research scientists, extension workers from different academic and professional disciplines and smallholder farmers and traders. The multiplicity of stakeholders in the PPT innovation is attributed its integrated nature to addresses problems of stemborers, *Striga* weed, soil fertility and moisture retention while at the same time offering opportunities for generating additional income from surplus yields such as grain maize, milk from livestock keeping and seeds and fodder from Desmodium and napier/Brachiaria grass.

Despite the impressive and extensive research on suitability, effectiveness and proof that the PPT is a necessary production intervention for the smallholder farmers, its adoption levels and impact on majority of the smallholder is still short of the expected. According to Khan et al. (2014a), the expected target for scaling up is to reach at least one million smallholders farm families implementing the technology by the year 2020 in the eastern African region alone. Only about 10% of the expected target has been achieved so far. That means more work is required. This is because the numbers of farmers implementing the technology is far below when compared with, those affected by the problems addressed and also the number of years the technology has been deployed. Although there are efforts to close these gaps through research collaboration with national research and extension partners within the east Africa region, it has been successful mainly on the joint research publications in journal articles, book chapters, books and manuals. Such impressive publication history should be emulated with similar impact on the smallholders in terms of increased adoptions, adaptation and emergence of PPT commercial enterprises. The change in approach for example, should consider a trans-level collaboration and engagement between researchers and other stakeholders including informal institutions (Khan et al. 2014a; Diebolt, et al. 2016).

The PPT based research findings have shown that farmer driven dissemination pathways with technical support from researchers and extension service providers is a major boost in enabling adoption. However, this relationship puts farmers at the end of the research engagement process. For example, De Groote et al., (2010b), study on the design and analysis of different cropping systems and models for the management and control of stemborer pests and *Striga* weed in western Kenya and eastern Uganda; they recommended that agronomists and economists should play a key role. The involvement of farmers in the experimentation was given prominence much later during evaluation. That means farmers knowledge and input is not treated as technical information from the start of research experiment. Rather as opinion to validate the experiments. To obtain different results in terms of increased adoption rates and knowledge sharing on the PPT, it requires significant change in terms of engagements whereby the research, extension and farmers work on joint basis during the research planning, implementation and evaluation stages.

Chapter 6:

Stakeholder Mobilization and Engagement: Organization of the Process

6.1 Introduction

Scientific research, in principle, generates innovations that are first regarded as possibilities to improve the life conditions of the intended users. However, many of these generated innovations may not be easy to implement, adopt or adapt, because they either fail to meet the context-specific requirements or address the real-life complexities faced the expected users. This is partly attributed to the fact that, this kind of research is sometimes carried out without focusing on the demand side of those it is intended for (Foster and Heeks 2013; Ul-Hassan et al., 2011). To overcome such challenges, stakeholder engagement during research and technology development is an important consideration in order to develop innovations that are tailored to the livelihood needs of the intended users, particularly the smallholder farmers. The term stakeholder is used in this study to refer to a person or group or organization(s) that have interest in or will experience the effect of the innovation or those whose activities and/decisions can affect innovation development and/or use (Freeman, 1984**;** Ul-Hassan et al., 2011**;** Regeer et al., 2009). Stakeholder engagement is used to describe a broader and inclusive public participation process in innovation development (Adekunle & Fatunbi, 2012). In this study, the stakeholders who were engaged during the planning and implementation of the Push-Pull technology (PPT) includes: research scientists, cereal based smallholder farmers, public extension service providers, input suppliers and youth group farmers. Participatory engagement of stakeholders during research process can effectively contribute to improved communication, and providing feedback with reliable information which is essential for decision making in innovation development (ibid.). However, the stakeholder engagement process is not always smooth (Parker & Crona (2012). It is possible that some groups or part of a group of stakeholders can have conflicting or incommensurable interests. It requires effective facilitation and leadership which values the differences in the diversity of the stakeholders' interests as an opportunity for learning and to spark innovation (Walker and Walker 1998; Leonard & Sensiper, 1998).

The next section of this empirical chapter covers the stakeholder identification, mobilization and engagement process during the study. This is followed by stakeholder assessment of the stemborer problem situation, roles and terms of engagement during PPT implementation and the last section on the summary of the main findings.

6.2 Stakeholder Identification and Mobilization

The research planning process started with an identification of the stakeholders. The first group of stakeholders was identified by the BiomassWeb project team during the training on facilitation skills workshop held in Addis Ababa, August, 2014. The training workshop was organized by the Center for Development Research (ZEF) and facilitated by an international consultant. The objective of the training was to equip the participants with skills on participatory research methods and tools, and how to conduct group facilitation for learning during stakeholder interaction workshops, meetings and practical on-farm implementation of the PPT.

The participants of this training workshop identified potential stakeholders who could participate in the joint implementation of PPT. This was done based on the criteria that, these stakeholders had; professional and organizational mandates, research and disciplinary specializations, or were in positions of influencing decision making or had interest in finding a lasting solution to the stemborer pest problem in maize crop. Among the identified list of stakeholders were; the researchers from Jimma University, Ethiopian Institute of Agricultural Research (EIAR) at Jimma and Bako Centers, and Jimma Plant health clinic. Other stakeholders were; crop protection experts the Federal Ministry of Agriculture (MoA), agronomists, extensionists and crop protection experts from the Oromia regional bureau of agriculture and zonal agricultural offices (Iluababora, East Wolega and Jimma) and mass media (Fana Radio/Oromia Television). The stakeholders list was further discussed during consultations with the International Center of Insect Physiology and Ecology (*icipe),* the Ethiopian Institute of Agricultural Research (EIAR) researchers and federal MoA senior officials in Addis Ababa. These consultations were undertaken with the aim to inform them on the progress made with the research planning process and also to get their impression and feedback on the suggested composition of stakeholders.

The researcher made personal visits to the identified stakeholders' offices or their workplaces with aim of introducing the concept of PPT, discussing and sharing research objectives, the joint research implementation, establishing demonstration farms for learning and implementing the PPT in their zones and *Woredas* (Bako Tibe, Jimma Arjo and Yayu). During these visits, the idea of organizing a joint planning workshop of the stakeholders was discussed. It was agreed to be held at a central location (Bedele town) within the Oromia region. The selection of the personnel or partners to participate during the first planning workshop (Appendix 2) was delegated to the management of their respective organizations and stakeholder groups. These participants were selected based on their: reputation of implementing agricultural practices, positions or responsibilities in their respective groups, willingness to participate during the day to day activities in line with PPT implementation among other characteristics.

The second planning workshops were held at the *Woreda* level. The participants were selected by the *Woreda* agricultural extension coordination officials, whose responsibilities are to coordinate functions different ministries and development activities. The *Wored*a offices of agricultural development, water and irrigation, women and youth affairs and the cooperatives sector were delegated to participate. The *Kebele* selected were connected with river water for irrigation and the area farmers were engaged in growing maize crop. The farmers who volunteered to become model farmers, their farms were used as demonstration plots for learning the PPT. Based on what Freeman (1994; cit. Mitchell et al., 1997, p.853) stated, "the principle of who or what really counts", all these stakeholders were drawn from various organizational, administrative to individual levels. This was because they were either directly affected by the stemborer problem and therefore were the potential users of the PPT, or had been engaged in research, had expertise or reputation to influence its implementation and development as an innovation. The identification and selection of the stakeholders was followed by in depth consultations and discussion during the engagement process on their interests, perceptions and decisions, and how this could feature during PPT implementation.

6.3 Stakeholders Engagement: Regional Stakeholder Planning Workshops

Stakeholders' engagement was undertaken during the planning workshops and practical implementation of the PPT. The stakeholders were contacted using phone call, faxes, emails and personal visits to their groups, offices or places of work to deliver invitation letters or request for their participate during the proposed planning workshops. The stakeholders planning and engagement workshop was conducted in Oromia region in the beginning of October 2014. The aim of the workshop was to introduce the concept of the PPT, objectives of the joint research implementation. The workshop was also an opportunity for setting the agenda for joint learning through knowledge sharing and interaction among the researchers, extension staff, farmers and other stakeholders. The workshop discussions were focused on how the implementation of PPT as an innovation could help to address the problem of maize yield losses from stemborer infestation and also to enable the stakeholders understand the research problem; outline their responsibilities, contributions and commitments as a collaboration for implementing PPT. As pointed by Clark and Holliday (2006), successful initiatives linking knowledge with action require dialogue and cooperation between the researchers and practitioners as the ultimate users. The participating stakeholders were drawn from the Ministry of Agriculture (MoA) from federal level, Oromia region, Zones (Iluababora, East Wolega and Jimma) *Woredas* (Jimma Arjo, Bako Tibe and Yayu), researchers from Jimma University, Jimma and Bako Agricultural Research Centers (ARC), representative from Environment and Coffee Forest Forum (ECFF), farmers from three *woredas* and Radio Fana.

The stakeholders were organized into three stakeholder groups representing research, extension and farmers. The separation was based on the group interests they represented during the workshop. It was assumed at this point that each of these stakeholders had divergent interests stemming from their research, professional and day to day experiences with stemborer pest's challenges. This assumption was based on the fact that during identification, different interests of stakeholders was taken into consideration pegged on disciplinary specialization, mandates of the organization affiliated and maize crop farming and related enterprises, among other characteristics. The journalists did not join any of these groups. They decided to be neutral so that they could interview these groups independently for their radio and Television programs. The facilitator of the workshop was a representative from Environment and Coffee Forest Forum (ECFF) and had participated during the facilitation skills training workshop. He had already acquired requisite skills during the facilitators training workshop and he combined this with his own experience to facilitate the workshop discussions.

6.3.1 Different Stakeholders Understanding of the Stemborer Pest Problem

The understanding of the research problem among the stakeholder groups of the researchers, farmers and MoA extension staff was an important step to start the engagement process. In order to elicit this, group discussions were conducted based their assessment of the current situation of stemborer infestation, how they predict the situation without the infestation and their perception by applying PPT as an innovation to address the problem.

The Researchers

The researchers in their separate group discussion appointed the Jimma University researcher as their facilitator. This group's deliberations were based on their scientific and technical viewpoints and understandings on the problem of stemborer from chemistry, ecology, weed science, entomology and socio-economics backgrounds. They prepared their presentation on flip charts outlining their discussions and suggestions. In their assessment, they were in agreement that the stemborer poses serious production challenges in cereal crops especially on maize and sorghum in the Oromia region and the country in general. Similar assessment has been documented by other researchers (Belay & Foster, 2010; Assefa, 1998; Getu et al., 2001). The researchers pegged their comments on their knowledge from either being involved in relevant research project or by dealing with the challenges and management of this pest. Although the deliberations did not exhaustively generate information on issues of stemborer, it had important inputs which contributed to understanding the problem. This was the first step towards finding a solution by acknowledging the prevailing problem that seeks immediate solution through innovative means:

> "Within our mandates and in the study *Woredas*, there is no collaborative research or partnership between the researchers and other stakeholders as practitioners aimed at solving the problem of stemborer …..and depending on environment, cropping season and type of cereal crop, the pest causes yield losses up to 40% of harvest… this is a concern for us and all other stakeholders" (*Chemical ecology researcher, stakeholder workshop, October 2014).*

Despite these challenges and problem scenario, the researchers were confident that in the near future, the problem of stemborer pest will be addressed fully. This was through undertaking research activities which will contribute to the management of the pest population not exceeding 5% threshold levels of dead hearts as a tolerable infestation limit (Suhail, et al., 2008; Waibel, 1986). Research on Integrated Pest Management (IPM) strategies preferably biological based measures such crop rotation, cover cropping and reduced pesticide application were recommended by the researchers. The application of the PPT which is a core IPM component and new platform was a novel idea to be implemented and undertaken as a research initiative. This is because the PPT re-introduces the concept of intercropping maize with a legume crop as a biological pest management strategy for the smallholder farmers. This assertion was supported that:

> "Stemborer is a devastating pest, and there are no effective practices in place on its control... it is difficult to control because it is not uniformly spread….it is in small but devastating patches everywhere….**.** It is a local problem, which need local solution. The PPT comes in as a technology which works and easy to use by the local farmers. It has a combination of scientific concepts which are easily applicable on small scale cereal crop farming context to control the pest. The PPT is addressing a real and pressing problem by applying agro-ecological principles of pest management involving the use of repellant and trap crops to manage and increase on-farm biodiversity of beneficial insects" *(Researcher and Pest control expert, Bako Tibe, April 2014).*

To achieve the desired changes of addressing the stemborer problem, the researchers were in agreement that a collaborative and joint action with other stakeholders from the research institutions, universities, plant health clinics, the MoA, the private sector and farmers could contribute to collective learning and action. The PPT implementation is practical based (e.g. spacing, seed varieties, weeding, harvesting) and the companion crops are perennial, thus providing sufficient timeline for stakeholder interaction and reflection on a long term basis. This also provides an opportunity for continued interaction and coordinating their joint actions. In addition to focusing on improving crop productivity and in the management stemborers, researchers were interested on how they could learn to address institutional challenges which require innovation and also creating trust between different stakeholders across different levels (Lamers et al., 2017; Leewis, 2000). The nature of implementation of PPT had provided an opportunity which seemed promising to be engaged in:

> "PPT as an innovation will provide an opportunity for the researchers and with the support of other stakeholders to initiate and implement research into sustainable management of stemborer pests. The technology fits well as an IPM component in the control of pests….It is a perennial practice, hence enabling continuous observations and learning on stemborer pests' incidences and crop performance….the observational data over several cropping seasons will provide an opportunity for informed action for the researchers to support farmers and farmers to support research and extension" (*Researcher, Entomology, stakeholder workshop, October 2014).*

The Smallholder Farmers

During a regional planning workshop two farmers participated as farmer representatives from each *Woreda.* These were also model farmers. The farmer based their discussion on day-to-day farm experiences and challenges posed by the stemborer. The discussion was facilitated with the assistance of a facilitator from ECFF who explained to them the discussion topics and types of information required to enable them be able to articulate their views. Their viewpoints were recorded on a flip chart with the assistance of the facilitator for plenary presentation and discussion with other stakeholders. They required assistance of the facilitator to help them in writing their views. During the joint plenary discussion, these farmers were able to expound what was entailed in each bullet points as was read on their behalf by the facilitator. The aim was to ensure that their opinion and contributions were understood and consolidated in the research problem definition and understanding. Their discussion showed that, that stemborer is a serious cereal crops production challenge, particularly on maize and contributing to almost half of yield loses:

> "Stemborer pest's infestations are high in maize and sorghum and reduce grain yields on average 20-40%.... … The stemborer starts to bore the maize stem making it to lose its resistance to strong wind, thus making them to easily lodge" *(Farmers, stakeholder workshop, October 2014).*

Based on their comments, the farmers have been noticing and observing that, the stemborer infestations are high when rainfall is not regular and there less when they are doing crop rotation. This was captured by the comments made by farmer participant:

> "The outbreak of stemborers increases when the rain stops….or when the rain starts late and not regular or when it is low and there are higher temperatures…. The intensity of infestation decrease when we practice crop rotation *(Farmers, stakeholder workshop, October 2014).*

As pointed by the farmers, crop rotation is a cultural control measure based on the premise that there are no carry over diapause larvae which is associated with residues from the previous infested crops. However, with the increased human populations, there is less land available to allow for crop rotations. Farmers are forced to continually grow crops on same parcels of land on a continuous basis. At the same time, due to the effects of climate change, the rainfall patterns are indeed unpredictable. This further exposes farmers to pest infestations. The stemborer were not the only pest problem faced by the farmers. There were other insect pests which cause damage to their cereal crops, such as the weevils and termites. The pest control or management approaches they were applying were local knowledge and practice based. This include the use of ashes or manually removing the infested plants to feed animals or burry into the soil. So far they haven't managed to address the problem especially when the infestations are widespread. They expressed hopes that, collaboration with researchers and extension staff in the near future will contribute to a permanent solution in the control and management of these pests. According to these farmers:

> "To control stemborers, pick out the affected maize and destroy it or use it as fodder for the animals, practice crop rotation and intercropping maize with other crops such as legumes to maximize production and improve on soil fertility" **(***Farmers, stakeholder workshop, October 2014).*

The participatory introduction and implementation of the PPT with researchers and other stakeholders, the farmers were looking forward to learn and benefit from its potential in addressing the stemborer problem and other benefits such a fodder, soil and water conservation. The farmers expressed willingness to start implementation of the PPT in their farms as model farmers in order to inspire fellow farmers and also as learning platform for stakeholder interaction. Apart from stemborer control, the farmers had other ideas which were important to them as well. For example, such a platform should include research on improved maize varieties which are tolerant to stemborer pests, provide linkages of farmers to input suppliers of hybrid maize seeds who are 'trusted', to select local maize varieties which are resistant to pests and develop climate adapted cereal crops. The farmers also had some questions and concerns beforehand:

> "How can Greenleaf Desmodium and Brachiaria grass be managed during off season especially with the presence of roaming and free grazing livestock? Any form of insurance or compensation for the farmer in case PPT fails?

The additional issues and questions were points of concern and were left open to be answered or responded to later during actual implementation. This was a learning based approach and indeed, the farmers together with other stakeholders could learn from these questions based on the real-life and on-farm practical experiences on the PPT than have prescribed answers from the researcher or extension staff. It was encouraging to see that the farmers from on their on farm realities, they were able to reflect far ahead into the future even before implementation started. In such as situation of stakeholder foresights, process facilitation plays a key role in enabling effective learning which will lead to adoption or adaptation of the technology. In worst scenarios, these concerns can also contribute to dis-adoption or total rejection of the technology. Such questions were the key points for learning processes and shared commitments among the stakeholders during implementation (Box 1). These questions can be likened as potential; 'spark plugs' which ignited learning commitments.

The Ministry of Agriculture Extension Officials

The MoA extension stakeholders were represented by the officials from the federal, regional, zonal and *Woreda* levels. Like other stakeholders, during their group discussions, they appointed one of their participants, the Yayu *Woreda* vice administrator in charge of agriculture as facilitator. This was based on his experience as an administrator and in facilitating group discussions. The MoA extension officials had documented evidences on high infestations of stemborer pests in the study area (Bako Tibe, Jimma arjo and Yayu *Woredas*) and in the Oromia region in general. This was by virtue of their work as extension officers in the area. They also pointed out that, the highest and the 'hotspot' areas were in Sibu- Sire *Woreda*, adjacent to Bako Tibe. In addition to stemborer, *Striga* weed (*Striga hermonthica*) identified a potential threat to cereal crop farming in East Wollega zone, Sassiga, and Limu *Woreda*s. Due to logistical challenges and time limitations, this study did not extend to this areas, but the overall PPT implementation under the BiomassWeb project was extended to this area during the subsequent cropping season 2015/2016. Despite the stemborer pest challenges, the extension officials were optimistic that collaborative efforts in PPT implementation will be an important step to address the problem of stemborer infestation and other commercial benefits such as livestock fodder production and income from sales of harvested Desmodium (Silverleaf or Greenleaf) and Brachiaria seeds. The extension officials didn't have any knowledge or experience on the performance of the PPT, except from what they heard through the mass media, reading or during workshops. It was an opportunity to learn from practical implementation.

Stemborer infestation is prevalent in Oromia. Therefore, introduction of PPT is an important step considered by extension stakeholders as an alternative practice for pest management. Introduction of the PPT was favorable due to the fact it fits into the local farming practices and compliments the government policy initiatives, on soil and water conservation, and intercropping cereal crops and livestock integration through fodder provisioning. During the discussions, the PPT was seen as advanced crop insurance. According to extension expert, "the technology is modeled along the traditional farming systems of mixed cropping which has been an age old insurance against on crop failure, pest control and food security". The only difference, it came with new crops which are perennial in terms of establishment. The extension personnel were in agreement that "PPT is an excellent opportunity to introduce maize- legume intercropping, not only for pest management, but also for soil conservation and fertility improvement". Apart from these direct benefits to the farmers, the officials were in agreement that:

> "PPT implementation will help create platforms for training and continuous awareness creation, experience sharing, practical demonstrations…and to provide a linkage among stakeholders from university, research, extension and farmers to engage in research for knowledge production….also to encourage mixed cropping as a form of insurance in case of one crop failure" (Agronomy and *Extension expert, stakeholder workshop, October 2014).*

The implementation of the PPT is seen as a platform upon which numerous activities will be initiated for the benefit of the stakeholders. The first time introduction of PPT sounded promising with a lot more benefits which can even out shadow the original design and purpose on stemborer pest problem.

6.3.2 The Stemborer Pest Problem and the Perception on the Push-pull Technology

The participating stakeholders jointly recognized stemborer problem situation as a threat to maize production which required urgent attention to find a lasting solution. Despite their differences either as researchers, experiences in delivery of extension services or on-farm observations on the stemborer effects, coming together and start working as a joint team to incorporate scientific with experiential knowledge was an important step. The stakeholders' experiences with the pest problem, although based on the Ethiopian context in the Oromia regional state, it is similar to other countries such as Kenya and Uganda (e.g. Kalule et al., 2006; Khan et al., 2008; Mugisha-Kamatenesi, 2008). In all these cases, stemborer infestation is a major problem affecting maize and sorghum production contributing to average yield losses of 20-40% (Kfir et al., 2002).

Jointly, the stakeholders felt that "the stemborer pest's infestation should be managed below economic threshold levels by applying Integrated Pest Management (IPM) strategies". The IPM strategies rely on a combination of approaches; biological, cultural, physical and chemical management using scientific research and then recommended to farmers for application. The PPT is one of the key components of IPM strategies and its implementation requires information, analysis and planning than just application. It was noted that, the PPT learning process is knowledge intensive and its effective implementation depended on several factors which are related or linked with farm and the farmer (Khan et al., 2007). Moreover, according to Leeuwis (2004), adoption or adaptation of new technologies such as PPT is attributed to the nature of communication and interaction among research scientists and the practitioners during its development and implementation. In view of this and on pilot basis, the stakeholders agreed to start participatory PPT implementation using action research as a learning and communication process from planning, implementation, on farm observations and evaluation of the activities. To be able to accomplish this, the stakeholders discussed and raised several questions and information requirements (Box 1 below). The summary of views was an account of a culmination of the different perceptions, interests, realities and goals of the researchers, farmers and MoA extension officials. These joint questions laid a foundation, important learning milestones and targets for the stakeholders during PPT implementation. The questions and related topical contents provided a basis for further discussions and follow-up during PPT implementation.

1. How shall the stakeholders be recruited to participate in the implementation of Push-Pull technology? What are terms of agreement (TOA) to ensure effective planning and sustainable implementation of PPT in maize and sorghum growing areas? How can the TOA be operationalized?
2. How can strong collaboration and commitments by different stakeholders from research institutions, universities, plant health clinics, MoA, NGOs and private sector be initiated and maintained to share and create new knowledge required for stemborer pest control/management?
3. What are the incentives for new stakeholders to become engaged and work together with other stakeholders in establishing PPT related farming enterprises such as Desmodium (Greenleaf or silverleaf) and Brachiaria seed collection and multiplication farms?
4. Using PPT as an opportunity for researchers and other stakeholders to initiate research into sustainable management of the stemborer pest problem, what are the steps for establishing on-farm learning sites?
5. How to manage Desmodium and Brachiaria during off season in the presence of roaming and free grazing livestock and in some places wild animals often practiced or experienced in most parts of the Oromia region?
6. How do we maximize the increased production of PPT repellent and trap crops (Desmodium and Brachiaria) to use as fodder crop for animal fattening and seed source (for sale)?
7. What is the insurance mechanism for PPT farmers in case of crop failure?

Box 1: Questions and learning topics of common interest among the stakeholders
Source: Authors compilation

The joint stakeholder workshop provided an opportunity for collaboration, information sharing and to initiate learning processes which were expected to take place during subsequent stakeholders interactions (Knickel et al., 2009). According to Tisenkopfs et al., (2015, p.15), such workshops provide a chance for the science-practice stakeholders interaction and alignment of their different perceptions, motivations and expectations into common cognitive frames and concerted actions towards addressing the problem at hand. The participatory nature of discussions and interaction during the engagement of the stakeholders, the participants freely expressed their opinions whether contradictory or in conformity with others or with PPT. However, most of the participants at the initial stages were optimistic and their view points were geared towards successful process. This means they become more satisfied when the PPT meets their expectations or disappointed if it fails. Some of these evidences were followed up and documented by this study and some for further research. For example, the question of managing

Desmodium and Brachiaria during off-season in the presence of roaming and free grazing animals was a threat to the success of the implementation process of the PPT beyond the first season of establishment. However, the one of the farmers suggested that, "lt is our responsibility; we need to fence as a sign of commitment for the success of the project and to solve the problem of pests". The commitments to embrace the technology from the beginning were high. "I watched PPT on TV, and am surprised that the technology has come to my *Woreda*. I am committed to embrace and implement it jointly with other stakeholders" This comment was made by the administrator in charge of agriculture in a *Woreda.* This was echoed by a senior agronomist from the regional bureau of agriculture:

> "We have the human capacity and commitment from MoA for awareness creation and implementation of PPT…After the success of the demonstration experiments at the selected *Woredas* and *Kebele,* the PPT shall be part of maize/sorghum production packages that will be included in the annual work plan of MoA and regional offices for wider implementation and adoption" (*MoA Federal Crop protection expert, workshop, October 2014).*

The openness by senior extension officials towards PPT was linked to the wider policy framework in the ministry of agriculture to ensure food security in the country. New technologies promoting cereal productivity and with such potential like PPT were embraced.

6.4 The Transdisciplinary Stakeholder Engagement Team (SET)

It is acknowledged that the relationship among the researchers is that of interdisciplinary, however their collaboration with other practitioners such as extension staff and farmers as an additional group who are more often treated as non-academic stakeholders, the relationship becomes transdisciplinary (Lang et al., 2012). This is because; it transcends disciplinary and interdisciplinary relationships among the researchers (Stokols et al., 2003). This shift in relationship is necessary in order to operate as a joint team towards understanding and solving the common problems confronting the society as a whole. In this study, addressing the stemborer in maize crop production was the central challenge for the stakeholders. Therefore their engagement to work as a team in addressing the stemborer problem with the participation of individuals with different organizational affiliations, disciplines, career focus and interests, and practical experiences is what makes it transdisciplinary in nature. For instance, the researchers' disciplinary backgrounds comprised of; entomology, weed science, chemical ecology, social science and soil science. The practitioners' professional backgrounds and experiences ranged from crop protection, agronomy, agriculture extension, and smallholder cereal cropping (Appendix 4). Other stakeholders were the private enterprises, NGO and the media. Such a diverse mix of stakeholders was meant to provide multiple viewpoints on the problem situation and contributions into the research process. Thus making the team was a combination of co-researchers, facilitators and resource persons. It was an opportunity to share and integrate the best available knowledge, reconcile existing values and preferences as a way of increasing the legitimacy, create ownership and accountability of the pest problem and the solutions thereafter (Lang et al., 2012; Gibbons et al. 1994; Hirsch Hadorn et al. 2006). Table 4 below shows the stakeholder team composition in terms of their disciplinary specialization, affiliations and their level of involvement in the research process.

Table 4: The SET composition, specialization, affiliation and involvement in the research process

Stakeholder group	Affiliation (organizational/individual	Discipline/Profession	Participants	Stages involved in the research process			
				Plan	Impl	JLO	Evl
Researchers	Jimma Research Center	Entomology, weed and soil sciences	3	✓	-	-	-
	Jimma University	Chemical ecology	1	✓	-	-	✓
	Jimma Plant Health Clinic	Entomology	1	✓	-	-	✓
	Bako Research center	Entomology	3	✓	✓	✓	✓
	ECFF	Social Science	1	✓	✓	✓	✓
Agriculture extension staff	Federal level	Crop protection		✓	-	-	-
	Jimma, West Shawa and East Wollega zonal offices	Crop protection Agronomy, Agriculture extension	3	✓	-	-	-
	Jima Arjo *Woreda*	Agricultural Extension and Agronomy	2	✓	-	-	✓
	Bako Tibe	Agricultural Extension and Administration	2	✓	✓	✓	✓
	Yayu Woreda	Agricultural Extension and Administration	2	✓	✓	✓	✓
	Iluababora zone	Administration-Zonal	1	✓	-	-	-
	Oromiya	Administration- Regional	1	✓	-	-	-
Smallholder model Farmers	Bako Tibe and Yayu Woredas	Smallholder farmers	6	✓	✓	✓	✓
Media	Fana Broadcasting (Radio and Oromia TV)	Journalists	2	✓	-	✓	✓
Others	Input suppliers/traders, follower farmers, students (school/college)	-		-	✓	✓	✓

Key: Stages involved in the research and PPT implementation process**:** Planning (**plan**), implementation (**Impl**), Joint learning and observation (**JLO**), Evaluation (**Evl**). The tick sign (✓) and minus sign (**-**) indicates that there was active and no participation of the stakeholders in each of the engagement stages respectively.
Source: Authors compilation.

The selection of the diverse stakeholders was meant to incorporate a wider and inclusive analysis of the stemborer challenge and also to answer wider range of questions that could arise during workshops or on-farm practical sessions. Working together of such a diverse group of stakeholders is not easy or smooth process. However, the need to address the common problem of stemborer pests necessitated their coming together. Otherwise these stakeholder groups work independently in their day to day life activities. The PPT was used to act as a boundary object to draw them together into communicative and collaborative spaces (Anderson & McLachlan, 2016). Terms of Engagements (ToEs) were outlined in order to; work together, address the common problem and foster joint learning. The facilitation of the process was central in playing a balancing role in such situations where the tensions and conflicts could arise out of institutional and cultural expressions of dominance or superiority (ibid.). This was bearing in mind that, each stakeholder group can be easily tempted to slide into their own disciplinary or professional or local practice silos where they are comfortable and able to achieve own interests.

6.5 Terms of Engagements of the Stakeholder Team

In order to address or respond to the questions and other issues which arose during the engagement workshop (Box 1) and any other during the research implementation process, each stakeholders group outlined their roles, responsibilities and expected commitments. These stakeholder obligations are what resulted into the Terms of Engagement (ToEs) outlining their interests to participate and contributions in process.

6.5.1 The Researchers

Interest to Participate in the PPT Implementation Process

The research stakeholder group comprised of weed and soil scientists from Jimma Agricultural Research Center, entomologists from Jimma plant health clinic and Bako Agricultural Research Center, and chemical ecologist from Jimma University, Faculty of Agriculture. They had read and heard about the PPT in theoretical terms. They were keen to see the PPT established so that they can learn first-hand on-farm practicability and application. This is because, the concept and performance of the PPT was in line with their research and career interests and also it is a biological pest control method. Equally they were interested to see how farmers could learn and adopt or adapt such an innovation in their farmlands. Some of the researchers were interested to join the *icipe and* ZEF research network, contacts and new projects for their career prosperity in international circles. Others wanted to prove whether the PPT really works in relation to what has been published. Based on their disciplinary training and areas of specialization, the researchers had individual and institutional interests to participate in the process. The weed scientist, for example, was interested to learn and contribute on management of *Striga* and large-scale production of Desmodium using farmers' fields. He was conversant with Desmodium application as a cover crop to smoother weeds in coffee farms within the research station or by large scale farmers. Therefore establishing Desmodium in controlling *Striga* and under smallholder farmers was intriguing and interesting concept. The entomologist from Bako research center was interested to compare the effectiveness of the PPT with other pest management in terms of environmental safety and economic feasibility. The chemical ecologist was interested in on-farm practical implementation and to assess the whether the performance and effectiveness of the PPT is similar as compared with the examples from Kenyan and other countries According to the chemical ecologist, who is also a lecturer at the university, "PPT is an opportunity to train a new cadre of Master of Science (MSc) students using the transdisciplinary approach in learning and implementing new technologies and also as a practical example on the application of the agro-ecological principles in pest control". Teaching students is usually done without practical exposure because the information exists in research publications. This is a challenge to both researchers in the universities and at the research centers:

> "Researchers know the PPT theoretically, I appreciated this as an opportunity to learn it in the field practically, and document its performances based on biological data collection and observations…Maize is important crop for national food security especially in the Bako Belt….Farmers lose yields up to 40-80% due to pests. So far there is no maize variety which is resistant to stemborer. The PPT can be a potential reprieve for maize breeder seeds (high yielders) which are highly susceptible to stemborers" *(Entomologist Bako agricultural research center, workshop, October 2014).*

The researchers were keen to participate in the PPT implementation and the research process in general. This was mainly to generate data and also make own observations against the theoretical claims made in the already published literature about the PPT.

The Researchers' Contribution to Achieve the Desired Change

The researchers' contributions towards the desired change varied based on their disciplinary orientations and career areas of interests. The weed scientist, for example, wanted to share research findings and knowledge he already acquired on weed science with other stakeholders e.g., on preliminary fact findings on the emergence of *Striga* in Illubabora zone (Chewaka *Woreda*) and its potential effect on cereal crops especially maize production. In addition, the weed scientist was interested to conduct research and establish how Desmodium effectively smothers other weeds apart from *Striga*. The chemical ecologist was keen to contribute towards the desired change by conducting on-station and on-farm research for the purpose of training students and developing a participatory based PPT implementation manual. The entomologist wanted to share research findings on stemborer control and gain new experiences on how to jointly work with other stakeholders in managing stemborer and adapting PPT into farmers' own management systems:

> "I decided to participate from planning stage of the research to site selection….and provide advice on crop protection/pest infestation. The PPT is a new technology with environmental safety features, benefits such as fodder provision, erosion control, economic benefits etc. The PPT contributes many research ideas, but from entomological perspectives; I have identified gaps for further research and on the technology itself from learning to its adaptation as a pest management strategy" (*Entomologist Bako agricultural research center, Interview, March, 2014).*

The researcher contributions are closely linked with their careers and expertise. This is attributing to their lines of specialization and also terms of employment and requirements.

The Researchers' Expectations from other Stakeholders

The different researchers expected different things from other stakeholders. For example, the weed scientist wanted to learn new knowledge on *Striga* weeds from the experiences of other stakeholder groups, whereas, the entomologist expected farmers to adopt and disseminate PPT through their learning groups in the pilot study area. With keen interest to develop a curriculum on IPM tools based on the example of PPT, the entomologist expected the input from the experiences of the extension staffs and from the mass media mainly radio and television in technology dissemination and awareness creation. The researchers expected the Woreda level policy makers to be part of PPT implementation process and to include it in their annual work plans as part of agriculture extension routine activities. This was because technology has potential benefits for the smallholder farmers, "It's a chemical free technology, cost effective because doesn't require use of chemical by small holder farmers to control stemborers" Comment by the Chemical Ecologist during planning discussions.

The researchers expected that PPT should be well understood, implemented and appreciated by other stakeholders. This is not only on its benefits of controlling stemborer infestation and increasing cereal yields in maize, but also learning new skills and information among the stakeholder such as field data observation collection and analysis on stemborer pests other related farming challenges. These views were shared by other researchers:

> "Climate factors are contributing to crop diseases and pests….PPT provides a platform to learn and address these constrains. We are willing to share the knowledge gained from its implementation from the grassroots to the national level". (*Entomologist Bako agricultural research center, workshop, October 2014*).

During the period of field research, there was an outbreak of maize lethal necrosis (MLN) disease reported in the Oromia region and in the Rift Valley of the country. The researchers from the plant health clinic at Jimma were conducting spot checks on the spread of the disease in the region. They became interested in the PPT to learn about plant-insect interaction with possibility of learning new insights which could be helpful in addressing the MLN disease. Their expectations from the PPT were part and parcel of their efforts of addressing the pest challenges on maize productivity. To them, the PPT was presenting new frontiers for research and learning.

The National Maize Research center (EIAR)-Bako, is mandated to undertake maize research. The crop protection research division within the center has been involved in maize stemborer and other pests. The researchers at the center think that, the PPT as an innovation, could contribute to their mandated research focus on stemborer research. They are obliged to seek or engage in additional research activities which are linked to their careers and also interact with other stakeholders such as farmers, the private sector (e.g., agro-dealers). In addition, they were willing to provide technical backstopping, working closely with the other stakeholders to understand and obtain first hand data and information on the stemborer pests' problem and to publish the research findings in refereed journals.

6.5.2 The Agricultural Extension Officials

Interest to Participate in PPT Implementation Process

According to the Central Statistical Agency of Ethiopia (CSA, 2012), over two-thirds of the farmers in Ethiopia grow maize as a subsistence food crop with 75% of it produced and consumed by the farmer household. Therefore maize is an important and major crop in the food security of the country. Stemborer infestation on maize and other cereal crops is prevalent in the country and is contributing to high production yield losses from 2-27% in the western to 39-100% in the northern parts (Melaku et al., 2006). Despite the fact that there are efforts by the extension, farmers and researchers to address the problem in terms of technologies, the stemborer effect is still a serious challenge. It is on this background that the MoA extension officials at the federal level and the *Woreda* office of Agriculture, together with other stakeholder, developed interest in the PPT as a potential intervention to address this problem. The interest, role and contribution of the MoA extension division was represented by officials from the directorates of plant health and agriculture extension at the federal, regional, zonal to *Woreda* levels. The MoA at the federal level was the entry point based on their overall policy mandate in the implementation of agricultural innovations. The PPT was incorporated as part of its national programs as a response strategy to addressing the challenge of stemborer to food security. However, the agriculture extension officials from the regional to *Woreda* levels had limited information about the PPT and its performance. "We have only heard about PPT on the media and during workshops…we want to learn how to translate that into practice" These officials were willing to participate during its practical implementation, provide technical backstopping and extension training on pest management, and also use it as a platform for extending other related farming messages to the farmers. They were also interested to be engaged in the production and distribution of Desmodium and Brachiaria seeds as essential inputs for PPT, which, apart from using the seeds for expansion, which could become tradable and high market value crops.

Contribution to Achieve the Desired Change

The MoA extension officials participated in the selection of sites, model farmers and also in the identification of relevant local stakeholders i.e., farmers, input suppliers/agro-dealers, and women farmer groups. The extension staffs provided necessary data and contacts for planning in the *Woreda* to facilitate effective dissemination and implementation of the PPT. They were also responsible in providing training/capacity building on Desmodium seed production, processing and marketing. Their contribution also included identifying potential sites for seed collection such as coffee farms, forests and fences/hedges, and on farm bulking. Similarly, making arrangements either informally or formally to engage other stakeholders such as forest enterprises initiatives (in Yayu *Woreda*), the youth farmer groups, small scale private seed enterprises/agro-dealers on seed production, collection and distribution to farmers for PPT expansion. Alongside these activities, they were involved in observation data collection, monitoring and evaluation on the PPT performance on various management practices, from planting, weeding, harvesting to utilizing crops and managing the PPT plots.

Expectations of Extension Officials from Other Stakeholders

The MoA extension officials expected support from other stakeholders; cooperation from the research scientists with inputs of technical knowledge on pest management, financial and logistical support to enable continuous stakeholder interaction for learning on regular basis. They expected farmers' willingness to participate in the bulking of Desmodium and Brachiaria seeds, and support from youth groups and agro-dealers in Desmodium and Brachiaria seed production and distribution.

6.5.3 The Journalists

Their interest to participate in the research implementation process was motivated by the fact that PPT was a new innovation introduced into the study area. To them, this was a nice story to cover/document. Their contribution to achieve the desired change was through information documentation and dissemination for a wider audience in the region and beyond using their platforms, mainly radio and television. Their expectation from other SET team members was on feedback from learning taking place and new knowledge gained and its widespread dissemination and application.

6.5.4 The Smallholder Farmers

The smallholder farmers' interest to participate in PPT implementation was to eliminate the perennial problems of stemborer and supply of fodder for livestock. They committed to share information and discuss openly their experiences, local knowledge to support successful PPT implementation from the social-economic information such as yields, local knowledge on pest constraints to volunteering their farms for establishing PPT learning sites. They were committed to fence their PPT farms during off maize season to keep roaming and free grazing animals away from destroying the fields. Their expected result was, having a platform for continuous interaction with other stakeholders, to have sustainable and timely supply of PPT input seeds of maize, sorghum, Brachiaria and Desmodium, and no stemborer attack on their cereal crops and production of high quality livestock fodder.

6.6 The Stakeholders Engagement: *Woreda* Level Workshops

Follow up workshops were organized at *Woredas* of the study areas. The organizers of the *Woreda* workshops were the stakeholder engagement team representatives from the regional planning workshop who comprised of extension officials, farmers and researchers. The team was tasked to meet and discuss with their respective *Woreda* authorities. Based on regional stakeholder workshop commitments, they identified other stakeholders i.e. *Kebele* administrators, local agro-dealer traders, community based youth groups and women farmer groups. They also identified irrigation potential *Kebeles* and held discussions with farmers on the criteria to select model farms for establishing PPT i.e. access to or has potential for irrigation, the farmer's willingness to participate in PPT implementation, the plot size not less than $30m^2$ and accessible to other farmers in the neighborhood. Other responsibilities of the *Woreda* stakeholder teams was to plan and organize focus group discussion, PPT awareness creation and training workshops at farmers levels, facilitate the execution of joint stakeholder implementation plans, set indicators for learning and evaluation, and document the process (pictures, videos and print materials such as manuals). Other *Woreda* level stakeholders were selected and delegated from the ministries of; youth and sport, women affairs, agriculture and water resource , local agro-dealers, local administration and smallholder farmers practicing cereal crop farming during both seasons (long and short rainy seasons).

Two *Kebeles* were selected in each of the Woredas. The farm level planning meetings and discussions with engagement team were on topics such as; the dates for planting maize, source and supply of inputs mainly Greenleaf Desmodium, Brachiaria, Maize and fertilizer and the discussion on their perceptions of joint stakeholder process and implementation of PPT to address the common challenges of stemborer pests, and fodder shortage in the area among other farming challenges

6.7 Stakeholder Engagement: On-farm-Level Activities

The participating farmers as stakeholders were first identified as; smallholder farmers who were engaged in mainly in maize crop farming among other farming enterprises, located in biomass Web project working sites and stemborer hot spot areas. The consultation process and information flow rather followed a top down approach. This was attributed to the nature of administrative structure of the agricultural extension system which was centrally controlled and managed by the officials. The farmers received information about the PPT from their farmer representatives and extension officials. The farmer representatives were selected to participate in the planning meetings because they are already model farmers and are known by the extension officials in the *Woreda*. These farmers have a reputation of implementing new technologies which are potentially beneficial to fellow farmers in the *Kebeles.* They are also known from being active in seeking for information on farming technologies from the extension officers and enjoy ‘trust’ from their fellow farmers.

Using the information received and awareness gained regarding PPT during the planning meetings, these farmer representatives took the initiative and commitment of mobilizing and organizing their fellow farmer into groups in readiness for practical PPT implementation. The farmers groups from the study areas became the key stakeholders who participated during Focus Group Discussions (FGDs). The FGDs was part of PPT awareness creation platform and consultation to identify farmers’ interest, willingness and the contributions during the implementation process. The smallholder farmers interest to participate in PPT implementation, not only was on the account of being affected by the perennial challenge of stemborer pests on their maize crop, they had other challenges such as soil erosion, fodder shortages and access to farming inputs on time. The introduction of PPT was a new idea to these farmers and it sounded promising with a potential to address these constraints. According to Midega et al. (2014), smallholder farmers consider learning and adopt/adapt new innovations which have accruable benefits and ability to address their production constraints. However, in most cases, smallholder farmers lack access, information and knowledge of such innovations. Despite its potential, the PPT implementation has a knowledge intensive approach and its effective performance depends on proper establishment and management of the cropping system i.e. the main crop of either maize or sorghum and that of companion crops of Desmodium and Brachiaria or Napier grass (Khan et al., 2007). This is the basis making it necessary that the farmers should have these skills before or during its implementation. It is as a result of this, joint on-farm practical demonstration and learning became a key requirement for PPT introduction.

The voluntary model farmers readily accepted PPT because they were also willing to learn; conduct own experiments and shares their findings with recommendations to fellow farmers and researchers.

The PPT implementation was a joint venture carried out at farmers' fields with participation of the stakeholder engagement team. Their activities were practical and geared at addressing the questions raised during planning meetings, consultative FGDs and joint efforts established by stakeholder engagement. The topics and question raised were put into perspective, discussed, tested and evaluated. The PPT learning fields provided an opportunity for the stakeholders' collaboration, interaction and learning from each other across disciplinary and knowledge realms. This included the farmers' practices and researchers' scientific and technical knowledge from land improvement, pest management to utilization of PPT products. The on-farm engagement of the stakeholders was guided and embedded on PPT implementation cycle from land preparation and layout, planting cereals (maize), Desmodium and Brachiaria, weeding and managing the PPT plot, harvesting of maize, harvesting of Brachiaria and Desmodium for both fodder and seeds, managing PPT plot during off-season for the subsequent maize planting seasons.

The Mass Media

The mass media either whether print or electronic have a responsibility to bring to the attention of the public and create awareness of the existence of new innovations which addresses farming challenges and the food shortage. As stakeholder, the journalists felt that PPT was worth spreading and they were keen to promote it using their digital platform tools of radio and television as a way of contributing to improving productivity in the farming sector. The radio and Television journalists covered the events during the PPT farmers' field days and documented the experiences of other stakeholders in attendance. It was an important interaction with the journalists who were not only conducting interviews with the stakeholders, but they simplifying the scientific information to local language for the local audience. They achieved twin objectives at the same time; spreading the new information regarding the PPT and simplifying the message. They were drawing on their vast knowledge on information dissemination and publishing. Thus, increasing the coverage and awareness of PPT from farmers to policy maker so as to equip and raise their interest to learn and apply the technology. Such an interaction for example, motivated the farmers to be interviewed as model farmers and the publicity received elevates their social standing. The, media is an important stakeholder:

> "The people trust the mass media and within a very short period of time, the information spreads very fast. It is easy for the extension to train farmers on what is already publicized via media" (*Bako Tibe extension expert, KI interview, April 2015).*

The media was represented by journalists from the Fana radio and Oromia Television with vast experience and network of coverage on news within the region and nationally. The media had previously been were reporting about the PPT and continued to play a significant role in the awareness creation and appreciation of PPT in the study area.

The Farm Input Suppliers

Provision of credit and access to agricultural inputs plays a key role in improving crop yields especially for major staples crops such as maize, sorghum and teff which contribute to food security. To make agriculture sector productive and competitive, a strong base of support involving input supplies and other services such as marketing, logistics, processing and storage are essential. The players in this sector have an important role to play in organizing timely supply of inputs to their customers. They don't just sell or distribute inputs; they also provide extension support on to the farmers on usage although at a limited scale. This is because the extension services in Ethiopia are largely in the hands of the public sector (Davis et al., 2009). In the study area, the function of input supply was in the hand of farmer cooperatives which were centrally managed under the Federal cooperatives agency with the support the co-operative union at the *Woreda levels*. It was noted that during off maize season, the input suppliers had no stock maize seeds and fertilizers for the farmers who were interested in irrigation. The introduction of maize growing during the off season using irrigation was a new dimension and therefore required that the input suppliers change their distribution strategy to avoid the shortage delays which the farmers were now faced during this period. The participation of the input suppliers and private agro-dealers during Woreda level meetings raised the concern of non-availability of seeds and fertilizer stocks in the store. They were told that, the seeds which were not planted in the previous season are returned to the central supplies for storage to maintain the viability. The input supply was a major limitation.

The private sector stakeholders were mainly agro-dealers. They were identified as important stakeholders during the *Woreda* level planning workshops as of traders dealing with small scale farming inputs such as seeds of horticultural crops and pesticides. They have networks to the village level. In addition to their accessibility, they play an important role making these inputs affordable through mini packaging them. This was seen as a sustainable model for small holder farmers who have no access to credit or disposable income to purchase in large quantity packages of 50kg in the case of fertilizers or full containers for pesticides. For the example, the case of the Jimma agro-dealer, in his shop he had repackaged seeds into smaller bags of half to quarter a kilo and were well labelled with different price tags based on what the farmers could afford. For example, in a situation a farmers wanted to plant a quarter an acre of plot, he doesn't need a whole bag fertilizer of 50kg as distributed by the cooperatives, the repackaged quantities provided farmers with flexible quantities based on need and affordability.

The availability and accessibility of farming inputs especially seeds of Brachiaria and Desmodium is critical requirements for the successful establishment of the PPT. These seeds were newly introduced products in the market specifically for PPT. Therefore the agro-dealers' participation as stakeholder was an important step towards addressing the sustainability question on the Desmodium and Brachiaria grass seeds from production to distribution. Based on their business model, they showed interest in PPT as a potential business opportunity where they could provide the market by purchasing seeds from the producers and sell it to the new PPT farmers. This was not limited to inputs alone. There was potential produce hay from the harvested PPT fodder to sell to other farmers with livestock, but not participating in PPT especially those located in the urban centers. Thus a thriving markets the farming products and inputs. Therefore, they wanted to see the technology grow fast to broaden the market base and reach. They were equally interested to learn about PPT. This was based on the fact that, they don't just sell or distribute farming inputs, but they also provide information support on the usage of their products although on a limited scale but restricted to what they sell.

The Youth Farmers

The youth farmers stakeholders, they were identified during the *Woreda* level planning workshop by the extension staff working with them in the field. The youth groups of farmers were aged over 18 and less than 40 years old. They have no formally designated land of their own. They hire land from other farmers for their farming enterprises. They were organized and work in groups to enable them pool labor and capital to afford renting farmland. They lack formal training in agriculture but engaging farming activities such as horticultural crop produces for the local market. Although they did not participate in the actual planning for PPT implementation, their role was recognized by *Woreda* administrations as important in the uptake of new innovations such as PPT. The stake of youth and their active participation in farming activities had drawn attention and taken seriously by the policy makers at *Woreda* levels. It was not limited to this study alone, in most cases; the youths and women are treated as an afterthought after planning has been finalized. They are treated as a special interest groups. This is what happened during planning for PPT whereby the inclusion of the youth farmer group was taken into consideration after field activities had started and after they had shown interest to join PPT activities on their own. This was initiated by one group of youth farmers who were keen on trying new innovations of horticultural farming such as tomatoes, kales, onions during dry season and was already growing maize for green cob production to sell in the market centers where they are consumed as roasted maize. They developed interest in PPT because it provided the platform for them to interact with researchers and extension staff, and a link to new opportunities such as trainings and exchange visits which they were seeking.

The Environment Coffee Forest Forum (ECFF) - NGO

The ECFF is a national NGO registered in Ethiopia, aimed at strengthening and promoting individual, institutional and organization efforts on the conservation and use of coffee forest resources. This is done through research on conservation planning, education and implementation of research results. They have strong partnership linkage with the Center for Development Research (ZEF) focal area of operation in Yayu forest, Yayu Woreda. The ECFF was part of the TDR team because they were involved during planning phase of the research and identification of stakeholders. They played key role in facilitation of stakeholder interaction. This was attributed to the capacity building from facilitator's training as part of ZEF contribution to the research process. They were important stakeholders based on their contact with the farmers neighboring the Yayu forests. As pointed out by Davis et al. (2009), NGOs don't work directly independently with farmers, but in collaboration with Woreda-level boards, this study benefited from its infrastructure and goodwill which already existed. In the Yayu forest, there are plenty of Desmodium growing as a wild plant and very prolific in producing seeds. Using the already existing programs for ECFF, where they work with farmers who are neighboring the forest, it was entry to meeting and discussing with to embrace PPT as an option to produce maize and produce fodder for their livestock instead of extraction of forest resources

6.8 Relationship Among the Stakeholders

The process and duration of identifying and engaging the stakeholders took about three months. The stemborer pest problem is specific to mainly cereal crops and which in this particular case the study was into specific *Woredas* of Oromia region. It means, to meet the specific persons of interest, it took some time to make to book appointments. This was attributed to the busy schedules with most of the stakeholders especially the researchers and MoA officials. Also the long distances of travel to different locations of the study areas especially between Jimma Arjo and Yayu *Woredas*. The location of Jimma University and Jimma research centers are a far apart from these sites and the availability of the researchers on a regular basis was a foreseen constraint from the limited time for field research and budgetary implications. Bako-Tibe *Woreda* was the only exception. It was convenient for the Bako researchers due to the location of Bako research center and also their mandate is focused on maize research. Although the researchers from Jimma were part of the stakeholder engagement team (Table 4), their participation during day to day research activities was a challenge. They were providing support and guidance through consultations and some joined later during evaluation stages of the field activities. They were still obligated to what they were tasked with; i.e. making follow-ups on the research questions raised, arrangements and commitments made during the planning workshop. This was a challenge to the research process which had a joint practical and action oriented approach spanning over a longer period of time and in different locations. This means that implementation process required investing in a lot of time and resources especially where the sites were located in different Woredas which were far apart from the research centers and university bases for researchers. Apart from the distances, the Agricultural research centers at Bako and Jimma have different focus in terms of mandates. Bako agricultural research center is mandated in maize research whereas Jimma agricultural research center is in coffee research. Such institutional and discipline oriented structures have influence on the development of the researchers career interests (Van Assche *et al.,* 2013). The researchers at Bako had more interest to participate in PPT than the researchers at Jimma, with the exception of weed scientist whose interest is closely linked with PPT on cover cropping. However, this doesn't mean their research and careers are closed and bounded to their research centers and mandates. For example, the entomology researchers have common interests on dealing with insect pests; the difference is the crops they are dealing with separates them.

The researchers' disciplinary understanding and knowledge of the stemborer played a key role in the planning and eventual implementation of the research process. Based on the discussion and interactions by the different stakeholders, it showed that the researchers had seemingly an upper hand in leading the process because they had strong focus on research careers and interests in insect-plant-environment interactions either as entomologists, chemical ecologists, weed scientists or social scientists. Despite the facilitator's efforts to bring out the ideas of the stakeholders as wide as possible, the other stakeholders, mainly extension and farmers and even journalists, limited their discussions to what they were used to do during day to day work. This concurs with Knorr-Cetina (2007), that such divisions are attributed to the culture of specialization arising out of long period career training and pursuits by the researchers whereas the other stakeholders mainly driven by intense division of labor and long periods of practice as professionals or smallholder farmers. The researchers saw research opportunities and were willing to explore PPT further into new frontiers, whereas, the extension professional saw an opportunity to reach farmers with new technology or intervention, and the farmers saw an opportunity to meet their immediate needs of cereal yields increase, fodder production and soil erosion control. Whereas, the journalist saw a story, the input supplier saw a potential business and youth farmer saw an opportunity to produce pumper harvest for quick sale and returns from the immediate market.

Despite the fact that PPT was introduced to address the perennial stemborer challenges, the different stakeholders, saw different opportunities as well as challenges. Such unique and different interests and understanding of the benefits and risks which come with PPT could be potentially become an opportunity or impendent for collaboration. This is because each stakeholder fosters own epistemic culture (Knorr-Cetina, 2007; 2009). Such a diverse interest base and perception of the PPT, requires mediation efforts for the stakeholders to work together not only to realize the benefits PPT, but also for team work and in the overall development of PPT as an innovation. Individually as stakeholders, they could not achieve their objectives without working together and making contribution in the implementation of the PPT. Regardless of their disciplinary, professional and practice experiences being diverse, transdisciplinary collaboration became a critical feature and was used as an opportunity to foster learning during PPT implementation.

The stakeholders had not implemented PPT before and its potential seemed rewarding to each of them and with immediate benefits and fears at the same time. However, they had questions (Box 1) which they required to learn in depth in the course of implementation process. For example, an extension staff from Yayu *Woreda*, raised the question on how to handle crop rotation with the perennial cropping nature of Brachiaria and Desmodium and what management practices farmers will to adhere to when rotating maize with crops such as *tef*, legumes or horticultural crops. Applying such seemingly complex and contradicting scenarios to already existing practices or preferences was interesting for the stakeholder as learning points from PPT. As opined by Evans (2005) and Gieryn (1983), these questions or scenarios were used as instruments for foster collaboration and enhance bold boundary crossing between the research and practice. According to Mollinga (2010), these questions were an indication of raised interests among the stakeholders and they can be likened to the kind of cross-over devices and procedures which should exist at the boundaries to make the collaboration even more interactive and effective. Each of the stakeholder groups was keen to learn about the questions or what the point of interest brings out in the course of PPT implementation.

6.9 Summary of Findings

The researchers' disciplinary understanding and knowledge of the stemborer plays a key role in the planning and eventual implementation of the research process. The long-term research experiences and competency of the researchers is linked with the PPT in terms insect-plant-environment interactions either as entomologists, chemical ecologists or weed scientists. The other stakeholders' competences are also linked to their own experiences to practice level activities on dissemination and farming. Despite the fact that the researchers and other practitioners are specialists, they acknowledge that, their total sum knowledge in addressing the stemborer challenges is greater than the knowledge of any single of them. This forms an important starting point for eventual stakeholder collaboration and engagement during the research and PPT implementation process. For example, the smallholder farmers and extension officials' contribution on research problem definition during the planning sessions were guided by their day to day experiences on the effect of stemborer pest damage on cereal crops. Their input was an integral part of the research process. This is contrary to what the researchers often refer to themselves to be on a higher level than other stakeholders in terms of initiating and leading the collaboration. This doesn't imply that, the researchers shouldn't lead the collaboration efforts, but there should be leadership and mediation of the process by other stakeholders.

The coming together of different stakeholders with diverse interests, view points and contexts and discussing on the same problem is a sign of commitment to finding a sustainable solution to a common problem. This was shown by their joint discussion and coming up with common questions as cooperation points to seek answers during the PPT implementation process. These questions form an important milestone and goal setting on how their interactions can contribute to the learning process and also strengthening their collaboration. However, coming and working together was not easy or automatic process. The process was faced resistances and occasional conflicts. As a safety precaution, the stakeholders tried to minimize these conflicts which potentially could halt the process using the terms of engagement (ToEs). These were deliberate efforts in order to work together, not only towards addressing the common problem but also in fostering joint learning. Facilitation of the process was central in playing a balancing role in such situations where the tensions could arise out of institutional or cultural expressions of dominance or in extreme cases personal differences.

The findings show that the mobilization and engagement of the right type of stakeholder plays a significant role in determining effectiveness of innovation development and its implementation. It starts with the understanding and definition of the common problem by the right type of stakeholders who are either affected, have interest and mandate to address the problem. Despite their diverse backgrounds, knowledge and experiences, the stemborer pests provided an opportunity and an important step for the different stakeholders to start to work as a team seeking for a solution. Facilitation skills acquired during the research process played a key role on knowledge and experience sharing among the local farmers' practices and scientific research approach to stemborer pest control. It ensures that, different stakeholders express their opinions freely and their diverse needs, ideas and interpretations become the basis for learning rather than contradictions.

Chapter 7:
Stakeholder Interaction and Social Learning: The Trans-disciplinary Action Research Process in Push-pull Technology Implementation

7.1 Introduction

The stemborer infestations contribute to significant maize crop yield loses which are incurred by farmers. This is also a challenge to the researchers and extension service providers who are the stakeholders in the agricultural sector and tasked to find a solution to this problem. The stemborer pest is a common problem which requires concerted effort and willingness to learn and act together among the stakeholders to finding a solution. This could be achieved from sharing and combining different views, interests, norms, values and knowledge both from the realm of practice and scientific perspectives (Bergman *et al*., 2005). Apart from learning, the participation of both researchers and other stakeholders is also a means for empowerment and increasing the legitimacy of the research engagement process (Siebenhüner, 2004) and taking ownership of the problem situation and solution in a way that benefits them. The prospects for success of such engagement can be built on the organization of the process and nature of interaction of the participating stakeholders (Renner et al., 2013). In this study, the practical on farm and joint stakeholder implementation of PPT was used as a platform for interaction and enhancing the social learning process. According to Keen et al. (2005, p. 4) “Social learning is the collective action and reflection that occurs among different individuals and groups as they work to improve the management of human and environmental interrelations”. That means, affected individuals have to learn together, innovate and adapt in response to their changing social and environmental needs. However, during the interaction process, the expectations of the different stakeholders will be driven or shaped by their epistemic cultures and interests. The major point of concern now is how the cross-boundary learning processes can be facilitated and made effective. Thus, social learning is not just participation or learning in a group setting, but active engagement of different individuals in a communicative process ensuring that there is mutual understanding of the challenges and creating strategies for improvement.

The interaction of the different stakeholders become more learning orientated in the way they tackle the problem at hand. In this study, social learning was sought to take place when researchers and other stakeholders shared their knowledge and experiences in a concerted action to address stemborer pest in maize and other related farming challenges. The on-farm PPT implementation provided an environment for facilitating learning through sharing and convergence of diverse interests, knowledge, understanding and expectations of the stakeholders on stemborer pest control. These efforts were expected to result in a change in behaviors, norms and procedures from the shared actions and practices (SLIM, 2004).

This chapter covers how different stakeholders' viewpoints based on their research, professional and past experiences came into play during PPT implementation and how this contributed to learning, gaining new insights, and hence the empowerment of the actors involved with regard to stemborer control and dealing with other new challenges which may be associated or emerging during the process. However, this may not be applicable to all the participants. Some may embrace fully or reject the whole idea from the start or drop later due to non-conformity with their needs. The transdisciplinary driven interaction process is assumed to be all democratic and allowing the participants to make decision independently without undue influence or coercion.

7.2 Following the Technology from Doubts to Appreciation

The introduction of PPT into the study area was a new intervention that was meant to address the perennial problem of stemborer pest in maize and other cereal crops. In order to appreciate its effectiveness or and as an alternative to previous practices, joint stakeholder learning was used to illustrate this during practical on farm implementation. This was also a basis for the negotiation and to foster links between researchers and other stakeholders who have interest in maize crop productivity and other related enterprises such as input distribution and marketing. These stakeholders had different knowledge bases, practices and interests emanating from the realm of their research and practice portfolios. Altogether, their interest on learning about PPT as an innovation ranged from its historical development, planning the implementation process to evaluation of its performance. Therefore, bringing such diverse groups of different stakeholders to start working and indeed learn together, require some sort of boundary work where such heterogeneity is acknowledged and appreciated (Akkerman and Bakker, 2011; Mollinga, 2010). Using the example of Tisenkopfs et al., (2015) who looked at how boundary work takes place in a network of farmers' organizations, researchers and extension systems, found out that:

> "boundary work and boundary objects can be used to illustrate how the process of learning takes place from the situation of unfamiliarity and lack of awareness and meaning to increased joint knowledge through intensive negotiation of meaning to gradually arriving at a similar level of familiarity, agreed definition of what the object means and how to deal with it" (Tisenkopfs et al., 2015, p. 21).

In this study, PPT was used as a boundary object and a shared practice for the stakeholders to learn and at the same time to address the challenge of stemborers pests in maize crop. During practical implementation process, the stakeholders had the opportunity to learn about and follow its activities along maize crop growth phenology. Like any other new technology, being introduced for the first time, there were mixed expectations and feelings during the initial stages of the implementation process among the participants. Some had high expectations on its performance while others were doubtful of its effectiveness. Nevertheless, the interest to learn more about PPT and the stemborer problem at hand kept them motivated from planning to implementation stages:

> "Initially I accepted PPT theoretically without seeing it practically. This was because of the challenges we are faced with from stemborers and wanted to learn more about the technology. I now understand its strategy and other benefits for the farmers from soil fertility improvement, stemborer control to providing additional fodder for livestock…..also the intercropping component of the technology, which we have been struggling to educate our farmers about, is now being introduced easily and simply by PPT" (*KI interview, extension expert, Bako, April 2015).*

The Ministry of Agriculture's extension office in the study area is encountered with resistance from the farmers on the practice of intercropping maize with an additional crop. Intercropping is supposed to act as a strategy for increasing productivity per unit area, stabilize yields and also to provide a good soil cover. However, this has not been easily accepted by the farmers. Conservation agriculture introduced by SG-2000 project (Sasakawa, 2007) reported similar experiences of difficulty for farmers accepting intercropping maize with other crops such as legumes. They regard the practice as an outdated and primitive farming. Partly this this was attributed to weeding challenges which are associated with intercropping and the nature of extension advice they received previously which laid emphasis on monocultures. For example, some farmers prefer to use an oxen drawn plough to weed their maize fields. Therefore, intercropping maize with another crop will make the ox-plough impossible and at the same time, hand weeding is labor intensive and expensive when the family has labor shortage. Moreover, most of the farmers regard maize monoculture as an age old practice of cropping the extension officials have been trained to advice their farmers on monoculture. Some of the extension officials saw PPT as an opportunity to re-introduce intercropping and hand weeding in maize farming. In addition to improving their knowledge on the concept of intercropping maize with Desmodium legume for stemborer control, but also an opportunity to use PPT as an extension message package.

7.2.1 Doubts and Rumors on the Push-pull Technology

The PPT implementation process was undertaken as a joint action among the researchers and other stakeholders on a continuous learning basis and evaluation of its activities. This was aimed at understanding its performance and other benefits. However, contrary to this, there were rumors which were peddled and targeted its adoption challenges dubbed as 'failings'. Some of these rumors include; introducing PPT was like cultivation of weeds on-farm, Desmodium leaves are very itchy when on contact with the human skin and also get stuck on the cloths and that land will be taken away by the promoters of the technology once it is established on farmers plots.

Some of these rumors are associated with the fear of the unknown and risk averseness of the farmers. The introduction of Desmodium as an intercrop was a new to the farmers in the study area. They knew Desmodium as a wild plant in the forest and when people get into contact, it immediately gets stuck on their cloths and is difficult to remove. They will have problem of always pecking off the seeds stuck on their cloths and their movements will be restricted on their maize farms due to dense growth and itchiness on their skins when on contact with Desmodium leaves. These fears and negative thoughts about the Desmodium sounded 'loud' than its perceived benefits. The negative rumors spread faster and have significant impact in swaying the perception of the users of new technologies such as PPT when introduced for the first time. These can potentially 'turn off' users from a beneficial technology. However, this is expected in a heterogeneous context where we have different stakeholders whose interests are diverse, undefined or conflicting right from the initial stages of technology implementation. Some of the stakeholders may think it is a threat to their comfort zones or existing enterprises or not keen to change their current status out of lack of trust to new technologies. For example, land ownership plays a critical role in ensuring family food and income security and also an inheritance to their children. Any transaction on land use and the implementation of new technologies has to be discussed and agreed by the family members. In situations where there is misunderstanding or lack of proper communication, the introduction of new technology, may be mistrusted and faced with low uptake or rejection. This was expressed by one of the farmers:

> "Initially I thought my husband sold land when he brought in PPT….. The selection of the farmers to participate in the implementation was done when I was away….. rumors went around the village that we shall lose our land to the promoters of the technology…..I confronted my husband on the issue…. I was not comfortable with PPT from the beginning". (*Female farmer during field visit, 16th February 2015, Jimma arjo).*

Apart from the rumors, there were also some of the stakeholders who expressed doubts on the suitability and the rationale of the PPT. They were of the opinion that the PPT is a concept which works technically but not practically especially on small holder farm conditions. Most of the smallholder cannot meet the management requirements of implementing PPT on a long term and sustainable basis. This concern was pointed out by one of the senior researchers with the Ethiopian Institute for Agriculture Research:

> "I doubt if the PPT can work on farmers' fields….my colleagues conducted on-station research experiments in the south of Ethiopia and they found out that Desmodium growth was faster and competing with maize crop for nutrients, thereby compromising on maize yields. Actually, to me, it is introducing weeds on farm" *(Researcher at Bako research center during interviews, November 2014).*

The establishment of PPT requires sufficient moisture for the seeds to sprout and establish. That means, without sufficient rains, farmers must irrigate their PPT plots. This was not possible to all the farmers and all the sites. Indeed, for learning purposes, we established some of the fields using irrigation supplemented with occasional short rains. However, during the season 2014/15, there was long period of drought which resulted to almost 100% crop failure. The PPT plots were not spared either. Due to high expectations, some of the farmers and other local stakeholders thought that PPT is a failure as a result of some plots failing to germinate:

> "I went to the field to see my farmers in Sombo village where you are conducting your experiment on establishment of PPT…..I found out that it failed….. Only maize germinated…..Desmodium and Brachiaria seeds failed to germinate. I think, it may not succeed in that area…..the technology require enough rainfall" (*Field extension officer, Yayu district, April, 2015).*

The farmers may have their skepticism regarding the intentions of the extension staff and even NGOs and generally the state and its agencies. This is based on the history of the country and the linear nature extension system camouflaged with political agenda. However, during this study, the rumors and doubts were generally targeted at the technology itself. Its newness, performance and the potential benefits were put into scrutiny by the stakeholders, from researchers, farmers and extension agents alike. In order to be placed or labeled as a trusted technology, these rumors and doubts were communicating the hurdles that the technology had to pass to become accepted or its performance understood or faces a rejection all together. As pointed out by Latour (1987) cited in (Bijker & Law, 1992) technologies do not have momentum of their own at the outset, they have to pass through a social medium where they are scrutinized, shaped and reshaped to either become novel forms or disappear altogether. The implementation of the PPT based on the transdisciplinary action research approach provided such a framework conditions where different stakeholders became engaged in learning and evaluating on its performance or worse case scenarios i.e. failings. For example, the rumor on Desmodium sticky leaves on clothing and itchy nature on human skin were dispelled during an on-farm joint stakeholder establishment and management of the PPT. It was discovered that, that the recommended Greenleaf type of Desmodium doesn't stick on their cloths. However, in the case of the silver leaf type, it does stick on the cloths when seeds have matured and ready for harvesting.

The rumored information became a basis for learning and a topic of interest during farmers training. The farmers were shown how the Desmodium seeds should be harvested and not let them stick to their cloths by wearing a polythene cover around the waist. In fact seeds sticking on their cloths were a dispersal mechanism by Desmodium plants. They also learned that harvested Desmodium seeds were a source of cash income due the demand created from the expansion of PPT to other areas and new farmers and not a nuisance as such. In general these rumors aroused curiosity, thus becoming an opportunity to learn more about the Desmodium. With respect to the rumor on lose of land to the promoters of PPT, this was initially attributed to lack of proper communication between husband and wife and later regarding the nature of establishment of the PPT companion crops which are required to stay on farm over longer term i.e. several cropping seasons. The Desmodium and Brachiaria grass remain in the farm even after the maize has been harvested. The rumor scared some of the farmers who thought that they cannot use the land for other purposes, apart from PPT. Equally this rumor was dispelled during on-farm interaction among the stakeholders. Some of the farmers who were affected by the rumors were invited for an exchange visit to Bako Tibe and Tolay *Woredas* where they exchanged experiences with other host farmers who had participated in the technology over three cropping seasons. The experienced farmers had also managed to undertake other management operations such as use of ox-plough and growing other legumes without compromising the performance of PPT.

The few farmers, who decided to participate in the technology, did it as a risk undertaking. Although the technology promised a solution to the problem of stemborer and provision of fodder, some of them were not convinced until they could see it happening or experience it first hand:

> "Initially I was doubtful of this technology, but decided to take the risk. …I was not sure if it will work out as promised….I wanted to see if it can result to not using chemicals in pest control" (*PPT Farmer during FGD, Bako Tibe district, March, 2015).*

The participatory nature of the joint stakeholder's practical learning especially to the farmers, enabled them to understand that, the interaction between their crops and the environment was a major factor contributing to pest and disease incidences and, at the same time, the management or manipulation of the same interactions can be applied to address the problem using tools such as PPT without resorting to applying chemicals.

7.2.2 Uncertainty of the Push-pull Technology

Some of the farmers and the local MoA extension officials were uncertain about the rationale and sustainability the PPT right from the beginning of the implementation process. The reasons for this ranged from unfamiliarity with the technology, fear of being required to incur expenses, commit their already constrained resources such as labor, land or incomes to changing of their traditional farming methods and practices. In addition, they had uncertainties on the new technology, because they were not sure of its performance and unforeseen consequences in case of failure. According to Rogers (2003), developer or promoter of a new product such as PPT must anticipate to face such challenges from either at institutional or individual levels of its targeted beneficiaries. The PPT is knowledge intensive (Khan et al., 2007) and was newly introduced in the study area. Therefore correct information exchange and right operational environment was crucial for its success and acknowledgement as an innovation addressing the problem of stemborer pests. To bring this to fruition, it required learning on a step by step basis in order to clear any doubts which may arise or become associated with it. For this reason, the farmers together with researchers and extension staff adopted a step by step learning-based strategy in order to improve the chances of success and clear any uncertainty in the process of following the technology through its activity implementation stages (Lynn et al., 1998). This strategy was adopted based on the previous experiences where agricultural technologies were introduced in the study area and a few farmers benefited while others were left out due to lack of correct information or some having a wait and see attitude due to fear or uncertainty:

> "Starting with SG 2000, many farmers rejected new farming technologies, because they lacked awareness. From that time, I learnt a lot about taking up and accepting new technologies and the benefits it brings to the farmers. Those farmers who took up the new technologies benefited a lot. I expect the PPT to be a success for me now and in the future….. I think I will gain more by practicing it on my farm" (*PPT farmer, Bako Tibe, March 2015).*

This particular farmer was able to recall and remember how some farmers benefited from learning and implementing new cropping technologies which were introduced by researchers and extension in the past to their area. However, some farmers failed to implement them due what they felt was related to uncertainties from lack of enough information, fear of failure or uncertainties. Other experiences showed that, when the researchers introduced new technologies as on-farm experimental trials, the farmers treated them as such and were for the researchers' interests. The results from the experiments required that farmers compare their own local practices with new experimental trials. Conducting these trials, over time, it created a sense of loss among the farmers. This was because of the perceived loss of land or space to these experimental trials. The experimental yields were obviously better while the control plot or usual practice was poor; hence, the farmer lost an opportunity to have good harvest from the so called control plots. They wished the whole farm was under new crop variety and not under experimentation. However, the set-up of the experiment requires that, the control and experimental plots had to be established side by side. The farmers were interested with results of better yields and not observable differences in performances under different treatments i.e. on control and experimental plots. In such instances, the farmers already had information on their plot's previous performance in term of yields. Such procedures of experimentation were associated with some of the farmers becoming risk averse with new technologies introduced to their area especially when they didn't see the need for certain implementation steps to be performed.

One notable example was a farmer and brother to the PPT farmer who wanted the researchers and extension farmers to help him establish the PPT plot first before he could go ahead with the technology. The farmer knew that the technology was benefiting the researchers and extension staff first and his will come much later. The extension staff together with other farmers assisted him establish the plot, but he never maintained the PPT plot. The Desmodium and Brachiaria grass were chocked by weeds. His focus was on harvesting maize crop. When he was asked why he ignored to maintain the PPT companion crops, he said:

> "The researchers and extension never showed interest in my plot after establishment as they did to my brother plot……I lost hope in it. I felt they were not interested with my farm and what I was doing" *(Follower farmer interview, Bako Tibe, March 2015).*

The example shows that, the PPT establishment faces uncertainty especially if it happens to be implemented by the farmers who are interested on immediate benefits. That means, it will be seen and treated like any other technologies which have been previously introduced into the area. The establishment of the PPT in the farmers' fields was not only meant to address the problem of stemborer pests, but also used as a site for joint learning among the researchers, farmers and extension staff. It was made clear from the beginning that, it was not a trial site to test the new companion crops (Brachiaria grass and Desmodium) or conduct survey interviews to assess farmers' perceptions on effectiveness of PPT. This was made deliberately to avoid repeating the incidents which were reported by the farmers. Previously new technologies were introduced on farmers' plots for on-farm trials and experimentation and their yield results were collected publications in scientific journals and no further follow up after the experiment. A notable and practical example cited was the introduction of bulking plots for Napier grass around the study site in Sedan Kite village of Bako *Woreda*. After the researchers experiment ended, the sites were abandoned and currently overgrown with the Napier grass. There were no follow up made on the next steps in terms of upscaling and training farmers to make use of the abundant seeds for Napier grass propagation. The farmers don't know what to do with the Napier grass.

The participatory introduction of the PPT was meant to overcome some of the uncertainty challenges. However, there was mixed results. Some farmers deliberately declined to participate in the technology while other took the technology just to see what 'goodies' may be associated with it:

> "The PPT is a good so far; I have received many visitors interested to see my farm and what I am doing with the new technology….however, its management requirements such as hand weeding are too demanding. Am a widow and my children are young. I cannot afford extra labor to pay for the weeding…..I may not be able to continue with PPT during the subsequent seasons…. (*PPT female farmer, comment during field visit, Sedan kite, Bako, April, 2015*)

This type of farmer, like others, decided to participate at the start but later realized that, the technology requires commitments and even investment in terms of labor and time during establishing and maintaining the plot. The choice and selection of farmers to initiate knowledge and labor intensive innovations such PPT can turn out to be tricky at the beginning of the implementation process. It requires farmers who are committed, ready to volunteer and also hanger their operations with risk taking in view of long term objectives or gains.

7.2.3 Appreciation of the Push-pull Technology

Despite the doubts, rumors and uncertainty expressed, not all stakeholders were of pessimistic on the PPT. There were those who started without doubts, dispelled rumors and developed confidence and even started conducting own research activities or making observations and looking for other potential benefits or applications with the PPT. Among the farmers, this group is mostly regarded as the innovators or early adopters. As opined by Rodger Everett (2003), these farmers know that a new innovation such as PPT has potential to benefit them and gain higher returns if they invest faster. The gains made are both on the short term and long term aspects:

> "During the first cropping season under the PPT, we made an observation and noticed that stemborer and birds which are perennial problems had started dropping at significant rate. However, for certainty, we decided to continue to follow these observations for some time during the next subsequent seasons. …i.e. after 2-3 years, we shall have an overall data and observations

to conclude and or make recommendations" (*Follower farmer comment during FGD, Bako Tibe, April 2015).*

The on-farm joint stakeholders PPT implementation showed that new knowledge or practices can be generated faster and as compared to the traditional research cycle. This was shown with the discussion and comments made by the Bako researchers:

> "We have researched for many years and in many places within Oromia region of Ethiopia. Still up to now, we are conducting research to find a permanent solution to stemborer problem. Now, with PPT and within a short period of time, it has been shown that is possible to control stemborers with additional 3 advantages: income, fodder and soil fertility…. I suspected PPT initially because I had my own thoughts as a researcher…. I have now started to change that position. I have seen practical benefits on the ground….PPT took a **s**hort period of time to address a perennial stemborer problem with other additional benefits….. Laboratory based research combined with field and on-farm trials takes over 7 years and not assured of finding a lasting solution to the stemborer problem. This is linked to many factors such as the pests developing resistance, variability of climatic conditions or sometimes farmers not interested with new crop varieties or approaches…. PPT provides a short-cut to this process and indeed an opportunity for other scientists and stakeholders to start learning and be engaged in its implementation" (*Interview, Researcher, Bako research center, February and March 2015, Bako Research Center*).

According to the Bako researcher, host resistant (maize) research takes a long time. To develop host resistance involves parent crossing and adaptation to different Agro-ecologies. The procedure for breeding for durable host resistance takes such a long time and farmers can't wait for these results. "Two years ago, Bako center received two maize varieties from Kiboko, Kenya for stemborer resistance research... these varieties are still under varietal verification committee. The process has not even started". According to the researchers, the collaboration and team learning, using the example of PPT is a short cut to the whole breeding process, where farmers and scientists come together and agree what is working and it's implemented basing on their needs and real-life-time conditions.

Apart from the problem of stemborer, the maize growing farmers constantly faced with other challenges such as soil erosion and lack of alternative sources of additional fodder for their livestock. With these challenges and hand the potential of the PPT, some of the farmers developed interest and were actively involved in its implementation:

"From the very beginning when I heard about the technology, I accepted to participate without any doubts…..this was because during the rainy season, I have suffered for many years due to the problem of soil erosion. I accepted to use the PPT as a measure to prevent soil erosion in addition to stemborer control…. I felt happy and accepted the technology to start on my farmland. However, initially the germination of maize was a problem and they looked yellowish and emaciated; gradually the maize growth improved with vigor. According to what I have learnt, this is attributed to the Desmodium and also the quality of the maize seed supplied from Bako Research Center…. At the same time, I haven't seen a lot of stemborers this time round in my maize crops. This is contrary to the previous cropping seasons, when the stemborers infestation is high and there are many birds attacking the maize crop….I hope this Desmodium protects maize from stemborers and from Birds!…. I think birds are searching for stemborers on the maize tassel, hence breaking it. I will verify these results on my own…. In this area, horticulture farming especially tomatoes is very challenging mainly due to pests and diseases. I also hope that Desmodium can do the same job on tomatoes or other horticultural crops? I would like also to find out this fact by my own…. I just want you to provide me with Desmodium seeds and I will provide you with results of my own research after 3 months" (*PPT Farmer comment FGD, Bako Tibe, April 2015).*

A farmer who takes lead as innovator becomes an example for the rest simply by the fact that he or she is open to learn more about the technology and its adaptation. Apart from seeing the potential benefits as prescribed by the promoters of the technology, such farmers seek for other hidden or additional benefits or opportunities. For example, this particular farmer, decided to engage in 'own research' and made 'own intuition' that birds attack maize cobs while searching for stemborer larvae on maize tassel. This observation and line of thought is completely outside what was initially thought by the researchers or promoters of the PPT. However, the joint implementation of PPT was participatory and gave the participants opportunity for learning and to conduct own observations and experimentation guided by their needs and perceptions. The priority problem at hand was soil and water conservation, not stemborer as such. This is what attracted the farmer to have interest and participate in the PPT. The same farmers saw the PPT as an opportunity to produce fodder for livestock while others considered it as opportunity to learn how to control pests in horticultural crops. This is an indication that immediate needs vary and is not necessarily the aligned to the common problem affecting other participating stakeholders. The implementation of the PPT is a continuous process following the maize cropping seasons from land preparation, planting, harvesting to processing for marketing. This is a platform providing entry opportunities for other players with diverse needs, interests and at different stages of crop management and development. The continuous learning during the process ensures that, even if one has developed some doubts, there are subsequent cropping stages and seasons to learn and make decisions or adjustments or sometimes drop PPT fully.

> "Initially when we planted maize, it was not good looking … by then Desmodium was small and had not grown and established well. As time progressed and maize matured and Desmodium covered the soil, everything now changed for the better. The maize was getting greener despite the fact that it was during dry season and we depended on irrigating the fields. The Desmodium cover retained lots of moisture during the day and we attributed all the good observations to Desmodium" (PPT *farmer, Sedan Kite village, March 2015, Bako Tibe district)***.**

The different stakeholders who were doubtful at the beginning of the implementation process was linked to either the newness or unfamiliarity of the technology and also had never heard nor known it before. However, their opinion changed as time went by. The maize crop performance was convincing and even better when compared to the previous seasons, although it was established under irrigation.

> "Initially I was feeling negative to take up this technology from the researchers and extension agents …..but now I don't want to lose the Desmodium…During main season, weeding is normally a challenge as weeds emerge very fast immediately after first weeding. Now with PPT, I think, much of the weeds will be smothered and there will be less weeding as compared when there is no Desmodium in the field. This technology has lots of potentials and is innovative in all respects…. addressing immediate farmer needs of food security and perennial fodder shortage for livestock" (*Interview PPT farmer, Jame Shono Village, March 2014, Yayu district).*

Based on the study conducted in the context of Khorezm agricultural system in Uzbekistan, Hornidge, et al. (2009), trust has to be built to become a basis for any form of cooperation, and precondition for the mutual transfer of new knowledge. They found that continuous cooperation through frequent meetings; workshops, group work during activity implementation and seminars, become crucial input to the overall process of building the trust. This is applicable not only among the participant stakeholders but also on what they are promoting or standing in for. In the current study, joint planning and on-farm PPT practical implementation provided an example of follow the innovation initiative from planning, plot layout, planting to crop harvesting and processing. During these stages the farmers and other stakeholders had frequent contact and worked together. With time, the stakeholders started to develop trust and confidence not only with PPT performance, but also its tangible benefits. This was concurred by comments made by the participants in Bako area in Ethiopia, notably:

> "We are now eating the maize. ….we managed to follow PPT from soil to the mouth of both human and livestock…..to health of humans and livestock….. It is beneficial for women who tend livestock; they can plant it on small plots and feed livestock" (*Comment made by female PPT during on farm visit, Sedan Kite, Bako Tibe district, April, 2015*).

The utilization of the PPT products, mainly healthy green maize and fodder is what culminated the confidence and trust on its benefits. Such immediate benefits formed the basis of building the initial trust which was important to get an acceptance from the farmers. As time went by and continuous interactions among the farmers, researchers and extension personnel, new insights were emerging not only about the technology benefits and opportunities but also challenges regarding the technology itself and also related to stakeholder collaborations and engagement.

7.3 Collaborations between the Researchers, Agriculture Extension Officials and Farmers

The introduction of the PPT was a new approach to the study area tailored to address the problem of stemborer pest infestation on cereal crops with specific focus on maize. The successful implementation depended on whether it got a buy-in by the different stakeholders starting during the initial stages of planning. These stakeholders were deemed as right actors who were faced by the stemborer problem, interested to learn and at the same time for the success of the process. At the federal and regional administrative levels of government, the stakeholders comprised of researchers, professional extension officials from line the ministries of; youth and representatives of women's affairs, water and irrigation, agriculture, livestock and cooperative development. At the *Woreda* level, the offices of vice administrators in charge of agriculture were the key stakeholders who are mandates to coordinate the different agricultural and related departments in their respective *Woredas* (MoFED, 2002). These offices were established in a view to overcome the challenges of inter-departmental boundaries, and to facilitate implementation of project activities which are essentially cross-cutting in addressing development needs the local level as possible. During the planning and implementation workshops for this study, the districts' vice administrators from the respective focal areas had interest on the PPT and provided necessary support. They embraced the participatory and transdisciplinary action research approach on PPT implementation based on the fact that it was corresponding with their coordination function and approach i.e., bringing together diverse stakeholders to work as a team towards solving a common development problem.

In addition, the *Woreda* administrative (coordination) offices have institutional, administrative and fiscal empowerment. This gives them the flexibility to initiate and collaborate with projects and programs with similar or complementary objectives. The PPT implementation process was undertaken in an already established framework of coordination under the leadership of the district vice-administrators in charge of agriculture. The administration officers organized regular meetings for follow-up to address any pressing or emerging issues within the *Woredas* and this study benefited from this setup by having frequent interactions and discussions with *Woreda* level policy makers on the implementation of the PPT.

Most of the *Woreda* level extension officials from different ministries accepted to voluntarily support and participate in the implementation of the PPT. They were interested on the science rationale and the concept of the PPT, and the agro-ecological principles on pest management which exploit crop-insect-environmental interactions to control stemborer pests. However, some were specifically assigned by the office of the coordinator to be part of the implementation team. The research implementation team was also supported by extension officials who volunteered from the study *Woredas*. Most of these extension officials were undertaking summer classes for bachelor degrees in plant and animal sciences or in natural resource management. They found the scientific concept of PPT closely linked it with their academic study programs, apart from addressing the problem of stemborer challenges facing their farmers. They were keen to learn more about the technology, from researchers and also from farmers' practical applications on-farm fields. All the DAs at the *Kebele* levels were mandated to participate in PPT implementation activities in in the study area. In addition, some DAs from the neighboring *Kebeles* participated in the PPT activities to learn and apply the knowledge in the course of their day to day work and in their academic persuasion.

The PPT, although science driven, its implementation process took into account of the already existing efforts of local practices and experiences on pests' control in the study areas. This interaction between science and society practices is an important aspect of the innovation ecology where a technology embraces diverse knowledge cultures and expert contributions from different stakeholders; a defining feature for sustainability of such systems (Caraca *et al*., 2009). This could be either solving the problem or learning from their experiences during interactions. This concurs with Leeuwis (2010), who stated that, innovations do not just consists of adopting technical devices, but also new social and organizational arrangements and relationships among the actors involved in the process. Such flexibility and openness in approaching the PPT implementation is responsible in creating framework conditions for learning among the participants. This is fueled by the problem at hand, but also the coming together of diverse stakeholders who would otherwise worked independently or not even aware of existence of innovations to address their challenges.

The practical implementation of PPT took place at farmers own fields. This created an opportunity which enabled farmer to farmer learning. The new PPT farmer fields were used as farmer managed learning sites for conducting events such as field days, whereby the new farmers were able to learn and appreciate the practical benefits from fellow farmers whom they share a lot of socio-economic and other related similarities (Amudavi *et al*. 2009a; 2009b). The participation and presence of the researchers and extension staff, who were eager to learn and share their knowledge, is an indication of relevance and importance of the technology for the farmers. This gave the farmers confidence to trust and freedom to open up to and 'embrace' the technology. This was happening against the backdrop of previous encounters whereby the farmers were always suspicious of new technologies or interventions. For example, during soil and water conservation campaigns which are conducted annually, the farmers always felt that they were 'forced' to participate in conservation efforts. This resulted in low adoption and lack of commitment to maintain the erected structures. This was because of the top down nature of the communication approach ingrained in the country's agriculture extension system which is centrally managed with strong political motives (Davis *et al.* 2007; Gebremedhin *et al*. 2006). A truly participatory extension is yet to evolve as a system in Ethiopia (Berhanu & Poulton, 2014). Hence prompting the need to have a locally embedded extension system approach which is matched to various agro-ecological zones (Abate *et al*., 2007) and responding to the needs and demands of the farmers and other stakeholders in these areas(Berhanu & Poulton, 2014). The lack of success in the previous technology introduction can partly be due to limitation of information provided to the farmers, lack of awareness and even, in some cases, to the extension staff (Sasakawa Global 2007). This is also linked to lack of capacity and empowerment of the relevant stakeholders to learn, acquire knowledge and adapt useful technologies.

Agricultural education and extension system requires significantly strong linkages with research and other stakeholders such as the private sector investments to meet the country's development objectives (Kassa 2005). There is need for the public sector extension services to go beyond participatory rhetoric (Abate *et al.*, 2011), and embrace joint development and implementation of innovations with local best fit and adaptation using a combination of both scientific and practice knowledge. Recently, it has been shown by Abate *et al.* (2011) that, a strong collaboration between national research and extension systems with regional administrations, cooperative unions, private sector and farmers is workable. This contributed to the accelerated adoption of new and high yielding varieties of three legumes i.e. common bean, chickpea and lentil) in Ethiopia. In light of these experiences, the participatory implementation of PPT using the TDR approach created an environment and framework conditions for farmers to learn stepwise, understand and finally be able to make decision on whether to continue or stop using the technology.

7.3.1 Farmer Experimentation

Innovative farmers are always try new technologies and sometime initiate own research or experiments using the observations or experiences they encounter in the course of their farming activities or when confronted with new challenges. They embrace new technologies and take risk of being the first to implement on their farms and outside the ‘prescriptive guidelines’. For example, one of the Push-Pull technology farmers from Amhara region of Ethiopia who feed her chicken with cereals, mainly maize, observed that, chicken were feeding on the Brachiaria grass she planted in her kitchen garden. With this observation, she decided cut and feed the chicken with mixture of chopped Desmodium leaves and Brachiaria grass under a caged structure. She later discovered that, the chicken liked and enjoyed feeding on the mixture and they were growing healthy. She attributed the observed change to the mixture of protein-starch supplement from Desmodium leaves and with maize grains respectively. Instead of feeding the chicken with only maize grains, she was able make a new chicken feedstuff with a mixture of Desmodium leaves, Brachiaria and maize grains. Although this was the first PPT farmer to report possibility of Desmodium and Brachiaria grass providing an alternative chicken feedstuff in Ethiopia, elsewhere in western Kenya, the PPT farmers have reported using the same mixture to feed their poultry as a supplement commercial feeds. Although, at the small scale or low input farming system, this is a new practice which farmers, out of their own observation and experimentation, they were able to discover. The high cost and lack of availability of commercial protein supplements are some of the contributing factors which are likely to prompt these farmers to seek alternatives solutions to increase productivity of their poultry or livestock in general.

The PPT farmer, from Sedan Kite village, Oromia region, has always embraced new agricultural technologies introduced to the area either as research or development projects by MoA and local administration. The recent project he implemented was the nurseries for Napier grass fodder and tree forestry. Although he doesn’t have own land, but does farming by renting in. This challenge hasn’t prevented him or shied him away from embracing new farming technologies. Previously, he worked with airports enterprises services in Addis Ababa as a daily laborer where he learned entrepreneurial skills. His entrepreneurial exposure and approach to farming activities have enabled him to identify potential benefits from new technologies before other farmers had noticed them. To this farmer, the PPT was not an exception. He said that, “since the introduction of the idea about the PPT, I accepted from the beginning. It has potential benefits for farmers. I took the risk and started. That is why I am currently encouraging other farmers to embrace the technology.” The interaction of this farmer with research and extension stakeholders exposed him to learn and have confidence to talk about the PPT to other farmers. He mentioned this by himself, based on the number of fellow farmers who were visiting him to make inquiries about PPT or ask him questions about the technology during social events. As host farmer he interacted with many visitors coming to his farm and he was able to express himself freely and clearly. He felt empowered through interactions with other stakeholders and started talk about PPT to fellow farmers and school going children with ease. This virtue was also noted during farmers' field day which he hosted, where he was able to articulate and clearly communicate the rationale and workings of PPT with additional personal experiences and insights. The interactions with researchers and extension officials gave him the exposure and improved his understanding on pest-crop-environment relationships. This made him to reflect on potential linkages to solving the problem of other pests affecting crops such as tomatoes, Irish potatoes and onions in the area. That is why went further to, initiate own research and experimentation to test the efficacy of Desmodium whether it can 'push' pests from maize crop:

> "I deliberately planted 3 rows of maize without Desmodium to see the performance of this technology. Indeed, the plants are infested. I am convinced that the technology is working. It is amazing…. I did this because I was not sure if the technology is working; now it is true to me that the technology is potentially addressing the problem. I think other farmers on seeing this too, they will believe that it works and become more interested….they are able to see it clearly" (*KI interview PPT farmer, Bako Tibe, March 2015).*

7.3.2 Communication between Farmers, Extension Officials and Researchers

The presence of researchers in the PPT implementation process was motivating and also attractive not only for farmers and local extension personnel, but also the students from the surrounding community who visited and interacted with the PPT farmers. This was contrary to the usual linear process of communication where researchers pass information to extension officials who do the same to the farmers. The new skills and attitudes of the different stakeholders developed in situ. For example, the PPT farmers could explain the rationale behind the PPT mechanism and how it addresses the stemborer problem using local examples and language. The farmers' attitude to speak publicly about the PPT attracted students from around the village schools who became interested to learn about it. This is what came to be 'science become simplified' and in the hands of farmers. This is linked from practical point of view, where the farmers could be able to talk and train others on a science-based technology by simply associating it with their knowledge and local practices on maize and other cereal crop farming.

Apart from joint stakeholder activities, during some days, the farmers undertook the activities on their own without the involvement of other stakeholders. During these events, they were able to make own observations about PPT performance and also failings. For example, during weeding, they observed that Desmodium makes 'soil soft'. They made this observation during the fourth month of establishing the PPT plot during their routine surveying and making observations on progress. They discovered that, it was easy to uproot weeds using hands. This was contrary to what was normally done during this stage of maize growth, when its cobs already matured and uprooting weeds is not easy due to soil compaction. They also observed that the maze stalks were still green. They attributed it with Desmodium, which besides improving soil structure; it retains moisture, making the farm look evergreen. The evergreen conditions are an indication for fodder abundance after harvesting the maize cobs. That means Desmodium improves soil, crop and animal health. In light of this, there was a contrast with the neighboring maize field which was initially established as a PPT plot, but Desmodium failed to germinate. The observable differences between the two plots were convincing that Desmodium was responsible to the observable changes on the soil conditions.

The absence or reduced of stemborer attacks on the maize was a sign for farmers to appreciate that PPT had a role to play in making the maize 'invisible' to the stemborer moths. This practical observation was explained by the researcher (entomologist) in the team. He explained how Desmodium produces a natural smell (semio-chemicals) which the stemborer moths doesn't like hence repelled ('pushed') away from laying eggs on the main crop (Maize) and they are attracted ('pulled') to lay eggs on the alternative host, Brachiaria grass, where when hatched, the majority don't survive to maturity. This was informative to the farmers and extension workers who knew the PPT concept without the actual practical observations. When they compared neighboring maize plot where Desmodium failed to germinate, it had an additional observable difference. This plot was established by farmers themselves with the assistance of DA in the absence of the researchers and *Woreda* level extension officials. During planting of this plot, the farmers failed to take note of the fact that Desmodium seeds were very small and when planting them, they should be covered with a thin amount of soil of fine tilt. Instead they covered them with same amount of soil to depths similar to when planting maize seeds. Also, using furrow irrigation, the water flow was uncontrolled which lead to flooding and burying the seeds further deep into the soil or sweeping them out of the rows.

The PPT is knowledge intensive (Khan et al., 2007). That means, it requires 'hand holding' for the new practitioners to understand and undertake the required steps. Apart from the fact that the technology fits in their farming practices, the plot layout plan and crops management practices should be adhered to for its effective performance. Equally, these insights provided the extension officials with an opportunity to learn and acquire new and technical skills for their work. For example, in order for "Desmodium and Brachiaria grass to establish effectively, there is need for sufficient moisture in the soil as compared to maize" a farmer commented based on own observations. In Jimma Arjo district and Yayu *Woreda* the Desmodium and Brachiaria failed to germinate but maize managed and they were established at the same time. The residual moisture was not sufficient for 'the new crops' to sprout. The host farmer was able to comment this through own observations and supported by fellow farmers. The extension officials used these observations as additional message for their extension work.

> "I will use the farmers' experiences and thoughts to train other farmers in the *Woreda* by establishing a farmer based learning and knowledge sharing platform…..I have learned a new extension approach from PPT implementation process" (*Interview, Development Agent, Jimma Arjo March 2015*).

Almost similar sentiment was echoed by another development agent at Bako Tibe district, who said:

> "I used to teach farmers using my own skills, expertise and knowledge without the role and input of the farmers' contribution. Now, I have gained new perspectives and insights for extension service delivery during the PPT implementation process […]. I will also use the farmers' experiences to train other farmers in the Woreda" (*Interview, Development Agent, Jimma Arjo April 2015).*

7.3.3 Opportunities for Extension Education and Training

Apart from using PPT to addressing the challenge of stemborer in farmers' fields, its practical implementation was seen as an opportunity for the agricultural college tutors to learn and have hands-on experience on the its workings. Infact farm implementation was an interesting opportunity for training not only new farmers but also the Bako agricultural training college students and tutors:

> "Now it is easy to read and understand printed materials on PPT and teach my students who will become DAs and eventually train farmers about this technology … This was a perfect opportunity for introducing practical technology as a tool for training and for learning by various disciplines in our college …and seems to touch all the departments… from technology trader, crops to animal health" (*Interview, Tutor Bako Agric. College, May 2015*).

From the experiences of Sasakawa Global 2000 (SG 2000) program, which was introduced in 1995 for the transformation of the agricultural sector, many farmers were reluctant to embrace new technology packages and recommendations of improved crop varieties such as maize, wheat, teff and sorghum. However, the first few farmers who accepted to implement them benefited a great deal by having substantial increases in crop outputs. These technologies came along with other production-influencing packages like the promotion of water harvesting and utilization techniques, improved post-harvest and agro-processing technologies, minimum tillage practices and grain inventory credit schemes (Abera, 2006). This resulted in the increased incomes and improved livelihoods for the few farmers who implemented them. From such past experiences, the farmers have learnt to take up new technologies as an opportunity for training and acquiring new skills to improve their farming activities. This time round, with the introduction of PPT and based on the past experiences of ignoring new technologies, they were keener to see how it works and possibly apply it. That means, they were ready and willing to learn, implement and see the opportunities coming with PPT. From such history, the farmers had learnt a lot about the importance of accepting new technologies which have potential benefits. Hence they had high hopes that PPT was likely to be a success. In most cases farmers are not keen to embrace new technologies which don't seem provide them with immediate benefits. They do not usually think about or look at the potential of these technologies in addressing the long-term problems. This could be attributed to lack detailed information and commitment of the promoters of these new technologies when introducing them. However, with PPT implementation, the stepwise implementation and continuous stakeholder interactions were meant to ensure that the participants were able learn and comprehend each and every stage and were part and parcel of the process.

> "New technologies take time to see benefits… Besides, its long term perspectives, PPT has immediate benefits to farmers such as fodder, soil and water conservation….continuous interaction with scientists, fellow farmers and even visiting farmers from other *Kebeles* during field days….. …With PPT, the farmers are able to see immediate benefits in 3 months... PPT is actual implementation and continuous learning" *(KI Interview, female expert, youth affairs, Bako Tibe district, April 2015).*

7.3.4 Desmodium Seed Collection and On-farm Bulking

Before PPT was introduced in the study area, some of the farmers knew that Desmodium was a crop which was introduced to their farms from the nearby Bako, Jimma and Matuu research centers. It was used either as fodder crop for livestock or as cover crop for coffee farmers. Whereas in Yayu and other areas, some of the farmers knew Desmodium as a wild plant growing in the forest and along the farm hedges. These farmers altogether, had never thought that Desmodium as wild plant could become an on farm crop, a traded commodity and as a source of income by from the sale of its seeds. For example, farmers in Jameshone *Kebele*, Yayu district, were impressed with the idea of collecting and bulking Desmodium seeds for sale. Silver leaf and modest quantity for green leaf Desmodium were abundant in Yayu forest. As a key component for establishment of PPT, the production source and market for Desmodium was promising from farmers' collections and demand. The farmers in the Yayu area were interested on how they can be contracted to collect the seeds from the forest or plant on large scale to produce enough seeds for the market. During these interactions, an agro-dealer from the nearby Jimma town dealing in seed production and marketing was contracted and he started buying Desmodium seeds from the farmers who were also collecting them from the forest (Fig. 15). The agro-dealer managed to collect and deliver to the Ministry of Agriculture 3 tons of Silverleaf Desmodium for new PPT farmers during the long rainy season in 2014/2015. Individual farmer seed collectors supplied 40kg from forest collection and Jimma Agricultural College supplied 16kg harvested from bulking plots. The private agro-dealer embarked on stabilizing the seed collection network. The entry of PPT stimulated the Desmodium seed demand and expanded market which, at the same time, has a significant influence on the sustainability of PPT. Desmodium seed production became as a learning opportunity for the stakeholders who started thinking on how to establish and meet the needs of the new and emerging market. For example, the Bako Agricultural College initiated a trainers program on Desmodium seed bulking as an enterprise for income among the youth and landless.

Figure 15: Farmer household collecting Desmodium seeds from a forest boundary

Field photo: Nyang'au I.M.

7.4 The Push-Pull Technology Fitting and Adding Value to Existing Local Farming Practices

The introduction of the PPT in the study area was treated as a complimentary farming practice which added value to the already existing farmer practices aimed at controlling stemborer and improving maize productivity. This came out during on-farm practical implementation when the farmers, researchers and extension staff learnt of PPT attributes which were fitting and adding value to local farming practices.

The frequent interactions among the stakeholders based on PPT activities contributed to learning on its performance in addressing the stemborer problem and provision of other additional benefits. Misconceptions, negative rumors and doubts that emerged during the initial stages of the planning process and introduction of PPT into the area turned out as 'triggers for learning' (Wals, 2009, pp.14). This was expected, based on the fact that it was being introduced for the first time. As time went by and interactions intensified, the farmers and other stakeholders learnt that PPT is an agro-ecological based approach that is culturally compatible and doesn't contradict their farming activities or enterprises. But rather, it is built on and compliments their knowledge and local farming practices with a combination of scientific research to address their challenges. This concurred with Altieri (1993), who pointed out that, for an innovation to succeed, its complementarity with local farming situation and needs is necessary and should be able to take advantage of the benefits of ethno-science during implementation:

> "After a severe stemborer outbreak, the farmers were ploughing into the soil or burnt to kill any remaining larvae. Infested plants were removed and composted or used as fodder. Despite all the efforts, the infestations were still high. These areas are stemborer hotspots. Whatever farmers did previously in the control of stemborers was not working" **(***Farmer during interview, Bako Tibe April 2015*).

Although not highly effective, farmers and local extension agents had devised various strategies using their local experiences and knowledge to address the problem of stemborers e.g. planting more than one maize seed per hole i.e., establishing high maize crop population. The farmers practiced this method as a stemborer pest management strategy such that when infested plants were identified, they were carefully pruned before the pest could spread to other maize crops in the field. They manually removed infested plants and either burned them or fed to livestock as fodder. This strategy was meant to ensure that at least, the remaining maize crop population was fairly sufficient to enable the farmers have a healthy crop or make some harvests. Farmers adopted this approach with hope that only a portion of maize crop will be infested. However, in the stemborer hotspot areas, the natural infestation is so severe that almost the spread affects more than half and sometimes the entire maize fields. The strategy of high crop density proved not only ineffective, but expensive for the farmers, from seed losses, fertilizer to soil nutrients depletion.

The on-farm implementation of the PPT enabled farmers to learn that, they don't need to apply high crop density on their farms as a stemborer management strategy. They are only required to maintain proper spacing and following the recommended plant population to achieve a pest free crop and good yields. For this reason, PPT added value to their farming systems by reducing crop population, seed wastage, and overcrowding, poor crop health and by replacing with proper spacing, nitrogen fixation from legume intercrop and fodder from border grasses. The extension officials, researchers and farmers' practical knowledge and experience, identified that early planting enables the maize crop to escape high stemborer infestations. The establishment of the PPT as a strategy re-introduced this practice of crop diversification and early planting. The PPT complimented the practice by emphasizing on early land preparation and planting to enable the establishment of the companion crops and for the 'Push' and 'Pull' effect to set in early. At the same time, the crops are able to exploit earlier rains for their establishment.

Traditionally, the small holder farmers practiced risk avoidance by using mixed cropping and flexible planting dates as a strategy meant to manage pests' infestation and increased chances of harvesting at least one crop in case of failure due to severe attack. "Nowhere is the potential of biodiversity and ethno-science more applicable than in pest management" (Altieri, 1993, p 257). The local farmers in the study areas, used to practice the mixed cropping technique, but due to extension advice to shift from the 'backward' practices to the so called 'modern' maize crop monocultures, has led to increased incidences of stemborer pest infestation. Farmers had knowledge that isolated maize monocrop plots were susceptible to attack by stemborer pests. This was because the stemborer moth is able to locate the host plant (maize) easily. The introduction of PPT overcame this challenge as a mixed cropping strategy. Researchers and extension officials used this as a platform and opportunity to share their knowledge and experiences with the farmers on the importance of mixed cropping and how the strategy interrupts the pests' life cycle and how the pest population is managed with the abundance of natural enemies due to enhanced biodiversity (Midega et al., 2005; Altieri, 1993).

The farmers together with local administration officials, EIAR and soil and water conservation section of the Ministry of Agriculture have been trying on annual basis to conduct public awareness and sensitization trainings on soil and water conservation measures. During these campaigns, the Vetiver grass is being promoted as best candidate grass for planting on areas susceptible to soil erosion. The grass was selected due to its deep rooting system which holds soil together and dense growth which prevents surface water runoff. The Vetiver grass is a drought resistant and perennial crop. However, it is not readily edible by livestock due to its stiff foliage. The PPT based Brachiaria grass has the same growth and adaptation properties like Vetiver grass with exception that it is soft, palatable and nutritious for livestock feeding. The introduction of PPT added value to the existing efforts on soil and water conservation to another a notch higher by introducing livestock feed component as part of the promotion campaigns. The widespread adoption of Vetiver grass for soil and water conservation could offer lessons for adaptation of PPT using Brachiaria grass in addressing the problem of soil erosion.

The local farmers are used to burning their farmlands to clear off crop residues, weeds, and insect pests in preparation for ploughing and planting. They have a belief that burning the previous harvest residues and vegetation around the farm kills the eggs of stemborer. This observation was agreeable by the researchers who shared information with farmers that, during dry period or off-crop season, the larvae remain dormant while waiting for the right environmental conditions (Khan *et al*., 1997). However, for PPT farmers, the burning will result to destroying the companion crops, Desmodium and Brachiaria grass and also killing soil micro-organisms. The burning also destroys the crop residues' bulk of biomass which could feed livestock and also used as organic manure when composted. For example….(see comment below made by Follower Farmer during FGD, Bako Tibe April 2015).

> "The farmers know that, when they burn the crop residues, the eggs and stemborer moths are destroyed, but at the same time, don't like it as it contributes to biomass loses. Using PPT, we can manage the pest problem simply …. Desmodium can smoother the weeds….and after harvesting; the residues are organic materials which can be converted to several other uses e.g. the biomass from maize is cattle feed…. Desmodium has brought a solution to hard questions raised by farmers in the past on stemborers control. A technology controlling stemborers without use of chemicals is a good technology".

During off-season of maize cropping, farmers had accessibility challenges to hybrid seeds and fertilizers. The researchers from Bako Research Center provided Gibbe II maize seed variety. The seeds were meant to initiate the PPT implementation as a stop gap measure. Gibe II, is a relatively high yielding variety of maize which is open pollinated. That means, it possible for farmers to recycle seed up to five subsequent seasons. As compared to the conventional hybrid maize, the open pollinated seed selection can help to address the challenge of hybrid seed dependence for the smallholder farmers who may not afford to purchase during each planting season. It can also cut the cost of maize seed input for the farmers. This information was useful for the farmers who wanted to participate in PPT. That meams they could recycle and use own maize seeds during off-season when the short supplies was witnessed and still achieve good yields. The promoters of hybrid seed varieties in most cases; they seek assistance of the Development Agents to popularize their seeds. This means that farmers have to purchase these seeds during each planting season. The joint and participatory implementation of PPT was a window of opportunity for especially the farmers to learn new information regarding the potential of Gibbe II maize variety, which they embraced and started selecting the best seeds for next planting season. They were impressed with its performance under the PPT. This was also useful information for the Bako researchers who were monitoring and evaluating the performance of Gibbe II maize breed seeds.

During weeding of PPT plots, it was noted that, the farmers deliberately left some plants or weeds to stand with crops or cleared them only partly and leaving some of the ‘ weeds’ to continue to grow. This observation, according Altieri (1993), is a relaxed form of weeding. It is usually not recommended by the researchers and extension officials who would rather prefer clean weeding i.e., ridding off any form of weeds from the main crop. However, after interaction and discussion with the farmers, it came out that; the farmers had reservation to the so called ‘weeds’. They deliberately left certain weeds to grow to serve useful purposes such as fodder for livestock, vegetables for humans or conserve moisture during low rain season or some could be allowed to grow into trees for fruit production or harvested for timber, firewood etc. For example, farmers knew that after maize cobs have been formed, the growth of weeds has no effect in nutrient competition. At this stage, they were concerned on conserving the moisture in the soil to support the growth and survival of the crop especially when the rains are low. In Bako area for example, the farmers allow weeds to grow in the later stage of maize growth (after formed cobs) and use it for feeding livestock either by cut and carry or as standing biomass for direct feeding after harvest when livestock is allowed to roam freely in the fields. This practice was an opportunity for the farmers to understand the logic of Desmodium and Brachiaria grass as intercrop and trap crops for stemborer pest control and use as fodder. The PPT introduces and increases biomass towards supporting the cereal-livestock production systems which depend on each other.

Cultural values or practices contribute to the learning process and influence the effectiveness of the interaction among the stakeholders during implementation of new innovations such as PPT. The notable example was ploughing using oxen. Considering the labor demands during land preparation, planting and weeding, farmers in the study area and in Ethiopia in general use of oxen drawn plough to perform these activities. To the farmers who were used to this age old practice, the introduction of PPT seemed too complicated and disruptive. None of the stakeholders had knowledge on how to establish PPT using oxen drawn plough especially on farm layout. The farmers, researchers and extension staff did a joint practice using ox-drawn plough during the first establishment and second planting. During PPT first establishment, the host farmers using their extensive knowledge on how to drive ox-plough, made straight lines for planting maze and Brachiaria. The researchers and extension officials provided information on spacing and farm layout to prevent soil erosion. During the second planting, the Desmodium was trimmed and the lines were visible and easily allowed the ox plough to be moved easily without uprooting it. This was also depended on the experience of the host farmers in handling the ox drawn plough. At this stage of PPT implementation, the farmers appreciated the significance of the inter-row spacing of 75cm. Initially some thought of it as a waste of space. Instead it made work easy when ploughing using ox-plough. The use of oxen drawn plough provided an opportunity for both local farmers and researchers to learn together and demonstrate their joint practices in implementing PPT.

7.5 New Knowledge and Insights Gained by the Stakeholders from Implementing the Push-pull Technology

This is in reference to new actionable knowledge and strategies developed as a result of the stakeholders interactions during planning and implementation of the PPT. This includes farmer innovations meant to address new challenges which came as a result of participating in PPT implementation. Out of the observations made and stakeholder interactions, new aspects came up, which were seen or learnt during PPT implementation process for the first time. The stakeholders had not come across such observations nor were aware of this kind of information before. As opined by McLean (2004), the PPT implementation process provided an opportunity for a continuous self-transcending through which one transcends the boundary of the old self into a new self by acquiring a new context, new view of the world and new knowledge.

One farmer during on-farm focus group discussion made an observation that Brachiaria grass looked fleshy, green and well growing despite the dry weather conditions. Why is this? He wanted to know. During the discussion, the researcher from Bako research center replied that, the Brachiaria grass is adapted to drought conditions in such a way that its rooting system is very extensive allowing it to tolerate low rainfall and enables it to have rapid growth after establishment. Its fleshy looking leaves were as a result of its efficient use of dew on the surface of its leaves and, as a result, able to maintain greenness even during the dry season. Apart from being an effective trap plant for stemborer, this also makes it an alternative forage crop. This was the first time farmers and extension officers were witnessing the Brachiaria grass growing on farm. Although they knew Brachiaria previously, but as a wild grass which grows in the forest. They had not thought of domesticating Brachiaria grass on farm as a crop.

The PPT has soil conservation properties. This supported the natural resource management initiatives by the Ministry of Agriculture. The PPT introduced new companion crops which were supporting soil and water conservation campaigns. This was appreciated by the stakeholders as an additional approach to the already existing initiatives. “The Desmodium and Brachiaria rooting systems strengthen the soil. Then, during dry season, the soil doesn’t crack thereby reducing the exposure to erosion”, farmer comment during focus group discussions. This was new experience for the farmers. The soil cover effect of the Desmodium before and after harvesting maize crop maintains moisture in the soil. Landscaping and beautification of farmland with the inter-row spacing to allow furrow irrigation without the effect of soil erosion and flooding, while at the same time, having a border crop separated from the main crop with a foot path for allowing the farmer undertake farm management operations without disturbing the crop was a new farming arrangement. This is what people are used to do in their compound and not on farm. These make farming attractive and the PPT farm a place to visit and learn:

"The maize and Desmodium rows and boundary grasses of the PPT plot beautify the maize field and the land looks neat and unique and it is attractive….." (PPT *Farmer during FGD Bako Tibe, March 2015*).

The age-old practice of allowing livestock to roam freely after harvesting cereal crops seemed to be getting re- assessment for possible future solution. During rainy season crops are planted in nearly all the farms and farmers have a social responsibility and as an obligation to guard or fence off their crop fields from being destroyed by livestock. At the same time, there is plenty fodder in the communal grazing lands, around the homesteads; the farmers are not challenged with livestock feeding. However, during the dry season, the farmers have the tradition of letting their livestock roam freely in search of feed and also make themselves free to travel to markets or visit relatives rather than stay around to guard their livestock. The PPT plot is perennial, so for it to survive during successive seasons, it has to be protected during off-season. Based on this, the farmers were considering the possibility to control roaming livestock during off-cereal cropping season. It will take some time to bring overall change to this. The PPT farmers had initiated this by fencing off their PPT farms. Therefore in order to institutionalize guarding or protecting the crop fields during dry season from roaming livestock, the situation needs further discussion among the stakeholders using the already initiated experiences of PPT farmers.

The PPT introduction created new business investment opportunities which did not exist before such as commercial collection or production of Desmodium and Brachiaria seeds. Previously, after harvesting maize, the animals were left to roam freely on the maize fields. Now with PPT, these plots have to be protected. The farmers had learned to use these plots to plant short-time maturing and high quality legumes such as chickpea.

"With PPT farmers have learned the practice of double cropping….when maize is harvested, the moisture retention under PPT plot is used to sow chickpea. There is no gap for the fields to be free and unattended. Chickpea is planted as a security to the plot under PPT. This knowledge is from the training farmers have received from researchers and extension staffs" (*Interview with icipe field technician, Tolay district, May 2015*).

The coming together of stakeholders and continuous interactions of the team during PPT implementation with diverse expertise and commitments opened up discussion on other potential benefits such as Desmodium seed collection, not only for income but as a forest enterprise for conservation and green maize during off rainy season. In the study area, for example the silver leaf Desmodium was available in plenty in the Yayu forest area and in the hedges along farm boundaries. With the introduction of PPT, the farmers started seed collection for sale to their neighbors and for the emerging market from new farmers elsewhere. In addition, the coming together of stakeholders during PPT enabled them to resolve a conflict which arose from water use and management during irrigation. Horticultural farmers growing crops such as tomatoes, onions and cabbage during the dry season were fighting over access and distribution of water for irrigation with PPT farmers. The horticultural crop producing farmers felt that water should not be diverted for maize production. This degenerated into a conflict. It took the intervention of the research team together with the affected farmers and officials from the Ministry of Water and Irrigation, to have a joint meeting where it was decided for a formal water use agreement. The Ministry officials together with farmers and local administrators facilitated the negotiation with other water users in the affected areas. The agreements covered on the time and amount of water to be used by each farmer participating in irrigation activities. The formal document had all the stakeholders appending their signatures. The potential triggers of the water use conflict were openly discussed and resolution mechanisms were well stipulated and agreed. The agreements outlined how to resolve future conflicts arising out of the water uses. The underlying motive of the agreements was based on the fact the water was being used by many people along the river and everyone had right to access and use. The ministry of water and irrigation officials facilitated the agreements and they have the overall responsibility to ensure that all the stakeholders along the riparian, have user rights without compromising the river ecosystems and other users downstream. These formal agreements overruled the informally agreed water use arrangements.

Fodder provision was a major livestock production challenge in the area attributed to reduced grazing lands from increased farmland (Fig. 16). The farmers learnt that it was possible to address these challenges through planting fodder for indoor livestock feeding. The practice of cut-and-carry fodder is a way to explore for the future reducing the quantity of livestock and with more attention to quality (Fig. 17). Cut-and-carry is potentially an environmental conservation approach which has win-win for farmers and the livestock. Cutting fodder and feed livestock at home or in a fenced area is hectic but more productive for the farmer as compared to allowing them to roam and graze freely in fields where they have less to feed on and, hence become less productive (Fig. 18).

Figure 16: Livestock scavenging for fodder.
Field Photo: Nyangau I.M.

Figure 17: Farmer carrying fodder for indoor feeding.
Source: Nyang'au I.M.

Figure 18. Family member feeding livestock with fodder harvested from PPT plot
Field photo: Nyang'au I.M.

7.6 New Strategies: Farmer Innovations to Address New Challenges with Push-pull Technology

The PPT implementation process had promising opportunities but it brought new share of challenges at farmers' level. Before the introduction of this technology, these farmers had not experienced such problems. Despite these, the farmers together with other stakeholders were optimistic and determined and in fact they used some of the challenges as opportunities for learning. During the process, they developed new strategies to deal with the challenges.

7.6.1 New Pests Attacking Push-pull Crops

In the study area, it was too early to notice any new pests associated with the PPT. However, the emergence of new pest attack was challenge cited by the PPT farmers with more than 1 cropping season. For example in Tolay area, farmers noted that, grasshoppers which were not a problem before PPT had emerged during the rainy season. The farmers observed that Maize, Teff and millet shoots are not attacked by grasshoppers, but only Brachiaria grass. Further they noticed that Brachiaria grass is susceptible to grasshoppers in black soils than in red soils and Brachiaria grass grows faster in red soil than in the black cotton soil. The farmers attributed the attack of grasshoppers by their preference to lay eggs in the black cotton to red soils.

During the discussions, it was revealed that some farmers replanted Brachiaria grass 2-3 times as a result of persistent attack by the grasshopper pests. This affected growth rate. In order to deal with the problem, the farmers, out of their own intuition, discovered that it was preferable to use root splits to establish Brachiaria in black cotton soils not only to manage the grasshopper pests but also for faster sprouting and tillering. This became an example of a local adapted knowledge based on farmers' own experimentation.

The Blister beetles was not common in the area before PPT. They were observed at Tolay fields where farmers were bulking Desmodium for seed production (Fig. 19). The blister beetles attacked Desmodium at flowering stage. The farmers observed that the problem was severe on mono crop Desmodium. This posed a serious challenge for commercial production of Desmodium seeds. At the moment, the farmers have no management strategies, but based on the advice of the chemical ecologist researcher and experience from Kenya, the only solution is polyculture arrangement of crops such that between the rows of Desmodium, there is another crop. This was agreeable as it was witnessed by the farmers who observed that in their PPT plots, the blister beetles were not attacking the Desmodium flowers. The mechanical destruction of Blister beetles is the only method farmers can apply but it is not sustainable. The chemical ecologist in the team recommended the use of simple baits as traps which should be easy to use e.g., the use of flowers as color attractants which are laced biological control agent e.g., fungus. There need to explore further on odor attractants.

Figure 19: Blister beetles feeding on Desmodium flowers

Field photo: Nyang'au I.M.

7.6.2 Harvesting of Push-pull Seeds

This was the first time the farmers were learning that seeds from Brachiaria and Desmodium can be harvested and used for establishment of PPT and also the right timing for harvesting the seeds. When the seeds were mature, they are ready for harvesting; otherwise they dropped to the ground and germinated. This was a loss for the farmers. During the process of stakeholders' interactions and field observations, the farmers learnt that Desmodium is harvested after maize has been harvested while Brachiaria is harvested before maize.

7.7 Summary of Findings

The on-farm implementation of the PPT was used as an environment for facilitating learning through sharing and convergence of diverse interests, knowledge, understanding and expectations of different stakeholders to address stemborer pests and other related farming constraints. These findings show that these efforts resulted to change in behaviors, norms and procedures from shared actions and practices. The involvement of different stakeholders in an interactive environment proved to be an innovation in itself. This is because, creates an opportunity for the stakeholders' empowerment, acknowledgment, appreciation and equally challenging the contributions from each other. This is different from the usual practice with top down nature of relationship and interactions. Under such circumstances, the local fit of PPT and its meaningfulness is acknowledged and at the same time its failings or misgivings were openly discussed or revealed. The stakeholders were open to solve the stemborer problem in a participatory and interactive fashion with mutual respect but at the same time to learn from successes and failures as well. The long-term nature of PPT implementation following the maize cropping seasons and along the maize growth phenology, provides sufficient timelines for these interactions and experiences to be explored.

The presence of career researchers and the senior extension staff during the implementation process was unique and interesting to the farmers and local administrative personnel. At the same time, the existence of a real-life stemborer pest problem which had not yet received any promising solution was a strong motivation and good entry point for PPT as an alternative measure to the use of non-effective chemical measures. The stakeholders in the area were willing to collaborate and share their local experiences in order to learn about the new technology with strong commitment to find a lasting solution to the stemborer problem and also partake other opportunities which could came along with it. The use of farmers' own fields for practical implementation provided an opportunity which enables critical assessment, relaxed learning about PPT. The farmers were able to learn and discover the practical benefits of the technology when they saw that it could perform in their own farm conditions. This motivated new and fellow farmers who gained trust and confidence to adapt the technology by initiating own research beyond the prescribed guidelines to exploit new knowledge and enterprises which came with the technology e.g. seed production/marketing and fodder production.

The introduction of the PPT as much as it sounded positive and progressive, it was not accepted wholesale by the all the stakeholder groups. It had its share of challenges and situations of conflicts especially where the new PPT management practices were different from usual practices e.g. use of ox-plough for land preparation and planting, fencing off PPT plot from freely grazing of livestock after harvesting maize during the subsequent cropping seasons while the Desmodium and Brachiaria are still intact on-farm. To some of the farmers, the introduction of PPT was seen to complicated and disruptive and less meaningful especially when they linked with high demands on labor for various management practices such as weeding among the families without enough manpower such as widows. Some felt uncertainties from lack of enough information or to fear of failure to the sustainability of its strategy. For example, they already knew Desmodium and Brachiaria grasses as wild plants which grow in the forest; therefore, introducing them on farm as crops was unusual practice with negative human effects such as irritability and at the same time they are non-edible to humans.

The participatory nature of introduction of the PPT to the study area and facilitation played a key role in such situations where some stakeholder showed unwillingness or encountered conflicts. To minimize misinformation, negative rumors or publicity, these challenges were addressed in situ and used as the essential points of learning rather than being source of conflict. In fact, these experiences were not unique to this area. In other countries such as Kenya, Uganda and Tanzania the implementation had taken place over 20 years. In those instances, farmers and other local stakeholder took time, at least 2-3 cropping seasons of on-farm implementation to learn and adopt the technology and even others deciding to drop even after trying.

Practical implementation of PPT proved to be fitting well with the recommended MOA maize planting and management practices. Instead of the traditional application of high maize crop density as a stemborer pest management strategy, the farmers learnt they are required to maintain the recommended spacing (75 cm between rows and 30 cm between hills in a row) and plant population (two maize seeds per hole and then thin to one plant per hill after the first weeding) to achieve a pest free crop and good yields. Early land preparation and planting was a locally preferred practice to escape pest infestations. The establishment of PPT as a strategy for pest control was a re-introduction of the practice early planting starting with companion crops for the Push and Pull effect to set in early. The crops are able to exploit earlier rains for their establishment. At the same time, PPT was fitting well with the age old traditional practice of mixed cropping technique which was neglected as a result of extension focus on crop monocultures. The farmers learnt the importance of intercropping as an alternative strategy to the management of stemborer and other pests such as *Striga*. At the same time, the introduction of PPT added value to the local efforts on soil erosion control where the use of Brachiaria grass was considered as a better replacement of the commonly used vetiver grass. Local farmers preferred the Brachiaria to vetiver grass due to the additional use as livestock feed. Traditionally, farmers prefer to use own produced seeds for planting than the commercial seeds due to cost implications and sometimes accessibility. Farmers were able to harvest Desmodium and Brachiaria seeds from their PPT plots, which they could use to expand their farms and at the same time sell to their neighbors. They could also re-cycle seeds harvested from the openly pollinated maize crops such as Gibbe II.

The PPT as a conservation farming practice of cover cropping was comparable with the practice of allowing weeds to grow in a maize plantation during the later stages of its maturity. The farmers use these weeds as fodder for livestock either used cut and carry or as standing biomass for direct feeding after harvest when livestock is allowed to roam freely in the fields. This practice is an opportunity for the farmers to understand the logic of Desmodium and Brachiaria grass as intercrop and trap crops for stemborer pest control, moisture retention and use as fodder. As opined by McLean (2004), PPT implementation process provided an opportunity for a continuous self-transcending through which one transcends the boundary of the old self into a new self by acquiring a new context, new view of the world and new knowledge. PPT achieved empowerment of the farmers with the creation of new business and investment opportunities in the production of Desmodium and Brachiaria seeds through the domestication of previously wild plants. The farmers learnt to solve conflicts amicably through formal arrangement, unlike previous arrangements where there were no written agreements. Indoor livestock feeding through cut and carry method was promising future of reducing the quantity of livestock and with more attention to quality with environmental benefits. Using PPT knowledge, farmers learnt that they could manage new pests such as grasshoppers by resorting to the use root splits instead of Brachiaria seeds. This is an example of a locally embedded knowledge based on farmers' own experimentation. They also learnt that mono-cropping is a recipe for pest infestations. This is seen in maize monoculture with stemborers and Desmodium with Blister beetles infestations. The intercropping strategy of maize with Desmodium, reintroduces the traditional intercropping system of smallholder agriculture as strategy to the use of for the control of pests.

Chapter 8:
Transdisciplinary Research: Empowerment and Collaborative Leadership towards the Sustainability of Push-pull Technology

8.1 Transdisciplinary Research as a Democratizing and Empowerment Tool

The uptake of academic research into policy and practice requires the input and active participation of other societal stakeholders. In transdisciplinary research, the non-academic or lay persons participation bring multiple knowledge and expertise which is vital to the research process where it is framed and conducted with flexibility (Bracken et al., 2015). Indeed, it is almost impossible to ignore transdisciplinarity when engaging in sustainability related research and vice versa. The sustainability challenges require new ways of knowledge generation and decision making through the involvement of the stakeholders outside academic research (Lang et al., 2012). The process is promising when they have clear set out goals and competent management to facilitate creativity, innovation and manage conflicts which may exist or arise out of the engagement of the diverse stakeholders (Wright et al., 2015). The Participation of non-academics in the process is meant to democratize research and to produce better and socially robust research outputs (Hirsch Hardorn et al., 2008; Hoppe, 2005; Lang et al., 2012; Nowotny et al., 2004; Stauffacher et al., 2008). The heterogeneous nature of participants and their contributions are meant to add meaning to decision making on research agenda. It democratizes knowledge production process whereby the dominant and non-dominant actors have equal access and ability to contribute in the knowledge production process to solve societal problems (Bunders-Aelen, et al., 2010).

Transdisciplinary research aims at establishing a form of collaboration which empowers stakeholders to influence the research, to question and to modify the dominant structures which guide epistemic processes (Popa et al., 2015). In other words, the process enhances mutual learning for knowledge production between researchers and other stakeholders to bring about empowerment of the participants either through education on areas of interest or to have their agenda and perspectives integrated in the knowledge production process (Siebenhüner, 2004). Such an authentic and inclusive participation empowers the stakeholders to become better agents of change in their community from problem identification to finding solutions (Mobjörk & Centrum för urbana och regionala studier, 2009; Mobjörk, 2010). This model of research in sustainability studies has embraced a sequence of stakeholder engagement and involvement from that of informing to consulting, to collaborating and to empowerment where practitioners are given authority to implement the research findings (Harris & Lyon, 2014). In this case, empowerment is seen as a process of providing stakeholder with the power to make decisions right from research planning to the use of the findings. Such kind of empowerment is bound to take place when is linked with leadership and innovation (Schäpke, et al., 2017).

Transdisciplinary leadership comes in handy when mediating stakeholder engagement and interaction for fruitful collaborations at the level of boundary-crossing (Crosby & Bryson, 2005; Bushe, 2009). Although the diverse sets of stakeholders are brought together by a common societal problem, they are ascribed to different disciplinary, organizational and institutional silos (Gray, 2008). In order for these players to come together and start working, this requires a collaborative leadership (Archer & Cameron, 2009; Chrislip, 2002; Frydman, Wilson, & Wyer, 2000). According to Linden (2002), collaborative leadership is required when people from different agencies or agency units work together in a common project to address a common problem. To make progress in tackling the common problems, all these stakeholders must take on the leadership challenge of building shared-power arrangements (Crosby & Bryson, 2005; Harris & Lyon, 2014). What stands out about such empowerment and active leadership is that, it is not motivated by personal power needs, but the potential through which such stakeholder collaboration can be used to address a common problem for mutual benefits, and the leaders are passionate on bringing results to fruition Pedrosa, 2009). A collaborative leader therefore, has a responsibility to provide guidance, coordinate the transdisciplinary research process and ensure that the other stakeholder groups participate in making decisions and taking actions in a democratic atmosphere to address the problem at hand. As stated by Gray (2008), a collaborative leader in the transdisciplinary research process is equated with a transformative leader who is able to combine cognitive, structural, and processual tasks:

> "The task of effective cognitive leadership is to provide a vision and commitment that links and motivates the scientific researchers to step beyond their disciplinary silos, relax old assumptions, and search for creative frame-breaking solutions…. Effective structural leadership adds value by breaking the gaps existing between science and practice through building bridges… Effective processual leadership task encourages trust and turns potentially destructive conflict into constructive and participatory interactions" (Gray, 2008, pp. 9).

Leaders with collaborative management skills may make a difference between success and failure in transdisciplinary efforts from their charismatic personality, knowledge base, broad network and engagement (EU SCAR, 2012), but they shouldn't be static in their engagements with their stakeholders. According to Wright et al. (2015), such leaders should have the ability to anticipate challenges during the transdisciplinary process, learn from failures in case they happen, and be flexible in the process and adapt to new conditions within the overarching objective of addressing the common problem. In this study, stakeholder interactions and engagements during PPT planning and implementation required such kind of collaborative approach and leadership.

During the planning stage of this study, the objectives were set and accountabilities defined based on decisions and commitments made across the stakeholders groups. The on-farm practical implementation of the PPT and the progress made was observed, measured, and new insights were generated among the stakeholders. The whole process encompassed stakeholder interaction and in depth about learning the PPT and other related enterprises or activities. Such innovative processes on joint implementation of the PPT required leadership with strong advocacy at scientific research and practice levels and, at the same time, willingness to play a central role in the promotion of a free and divergent thinking, risk taking, and readiness to challenge the established methods, theories and practices (Henriksen, 2011).

The researchers, extension workers and farmers jointly worked together as a team during all the critical stages of the PPT implementation from planning workshops to farm establishment, management and evaluation processes. This included practices such as land preparations and measurement, planting and weeding, field observations and assessment on stemborer infestation, crop health, harvesting and utilizing the products such as green/grain maize crop, livestock fodder and soil conservation. Stakeholder interaction and collaboration was instrumental to ensure that the team worked together and focused on these practical activities during the whole process. This chapter highlights how during PPT implementation, the collaborative leadership was enhanced among the stakeholders especially the smallholder farmers and contributed to their empowerment through learning, creation of new linkages and relationships and sustainability of the PPT.

8.2 Transdisciplinary Collaboration as an Opportunity for Farmers Empowerment

The PPT planning and implementation process was undertaken based on a joint and collaborative environment during workshops and on-farm discussions and activities, where the researchers and other stakeholders interacted, contributed and applied their knowledge and practices on how PPT activities could address the problem of stemborer pests and other challenges such as fodder for livestock, soil and water conservation. During the process, the researchers' contributions were based on their scientific knowledge mainly from laboratory and on station research experiments while the farmers and extension staff contributions were based on their experiential and on the day to day encounters with these problems at farm level. In the conventional research-extension-farmers linkages, the farmers are regarded as mere recipients of the already tested and ready to use knowledge or practices. Joint stakeholder implementation of PPT was a different approach to overcome such boundaries which exists between research and practice where the farmers as stakeholders are empowered and had a role to play in bridging the gap between research and practice and make the linkage stronger and more effective.

Several efforts have been made in Ethiopia to bridge research-practice gap through the introduction of new technologies (Deneke and Gulti, 2016). However, in a situation where there are different levels of participation and the farmers are the recipients of technologies and the research and extension organizations are controlling resources for implementation, it is not easy to eliminate such a gap (Wenger et al 2002; Deneke and Gulti, 2016). With such type of relationship, the farmers believe that, whenever these new technologies are introduced, their level of participation is limited to mere following instructions provided (Wenger et al., 2002). However, under this study, the initiative of transdisciplinary research approach was an opportunity for empowerment through bestowing confidence in the farmers and making their views, knowledge and skills shared with researchers and extension staff. The new skills learnt and knowledge generated was meant to inform further research and practice.

In Ethiopia, the extension staff tends to serve as agents of centralized political power in their respective *Woredas* or *Kebeles*. In the course of their work, they are mostly engaged in delivering political messages and undertaking tasks on behalf of the ruling party such collecting taxes under the cover of extension work (Berhanu & Poulton, 2014). Under such circumstances, the farmers lose trust whenever new initiatives are introduced by the same people who they suspect to have an underhand for the 'state authorities'. However, in a situation where there are efforts to build the trust and confidence, the farmers are able to take the initiative seriously and even to a step further. For example, the sustainability of PPT is not only dependent on its performance, but on market forces such as availability of seed inputs. In addition, it is depended on leadership initiatives from micro level i.e. at the household level where the head ensures that all members of the household participate and are empowered through practicing PPT. The farmer is able to organize and allocate his farm family in terms of labor and responsibilities on PPT activities. In this case, PPT is implemented as an enterprise where the different family members are empowered to exploit the various other benefits and opportunities which come with the technology e.g. from seed production, fodder production for livestock fattening, milk production and marketing. This is also in anticipation that one of the family members is incapacitated or moves on to other activities, the rest of the family members are able to continue with the technology implementation.

This sort of leadership at family level is built from the confidence and empowerment made on the farmers whereby their role in the process is recognized by both research and extension professionals. The farmers' leadership was demonstrated by their ability to initiate, conduct experiments and take decisions freely regarding the PPT implementation. For example, researchers recommend the establishment of the PPT using line planting where the seeds are sown in holes or drills using a straight line. However, the farmers in the study area preferred to use ox-drawn ploughs to drill the lines (Fig 20 below). These lines may not be straight as required by the research or extension, but the farmers in a democratic atmosphere; they were able to make decisions and had valid reasons on what works best for them. This was different from previous relationships where they were dictated by the DAs or local administration and researchers on what to do during on-farm trials. This time round, they were able to use own measurements and tools:

> "The joint implementation of PPT enhances participatory leadership in its approach whereby it enables everybody from farmers to researchers to participate in the technology. Thus enabling all the participants (i.e. stakeholders) to develop and contribute skills to manage its implementation and also push the research agenda… Through this approach new players are attracted into the research process and contribute to good results e.g. the private sector, youths and women….all the players involved are able to learn new skills on PPT openly from each other and by drawing on own experiences" (*KI Bako researcher, April 2015, Bako research center)*.

Figure 20. Pictures of the farmers and extension staff planting PPT plot using oxen drawn plough

Field photo: Nyang'au I.M.

The effort to change research and extension services provision is in line to what has been recommended by Deneke and Gulti (2016), i.e., linear relation should be replaced by systems which are iterative, interlinked and also overlapping where by the role of the farmers is not that of recipients of technologies developed elsewhere but to empower them to have confidence and trust in order to contribute to decision making together with other stakeholders. Stakeholder collaboration process was organized in such a way that, the on-farm implementation was undertaken in a participatory manner by the team consisting of the farmers, grassroots extension personnel (DAs and district level extension) and researchers. The on-farm PPT activities created a platform for these stakeholder groups to interact and learn various topics related to stemborer pest control, soil and water conservation and fodder production (Fig. 20 above). Such joint working relationship was an opportunity for each stakeholder to introduce and contribute skills on the management and implementation of PPT and other related emergent enterprises or benefits:

> "The DAs, researchers, visitors from overseas, Germany and Kenya, have been with us from the start to date… Team work always has positive outcomes…. The team has been around from sensitization, training, planning for all the implementation stages to now…This has formed a continuous interaction process for learning and appreciating the efforts of each other"
> (*Development Agent, Bako Tibe, March 2014).*

The farmers were confident with the promoters of the technology. This was based on the reputation of PPT which they heard; it has been researched vastly and there were a lot of experiences to draw from other countries in the eastern African region such as Kenya, Uganda and Tanzania. They share similar circumstances with farmers from these countries who are also faced same stemborer challenges. They were flexible and at ease to make decisions about the PPT from the beginning. In their own circumstances as Ethiopian farmers, 2-3 cropping seasons with PPT, when they shall have had own concrete experiences. At the moment, for example, this particular farmer who was optimistic said that:

> *"icipe* Director General is Ethiopian and she is supporting this technology…. She is fully aware of its benefits, so we shall fully embrace it and make it a model. What she thought for her country and population to come out of poverty and challenge of being faced with pests, erosion, and fodder. We are receiving this information through the extension and researchers at the local level"
> (*PPT farmer, Bako Tibe, April 2014).*

In addition to cereal crops, farmers grow horticultural crops for household consumption and for the local market as a source of cash income. These crops have similar pest problems such as nematodes, armyworms, Aphids etc. Out of interest to find a solution to the pest problem as well, a farmer raised a question whether Desmodium could help in addressing the pest problems on tomatoes and cabbages on his farm. This was an interesting question for the researchers and extension alike. The farmer took the initiative to raise the question because; he observed for the first time, that the maize crops had less infestation of with stemborer pests when compared to the previous seasons. Parallel to the question, instead of waiting for an answer from researchers, he offered to run the trial experimentation by growing tomatoes on 25m by 25m plot intercropped with Desmodium. Out of this plot, he planned to make observations which he could share with researchers and extension staff. Such a gesture from the farmer could be attributed to empowerment and confidence gained from the joint nature of interaction with researchers and the extension staff. This also was a boost to the farmers to believe that their ideas and simple experiments can make a contribution towards generating new knowledge in a research process. Such experimental test is an example of how empowering and enhancing farmer's confidence to engage researchers and also raise research questions and challenge methodology could contribute to generation of new knowledge in pest control. The farmers experimentation combined with the laboratory based methods can potentially reduce the time taken to generate results or waiting time to address their immediate needs or real life problems.

Weeds compete with the maize crops for nutrients and moisture. It is assumed that the farmers should free their maize off weeds even when the crops have matured. However, the farmers had a different perspective. At the later stages of maize growth when they start flowering or forming grains, the farmers stopped weeding. From their point of view, the weeds together with maize stalk leftovers were to be used as fodder for livestock after harvesting the maize cobs. At the same time, weeds retain soil moisture due to sufficient soil cover. With the introduction of PPT, some farmers in the area similarity with weed retention. They were able to connect with what they already knew and what the PPT had in store for them. Instead of previously leaving weeds to grow with their crops, the introducing Desmodium was a novel idea. It address the stemborer problem and as an additional source of fodder. This helped to dispel the rumors which were initially spreading in the study areas that Desmodium was a weed being introduced by researchers and extension staff. However, only a few farmers could see or overcome the rumored messages. The group of farmers who went ahead to implement PPT despite the rumors became the lead farmers and eventually they are seen as leaders to their community. They embrace leadership role for fellow farmers to emulate. They are also able to make decisions based on their experiences and what they think is of best interest to their community.

> '…..the overgrown weeds are fodder for livestock. Immediately after the harvest of maize, animals are left to freely loam and feed on "weeds" plus the maize stovers. …Now with PPT, Desmodium does the same. Besides, it is a perennial crop which can be cut back and fed to livestock. It is a permanent source of fodder ….. this is good" (*PPT farmer, during FGD interviews, March 2014).*

The concept of intercropping Desmodium with maize and as effective cover crop did not flow smoothly as one would have thought or expected. Some of the farmers were reluctant to embrace the PPT either due to cultural orientation or personal attributes such as fears or not trusting new information or technologies or being swayed by rumored information. For example in Yayu *Woreda* some farmers were thinking that Desmodium was weed and wild plant being introduced into their farms to bring unnecessary competition with food crops or to be just a nuisance. According to some of these farmers, Desmodium was annoying. It gets stuck on cloths when walking through or weeding their maize fields. Some of them knew Desmodium as a wild plant growing on the farm hedges or in the forest and couldn't comprehend the fact that it can be an intercrop with maize. At the same time, freely roaming of grazing livestock is a common practice in the area after harvesting maize. Therefore, to some of these farmers and some of the researchers and extension staff, the introduction of PPT was not likely to work. This was because, immediately after harvesting, livestock are released to roam freely through their farms. This potentially will destroy PPT companion crops are perennial. However, such doubts were expected because PPT was being introduced into the area for the first time. The emergence of negative rumors, lack of prior and correct information are some of the key areas concern which had to be understood and addressed from the beginning of the implementation process to allay any further fears on the technology. These issues are what turned out to be the key learning points or resources for learning (Akkerman & Bakker, 2011).

> "I had many questions in my mind on the future and sustainability of this technology. Now slowly the questions are being answered as…such as roaming of livestock immediately after harvesting maize, preparing land for planting maize in the next season in the presence of Desmodium and Brachiaria grass….. because of these interactions we have had together over time, I have cleared my doubts*" (PPT Follower farmer, FGD in Bako area, March 2014).*

8.3 Farmer Leadership in the Push-pull Technology and Related Activities

The transdisciplinary research using PPT implementation as a process was meant to empower and also enhance leadership through hands-on and joint learning among the farmers in particular. During various activities of PPT implementation, the farmers had frequent interactions with scientists/extensionists, they tended understood and learnt the performance, benefits and challenges of the technology. For the first time, group of farmers who took the initiative and were confident they established PPT on their farms. These farmers are referred as PPT farmers and the rest other farmers who were learning from them were the follower farmers. The PPT farmers turned out to be farmer leaders in their own right through sharing and extending information about to fellow farmers during events such as field days and take on the role as the farmer teachers (Amudavi, 2009a; 2009b) while at the same time playing a key role as key stakeholders in the research process. This statement was echoed by an extension expert:

> "PPT has become a "school feed", produces a lot of knowledge, food to feed us humans and livestock… most farmers resist new technologies, but the model lead farmers accepted to implement PPT for the first time…. Other farmers from other *Woredas* will learn from their example by attending such field day's events which is an important platform for learning and

experience sharing" (*Extension expert, Bako Tibet, during PPT farmers' field day Sedan Kite Kebele, March 2014)*.

The PPT was introduced into *Woredas* for the first time at the farm level during the period of this study. The initial nine farmers from four farmers groups who took the initiative to participate in the implementation of the technology became the first and lead PPT farmers. They also played a facilitator role in ensuring that the researchers, extension and fellow farmers were welcomed and freely interacted in their farms/homes. These farmers can be equated in the category of the opinion leaders (Rodgers, 2003). Opinion leadership is whereby an individual farmer is able to informally influence other farmers to change their behaviors (Cross, Parker, & Sasson, 2003). This group of farmers was similar to other farmers in their groups. The only exception, they were the first group of farmers who were willing to take new initiative of establishing PPT on their farms for their individual benefits and also for their community in general. They are also easily identified or selected by fellow farmers based on their history of their commitment, risk taking and activeness in sourcing and implementing new information to improve agriculture in their farms. In this study, many other farmers were eligible for participation and indeed implement PPT, but not all of them were ready to start the process at the same. This was mainly associated with the season when the study was implemented. This season, majority of the farmers had either planted maize, was interested to grow horticultural crops such onions, cabbages and tomatoes or had not access to irrigation. The PPT farmers were growing maize crop during the short rainy season and had access to irrigation waters.

The PPT learning plots were established and placed under the management of the host farmers. This gave them an opportunity to experience the first hand gains of PPT on their farms and knowledge about the technology as compared to fellow farmers who were visiting to learn. The day to day interaction with research and extension experts, new farmers and inquiries, elevated their quest to search and learn more information about the technology. This increased their level of expertise, not only on PPT, but other management skills such as decision-making and communication skills from their greater contacts beyond their immediate surroundings (Rodgers, 2003). Their contact with other stakeholders such as the researchers and extension personnel during the planning and implementation, monitoring and evaluation of the PPT activities, visitors from other countries was a learning journey for them. The information and new knowledge gained by these farmers was hoped to be freely shared with their fellow farmers through social events such as community meetings, market places and even churches. Their social standing in the community through undertaking such new initiatives was also elevated. It was hoped that it could eventually lead to a "critical mass" of learners who were expected to adopt PPT in the subsequent cropping seasons. As time goes by these farmers, combined with to their elevated social status, they turn out to become the opinion leaders on other productive sectors of their community apart from agriculture. Thus it is difficult to evade the conventional wisdom whereby such farmers turn out to be mediators of new development activities into their community. This is an indication that all the farmers are potential leaders from the beginning if they take active role to participate in learning and implementing new initiatives. To be able to illustrate this aspect in detail, I will take an example one of the PPT host farmer.

The PPT host farmer *Kebele* 1 is an illustration contrary to the conventional wisdom, that lead farmers should be well established with good social standing and well to do in the society in terms of assets and landed property or formally educated. However, this particular case is a farmer aged about 38 year without formal education, no family and land of his own. He lives with his elder brother's family and among other extended family members. He takes care of his extended family large herd of livestock of over 30 animals consisting dairy cattle, oxen, sheep, goats and donkeys. He rented the land from his brother to plant maize and accepted to participate in the implementation of PPT. He is the most active member of the family despite the fact he has no family of how own but from his active farming and other social activities, he is respected by the community members. The selection for participation was based on his interests as the farmer to take up new initiatives and the respect he had earned himself from fellow farmers in the village.

> "Innovative/model farmer is the one who is ready to accept, learn lessons, pass lessons to other farmers, conduct own research and share with fellow farmers and researchers how technology works on reducing the losses due to stemborers pests" **(***Interview, small scale irrigation and drainage expert, Bako Tibe, April 2015).*

During further discussion with the irrigation expert, he had the same farmer in mind, from *Kebele* 1. He commented that this particular farmer was always willing to offer his rented farm for trial of new technologies. He is a risk taker and previously he had participated in the trial of new technologies such as tree nursery for agroforestry in his community as a lead farmer. PPT is part of the initiatives he is keen to try and bring to fruition by working closely with the researchers and extension staff. "Apart from the immediate benefits such fodder, reduced pest infestations and soil conservation properties, PPT is a promising technology. He is fully in it and looking forward into the future on what the technology has to offer to him, fellow farmers and to the community:

> "The technology is interesting for farmers, researchers and student learning. It addresses complex challenges simply….. Many schoolchildren from around the village are interested to learn how the PPT mechanism works in controlling pests in such a simple way. It is science-simplified and

in the hands of farmers. I am able to talk about science-based practice and practically implementing it in my own farm…. ” (*Interview,* t*he PPT farmer, Bako Tibe, March 2015).*

This particular farmer was able to talk easily and with confidence about the new PPT because he had understood how it works and it was practically implemented on his farm. He took it upon himself to become as a leader in information sharing with fellow farmers and school going students who had interest in learning the technology. The ‘teaching’ aspect is what motivated and made him pay attention during interaction with researchers and extension staff to learn great detail and later to respond with accurate information to questions was raised by those seeking know more about PPT. Combining with his own intuition with local knowledge and understanding crop-pests interactions and practical observations, he was able to talk about the PPT freely and easily. This according to him, it was indeed science demystified (Allen et al., 2014) and gave him an opportunity to become a leader. Apart from stemborer challenges, he was motivated to participate in the PPT to address other problems of soil erosion and mono-cropping culture. These practices contribute to soil fertility losses in the area and the PPT was a new idea which was fitting into and has potential to address them. The fellow farmers had no experience on cereal crops intercropping practices. They are dependent cereal-livestock production system which is constrained by fodder shortages. To this farmer, the PPT became was an opportunity to learn and share information:

“Apart from pest control, food and fodder production to environmental conservation, PPT is easy to understand and use despite the underlying scientific principles at play. The resource constrained farmers are not able to afford expensive farming inputs aimed at increasing productivity such as fertilizers and pesticides,” (*Interview PPT farmer, Bako Tibe, March 2015).*

Another example is a farmer, from the neighboring village who had actively participated as lead farmer in other technologies previously introduced in the village, thus his social standing was already elevated. Whenever new opportunities arose, he still stands out to be selected by fellow farmers as their leader.

“I have participated in other extension packages such as tomato, onion, and maize production. Am ready to make PPT a model and aesthetic farm in my village. I previously learned from Sasakwa Global farm extension model plot, so am determined. I have become a lead farmer through training and actively trying extension packages. Previously I was selected by the *Kebele* administrator as a model farmer in the village. Am happy with being model farmer, it is rewarding from the certificates of participation and sense of satisfaction either socially or economically.….I have managed to invest in a new house, bought a mule and cart from increased

> farming income from being a model farmer." (*Interview with PPT farmer, Bako Tibe, March 2015).*

The selection of farmer leaders was undertaken by the other farmers who had trust, confidence and were comfortable to have one of their own to take lead and whom they could learn from. Their elevated social status after participation in new technologies was a motivating factor for other farmers with similar backgrounds to emulate. Although it may seem to be pointing to replicating the 'farmer opinion leadership' where an individual farmer is believed to influence other farmers' attitude and opinion (Rogers 2003), but farmer participation in PPT was a different. It involved participation of other stakeholders (academic and non-academic researchers) in sharing of their diverse forms of practices, expertise and knowledge on stemborer pest control and their input and contribution to the research process was a collective.

8.4 The Push-pull Technology Implementation: An opportunity to Manage or to Escalate Conflicts?

The introduction and implementation of PPT in the study area had mixed blessings. Not only it brought new knowledge on managing stemborer and other benefits, but also new dimensions of conflicts which were not expected nor existed before.

> **"**Initially we had an informal agreement on water use and allocation mainly for irrigation purposes. Now with the introduction of PPT, some farmers who didn't understand about the technology started questioning why water was diverted to these plots…This caused us to have irrigation water use conflicts, forcing us to irrigate PPT plots at night with the aid of torch." (*Interview with PPT Farmer, sedan kite Kebele, Bako Tibe, March, 2015).*

The implementation of PPT in the area had contributed to the emergence of water use conflicts which had not been experienced before. The conflict was as a result of using irrigation water in PPT plots as a supplement to low rainfalls in the area during the period of the study. The result may be seen as a negative outcome, it brought the problem into attention under the ministry of water and irrigation for an intervention. Previously, water use agreements in the area were informally set up among the farmers who were practicing horticultural farming and other users along the Gibbe River. However, with the introduction of PPT, it generated mixed reactions on water use allocation which was on high demand from many users along the river. According to the horticultural farmers and other users, there was no water allocation for PPT. According to them, the allocation was causing unnecessary demand on the irrigation water. Despite the allegations, the PPT farmers attributed these conflicts to jealousy from their fellow farmers. This was because; the PPT farms were outperforming the horticultural crops in terms of productivity and market prospects. Previously, without PPT, some of these farmers were planting maize using the same water and such conflicts were not witnessed. In order to manage the resultant conflict from escalating or recurring in the future, the officials from the Ministry of water and irrigation who were part of the research team, together with other stakeholders, convened a meeting and agreed to have a formalized the water use arrangement. This was a bottom up approach of formalization through stakeholder mobilization and engagement. The agreements were put on paper with a clear outlines on who, when, where and amount of water allowed to be used for irrigation along the river taking into consideration of other users downstream on the Gibbe River, which cuts across many *Woredas* in the region. According to Gray (2008), absence of conflict resolution is a detriment to any form of transdisciplinary collaboration which requires integrating of diverse aims and interests among the stakeholders. Leadership with process skills to manage and facilitate conflict resolution plays has a role to play in the success or failure of transdisciplinary efforts.

Some of the farmers, extension and researchers were skeptical on the introduction of PPT. Some researchers referred Desmodium as a weed introduced into farmland. "Desmodium is an obnoxious weed. When introduced into the farmland, it competes for space and nutrients with the main crop and it is non-edible for humans." A senior researcher at Bako research center made such comments based on the experience he had on intercropping maize using edible legumes such as cow peas and soya beans as protein sources and also improving soil fertility. He had not experienced the performance of Desmodium as a maize intercrop under PPT.

At the household level, one of the lead farmers in Jimma Arjo *Woreda* area and his wife had a domestic brawl on the introduction of PPT in their farm. The wife heard a rumor that, once established, PPT crops stay on-farm forever, and therefore their land will be taken over by the promoters of the technology. "My wife was skeptical and lost interest in the technology. She felt that I have been misled and sold out the land without her knowledge," farmer comment. To this particular farmer, this was some sort of land grabbing where she could lose access to her land which she previously could grow crops for her livelihood.

Land is an important resource in terms of investment and food production opportunities for the socio-economic and environmental wellbeing of the owners. So when the same land is acquired by outsiders who are either individuals or companies to serve their interests at the expense of its owners, it can be seen as land grabbing. Land grabbing is equated with large scale land acquisitions and transaction that are carried out by transnational corporations or initiated by foreign governments in developing countries through either leasing or purchasing (Cotula et. al, 2009). These holdings are normally larger in size compared to the national average land holdings in these countries. However at the smallholdings in densely populated areas, land grabbing can also take place through introduction of commodity crops by multinational companies e.g. sugar cane, tea, coffee, Jatropha etc. These crops are perennial i.e. they are planted once and remain in the farm over the years. These farmers are subcontracted to supply these crops as raw materials to industries where it is exported to the investor countries. In most instances the owners of the land are poorly informed of the consequences of the investments and growing certain crops on their farms. There are a number of reasons given by the proponents of land grabbing; e.g. food production, technology transfer, job creation and infrastructure development in those areas. For example, they argue that, such investments on land will enhance and close productivity yield gaps through the supply of high capital agricultural inputs such as irrigation and other technologies (Anseeuw et al., 2012). However, the weak land legislation in most of these countries especially in Africa does not protect the local people's right to land. In such situations, large amount of land is controlled by the foreign investors and under vastly unequal power relations (Matondi et al, 2011). Such relation is reflected negatively on livelihoods of the local people where the land becomes unavailable to farmers for their livelihood especially in the case food crops which are cleared and commodity crops are planted.

With awareness creation and information availability either through media or civil society groups, the farmers are becoming sensitive with new technologies which are tailored or based on land investments. PPT is such an example. It was introduced as a new technology with perennial companion crops planted under smallholder farming systems. At the same time it was being introduced by researchers from other countries. With this type of technology characteristics, PPT can be easily attached to negative rumors linked with land grabbing. For example, in Yayu *Woreda*, rumor was spreading that Desmodium is a nasty crop introduce on farm. Once it gets stuck on the farmers' cloths, it takes a long time to remove. "It is embarrassing when in the marketplace and people are pecking on me to remove the Desmodium seeds stuck on my cloths. I don't like it," remarked anonymous.

There was no formal Memorandum of Understanding (MOU) among the stakeholders with details on collaborative working arrangements between the researchers and extension staffs from different ministries and departments. The working arrangements were based on individual commitments by the staffs from the different department. However, between partner organizations, it was not smooth running. For example, some of the stakeholders were interested in payments to participate. They were seeing the PPT implementation as not part of their mandate or their acknowledgement was unspecified. Some of the extension personnel and researchers felt that participating in PPT implementation was conflicting with their day-to-day activities unless it was formally arranged. The MOU concerns were necessitated by the fact that previous initiatives on joint stakeholder engagements had not yielded tangible results but limited to boardroom agreements. For example, the Agricultural development partners' linkages advisory council

(ADPLAC) was meant to strengthen linkages among researchers, extension staff and farmers. However, this has not been easy to operationalize overally due challenges such as lack of actor commitment, financial limitations, staff time and frequent transfers turn overs. Therefore, it was hopped that MOU based PPT activities with specific stakeholders could a better way to learn how to deal with these kind of bottlenecks.

The introduction of PPT in some instances caused conflicts by challenging the locally entrenched practices by the farmers themselves and even the extension and research officials. For example, intercropping maize with an additional crop was commonly practiced among the farmers and some of the extension staff had no experience on how to go about it. In this case, introducing PPT was conflicting with their already entrenched and established culture of mono-cropping. The extension officials were accustomed to the culture of conventional and linear technology transfer as the main source of extension messages. The participatory process of stakeholder planning and implementation of activities on joint basis was seen as a source conflict by some of these officials. The farmers are placed at the receiving end and they are only supposed to implement what have been instructed by the extension or by researchers. Correspondingly, the participation of the landless farmers and private sector/traders in extension services was a not common practice of working with the extension professionals in the study area. The off-season Brachiaria and Desmodium crops management introduced by PPT was a new activity which was conflicting with their long-established tradition of allowing livestock to roam freely after harvesting maize crop in each season. Establishing PPT demanded that, the farmers have to fence off their farms or guard their farms. This was conflicting with the age-old traditional practice. Some of the farmers and the extension staff were doubtful on whether the establishment of PPT could withstand the tramping and overgrazing which takes place when the animals are freely roaming all over the harvested fields scavenging for fodder.

In the situations where the new ideas from PPT were a cause of conflicts, it was embraced and used as an opportunity for in-depth learning about the technology and also to find solutions and its possible adaption. According to (Suchman, 1994), these are the situations requiring boundary crossing and indeed effective leadership to manage the transitions. During an interview with an agriculture extension expert, at the Bako Tibe *Woreda* on what sort of leadership required among the stakeholder teams that will enable successful learning of PPT despite situations where it has conflict with local practices, he said:

> "There is need for flexibility among the collaborative stakeholders. The actors have to understand the needs of others, their potential strengths and capacities. Understanding the needs of the people and working on their minds is challenging……but, the leaders should be experts

who are committed with a guided vision long into the future…" (*KI extension expert, Bako Tibe district, March 2015).*

The joint implementation of PPT by researchers and others stakeholders, especially to the farmers, it came in with new information which was inconsistent with their usual maize cropping practices, thus creating an uncomfortable psychological state due to uncertainty from what the technology had in store for them and were not sure about. However, this can be overcome by working in concert and combining different ways of knowing and learning among different social actors (Siebenhüner, 2004).This challenge stems from the fact that lack of effective communication between such individuals who are not similar may cause cognitive dissonance (Cross et al., 2003). Medlin (2001) indicated that such differences as technical competencies, cultural beliefs, and social status in the community and language barriers may lead to mistaken meaning, thereby leading to distorted or even unheeded messages. Indeed to be able to break or span between these different states, the interaction among the stakeholders on a continuous basis was a necessary input which PPT was expected to provide. The implementation PPT activities should last at least 2-3 maize cropping seasons for effective performance and learning to take place. This gives sufficient time and allows stakeholders involved to become familiar with each other and adjust their local practices and beliefs to new technology and even the ways of working. This means that the organization and leadership of the process plays a central role towards successful interaction, fruitful collaboration and learning. With notable example of Ethiopia, the organization and implementation of PPT requires institutional changes such as embracing participation by both of non-traditional players such as private sector and youthful farmers who are increasing showing interest in commercial or enterprise based farming activities. This will broaden the collective learning beyond traditional communities and approaches of academic researchers and state run extension agencies. This view was echoed by the key informant:

"What we have learned so far never existed before on intercropping cereals with Desmodium… The PPT implementation process brings on board other new players such as the farm input sellers, youths and women to contribute to agriculture…During dry season, farmers plant tomatoes, onions and cabbage as horticultural crops using furrow irrigation. This is a new custom of planting maize with Desmodium and Brachiaria grass during dry time." **(***Interview, agriculture extension expert, Bako Tibe, April 2015).*

8.5 The Sustainability of the Push-pull Technology as an Innovation: New Linkages Created during the Transdisciplinary Stakeholder Engagement

The implementation of the PPT is associated with either stemborer pests control, *Striga* seed bank depletion in the soil or provision of fodder for livestock. This is based on the immediate results or the products farmers benefit from practicing PPT. However, beyond these benefits lies the question of sustainability. Apart from the durability and effective performance of the companion cropping, the sustainability of the PPT is depended on the strength of relationship and learning processes among the stakeholders, type and nature of new enterprises and activities created as a result of its implementation. The PPT sustainability is also concerned whether the implementation of these activities will continue over successive seasons, fitting or adapted to the already existing cereal crop based farming activities. New ideas were raised and discussed by the stakeholders regarding the question on sustainability of the PPT.

8.5.1 Opportunities for Interactions

The transdisciplinary action research and the practical on-farm nature of PPT implementation provided frequent interactions and continuous learning on its workings and even challenges for both researchers and other stakeholders. This was evidenced by their comments:

> “PPT is a unique technology. I think it is sustainable based on its integrated nature, and continuous learning on step by step basis…. There are many questions which can be raised and answered with the introduction of PPT on the farm. The major one being, it is addressing the serious challenge of stemborer pests in maize production…. Yes, we can have the best breeder seed, best fertilizer, enough rainfall and well prepared field, but without a sustainable, affordable pest control, still productivity will be affected or reduced. You may have all the capital, but if no pest control, you still have low crop yields. In the future, this technology has lots of potentials.” *Interview with Bako researcher, April 2015.*

> “PPT is a useful technology for the new generation of farmers. This is because it lasts longer in the field and provides opportunities for continuous learning and interaction…..farmers have started to understand how environmental factors contribute to pest problems and how the same can be used on their management….” *Interview PPT farmer, Bako Tibe, March 2015.*

The smallholder farmers like to participate in new technologies which can give them flexibility to improve in their farming enterprises or maximum returns on their investments. For example, the minimum average plot size recommended for PPT is about $600M^2$. In the study area, due to population increase, the land is scarce and most farmers own less than two ha of land. PPT plot require management practices which farmers can acquire with time and when convinced with the performance results, they can expand to the entire farm or if not convinced, they can drop the technology. This makes the practice of PPT a learning journey. For example, in the case of *Striga* control, PPT requires up to 6 cropping seasons to have the *Striga* seed bank almost fully depleted from the infested soils (Khan et al. 2008b). The benefits such as fodder and stemborer control are witnessed within one maize cropping season. This requires patience to get full benefits and even to make decisions. During the interaction process among the stakeholders, PPT provided opportunities for learning about other farming methods and related enterprises e.g. farmers were able to learn how to plant maize under irrigation. In the past, farmers in the study area have been growing horticultural crops using irrigation. Currently under irrigation the PPT farmers were produce maize for food and additional fodder for their livestock using irrigation. During dry seasons, most farmers don't participate in cereal crop farming and the let their livestock to roam freely scavenging for scant fodder in the harvested fields. This not only affects the production levels of the livestock, but also contributes to environmental degradation through overgrazing and destruction of vegetation cover. Push pull technology had shown the potential that these negative environmental conditions can be addressed and even reversed:

> "….Land for grazing is reducing and slowly in-door feeding is gaining currency in the district. Ethiopia has highest number of cattle in the region, but the quality and productivity is poor due to low quality feeding. Therefore, PPT is part of the solution in terms of complementary fodder production for livestock in the area." *Interview, livestock production expert agriculture, Bako Tibe, April, 2015.*

The application of PPT as a method for stemborer pest control had not been used previously by the MOA officials in the study area. Despite this, as decision makers, their commitment and policy support was needed from grass root to national levels of administration. The commitment shown from farmers on learning and willingness use the PPT was an encouragement for the officials to provide the necessary support. This is what culminated to the inclusion of PPT as part of MOA extension and soil and water conservation programs. PPT was included as part of the Ministry's programs Integrated Pest Management (IPM) and also in the soil and water conservation measures. This was because it was complementing the already existing efforts. For example, the MOA officials encouraged farmers to plant Brachiaria grass along the farm borders and slopes and intercropping maize with Desmodium to reduce surface water run-off and prevent soil erosion. In the past, the same program promoted the use of vetiver grass as a cover crop; however, due to the turf nature of its leaves, it is not preferred for harvesting as fodder for livestock. Brachiaria grass was preferred alternative to vetiver grass, which has same growth and conservation properties, but with soft leaves makes it easy for feeding livestock.

The soil and water conservation such as terracing, planting grasses on the hillsides or planting trees in the country are conducted as mass campaigns mainly with long term objectives. The difference with PPT, it was a done on personalized contact with individual farmers and the conservation benefits have both immediate and long term returns e.g. Brachiaria grass providing fodder and stabilizing soil on the hillsides. Despite the fact that the technology was proving as a potential platform upon which both immediate and long term farming enterprises be built, the sustainability question was still lingering in the minds of the stakeholder engagement/research team. To address the sustainability issues of PPT, the team raised and discussed among other issues, on the potential linkages with new market opportunities and also as content for training agriculture students in the technical and vocational centers.

8.5.2 Promoting the Push-pull Technology Based New Market Opportunities

The implementation of PPT came with new market opportunities for the farmers and other stakeholders to participate i.e. commercially-oriented farming. Some of these farming enterprises include dairy, beef (fattening), commercial seed production and agro-dealership for PPT inputs. The coming together of several actors creates a market place; network of PPT practitioners with a broad-based social capital to draw from and also for learning and dissemination of PPT. As a learning platform, PPT can be used to promote other technologies which have a linkage to it. For example, during off season, the PPT plots had sufficient soil and residual moisture which farmers used it to grow chick pea. The high demand and good market prices for chickpeas in Addis Ababa and other big cities was a strong incentive for other farmers to participate in PPT. This was because, during dry season, only PPT farms in the area had some residual moisture due to soil cover provided by Desmodium. This was an incentive:

> "For the sustainability of this technology, we need to supply seeds for planting and target young farmers and develop local structures on seed supply…… PPT is setting up the pace for accepting other new technologies. We have to use the existing platforms for us to get maximum benefits and, for its sustainability, we have to ensure seed source from own production." (*KI Interview, Women and youth affair affairs expert, Bako Tibe, April 2014).*

Sufficient production and distribution of Desmodium and Brachiaria seeds forms the basic component for sustainable expansion of the technology. The involvement of farmers in PPT seed collection and production is a very important practice towards achieving this goal. This can only be achieved if the farmers and traders will have the interest to invest in seed production and distribution.

> "Bako research center has no mandate to produce and sell the Desmodium seeds; we are only engaged in conducting research and producing breeder seeds. However, we can provide leadership on the distribution of the produced seed i.e., support seed production and coordinate

the distribution, but the government authorities should provide guidelines on production and distribution." *(KI Interview, researcher Bako Research center, November 2014).*

"Farmers in the area know Desmodium as non-indigenous crop which came from the research centers. It was introduced as a fodder and cover crop for livestock and in coffee farms. Farmers at the same time had no knowledge on seed production, processing and selling as a source of income. This is an opportunity for learning and to meet the demands of the new and emerging Desmodium seed market." (*KI interview, researcher Matuu Agric Res Center, March 2014).*

There is potential for the production of for silver leaf and modest quantity for green leaf Desmodium from the Yayu and Jimma areas adjoining forests and along the farm hedges. This is an opportunity for the youths and women farmer groups to participate in PPT through Desmodium seed collection as a response to the demand and market for supplying Desmodium seeds for the new PPT farmers in the country. For instance, 3 tons Desmodium seeds were bought by *icipe* in March/April 2015 from the farmers, Metu and Jimma Research Centers, and agro-dealers in Jimma. This was a good incentive for the producers to collect more seeds and an opportunity to generate cash income for the farmers. The market linkage was associated as a measure for sustainability of PPT. The private agro-dealers have an existing network of seed collection and distribution and Desmodium is one of the seeds collected and traded. That means, the successful promotion and expansion of PPT will increase their market penetration with Desmodium seeds and this has significant influence on the sustainability of PPT.

8.5.3 Applying Push-pull Technology Knowledge as Training Content

The PPT content is suitable as a curriculum material not only for training farmers, but also for training college students. The participation of college tutors and students during farmers' field days was an opportunity for them to link theory with practical realities on the farmers' fields. This stimulated their interest to learn more with intentions to apply the knowledge when they graduate**.** They learnt that, the technology touches on key sectors of their training: crops, livestock and natural resources management. This was noted by one of the students who participated during the farmer field days:

"PPT is simple to implement, it is cheap, uses less expensive inputs, it is very important for the livelihood of the farmers. Bako College is a center of excellence for training Development Agents (DAs) in plant science and animal health. Including PPT in our curriculum will be an opportunity for information transfer to the students who will finally become DAs….and will transfer the same knowledge to our farmers." (*Interview, student Bako College, April 2015).*

Bako technical and vocational training college is mandated to train frontline extension staffs, who are otherwise called Development Agents. They are employed immediately after graduating to work as village extension staff. During interview with one of the tutors who attended farmers' field days, he said:

> "In our college, we provide DA's training in two types. That is occupation-based and project-based. The former one is based on Ethiopian occupational standard prepared by Ministry of Education. For the second one, the projects are prepared based on the competencies or topics selected from list of occupations like crop production, animal production and natural resource conservation. The project-based training contains competence, entrepreneurship and technology. So having our curriculum content with technologies like PPT is important for our students who will eventually teach farmers." *(Interview, Bako college tutor, April 2015).*

This statement was backed up by another tutor from the college:

> "PPT field day provides an opportunity for the teachers to learn and have experience with the new technology. Now with practical knowledge, it is easy to read and understand and transfer to learners who will become DAs…. This is a perfect opportunity for introducing the technology as a tool for training and for learning by various disciplines….and seems to touch all the departments…from technology, trade, crops to livestock/health etc." **(***Comment by Bako college tutor during farmer' field day, April 2015).*

8.6 Mutual Trust in Transdisciplinary Stakeholder Interaction

The critical basis for stakeholder collaboration and cooperation is trust which is built and maintained through regular meetings, openness, transparency and offering something of immediate importance to the stakeholders (Hornidge et al., 2011). However, building trust is a major practical challenges facing TDR process among the stakeholders with diverse interests, disciplinary backgrounds and experiences. Therefore, attention has to be given to building trust in order to make the process a success. The PPT implementation process follows maize crop phenology and covering several cropping seasons. The stakeholder interaction during these seasons has the potential to generate mutual relationship and agreements and among the stakeholder involved. Sometimes, it can also lead to disagreements. As opined by Cundill et al (2015), in normal situations, for such interaction to come to a point of developing trust requires some time and sustained interaction. During PPT implementation over successive seasons, the stakeholders have an opportunity to frequently interact and learn over common and emerging issues related not only to stemborer pest control and other farming enterprises, but also strong relationship among the stakeholders.

According to Wenger (2000), people must know each other well enough to be able to interact productively and know who to call for help or advice. They must trust on each other and also have no doubt on their willingness to contribute to the common enterprises of their community. This makes them to feel comfortable to openly discuss and speak truthfully to each other in an attempt to address their common challenges. In Ethiopia, for example, as an outsider, I made observation that there is a culture of benevolent trust among the people especially in the rural areas. This means that nobody is willing to share information which can lead to harm a neighbor. They may prefer to keep useful information rather than share what is injurious to their neighbors. This is because the consequences will be known and seen an enemy to the other members. This culture makes them share information on new technologies or opportunities which directly are meant address their real life challenges expecting similar response in future. For example, achieving the expected increase in maize production by 4-5ton/ha and provision of high quality livestock fodder which are associated with introduction of PPT, is an incentive of immediate benefit for the farmers and other stakeholders to develop interest and share information regarding the technology. However, at the same time, if these farmers don't trust the source of information, they could easily give up on its benefits. The trust is even higher if the information is from a competent based source i.e the person is knowledgeable about a given subject. Such a culture of appreciating new information from competent based sources and sharing it freely is an entry process to the learning journey. "Farmers easily trust new technologies if it is from competent contacts or sources in the community such as lead farmers, extension staff and researchers whom it is assumed have already tested or put into use before introducing or recommending it to us" comment from a PPT follower farmer during FGD. There may be histories of mistrust or communication barriers between farmers, researcher and extension services providers in the past, however, TDR approach, it may have contributed to some extent to some sort of improved ties between the different stakeholders. Therefore, the researchers, extension staff and smallholder farmers started to work together towards solving a common problem of stemborer pest from the point of trusting each other's contributions. Although building such trust requires time which is longer than the time than this study period, however, some 'sort of ties' prevailed which ensured that implementation process was initiated.

> "I learnt that the Ethiopian farmers are interested to take up and adopt PPT more than Kenyan and Ugandan farmers. It will take a short time to achieve the high adoption numbers due to the fact that we trust new information from competent sources so long as it addresses the problem at hand**." (***Comment by follower farmer who visited Kenya and Uganda exchange visit, FGD, May 2015).*

This observation was based on the fact that PPT technology has been promoted in Kenya and Uganda for longer time than in Ethiopia. The reasons cited for low adoption rate was related to the commitments by the research and extension systems of these countries which had not taken up the technology at policy levels and promotion mainly supply and research led. The Ethiopian ministry of agriculture officials requested for the introduction of PPT into the country from the *icipe* researchers with the support of donors in the year 2012. This signifies high level of trust the MOA officials have on *icipe* researches and also commitment for new information to address the problem of stemborers. However, this dependence on research and extension officers as the main source of information and knowledge on new technologies is not sustainable on the long-run. For example, every year the government sets aside 30 days dedicated for soil and water conservation efforts. The farmers are compelled to participate in digging terraces, planting soil cover crops such as vetiver grasses on the sloppy areas. In most instances, this has degenerated to mistrusts, whereby the farmers don't trust the intention of the government officials whether from research centers or extension services. This is also linked to some of the cases where the DAs are used to collect 'taxes' on behalf of the government. The farmers are forced to cooperate and according to the political power needs. This is completely conflicting with agricultural extension activities where farmers are supposed to be treated with freedom and trusting by the extension agents.

Farmers often have some apprehension new technologies whenever introduced in their localities. Connecting with the previous experiences during SG2000 technology promotion, the farmers were not sure what PPT had in store for them. This was attributed partly to lack of enough information at the initial stages of implementation. However, through continuous interactions with researchers and extension personnel, they were slowly appreciating the technology and learning in detail on how it functions. For example, the farmers had noticed that with their current maize crop, the perennial pest problem of stemborer and birds had dropped.

> "I haven't seen stemborer attack this time round in my maize field…. This is contrary to during the normal cropping season, the stemborer always infest stems and birds always attack the maize tassel…. I think birds are searching for stemborer eggs on the maize tassel, hence breaking it… I hope this Desmodium protects maize from stemborer and from birds…. I will continue to observe this trend in the coming seasons. In future I will make some conclusion". *(PPT Farmer interview, April 2015, Dembi Gobu, Bako Tibe).*

However, this observation did not last long. Towards the end of season, the birds started attacking the maize crop but the effect was less, because the cobs had already matured and it was difficult for the birds to feed on mature maize cobs. This was an advantage to the farmer. This keenness of the farmers to make observation and try to make sense of it either by conducting own research or engaging researchers for further discussions was a significant step towards appreciating the technology. This was not only in addressing the pest problem, but also an opportunity for to learning by seeking answers to 'new observations' made. For example, why the birds did not recognize the maize earlier? Was maize made invisible as a result of intercropping with Desmodium? Some of these questions were raised by the farmers based on the observations made for the first time and during the first cropping season. However for certainty, they decided to continue to follow on this observation for some time and during subsequent seasons. They hoped that after 2-3 years of continuous cropping, they shall have formed an opinion based on the long term observations on the performance of the technology and even make recommendations for changes or adaptations. In the meantime, it came out from the discussions that, there is no scientific method so far for scaring or control birds. Locally the farmers use a cassette tape ribbon which they wind along the orders of the maize field. The hissing sound and reflection produced by the ribbon due to the winds blowing is used scare the birds. However, this is effective for small plots of land, of less than half a hectare (½ ha). On the larger fields, they rely on manual birds scaring away mainly by throwing stones into the maize plantation. This lasts for about 2 weeks, after which the maize cobs mature and the birds cannot manage to feed on them. However, during off-season crop, the population of birds is too high and feeding on the grain can be intense within a very short period of time, causing huge loses to the farmer.

8.7 Summary of Findings

The findings showed that; effective collaborative leadership and empowerment provides a chance especially for the farmer stakeholders to participate in the technology learning and decision making by enabling them to contribute skills towards development, refinement and adaptation of the technology. Although PPT perennial nature of cropping provided opportunities for continuous interaction and learning, it requires committed leadership and institutional engagements at the initial stages of implementation from researchers and extension staff to sustain such collaboration. PPT implementation was being implemented in the study area for the first time and there was high level of personalized interests among the researchers and extension staff. Although the working process was on joint basis, these stakeholders represented their respective interest group. That means that collaboration with 'personally' committed leadership will most likely increase the continuity and sustainability of PPT when the personal interests are met. For example, if farmers harvest a good crop, the researchers are able to validate their research findings and the extension staffs are able to reach the critical mass of farmers participating and implementing new technologies, they will definitely promote it. Market forces and the involvement of private sector players have a role to achieve this as shown by the interests of individual farmers and traders in learning on Desmodium and Brachiaria seed production, collection and distribution. These immediate PPT benefits will sustain the stakeholder interests and gain their trust for continued interaction and learning about PPT. This will incrementally contribute to the long-term benefits such as soil and water conservation and Desmodium and Brachiaria seed production.

Chapter 9:

The Push-pull Technology: Adoption and Non-adoption; Reasons and Challenges

9.1 Introduction

During the last two decades, the agricultural and extension efforts in Ethiopia have been geared towards enabling the use of modern agricultural technologies among the smallholder farmers for increased production and productivity. As stipulated in the Agricultural Development Led Industrialization policy framework, the adoption of agricultural technologies plays an important role to bring about improved agricultural production (Tefera et al., 2016). That means; the uptake of the new technologies by the end users is the ultimate objective of any technology development and dissemination efforts. When the farmers' adopt new technologies and freely share the information with fellow farmers and stakeholders in the community, it is seen as a sign of confidence on the new technology. However, there are many promising technologies in agricultural sector that are not adopted, with failed attempts or abandoned due to perceived risks (Simtowe, 2006). In other instances, there are technologies which fail to be scaled up locally or even to spread to other areas either due to the specific nature of their intended outcomes or they are deemed not locally fitting by the intended users.

In Ethiopia and other sub-Saharan African countries, there are several initiatives by research and extension systems to promote and disseminate new agricultural technologies, but the adoption rates are low and below expectations (Meijer et al., 2015; Tefera et al., 2016). Influencing adoption decision is a challenging task for the developers and the promoters of these technologies (Meijer et al., 2015). The decision to adopt or not adopt is either depended on the characteristics of the technology itself or external factors e.g. the motivational and socio-psychological traits of the farmer, and the bio-physical environmental conditions (Valera et al. 1987). Using the findings of the Uganda National Household Survey 2005/06, it was found that, only one percent of the farmers were found to be using inorganic fertilizer (UBOS 2007). It was also established that these farmers have limited scientific information on proper agronomic application of fertilizer on crops with different agro-ecological zone requirements. This explains why they apply much less fertilizer to their crops than the optimal requirements from a commercial point of view. Thus, they are unable to realize the productivity associated with each additional unit of fertilizer applied (Bayite-Kasule et al., 2011).

At the center of these efforts from technology development to dissemination is the farmer who has the final decision. The farmers have the sovereignty in terms of resources allocation, in adaptation, modifying and rejecting technology disseminated. According to Mosher (1987), adoption of a new technology is the process by which a farmer is exposed to, considers and finally accepts or rejects the technology. The adoption can involve a new technology or adaptation of an existing practice (Meijer et al., 2015). The decision to adopt is a process, which according to Rogers (1983), an individual farmer is first exposed to the knowledge of the new technology, to forming an attitude towards it, to decision to adopt or reject to implement the new idea. Despite the existence of production enhancing technologies, why do we have low levels of adoption by the smallholder farmers? Using the example of the PPT implementation in Ethiopia and other countries on the region, there are a reasons or excuses which are cited by the farmers and other users regarding adoption of new technologies. According to Marra et al. (2003), the low adoption levels could be associated with risks and uncertainties linked to these technologies. There are also numerous nuanced and interrelated socio-cultural and economic explanations for non-use or low adoption of the new technologies associated with the everyday life of the farmers (Lang et al., 2011). For example, the smallholder farmers conduct their farming enterprises on limited land spaces and other resources such as labor and capital. When new technologies such as the PPT are introduced, they are assessed based on their socio-economic implications to the real life conditions of the farmers. That means, any technology which requires new investments or change of existing practices, farmers take time to asses it before adoption, adapt or reject it altogether.

9.2 Critical Engagement with the Farmers and Other Stakeholder on the Push-pull Technology

The implementation of the PPT requires that the companion crops of Desmodium and Brachiaria remain on farm over several and successive maize planting seasons. This means that, the farmers have to protect the companion crops from being trampled upon or destroyed by the roaming livestock and wild animals during off-maize cropping season. At the same time, the rainfall is very unreliable due to the varying weather conditions. The long period of dry season, is a threat to the survival of the PPT companion crops. These are some of the issues or areas of concern among the stakeholder and they turned out to be questions on the sustainability of the PPT i.e. whether the PPT is able to fit to or adapt to the existing farming practices and whether it has ability to withstand long and extreme weather conditions. These points of concern by the stakeholder during planning workshops:

> "How can Greenleaf Desmodium and Brachiaria grass be managed during off season with the presence of roaming wild animals and freely grazing livestock? Any form of insurance or compensation for the farmer in case PPT fails?

On the same question of local fit of the PPT, an agricultural extension officer from Yayu *Woreda*, raised questions on; how to handle crop rotation in the presence of Brachiaria and Desmodium on the same plot, and the PPT management practices farmers will have to adhere to when rotating maize with crops such as *tef*, legumes or horticultural crops. The introduction of PPT appeared to be complex in terms of fitting the local practices of crop rotation management. As opined by Evans (2005) and Gieryn (1983), these questions or scenarios, although seeming contradictory, were used as instruments to seek collaboration for learning and enhance bold boundary crossing between research and practice and vice versa.

The PPT is promoted as a smallholder farmer based technology. The dissemination process is mainly driven by farmer based approaches (Murage, et al. 2011) which have limited scope of coverage in content and space. The limited or lack of interest by the private sector players to invest in PPT related enterprises such as seed production and distribution has led to the limited supply and access to Desmodium seeds. As constraint, the availability of the Desmodium seeds has contributed to low adoption rates and expansion (Amudavi et al., 2008). The large area to be covered and logistical constraints to research and extension services providers also contribute to this. Thus requiring need to strengthen both formal and informal seed production and distribution systems to reach many farmers as possible. Apart from seeds, other reasons cited for low adoption rates are linked to: Lack of enough family labor, the PPT not flexible with food legumes, general negative perceptions on new technologies introduced by researchers and extension officials, lack of regular supervision/monitoring by extension officials or some farmers not taking stemborer pest or *Striga* weed as constraints to their farming activities.

9.3 Is the Push-pull Technology only Positive Technology as Being Promoted?

According to Bijker & Law (1992, p.3), "The idea of pure technology is non-sense". The development of the technology has to balance between social and technological aspects. Although the PPT rationale, workings and indeed benefits, show that it contributes to positive outcomes from the reduction of stemborer infestations, soil and water conservation to additional sources of income for farmers, it has its share of negative outcomes and challenges as well. These attributes have contributed to adoption and non-adoption or rejection during the last 20 years of promotion in the eastern African region. Although the PPT was introduced into the study area for the first time, the experiences from other countries in the region can be applicable. The farmers in the rural settings of Ethiopia and elsewhere in the region receive new agricultural information mainly from frontline extension officials or the Development Agents (DAs). In the Ethiopian context, such information is stuffed with ruling party political messages. This is not only meant to convince farmers to take up the new agricultural information, but also for tight political control. The DAs are seen as government prolocutors rather than facilitators of agricultural innovation and development (Berhanu & Poulton, 2014). In most cases, the truth is distorted to serve ruling class and political interests. This type of relationship has the created a situation whereby farmers are suspicious with 'new technologies' introduced by the DAs and researchers to be having political undertones. The farmers out of fear of intimidation may accept to implement the technologies just to make the researchers or extension agents happy:

> "…we have never trusted extension staff…they come here under the cover of agricultural extension but they are the under hands of the state and pushing the ruling party agenda" (*Female farmer, Bako area, March 2015*).

The really negative thoughts could be hidden or disguised as positive comments. This concurs with Scott (2008), in his analysis of everyday forms peasant resistance and the reasons why they don't openly revolt. He observed that, beneath the surface of symbolic and ritual compliance there is an underhand of resistance and just beneath the surface of peace there is an element of continuous material resistance. Those who are seen or heard acting openly and contravention of state directives are treated as traitors. This came into play in the course of field research. One of the government ministry officials at the *Woreda* level was very supportive and committed towards successful implementation of the PPT. As a youth officer in charge of the *Woreda,* he recruited one of the youth group farmers to participate in the PPT implementation. However, in the middle of the process, he was demoted and transferred to another *Woreda* outside the study area. I followed and later met him to find out why he left, he said:

> "Some people in the *Woreda* administration were not happy with my freeness and the way I was mobilizing the youth and providing them with civic education, they thought I was radicalizing youths against the government and party agenda".

The official, who took over from him, had a royal and seemingly pro-government and non-controversial approach. He was doing this to avoid problems; losing his job or being transferred and even arrested. In such circumstances, most of the extension and other public officers are forced to speak only positive comments and avoid any situations where they are no longer trusted by the authorities. They may be having the negative thoughts or alternative opinions, but cannot share in public. This non-controversial approach is equally applicable to farmers who accept to implement new technologies so that they are in right books with the *Woreda* administration. For example, in Bako *Woreda,* one of the PPT farmers confessed that he accepted to participate in PPT implementation because he was approached by the extension staff in his *Kebale*. Previously he had been recognized and awarded by the same extension as a model farmer. The award came with some free inputs such as seeds and fertilizer and invitations to participate in farmer training workshops and tours. Such types of farmers are more likely to dis-adopt once their relationship with authorities is cut or their perceived benefits are not forthcoming. Indeed based on the promotion history of PPT of over 20 years, there are many new farmers recruited for adoption and the old farmers dropping. This could be attributed to the technology and also the nature of relationship established with the farmers by the promoters i.e. extension and research stakeholders. The focus could be more research based than problem driven. That means, when the researchers are seen not interested with data collection, the farmers drop the technology to such a time when the researchers come back and process start again. However for the case of the study area, a follow-up study is important to ascertain some of these assumptions. These different viewpoints could be purely based on particular settings of the individual farmers and their perceived benefits of the PPT.

In terms of positionality as a researcher from another country with a communication language barrier, some of the negative comments and critical review about the PPT may have been shared freely but the translator decided to ignore. However, among the farmers who had implemented the technology, on close discussion and frequent interaction, they were free to share their challenges and misgivings what they thought or felt about the PPT not doing well or not working. The dissatisfaction was not limited to the study area. Elsewhere in the region, the adoption rates and expansion have been rather low and slow when compared to the targeted number of over 1 million smallholder farmers by 2020. The numbers of farmers so far are less than 20% (Khan et al., 2014) of the targeted projection. For example, the problem of wild and domestic animals roaming during off-season was cited as the major challenge to the expansion of the PPT in the areas where farmers practice free livestock grazing. That means, the Desmodium and Brachiaria grass will either stumbled on or uprooted during free grazing. This is discouraging to some of the farmers:

> "The major challenge of the PPT is how to deal with birds and roaming animals…How are we going to deal with the problem? Do we have any scientific or cultural means to deal with the problem?" (*PPT follower farmer, during FGD Sedan Kite, Bako Tibe, March, 2015*).

Figure 21: Maize cob attacked by birds
Field photo: Nyang'au I.M.

Despite the fears, doubts and rumors spread, some of the farmers decided to go ahead with the PPT implementation process to either discover by themselves or learn something out of these concerns. For example, the rumors on lose of land promoters of the technology was a sensitive remark and potentially detriment to the success of the technology. The PPT sustainability and effectiveness is depended on the number of seasons it has been existing. That means, companion crops have to be maintained on the farm for as long as the farmer can manage. This long term nature of establishment was misconceived to imply that farmers' plots will be fully managed by the promoters. Such spread of negative rumors is known to have a significant impact in the lives of people in terms of distorting information, facts and influencing their perceptions on new ideas (Wang et al., 2017). In the Ethiopia context, the PPT was being introduced for the first time, so some sources of misinformation were acting out of fear of the unknown. In other words, they could rather stay in their comfort zone than take up what they are uncertain about.

9.4 Summary of Findings

The adoption of PPT is expected to empower farmers through its benefits; increased cereal yields and income from the control of stemborer pests. While it is acknowledged that there is remarkable success in terms of awareness creation and adoption of PPT by some of the farmers, the rate and intensity of adoption is still low and below the expected target. This performance is partly attributed to some farmers not able to adopt the technology either due to incapability or unwillingness. The unwillingness can be directly or indirectly linked to the technology itself e.g. not seeing the immediate need for the technology or having low or poor perception on its performance and sustainability. The spread of negative rumors, fear and uncertainty seem to draw attention of some of these farmers. Such scenario is partly attributed to insufficient information and trainings on the workings of the technology. The spread of negative information by the farmers who are supposed to be the eventual beneficiaries is a sign of a state of unpreparedness or unwillingness to take up the technology. The non-adoption of the PPT is mainly as a result of lack of enough or timely information and access to required inputs (mainly Desmodium and Brachiaria seeds). The overall PPT adoption process takes time and depends on the farmer decision making. However, in situations of a dis-adoption, this is when the performance of the technology is measured or evaluated. There is need to strengthen farmer based dissemination together with other channels such as field days, mass media and printed materials to improve farmer communication and engagement. Follow up studies on some of the cases of non-adoption and dis-adoption will point out the exact weakness or 'sparkplugs' on its performance for further research and development.

Chapter 10:
Conclusion and Recommendations

This study intended to analyze how researchers and other stakeholders interacted in a transdisciplinary and participatory environment during the introduction and implementation of the PPT in terms of enhanced learning and strengthening its local adaptability and improving productivity in Ethiopia. The study sought to assess how the scientific research and practice cultures of different stakeholders influence their interactions and collaborations to address the existing gaps, generate new knowledge and practices during the activity stages of the PPT implementation. In this thesis, I have argued that, sharing knowledge across research and practice levels is an important milestone to address common societal problems. I have made special reference to the problem of stemborer pests and its effect on the low productivity of maize crops experienced by the smallholder farmers. The outcomes of such interactive collaboration among researchers and other stakeholders are the opportunities for mutual learning and to inspire innovation for scientific research and practice.

The study findings show that, the introduction and implementation of PPT had mixed blessings not only in addressing the stemborer pest problem, but also as cause of some of unexpected results i.e. ‘conflicts’. The outcome of conflicts and tensions is attributed to misinformation, negative rumors and uncertainties arising from the implementation of the PPT. Such situations are associated with the system of agricultural extension which has a culture of dominance and exerting fear on the farmers to keep them under control of the state power. The non-adoption of the PPT is often attributed to lack of timely access to right information, knowledge and farming inputs, but may also be a sign of deep rooted anger, fatigue and resentment by the smallholders to the extension system which is under state control. They may not openly revolt due to fear for intimidation by the state agents. However, this can be seen with the way the farmers portray negative thoughts disguised as positive whenever they are engaged with the extension or the Development Agents (DAs). Although the agricultural extension system in Ethiopia is a public good, it has been infiltrated by the ruling party operatives who masquerade as DAs. This contributes to a situation where there is mistrust between the farmers and the DAs who are viewed as traitors and underhand working for the ruling party and state agencies. This is also rooted in the historical developments of the extension system where the intrusive state power has maintained a linear nature of relationship with monopoly of power in the hands of elite politicians and their agents. In this case, the role and contributions of the farmers and their informal institutions is not given prominence in the decision making. This is a contradiction of what the formal extension system claims as ‘participatory’ to become a mere rhetoric.

Land use and water allocation for irrigation are critical natural resources whose management can potentially contribute to new technology becoming a success or a potential ‘curse’ if it is not well addressed. The spreading of negative rumor on the forceful taking over land belonging to the PPT farmers portrays its implementation as a form ‘land grab’ where the farmer land rights are taken over by the state agents or the promoters of the technology. The casting of doubts and questioning the essence of irrigating the PPT plots instead of horticultural plots, is an indication of lack of trust between by the farmer beneficiaries on the various agricultural initiatives and activities which are organized by the DAs on behalf of other development agencies. This is closely linked with the memories during the imperial and Derg regimes when land was either in the hands of landlords or forcefully taken away from farmers and were forced to work as sharecroppers or join cooperatives to implement government-led projects. The utilization of land and water use for irrigation is centered on scarcity, therefore decisions on their allocation and utilization should be a collective affair either at the family or community levels to reduce conflicts or mistrusts thereof.

Stemming the escalation of the resource based conflicts associated with the PPT, stakeholder engagement during planning and implementation plays an important role in improving the general perceptions the users will have on the technology and its promoters. The practical and long term nature of PPT implementation plays an instrumental role in managing such challenges. The findings show that, during on-farm demonstrations, some of these challenges turned out to be the essential points for learning rather than being used or seen as weak or breakup points on PPT implementation and uptake. The farmers and other local stakeholders can effectively use the PPT as a window of opportunity for continuous interaction and learning for a minimum of about 2-3 cropping seasons and along the maize growth phenology. During this period, participating stakeholders with doubts or suspicions or questions have a chance to overcome or confirm them. That means, they are able to follow the technology from doubts to appreciation or vice versa. This gives the farmers the ‘space’ to learn and make decision whether to adopt, adapt or not to adopt and even to drop after adopting for some time. The emergence of new problems or conflicts which have no immediate solutions puts to task on the facilitation and performance of the stakeholder engagement team on how they are able to deal with multiple viewpoints and diverse knowledge bases of different stakeholders. Effective facilitation of the stakeholder interaction process is seen as the fallback plan whereby the points of conflict are turned into ‘spark plugs’ for in depth learning and searching for solutions. The findings show that, in situations where there are such ‘new conflicts’, they should be embraced and used as opportunities for learning and also as a way of finding practical solutions to the underlying problems than being sources of contradiction or misunderstanding about the PPT.

The transboundary nature of water flow in the Omo River and the demand for water during crop irrigation requires multiple stakeholders work together and negotiate on the use of the water along the river bed. The informal water use arrangements are unwritten and may not be effectively understood or applicable with the trans-disciplinary and cross-border teams due to differences in cultures, disciplines, ethnicities and even countries. This is because, during formulation of the informal water use agreements, they are limited to local use situations. Thus, the need to have formal agreements to accommodate changing water needs and circumstances in terms of volumes, different uses and types of users across culture and boundaries. In the agreements, conflicts mitigation and resolution mechanisms are well stipulated. This kind of new arrangement came up as a result of an unexpected conflict on water use during the implementation of the PPT activities. The allocated time and amount of water was used by each participating farmer in irrigation activities was well elaborated in a formally signed document.

Individual farmers are willing to take the leadership roles whenever they are introduced to with new interventions such the PPT. The findings show that, they are able to do so when they have or seen the incentives and also when they have been selected by fellow farmers or appointed by *Woreda* extension officials. Apart from the control of stemborers, the farmers were attracted with other incentives such as fodder provision for their livestock and controlling soil erosion. In the transdisciplinary research process, leadership roles taken by the farmers is a form of empowerment in terms of their ability to reflect on their own practices and needs instead of depending on the expert knowledge or information supplied from the researchers and extension agents. This also enables them to take lead in new technology implementation and information sharing with fellow farmers and other stakeholders. The findings suggest that, technologies which are newly introduced and with ‘quick’ implementation benefits are more likely attract attention from the users than those with ‘longer term’ benefits. The PPT has both short and longer term benefits where the former is likely to spur interest for learning and eventually influence the decision whether to adopt or reject. The long term benefits are achieved after the short term benefits are realized.

The PPT implementation complements soil and water conservation measures which involve digging drenches or planting trees. In Ethiopia, these measures are undertaken on an annual basis and campaigns are organized by the local administrative authorities and demonstrated by extension officials at farmer training centers. Afterwards the farmers are required to implement these measures on their own farms. However, it has been shown that, there is general fatigue and resistance shown by the farmers when implementing these measures because there are no immediate incentives or ‘pull factors’ while at the same time, the information is pushed down to them by the authorities. The top down approach tendency in extension service delivery has been inherited from the past political regimes and administrations. Such a historical background has contributed to the smallholder farmers becoming risk averse. They are not keen to participate or implement new technologies which are introduced to them by outsiders who don't seek their opinion or input in the planning and implementation process.

Although the nature of agricultural extension systems delivery system in Ethiopia can be described as linear in terms of knowledge and information dissemination, with improved interpersonal relationships among the stakeholders, it becomes bottom-up. The findings showed that, the PPT can effectively be used to overcome this as boundary object i.e. in the creation of conditions for learning, collaboration and interaction among researchers and other stakeholders to understand a common problem and address a common or a newly emerging problem. This was shown where new practices which were not previously applied became locally embedded as a result of the different stakeholders working together in the implementation of the PPT e.g. indoor livestock feeding through cut and carry method, farmers are able manage new pests such as grasshoppers by resorting to the use root splits instead of Brachiaria seeds.

Apart from being disseminated by extension officials and researchers as a modern farming technique, mono-cropping is seen as recipe for pest infestations. The intercropping strategy of maize with perennial crops such as Desmodium, reintroduces the traditional intercropping system of smallholder agriculture as strategy for the control of pests. At the same time, it introduces a new dimension on the practice of roaming livestock after harvesting maize or other cereal crops. In order to protect the PPT plots, the farmers have to start fencing and guarding their livestock instead of allowing them to move freely through the harvested fields where they degrade the soils and also destroy the PPT companion crops.

With human population increase, the demand for food and the pressure on land is increasing. The traditional practice of keeping large herd of livestock which roam after crop harvesting is not only degrading the environment, but reduces its productivity. Therefore introducing innovations which promote intensification of farming activities is novel. The perennial nature of PPT companion crops allows other crops such as food legumes to be planted during the off-maize cropping season. This aspect is contributing to change of crop farming and management practices of having a crop during off maize-season. This provides a permanent soil cover with the crops and the intercropping arrangement has flexibility and adaptability which allow management operations such as weeding, irrigation, use of ox-plough during planting to continue without disruptions. This doesn't allow the free roaming of livestock after crop harvesting.

The research and development process of the PPT has taken place over the past 25 years and has been influenced by the urgent need to address the challenges faced by farmers from the stemborer pest, low soil fertility, shortage of fodder to the effects of climate change. At the core of these efforts are the smallholder farmers who have contributed and volunteered information which has enabled the researchers to move the research agenda forward and make further modifications without compromising the PPT performance. During this period, the PPT has developed into a multi-functional strategy based on a holistic and concerted approach involving the engagement of researchers, farmers and others stakeholder in a transdisciplinary process. This is shown from the initial stages of development, when the companion crops i.e. Desmodium and Napier/Brachiaria were incorporated in the PPT strategy through screening and selection process mainly driven by the researchers during the laboratory and on-station experiments. As time went by, the farmers' experimentation and involvement in the research process played a major role in the development of the PPT and finding solutions to second generation research challenges such as; Napier stunt disease, Desmodium blister beetles, integrating edible legumes into the PPT and the use vines to establish Desmodium. The participation of farmers as key stakeholders brought in new ideas which the researchers had not known nor considered before. This is a major contributing factor which has kept the research and development of the PPT on-going during the last 2-3 decades. The most recent development was seen in the outbreak of Fall Armyworm (FAW). The farmers' observations on their PPT farms were brought to the attention of the researchers, where the maize crop under the PPT was not attacked by the FAW pest as compared to non-PPT plots where there infestations.

The uptake of the PPT is a concern for the different stakeholders involved. Although its introduction and implementation may seem positive, not all the stakeholders have interest or willingness to adopt it. This is stemming from its adoption weaknesses or challenges such as lack of timely access to information and the required inputs mainly Desmodium and Brachiaria seeds. Equally, some are completely not interested because the PPT doesn't address their farming needs. The transdisciplinary processes enabled me as a researcher to understand that, the coming together of different stakeholders with diverse research-practice interests and experiences to discuss on the problem of stemborer pests, fodder challenges, soil and water conservation, it was sign of commitment to finding the solutions. They were able to come up with different questions, view points and interpretations drawn from their knowledge perspectives as points of cooperation and upon which to seek answers to address the problems. However, working together was not an easy process. This is due to resistances and occasional conflicts arising out of institutional, political or cultural expression of dominance, or where the PPT management practices are different or thought to be conflicting with the traditional practices. For this reasons, the PPT uptake, or non-uptake is the outcome of the facilitation process and more importantly individual farmer decision making. The transdisciplinary approach in the PPT implementation process entrenches the spirit of empowerment in decision through research-practice interactions and linkages e.g. the participation of farmers in the production and marketing of Desmodium and Brachiaria seeds.

The PPT out scaling, requires, the mobilization and engagement of the right type of stakeholders. It starts with those who understand problem by the either being affected, have interest and mandate to address the problem. The process doesn't exclude those with conflicting viewpoints. They are accommodated through effective facilitation. This is because, they have a legitimate claim, interest to learn and address the problem at hand rather than being seen as source of confrontation and negative innuendos. That means new conflicts which come either with the PPT as a technology or organization of the process, should be embraced and addressed in situ and used as the essential points of learning. The PPT practical nature of implementation which lasted over several cropping seasons provides a framework for long term interaction and fostered learning among the research-practice stakeholders. In that case, the long term prosperity of the PPT as an innovation and transdisciplinary research can be achieved through constant pursuit of its development as a product and a process by the researchers and other stakeholder as the practitioners.

The farmers' uptake of the PPT is less than 20 percent of the target of over 2 million smallholder farmers in the Eastern Africa region. This is too low compared to the population of farmers who are affected by the problem addressed by the PPT. Therefore to obtain different results in terms of increased uptake and farmer to farmer knowledge sharing, the PPT dissemination process requires significant change in terms of engagements with research, extension and farmers in the research planning, implementation and evaluation. In such an arrangement, the transdisciplinary process, the farmers are able to motivate researchers and extension staff to step out of their disciplinary and professional silos and challenge their own laid down research-practice protocols/procedures. This engagement involves the fusion of ideas and knowledge perspectives of these stakeholders. The informal institutions are an important learning platforms and source of social capital and networks. The mutual trust inherent within such informal networks can be tapped and used as entry to the community and providing a link between the researchers and other stakeholders engaged in agriculture research and extension services.

Over 5 decades Ethiopia has implemented various approaches of agricultural extensions under different regimes. The impacts of these approaches have limited productivity due to lack of institutional atmosphere with a truly participatory stakeholder engagement. The role and contribution of the farmers' initiatives, informal institutions and the private sector, despite their immense potentials, they are not given prominence they deserve in extension services provision and policy relevance. They are in most cases viewed as a threat and intrusive to state power. As a policy recommendation, in order for a truly participatory innovation development and implementation to take place, the user oriented research, extension and training services should operationalized under the transdisciplinary processes where the role and contribution of the farmer led initiatives and their institutions is given prominence in the research-extension service provision. This is informed by the fact that, the participatory introduction of

PPT enabled it to be seen as fitting to the local farming practices e.g. intercropping cereal crops with additional crop such as legumes and complimenting the government policy initiatives; soil and water conservation and livestock integration through fodder provisioning. The adoption of such new technology can be based on selective attributes which have relevance to particular stakeholders' needs and regions. Later on it is scaled up and become part of agricultural extension packages and its activities incorporated in the MoA annual work plans.

The methodology of transdisciplinary processes recognizes the importance of fusing different viewpoints and diverse knowledge held by different stakeholders in addressing societal challenges. In order for these positions to be concretely understood, appreciated and integrated, the stakeholders require longer time to interact and learn together. The PPT long term practical implementation of activities covering over several cropping seasons, provides sufficient timelines and 'spaces' required to reflect and put into perspectives the different opinion held by the stakeholders to generate new perspectives. However, the traditional or normal practices held by the different stakeholders are not easily replaced by new interventions introduced for the first time. At the same time, the internalization and appreciating of new practices or changes takes time to be reflected or effected by the intended practitioners. Although this may be true, the quick nature of assembling the stakeholder engagement team during this study was necessitated by the need to start the implementation of the research process as early as possible within the time line available for field research. This did not give sufficient time for the group dynamics of the stakeholders to evolve and internalize these perspectives into their institutional, cultural and political contexts ways of doing things.

In order for the transdisciplinary processes and the uptake of the PPT activities to take effect, the longer periods of engagement and assessment need to be considered in order to come up with strong conclusions and recommendations which can be scaled up to other contexts. Consequently, a follow-up to this study should be considered to document the changes on how the new PPT practices and transdisciplinary relationships faired on after 2-3 years down the line. In particular, it should focus on evaluating; the adoption and dis-adoption rates and the underlying factors and compare this with other countries in the region; the perception of stakeholders who were skeptical and expressed doubts and uncertainty about the PPT, whether their fears are still on or already answered, and if not what are the reasons.

List of References

Abate, H. (2007). Review of extension systems applied in Ethiopia with special emphasis to the participatory demonstration and training extension system. Rome: Food and Agriculture Organization of the United Nations.

Abate, T., Shiferaw, B., Gebeyehu, S., Amsalu, B., Negash, K., Assefa, K., … Hagmann, J. (2011). A systems and partnership approach to agricultural research for development: Lessons from Ethiopia. *Outlook on Agriculture Journal*, *40*(3), 213-220.

Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., … Keno, T. (2015). Factors that transformed maize productivity in Ethiopia. *Food Security*, *7*(5), 965–981. https://doi.org/10.1007/s12571-015-0488-z

Abdissa G., Ethiopian Agricultural Research Organization, & International Maize and Wheat Improvement Center (Eds.). (2001). *Farmers' maize seed systems in western Oromia, Ethiopia*. Addis Ababa, Ethiopia: Ethiopian Agricultural Research Organization : International Maize and Wheat Improvement Center.

Adane, K. & Abraham, T. (1998). Yield loss in sorghum caused by sorghum shoot fly and maize stalk borer at Bako. Eth. J. Pest Mgt. 2:71-78.

Adekunle, A. A., & Fatunbi, A. O. (2012). Approaches for setting-up multi-stakeholder platforms for agricultural research and development. *World Applied Sciences Journal*, *16*(7), 981–988.

Adem, T. A. (2012). "The Local Politics of Ethiopia's Green Revolution in South Wollo." In *African Studies Review*, Volume 55, Number 3 (December), pp. 81–102.

Agricultural Research Task Force (1996), Ethiopia Agricultural Research and Training Project, Part I: Review of the Agricultural Research System and Recommended Future Directions, Addis Ababa. *Agriculture: Extension service from input-supplier to knowledge broker and facilitator*. Addis Ababa: International Livestock Research Institute.

Akkerman, S. F., & Bakker, A. (2011). Boundary Crossing and Boundary Objects. *Review of Educational Research*, *81*(2), 132–169. https://doi.org/10.3102/0034654311404435

Alemayehu, S. (1968). Iddir in Addis Ababa: A Sociological Study. Ethiopia Observer. Vol. 12, no. 1.

Alemu, D. (2010). *The Political Economy of Ethiopian Cereal Seed Systems: State control, market liberalization and decentralization*. Working Paper 017. Brighton: Future Agricultures Consortium.

Allen, W., Ogilvie, S., Blackie, H., Smith, D., Sam, S., Doherty, J., … Eason, C. (2014). Bridging Disciplines, Knowledge Systems and Cultures in Pest Management. *Environmental Management*, *53*(2), 429–440. http://doi.org/10.1007/s00267-013-0180-z.

Altieri, M. A. (1993). Ethnoscience and biodiversity: key elements in the design of sustainable pest management systems for small farmers in developing countries. *Agriculture, Ecosystems & Environment*, *46*(1–4), 257–272.

Amankwah, K., Shtaltovna, A., Kelboro, G., & Hornidge, A.-K. (2015). ZEF. Retrieved from http://www.zef.de/uploads/tx_zefnews/zef_wp_138.pdf

Amudavi, D. M., Khan, Z. R., Wanyama, J. M., Midega, C. A. O., Pittchar, J., Hassanali, A., & Pickett, J. A. (2009a). Evaluation of farmers' field days as a dissemination tool for push-pull technology in Western Kenya. *Crop Protection*, *28*(3), 225–235. https://doi.org/10.1016/j.cropro.2008.10.008

Amudavi, D. M., Khan, Z. R., Wanyama, J. M., Midega, C. A. O., Pittchar, J., Nyangau, I. M., … Pickett, J. A. (2009b). Assessment of technical efficiency of farmer teachers in the uptake and dissemination of push–

pull technology in Western Kenya. *Crop Protection*, *28*(11), 987–996. https://doi.org/10.1016/j.cropro.2009.04.010

Anderson, C. R., & McLachlan, S. M. (2016). Transformative research as knowledge mobilization: Transmedia, bridges, and layers. *Action Research*, *14*(3), 295–317. https://doi.org/10.1177/1476750315616684

Angrosino, M. V. and Mays de Perez, A. K. (2000). Rethinking Observation: From method to Context. In Denzin, N.K. and Lincoln, S.Y. (eds), *Handbook of Qualitative Research*. California: Sage publications.

Anseeuw, W., Boche, M., Breu, T., Giger, M., Lay, J., Messerli, P., e t al. (2012). Transnational land deals for agriculture in the global south: Analytical report based on the Land Matrix database Geographica Bernensia. CDE/CIRAD/GIG A, Bern/Montpellier/Hamburg.

Archer, D., & Cameron, A. (2009). *Collaborative leadership: how to succeed in an interconnected world*. Amsterdam: Elsevier/Butterworth-Heinemann.

Aredo D., (1990), "The Evolution of Rural development Policies", in Pausewang, S., Fantu Cheru, Stefan Brune and Eshetu Chole (eds.), Ethiopia: Rural Development Options, London: Zed Books.

ASA (American Statistical Association) (1997). Section of Survey methods. American Statistical Association, USA.

Ashworth, V. (2005), *The Challenges of Change for Agricultural Extension in Ethiopia: A Discussion Paper*, Federal Democratic Republic of Ethiopia, Addis Ababa.

Assefa, G.A. (1985). Survey of Lepidopterous stemborers attacking maize and sorghum in Ethiopia. Eth. J. of Agr. Sci. 7:55-59.

Assefa, G.A. (1998). Development of maize stalk borer, Busseola fusca (Fuller), in wild host plants in Ethiopia. J. Appl. Entomol. 106, 390–395.

Atkinson, M., Jones, M., & Lamont, E. (2007). Multi-agency working and its implications for practice. *Reading: CfBT Education Trust*.

Bacon, C. M., C. Getz, S. Kraus, M. Montenegro, and K. Holland (2012). The social dimensions of sustainability and change in diversified farming systems. *Ecology and Society* **17**(4): 41. http://dx.doi.org/10.5751/ES-05226-170441.

Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice Hall.

Barker, K., Bosco, C., & Oandasan, I. (2005). Factors in implementing interprofessional education and collaborative practice initiatives: Findings from key informant interviews. Journal of Interprofessional Care, 19 (Suppl 1), 166-176.

Bass, B. (1985). *Leadership and performance beyond expectations*. Free Press; New York.

Baye, T. G. (2013). Peasants, land reform and property right in Ethiopia: The experience of Gojjam Province, 1974 to 1997. *Journal of African Studies and Development*, *5*(6), 145.

Baye, T. G. (2017). Poverty, peasantry and agriculture in Ethiopia. *Annals of Agrarian Science*, *15*(3), 420–430. https://doi.org/10.1016/j.aasci.2017.04.002

Bayite-Kasule, S., Korugyendo, P. L., Benson, T., Productivity, I. A., Challenges, N., Hall, A., & Ababa, A. (2011). 'Fertilizer use among smallholder farmers in Uganda.'. In *conference: Increasing Agricultural Productivity and Enhancing Food Security in Africa: New Challenges and Opportunities* (Vol. 13).

Becker, E. and Jahn, T. (eds) (1999). *Sustainability and the Social sciences. A cross disciplinary approach to integrating environmental consideration into theoretical Reorientation*. London: Zed Book; pp 284-289.

Beddington J., Asaduzzaman M., Clark M., Fernández A., Guillou M., Jahn M., Erda L., Mamo T., Van Bo N., Nobre C.A., Scholes R., Sharma R., Wakhungu J. (2012). Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org/commission.

Belay, D. and Foster, J.E. (2010). Efficacies of habitat management techniques in managing maize stemborers in Ethiopia. Crop Prot. 29: 422-428.

Belay, K. (2003). Agricultural extension in Ethiopia: the case of participatory demonstration and training extension system. *Journal of Social Development in Africa*, *18*(1), 49–84.

Belay, K., & Abebaw, D. (2004). Challenges Facing Agricultural Extension Agents: A Case Study from South-western Ethiopia. *African Development Review*, *16*(1), 139–168.

Bergman, M., Brohmann, B. Hoffman, E., Loibl, M.C., Rehaag, R., Schramm, E. and Voß J.-P. (2005). Quality Criteria of Transdisciplinary Research: A Guide for the Formative Evaluation of Research Projects. ISOE-Studientexte, No 13, Frankfurt am Main.

Berhanu, K., & Poulton, C. (2014). The political economy of agricultural extension policy in Ethiopia: economic growth and political control. *Development Policy Review*, *32*(s2), s197–s213.

Bhardwaj, T., & Sharma, J. P. (2013). Impact of Pesticides Application in Agricultural Industry: An Indian Scenario. *International Journal of Agriculture and Food Science Technology*, *4*(8), 817–822.

Bijker, W. E., & Law, J. (Eds.). (1992). *Shaping technology/building society: studies in sociotechnical change*. Cambridge, Mass: MIT Press.

Bililign, S. (2013). The Need for Interdisciplinary Research and Education for Sustainable Human Development to Deal with Global Challenges. *International Journal of African Development*, *1*(1), 8.

Bortz, J. & Döring, N. (2003). Forschungsmethoden und Evaluation für Human- und Sozialwis-senschaftler. Heidelberg Berlin, Springer-Verlag.

Botha, N., Klerkx, L., Small, B. and Turner, A.J. (2014). Lessons on Trandisciplinary research on a co-innovation programme in the New Zealand Agricultural sector. Outlook on **AGRICULTTRE** Vol 43, No.3. pp 219-223.

Bracken, L. J., Bulkeley, H. A., & Whitman, G. (2015). *Transdisciplinary research: understanding the stakeholder perspective* (Vol. 58). https://doi.org/10.1080/09640568.2014.921596

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D.J., Newig, J., Reinert, F., Abson, D.J., Von Wehrden, H. (2013) A review of transdisciplinary research in sustainability science. Ecological Economics 92, 1-15.

Bray, Z. (2008). Ethnographic Approaches. In: *Approaches and Methods in the Social Sciences: A Pluralist Perspective* [Porta, D.D. & Keating, M. (Eds.)]. Cambridge University Press: Cambridge, 296-315.

Bunders-Aelen, J. G. F., Broerse, J. E. W., Keil, F., Pohl, C., Scholz, R. W., & Zweekhorst, M. B. M. (2010). How can transdisciplinary research contribute to knowledge democracy? In R. In't Veld (Ed.), *Knowledge Democracy – Consequences for Science*, *Politics and Media* (pp. 125-152). Heidelberg: Springer. DOI: 10.1007/978-3-642-11381-9_11

Bushe, G. R. (2009). *Clear leadership: sustaining real collaboration and partnership at work* (Rev. ed). Mountain View, Calif: Davies-Black Pub.

Caraça, J., Lundvall, B-Å., & Mendonça, S. (2009). The changing role of science in the innovation process: From Queen to Cinderella? *Technological Forecasting and Social Change*, *76*(6), 861-867.10.1016/j.techfore.2008.08.003.

Carlile, P. R. (2002). A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science*, *13*(4), 442–455.

Central Statistical Agency (Ethiopia) & ICF International (2012). Ethiopia Demographic and Health Survey 2011. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International.

Chakravarthy, A. K. (Ed.). (2015). *New Horizons in Insect Science: Towards Sustainable Pest Management*. New Delhi: Springer India. Retrieved from http://link.springer.com/10.1007/978-81-322-2089-3.

Chamberlain, K., Khan, Z. R., Pickett, J. A., Toshova, T., Wadhams, L. J. (2006). Diel periodicity in the production of green leaf volatiles by wild and cultivated host plants of stemborer moths, Chilo partellus and Busseola fusca. *Journal of Chemical Ecology*, 32: 565-577.

Chanyalew, D., Adenew, B. & Mellor, J. (2010): "Ethiopia's Agricultural Sector Policy and Investment Framework: Ten-Year Roadmap (2010-2020)" Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development.

Choi B.C. & Pak A.W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. definitions, objectives, and evidence of effectiveness. Clin Invest Med Dec;2006 29(6):351–64. [PubMed: 17330451]

Choi, B. C., & Anita, W. P. (2008). Multidisciplinarity, interdisciplinarity, and transdisciplinarity in health research, services, education and policy: 3. Discipline, inter-discipline distance, and selection of discipline. *Clinical & Investigative Medicine*, *31*(1), 41–48.

Chrislip, D. D. (2002). *The collaborative leadership fieldbook: a guide for citizens and civic leaders*. San Francisco: Jossey-Bass.

CIMMYT (2001). CIMMYT-Kenya Annual Report. Nairobi, Kenya: CIMMYT.

Clark, W & Holliday, L (2006) Linking Knowledge with Action for Sustainable Development: The Role of Program Management - Summary of a Workshop National Academies Press

Clark, W. C., Tomich, T. P., van Noordwijk, M., Guston, D., Catacutan, D., Dickson, N. M., & McNie, E. (2011). Boundary work for sustainable development: Natural resource management at the Consultative Group on International Agricultural Research (CGIAR). *Proceedings of the National Academy of Sciences*, 200900231.

Connor, D. J., Loomis, R. S., Cassman, K. G., & Loomis, R. S. (2011). *Crop ecology: productivity and management in agricultural systems* (2nd ed). Cambridge ; New York: Cambridge University Press.

Cook, S.M, Khan Z.R. & Pickett J.A. (2007). The use of "push-pull" strategies in integrated pest management. Annual Review of Entomology 52, 375-400.

Cotula , L., Vermeulen, S., Leonard, R., & K eeley , J . (2009). Land grab or development opportunity? Agricultural investment and international land deals in Africa. London: IIED.

Crosby, B. C., & Bryson, J. M. (2005). *Leadership for the common good: tackling public problems in a shared-power world* (2. ed). San Francisco: Jossey-Bass.

Cross, R. L., Parker, A., & Sasson, L. (Eds.). (2003). *Networks in the knowledge economy*. New York: Oxford University Press.

Cundill, G., Roux, D. J., & Parker, J. N. (2015). Nurturing communities of practice for transdisciplinary research. *Ecology and Society*, *20*(2). http://doi.org/10.5751/ES-07580-200222

Davis, K., Swanson, B., & Amudavi, D. (2009). Review and recommendations for strengthening the agricultural extension system in Ethiopia. *IFPRI, Washington, DC*.

Davis, K., Swanson, B., Amudavi, D., Mekonnen, D., Flohrs, A., Riese, J., Lamb, C. and Zerfu, E. (2010) *In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendations for Improvement*. IFPRI Discussion Paper 01041.Washington, DC: International Food Policy Research Institute (IFPRI).

Davis, K., Swanson, B., Amudavi, D., Mekonnen, D., Flohrs, A.,Riese, J., Lamb, C. and EEA/EEPRI (Ethiopian Economic Association/Ethiopian Economic Policy Research Institute) (2006). Evaluation of the Ethiopian Agricultural Extension with particular Emphasis on Participatory Demonstration and Extension Training System (PADETES). Addis Ababa.

Davis, K.D., J. Ekboir, W. Mekasha, C.M.O. Ochieng, D.J. Spielman, and E. Zerfu (2007). Strengthening agricultural education and training in Sub-Saharan Africa from an innovation systems perspective: Case studies of Ethiopia and Mozambique. Washington, D.C.: World Bank.

De Groote, H., Rutto, E., Odhiambo, G., Kanampiu, F., Khan, Z.R., Coe, R. and Vanlauwe, B. (2010b). Participatory evaluation of integrated pest and soil fertility management options using ordered categorical data analysis. Agricultural Systems 103: 233–244.

De Groote, H., Vanlauwe, B., Rutto, E., Odhiambo, G., Kanampiu, F., Khan, Z.R. (2010a). Economic analysis of different options in integrated pest and soil fertility management in maize systems of Western Kenya. Agricultural Economics 41: 471 - 482.

Decron S., Bold T., De Weerdt J. & Pankhurst, A. (2004). Extending Insurance? Funeral Associations in Ethiopia and Tanzania. OECD Development Centre, Working Paper no. 240

Decron, S. (2003). Insurance against poverty. World Institute for Development Economics Research, United Nations University.

Degaga, E.G., Overholt, W.A. and Kairu, E. (2001). Ecological management of cereal stemborers in Ethiopia. Paper presented during the 17th Eastern and Southern Africa Regional Maize conference on 11-15th February (pp. 55-59).

Dejene A. (2003). Iddir: A Look as a form of Social Capital in A. Pankhurst (ed.) Iddirs: Participation and Development. Proceedings of the Ethiopian National Conference ACORD. Addis Ababa.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Courbois, C. (1999). International Food Policy Research Institute, International Livestock Research Institute (Eds.). *Livestock to 2020: the next food revolution*. Washington, DC.

Deneke, T. T., & Gulti, D. (2016). Agricultural Research and Extension Linkages in the Amhara Region, Ethiopia. In F. W. Gatzweiler & J. von Braun (Eds.), *Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development* (pp. 113–124). Cham: Springer International Publishing.

Dessalegn, Y. (2013). Inter and Transdisciplinary Research Methods: Relevance to rural transformation in Ethiopia. *Inter-and Transdisciplinary Research Methods in Rural Transformation*, 5.

Diebolt, C., Mishra, T., & Parhi, M. (2016). *Dynamics of Distribution and Diffusion of New Technology*. Cham: Springer International Publishing. Retrieved from http://link.springer.com/10.1007/978-3-319-32744-0

Djanibekov, N., Hornidge, A-K and Ul-Hassan, M. (2012). "From Joint Experimentation to Laissez-Faire: Transdisciplinary Innovation Research for the Institutional Strengthening of a Water Users Association in Khorezm, Uzbekistan." *The Journal of Agricultural Education and Extension* 18 (4): 409–23. https://doi.org/10.1080/1389224X.2012.691785.

Dörendahl, E. I. (2015). Boundary Work for Collaborative Water Resources Management - Conceptual and Empirical Insights from a South African Case Study. Wissenschaftliche Schriften der WWU Münster, Reihe XVII - Band 2.

Doss, C.R. (2006). Analyzing Technology Adoption using Micro-Studies: Limitations, Challenges, and Opportunities for Improvement. In: Agricultural Economics 34 (3):207-219.

Durosomo B. (1993). Technology adoption and Sub-Sahara african agriculture: The sustainable development option. Agriculture and Human Values.Volume 10, Issue 4, pp 58-70.

Edelenbos, J., van Buuren, A., & van Schie, N. (2011). Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environmental Science & Policy*, *14*(6), 675–684. https://doi.org/10.1016/j.envsci.2011.04.004

Edquist, C. (1997), Systems of Innovation: Technologies, Institutions and Organizations, Pinter Publishers/Cassell Academic, London.

Edwards-Jones, G. (2006). Modelling farmer decision-making: concepts, progress and challenges. *Animal science*, 82 (06), 783–790.

EEA/EEPRI (Ethiopian Economic Association/Ethiopian Economic Policy Research Institute) (2006) Evaluation of the Ethiopian Agricultural Extension with particular Emphasis on Participatory Demonstration and Extension Training System (PADETES). March 2006. Addis Ababa.

Efa, N., Gorman, M. and Phelan, J. (2005), Implications of an Extension package approach for farmers' indigenous knowledge: The maize Extension package in south-western Ethiopia. Journal of International Agricultural Extension and Education 12 (3): 67–78.

Egziabher, K. G., Mathijs, E., Deckers, J. A., Gebrehiwot, K., Bauer, H., & Maertens, M. (2013). *The Economic Impact of a New Rural Extension Approach in Northern Ethiopia*.

Elias, A., Nohmi, M., Yasunobu, K., & Ishida, A. (2013). Effect of Agricultural Extension Program on Smallholders' Farm Productivity: Evidence from Three Peasant Associations in the Highlands of Ethiopia. *Journal of Agricultural Science*, *5*(8). doi:10.5539/jas.v5n8p163

EU SCAR (2012), *Agricultural knowledge and innovation systems in transition – a reflection paper*. Standing Committee on Agricultural Research (SCAR), Collaborative Working Group on Agricultural Knowledge and Innovation Systems (AKIS), European Commission, & Directorate-General for Research and Innovation. Brussels.

Evans, R. (2005). Introduction: Demarcation socialized: Constructing boundaries and recognizing difference. *Science, Technology and Human Values* 30 (1): 3-16

FAO (2000).The elimination of food insecurity in the Horn of Africa. A strategy for concerted government and UN agency action final report. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2001). FAO Statistical Databases. Food and Agriculture Organization of the United Nations (http://apps.fao.org/).

FAO (2008). Climate Change and Food Security: A Framework Document, Food and Agriculture Organization of the United Nations Rome.

Feder, G., R.E. Just & D. Zilberman (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change 33, 255-298.

Fischer, G., Shah, M., Tubiello, F., van Velthuizen, H. (2005). Socioeconomic and climate change impacts on agriculture: an integrated assessment, 1990–2080. *Phil. Trans. R. Soc. B* 360, 2067–2083. *(*doi:10.1098/rstb.2005.1744*)*

Forget, G. (1993). Balancing the need for pesticides with the risk to human health. In: Forget, G., Goodman, T., De Villiers, A. J., & International Development Research Centre (Canada) (Eds.). *Impact of pesticide use on health in developing countries: proceedings of a symposium held in Ottawa, Canada, 17-20 September 1990*. Ottawa, Ont.: International Development Research Centre.

Freeman, R. E. (1984). *Strategic management: a stakeholder approach*. Boston: Pitman.

Frydman, B., Wilson, I., & Wyer, J. (2000). *The power of collaborative leadership: lessons for the learning organization*. Boston: Butterworth-Heinemann.

Funtowicz, S.O. & Ravetz, J.R. (1993). Science for the post-normal age. Futures 25, 739-755.

Fuqua, J., Stokols, D., Gress, J., Phillips, K., & Harvey, R. (2004). Transdisciplinary Collaboration as a Basis for Enhancing the Science and Prevention of Substance Use and ?Abuse? *Substance Use & Misuse*, *39*(10–12), 1457–1514. https://doi.org/10.1081/LSUM-200033200

Gebremedhin, B., Hoekstra, D. and Tegegne, A. (2006). Commercialization of Ethiopian agriculture: Extension service from input supplier to knowledge broker and facilitator. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 1. ILRI (International Livestock Research Institute), Nairobi, Kenya. 36 pp.

GebreMichael (2006). For FAIR (Farmer Access to Innovation Resources): a project of Prolinnova. Addis Ababa.

Getu, E., Overholt, W.A., Kairu, E. & Omwega, C.O. (2002). Status of stemborers and their management in Ethiopia. Integrated Pest Management Conference Proceedings. 8-12 September, Kampala, Uganda.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. Sage.

Gibson, E., & Gebken, R. (2003). Design quality in pre-project planning: applications of the Project Definition Rating Index. *Building Research & Information*, *31*(5), 346–356.

Gieryn, T. 1999. *Cultural boundaries of science: Credibility on the line*. Chicago, IL: University of Chicago Press.

Gilbert, L. E. (1998). Disciplinary breadth and interdisciplinary knowledge production. *Knowledge, Technology & Policy*, *11*(1–2), 4–15.

Giller, K. E., Tittonell, P., Rufino, M. C., van Wijk, M. T., Zingore, S., Mapfumo, P., … Vanlauwe, B. (2011). Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. *Agricultural Systems*, *104*(2), 191–203. http://doi.org/10.1016/j.agsy.2010.07.002.

Giovannucci, D., Scherr, S. J., Nierenberg, D., Hebebrand, C., Shapiro, J., Milder, J., & Wheeler, K. (2012). Food and agriculture: The future of sustainability. *The Sustainable Development in the 21st Century (SD21) Report for Rio, 20*.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S. , Thomas, S. M. and Toulmin, C. (2010). Food Security: The Challenge of Feeding 9 Billion People. *Science* Vol. 327, Issue 5967, pp. 812-818.

Gray, B. (2008). Enhancing Transdisciplinary Research Through Collaborative Leadership. American Journal of Preventive Medicine, 35(2), S124–S132.

Habtemariam, A. (1997), *Targeting Extension Service and the Extension Package Approach in Ethiopia,* Addis Ababa, Ethiopia.

Hall, A. and Nahdy, S. (1999). New Methods and Old Institutions: the 'systems Context' of Farmer Participatory Research in National Agricultural Research Systems. The Case of Uganda. Overseas Development Institute, Agricultural Research & Extension Network (AgREN), London, United Kingdom.

Harris, F., & Lyon, F. (2014). Transdisciplinary environmental research: a review of approaches to knowledge co-production. *Nexus Network Think Piece Series, Paper, 2*.

Henriksen, D. (2011). *We teach who we are: Creativity and trans-disciplinary thinking in the practices of accomplished teachers*. Michigan State University.

Heong K.L., Escalada, M.M & Vo Mai. (1994). An analysis of insecticide use in rice: case studies in the Philippines and Vietnam. International Journal of Pest Management, 1994, 40(2) 173-178

Hirsch Hadorn, G. (Ed.). (2008). *Handbook of transdisciplinary research*. Dordrecht ; London: Springer.

Hirsch Hadorn, G., Bradley, D., Pohl, C., Rist, S., & Wiesmann, U. (2006). Implications of transdisciplinarity for sustainability research. *Ecological Economics*, *60*(1), 119–128. https://doi.org/10.1016/j.ecolecon.2005.12.002

Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., Zemp, E., (2008) Handbook of Transdisciplinary Research. Springer.

Hoppe, R. (2005). Rethinking the Science-Policy Nexus: from Knowledge Utilization and Science Technology Studies to Types of Boundary Arrangements. Poiesis Prax 3, 199-215.

Horlick-Jones, T., & Sime, J. (2004). Living on the border: knowledge, risk and transdisciplinarity. *Futures*, *36*(4), 441–456. https://doi.org/10.1016/j.futures.2003.10.006

Hornidge, A.-K, Ul-Hassan, M. & Mollinga, P.P. (2011).Transdisciplinary innovation research in Uzbekistan – one year of 'Follow-the-Innovation', Development in Practice, 21(6), 834-847.

Hornidge, A.-K, Ul-Hassan, M. & Mollinga, P.P. (2009). 'Follow the Innovation'-A joint experimentation and learning approach to transdisciplinary innovation research. ZEF working paper series, No. 39.

Hornidge, A.-K. (2007). *Knowledge society: vision and social construction of reality in Germany and Singapore*. Münster: Lit.

Hornidge, A.-K., & Ul-Hassan, M. (2010). From "plausible promises" to transdisciplinary innovation research in Uzbekistan–process outline and lessons learnt. Rural Development News, 2(1), 53–63.

Hurni, H. (1998). Agroecological Belts of Ethiopia. Explanatory Notes on Three Maps at a Scale of 1, 1. Soil Conservation Research Programme, Research Report.*Journal of Technology and Globalisation, 2*(3/4), 279-287.

Ingold T. (2002). The Perception of the Environment, Essays in livelihood, dwelling and skill. Published by Routledge Taylor & Francis Group, London and New York. p. 294-322.

InterAcademy Council (2004). Realizing the Promise and Potential of African Agriculture. InterAcademy Council, Amsterdam, The Netherlands.

International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD Project), & McIntyre, B. D. (Eds.). (2009). *Global report*. Washington, DC: Island Press.

Ison, R.L.; Steyaert, P.; Roggero, P.P.; Hubert, B. and Jiggins, J. (2004). The SLIM (Social learning for the integrated management and sustainable use of water at catchment scale) Final Report. The SLIM Project supported by the European Commission.

Jabbar, M.A., Pender, J., Ehui, S.K. (Eds.). (2000). Policies for Sustainable Land Management in the Highlands of Ethiopia: Summary of Papers and Proceedings of a Seminar Held at ILRI, 22–23 May 2000, Addis Ababa, Ethiopia. Socio-economics and Policy Research Working Paper No. 30. ILRI (International Livestock Research Institute), Nairobi.

Kalule, T., Khan, Z.R., Bigirwa, G., Alupo, J., Okanya, S., Pickett, J.A. & Wadhams, L.J. (2006). Farmers' Perceptions of Importance, Control Practices and Alternative Hosts of Maize Stemborers in Uganda. International Journal of Tropical Insect Science, 26(2), 71-77.

Kassa B., (2003), "Agricultural Extension in Ethiopia: The Case of Participatory Demonstration and Training Extension System" Journal of Social Development in Africa, V0l 18 (1): 49-83.

Kassa, B., & Alemu, D. (2016). Agricultural research and extension linkages: Challenges and intervention options. *Ethiopian Journal of Agricultural Sciences*, *27*(1), 55–76.

Kassa, H. (2005). *Historical development and current challenges of agricultural extension with particular emphasis on Ethiopia.* Ethiopian Econpmic Association (EEA)/Ethiopian Economic Policy Research Institute (EEPRI) Working paper No. 2/05. Addis Ababa:EEA/EEPRI.

Kassa, H. (2008). Agricultural extension in Ethiopia: Historical evolution, relevant policies, and challenges. In: Assefa, T. (ed.) *Digest of Ethiopia's national policies, strategies and programs*. Forum for Social Studies. Addis Ababa, Ethiopia. pp. 153-175.

Kates, R.W., Clark, W.C. ,Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I…… Dickson, N.M. (2001). Sustainability Science. Science 292: 641-2.

Kawulich, Barbara B. (2005). Participant Observation as a Data Collection Method [81 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *6*(2), Art. 43, http://nbn-resolving.de/urn:nbn:de:0114-fqs0502430.

Kebede, B. (2008). Land reform, distribution of land and institutions in rural Ethiopia: analysis of inequality with dirty data. *Journal of African Economies*, *17*(4), 550–577.

Keeley, J. and Scoones, I. (2000) 'Knowledge, Power and Politics: The environmental policy-making process in Ethiopia', *Journal of Modern African Studies* 38(1): 89–120.

Keen, M., Brown, V., and Dyball, R., eds. (2005) Social Learning in Environmental Management: Towards a Sustainable Future, London: Earthscan.

Kemmis, S., & McTaggart, R. (2005). Communicative action and the public sphere. Denzin, NK & Lincoln, YS (red.), The Sage Handbook of Qualitative Research, 3, 559–603.

Ketsela, Y. (2006a) 'Attendant Issues in the Current Agricultural Extension Programme', in K. Berhanu and D. Fantaye (eds), Ethiopia: Development policies, trends, changes and continuities. Addis Ababa: Addis Ababa University Press.

Ketsela, Y. (2006b) ‘Post-1991 Agricultural Policies: The role of the national extension programme in addressing the problem of food security’, in A. Attilio, K. Berhanu and Y. Ketsela (eds), Ethiopia: Politics, policy making and rural development. Addis Ababa: Addis Ababa University Press.

Kfir, R., Overholt, W.A., Khan, Z.R., Polaszek, A. (2002). Biology and management of economically important lepidopteran cereal stemborers in Africa. Ann. Rev. Entomol. 47, 701–731.

Khan Z. R, Hassanali A, Overholt W, Khamis TM, Hooper AM, Pickett AJ, Wadhams LJ, Woodcock CM. (2002). Control of witchweed Striga hermonthica by intercropping with Desmodium spp., and the mechanism defined as allelopathic. Journal of Chemical Ecology 28, 1871–1885

Khan, Z. R., Chiliswa, P., Ampong Nyarko, K., Smart, L. E., Polaszek, A., Wandera, J., Mulaa, M. A. (1997). Utilisation of wild gramineous plants for management of cereal stemborers in Africa. Insect science and its application, 17 (1): 143-150**.**

Khan, Z. R., Midega, C. A. O., Amudavi, D. M., Njuguna, E. M, Wanyama, J. W., Pickett, J. A. (2008b). Economic performance of the ‘‘Push-pull'' technology for stemborer and Striga control in smallholder farming systems in western Kenya. Crop Protection, 27: 1084-1097.

Khan, Z. R., Midega, C. A. O., Pittchar, J. O., Murage, A. W., Birkett, M. A., Bruce, T. J. A., & Pickett, J. A. (2014a). Achieving food security for one million sub-Saharan African poor through push-pull innovation by 2020. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639), 20120284–20120284. https://doi.org/10.1098/rstb.2012.0284

Khan, Z. R., Midega, C. A. O., Wadhams, L. J., Pickett, J. A., & Mumuni, A. (2007). Evaluation of Napier grass (Pennisetum purpureum) varieties for use as trap plants for the management of African stemborer (Busseola fusca) in a push?pull strategy. *Entomologia Experimentalis et Applicata*, *124*(2), 201–211. https://doi.org/10.1111/j.1570-7458.2007.00569.x

Khan, Z. R., Midega, C. A. O., Wanyama, J. M., Amudavi, D. M., Hassanali, A., Pittchar, J., and Pickett, J.A.(2009). Integration of edible beans (*Phaseolus vulgaris* L.) into the push–pull technology developed for stemborer and striga control in maize-based cropping systems. Crop Protection 28: 997-1006.

Khan, Z. R., Midega, C. A., Pittchar, J. O., Murage, A. W., Birkett, M. A., Bruce, T. J., & Pickett, J. A. (2014). Achieving food security for one million sub-Saharan African poor through push–pull innovation by 2020. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639), 20120284.

Khan, Z. R., Pickett, J. A., Van den Berg, J., Wadhams, L. J. & Woodcock, C. M., (2000). Exploiting chemical ecology and species diversity: stem borer and Striga control in maize in Kenya. *Pest Management. Sci*ence, 56: 957-962.

Khan, Z. R., Pickett, J. A., Wadhams, L.J., Hassanali, A., Midega, C. A. O. (2006).Combined control of *Striga hermonthica* and stem borers by maize-Desmodium spp. intercrops. *Crop Protection*, 25:989-995.

Khan, Z.R., Amudavi, D.M. Midega, C.A.O., Wanyama J.M. and J.A. Pickett (2008a): Farmers’ Perceptions of a ‘Push–Pull’ Technology for Control of Cereal Stem Borers and *Striga* Weed in Western Kenya. In: Crop protection 27 (6): 976-987.

Khan, Z.R., Amudavi, D.M., Midega, C., Pittchar, J., Nyagol, D., Genga, G., Ndiege, A., Akelo, P., Pickett, J.A., Wadhams, L.J., Muyekho, F. and Nyateng, B. (2007). Push-Pull Curriculum for Farmer Field Schools. International Centre of Insect Physiology and Ecology, Nairobi, Kenya (ISNB 92-9064-1886)

Khan, Z.R., Midega, C.A.O., Nyang’au, I.M., Murage, A.W., Pittchar, J., Agutu, L., Amudavi, D.M., Pickett, J. A., (2014b). Farmers’ knowledge and perceptions of the stunting disease of Napier grass in western Kenya. Plant Pathology 63, 1426–1435)**.**

Khan, Z.R., Ampong-Nyarko, K., Chilishwa, P., Hassanali, A., Kimani, S., Lwande, W. *et al*.(1997) Intercropping increases parasitism of pests. *Nature*, **388**, 631–632.

Kirkpatrick, S.A., & Locke, E.A. (1996). Direct and indirect effects of three core charismatic leadership components on performance and attitudes. Journal of Applied Psychology, 81, 36-51.

Klein, J. T., Häberli, R., Scholz, R. W., Grossenbacher-Mansuy, W., Bill, A., & Welti, M. (Eds.). (2001). *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society*—an effective way for managing complexity. Birkhauser Verlag; Basel.

Klerkx, L., Hall, A. & Leeuwis, C. (2009) 'Strengthening agricultural innovation capacity: are innovation brokers the answer?', Int. J. Agricultural Resources, Governance and Ecology, Vol. 8, Nos. 5/6, pp.409–438.

Klerkx, L., Seuneke, P., de Wolf, P., & Rossing, W. A. H. (2017). Replication and translation of co-innovation: The influence of institutional context in large international participatory research projects. *Land Use Policy*, *61*, 276–292. https://doi.org/10.1016/j.landusepol.2016.11.027

Klerkx, L., van Mierlo, B., & Leeuwis, C. (2012). Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In I. Darnhofer, D. Gibbon, & B. Dedieu (Eds.), *Farming Systems Research into the 21st Century: The New Dynamic* (pp. 457–483). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-4503-2_20

Knickel, K., G. Brunori, S. Rand, & J. Proost. (2009). "Towards a Better Conceptual Framework for Innovation Processes in Agriculture and Rural Development: From Linear Models to Systemic Approaches." Journal of Agricultural Education and Extension 15 (2): 131–146. doi:10.1080/13892240902909064.

Knorr-Cetina, K. (1999): *Epistemic Cultures: How the Sciences Make Knowledge*; 1999, Cambridge, MA, Harvard.

Knorr-Cetina, K. (2007). Culture in global knowledge societies: knowledge cultures and epistemic cultures. *Interdisciplinary Science Reviews*, *32*(4), 361–375.

Kohler, T., Fueller, J., Matzler, K., & Stieger, D. (2011). Co-creation in virtual worlds: the design of the user experience. *MIS Quarterly*, *35*(3), 773–788.

Koppel B. (1978). Agricultural Change and Social Structure: A Longitudinal Analysis. Philippine sociological review 26 (1978) 57-73.

Lamers, John P. A., ed. (2014). *Restructuring Land Allocation, Water Use and Agricultural Value Chains: Technologies, Policies and Practices for the Lower Amudarya Region*. Goettingen, Germany : V & R unipress.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., … Thomas, C. J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, *7*(S1), 25–43. https://doi.org/10.1007/s11625-011-0149-x

Larebo, H. (1987). The Ethiopian Orthodox Church and Politics in the Twentieth Century: Part I. *Northeast African Studies*, *9*(3), 1-17. Retrieved from http://www.jstor.org/stable/43660244 on 6th September 2018.

Latour, B. (1987). Science in Action. How to follow scientists and engineers through society. Milton Keynes: Open University Press; and Cambridge, MA: Harvard University Press.

Lauth, H. J. (2000). Informal institutions and democracy. *Democratization*, *7*(4), 21–50.

Lawrence, R. J. (2010). Deciphering interdisciplinary and transdisciplinary contributions. *Transdisciplinary Journal of Engineering & Science*, *1*(1), 125–130.

Lazaro A.A., Rubia, E.G., Almazan, L.P. & Heong, K.L. (1993). Farmers' estimates of percent whiteheads (WH). International Rice Research Notes, 18,31. Mitcham C. 1978. Types of Technology. Research in Philosophy and technology 1: 229-294.

Leavy, P. (2011). *Essentials of transdisciplinary research: Using problem-centered methodologies*. Walnut Creek, CA: Left Coast Press.

Leeuwis, C. (2010). Changing views of agricultural innovation: Implications for communicative intervention and science. *Research to Impact: Case Studies for Natural Resource Management for Irrigated Rice in Asia*, 15.

Leeuwis, C. and van den Ban, A. (2004). Communication for Rural Innovation: Rethinking Agricultural Extension (Third Edition) London: Blackwell.

Leta, Gerba, Girma Kelboro, Till Stellmacher, Kristof Van Assche, and Anna-Katharina Hornidge. (2018). “Nikinake: The Mobilization of Labour and Skill Development in Rural Ethiopia: *Gerba Leta* et Al. */ Natural Resources Forum*.” *Natural Resources Forum* 42 (2): 93–107. https://doi.org/10.1111/1477-8947.12145.

Linden, R. M. (2002). *Working across boundaries: making collaboration work in government and nonprofit organizations* (1st ed). San Francisco, Calif: Jossey-Bass.

Loubser, J. A. (2002). “Two revolutions behind: is the Ethiopian Orthodox Church an obstacle or catalyst for social development?” *Scriptura: Journal for Contextual Hermeneutics in Southern Africa*, *81*(1), 378–390.

Lundvall, B.-Å., ed. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*.London: Frances Pinter.

Marra, M., Pannell, D.J., & Abadi Ghadim, A. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?*Agricultural systems*, 75 (2–3), 215–234. doi: 10.1016/S0308-521X(02)00066-5.

Massawe, C. R., Kaswende, J. S., Mbwaga, A. M. & Hella J. P. (2001). On farm verification of Maize/cowpea intercropping on the control of Striga under subsistence farming. The 17th East and Southern African regional Maize conference, held between 11th and 15th Feb 2001, pp 165-167.

Matondi, P. B., Ha vnevik, K., & Beyene, A. (2011). Biofuels, land grabbing and food security in Africa. Zed Books.

Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., & Moore, H. (2013). Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability*, *5*(3-4), 420–431. http://doi.org/10.1016/j.cosust.2013.07.001

McLean, L. D. (2004). A review and critique of Nonaka and Takeuchi’s theory of organizational knowledge creation. In *Proceedings of the Fifth UFHED/AHRD Ireland Conference. Available: http://www. mcleanglobal. com/public/MGC/publications/Nonaka% 20and% 20Takeuchi. pdf [accessed May 2014]*.

Medlin, B. D. (2001). *The factors that may influence a faculty member’s decision to adopt electronic technologies in instruction*. Virginia Polytechnic Institute and State University.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *13*(1), 40–54.

Melaku W., Fritz S., Kairu E., Charles O. (2006). Cereal yield losses caused by Lepidopterous stemborers at different nitrogen fertilizers rates in Ethiopia. J. App. Entom. 130:220-229.

Mercer, D. (2004). Adoption of agroforestry innovations in the tropics: a review. *Agroforestry systems*, 61 (1), 311–328.

Midega, C. A. O., Bruce, T. J. A., Pickett, J. A., & Khan, Z. R. (2015). Ecological management of cereal stemborers in African smallholder agriculture through behavioural manipulation: Ecological management of stemborers in Africa. *Ecological Entomology*, *40*, 70–81. http://doi.org/10.1111/een.12216

Midega, C.A.O., Khan, Z.R., van den Berg, J., Ogol, C.K.P.O. (2005). Habitat management and its impact on maize stemborer colonization and crop damage levels in Kenya and South Africa. African Entomology 13: 333-340.

Miller, J. R. & Cowles, R. S. (1990). Stimulo-deterrent diversion: A concept and its possible application to onion maggot control. *Journal of Chemical Ecology*, *16*(11).

Miller, T.R., Baird, T.D., Littlefield, C.M., Kofinas, G., Chapin, F. & Redman, C.L. (2008). Epistemological pluralism: reorganizing interdisciplinary research. *Ecology and Society 1*3(2): 46.

Minh, T.T., Larsen, C.A.S. & Neef, A. (2014). Challenges to institutionalizing participatory extension: the case of farmer livestock schools in Vietnam. J.Agric. Educ. Ext. 16, 179–194.

Ministry of Finance and Economic Development (MoFED), Federal Democratic Republic of Ethiopia (2002). Ethiopia: Sustainable development and poverty reduction program. Addis Ababa.

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts. *The Academy of Management Review*, *22*(4), 853. http://doi.org/10.2307/259247

Mitiro D. (2014, March 19). Nyanza, Western get disease resistant Napier grass. The Standard newspaper. Retrieved on 30th January 2017 from https://www.standardmedia.co.ke/article/2000107280/nyanza-western-get-disease-resistant-napier-grass

Miyan, M. A. (2015). Droughts in Asian Least Developed Countries: Vulnerability and sustainability, Weather and Climate Extremes, Volume 7, Pages 8-23.

MoA (Ministry of Agriculture) (2000). Agroecological Zonations of Ethiopia. Addis Ababa, Ethiopia. p. 89.

MOARD (Ministry of Agriculture and Rural Development) (2001). Rural development policies, strategies and instruments. Addis Ababa, Ethiopia: MOARD.

Mobjörk, M. (2010). Consulting versus participatory transdisciplinarity: A refined classification of transdisciplinary research. *Futures*, *42*(8), 866–873.

Mobjörk, M., & Centrum för urbana och regionala studier. (2009). *Crossing boundaries: the framing of transdisciplinarity*. Örebro: Centrum för urbana och regionala studier, Örebro universitet.

Mollinga, P. P. (2008). The rational organisation of dissent: Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management. ZEF working paper series.

Mollinga, P. P. (2010). Boundary work and the complexity of natural resource management. Crop science 50: S1-S9.

Moore, S.A. & Mitchell, R.C. (2012). Transdisciplinary approaches to young people's citizenship. From bystanders to action. In Mitchell, R. C., & Moore, S. A. (Ed.), *Politics, participation & power relations transdisciplinary approaches to critical citizenship in the classroom and community*. Rotterdam; Boston: SensePublishers.

Mørk, B. E., Aanestad, M., Hanseth, O., & Grisot, M. (2008). Conflicting epistemic cultures and obstacles for learning across communities of practice. *Knowledge and Process Management*, *15*(1), 12–23. https://doi.org/10.1002/kpm.295.

Mosher, A.T. (1987). An introduction to Agricultural extension. Singapore University Press. (Cited by FA Cruz. 1978. Adoption and diffusion of agricultural extensions. In An introduction to extension delivery systems by JB Valera, VA Martinez, and RF Plopino eds.) 1987. Island Publishing House, Manila. P. 97-127.

Mugisha-Kamatenesi M., Deng, A. L, Ogendo, J.O., Omolo, E.O., Mihale, M.J., Otim, M. (2008). Indigenous Knowledge of field insect Pests and their Management around Lake Victoria basin in Uganda. Afr J Environ Sci Technol. ;2(Suppl 8):342–348.

Mumford L. (1946). Technics and Civilization. London: Routledge.

Murage, A. W. , Amudavi, D. M. , Obare, G. , Chianu, J. , Midega, C. A. O. , Pickett, J. A. & Khan, Z.R. (2011) 'Determining smallholder farmers' preferences for technology dissemination pathways: the case of 'push-pull' technology in the control of stemborer and Striga weeds in Kenya', International Journal of Pest Management, 57: 2, 133- 145.

Murage, A. W., Obare, G., Chianu, J., Amudavi, D. M., Midega, C. A. O., Pickett, J. A., & Khan, Z. R. (2012). The Effectiveness of Dissemination Pathways on Adoption of" Push-Pull" Technology in Western Kenya. *Quarterly Journal of International Agriculture*, *51*(1), 51.

Murage, A. W., Obare, G., Chianu, J., Amudavi, D. M., Pickett, J., & Khan, Z. R. (2011a). Duration analysis of technology adoption effects of dissemination pathways: A case of "push–pull" technology for control of Striga weeds and stemborers in Western Kenya. *Crop Protection*, *30*(5), 531–538. https://doi.org/10.1016/j.cropro.2010.11.009

Murage, A.W., Amudavi, D.M., Obare, G., Chianu, J., Midega, C.A.O., Pickett, J.A., Khan, Z.R., (2011b). Determining smallholder farmers' preferences for technology dissemination pathways: the case of 'push-pull' technology in the control of stemborer and striga weeds in Kenya. International Journal of Pest Management 57: 133-145.

Nelson, R.R. (ed.) (1993), National Innovation Systems: A Comparative Analysis, Oxford, Oxford University Press.

NEPAD (2002). Comprehensive Africa Agriculture Development Programme. New Partnership for Africa's Development (NEPAD).

Nkedianye D., Radeny M., Kristjanson P., Herrero M. (2009). In: Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands, eds Homewood K, Trench P, Kristjanson P (Springer, London), pp 115–150.

North, D. C. (2005) *Understanding the Process of Economic Change*, Princeton University Press, Princeton, NJ.

Nowotny, H., Scott, P., Gibbons, M. (2004). Re-thinking science. Knowledge and the public in an age of uncertainty. Polity Press, Oxford.

Obura, E., Masiga, D., Wachira, F., Gurja, B. and Khan, Z. R. (2011). Detection of phytoplasma by loop-mediated isothermal amplification of DNA (LAMP). Journal of Microbiological Methods 84: 312–316.

Ouma, M. A., Onyango, C. A., Ombati, J. M., R., K. Z., O., M. C. & J., P. (2014). Use of Participatory Video in Enhancing Sorghum Production among Smallholder Sorghum Farmers' in Rachuonyo North Sub-County, Kenya. *IJRAS*, *1*(3), 189-193**.**

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, *19*(3), 354–365. http://doi.org/10.1016/j.gloenvcha.2009.06.001

Pankhurst, A. and D.H. Mariam (2000). The Iddir in Ethiopia: Development, Social Function and Potential Role in HIV/AIDS Prevention and Contorl. Northeast African Studies Vol. 7, No. 2. pp35-58.

Pankhurst, A. and Damen Haile Mariam (2000). The Iddir in Ethiopia: Historical Development, Social Function, and Potential Role in HIV/AIDS Prevention and Control. Northeast African Studies. Vol. 7, No. 2, pp 35-58.

Pankhurst, R and Endreas Eshete (1958). Self-help in Ethiopia. Ethiopia Observer vol. II. No,11.

Pannell, D.J., *et al*., (2006). Understanding and promoting adoption of conservation practices by rural landholders. *Australian journal of experimental agriculture*, 46 (11), 1407–1424.

Paris, T. R. (no year) Integrating the gender variable in farming system research. (unpublished).

Parker, J., & Crona, B. (2012). On being all things to all people: Boundary organizations and the contemporary research university. *Social Studies of Science*, *42*(2), 262–289. http://doi.org/10.1177/0306312711435833

Pedrosa, A. (2009)."Motivating stakeholders for co-created innovation." *Open Source Business Resource* December 2009

Pickett, J. A., Woodcock, C. M., Midega, C. A., & Khan, Z. R. (2014). Push–pull farming systems. *Current Opinion in Biotechnology*, *26*, 125–132. https://doi.org/10.1016/j.copbio.2013.12.006

Pingali, P. L. (2012). Green Revolution: Impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences*, *109*(31), 12302–12308. https://doi.org/10.1073/pnas.0912953109

Pohl, C. (2011). What is progress in transdisciplinary research? *Futures*, *43*(6), 618–626. https://doi.org/10.1016/j.futures.2011.03.001

Pohl, C., Hadorn, G. H., & Zimmermann, A. B. (2007). *Principles for designing transdisciplinary research*. oekom Munich.

Pohl, C., Van Kerkhoff, L., Hadorn, G.H., Bammer, G. (2008). Integration. In: Hadorn, G.H., Hoffmann-Riem, H., BiberKlemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, R., Zemb, E. (Eds.), Handbook of Transdisciplinary Research. Springer, Dordrecht, pp. 411–424.

Popa, F., Guillermin, M., & Dedeurwaerdere, T. (2015). A pragmatist approach to transdisciplinarity in sustainability research: From complex systems theory to reflexive science. *Futures*, *65*, 45–56. https://doi.org/10.1016/j.futures.2014.02.002

Poteete, A. R., Janssen, M.A. & Ostrom, E. (Eds.) (2010). *Working together: Collective action, the commons and multiple methods in practice*. Princeton, NJ: Princeton University Press.. International Journal of the Commons. 5(1), pp.152–155. DOI: http://doi.org/10.18352/ijc.267.

Prabhakrar, C.A and Alemu, Y. (2013). Agricultural development-led industrialization strategy in Ethiopia: An overview. *African Journal of Political Science and International Relations*, *7*(5), 237–246. http://doi.org/10.5897/AJPSIR10.042.

Pyke B., Rice M., Sabine B., Zalucki M. (1987). The push-pull strategy— behavioural control of Heliothis. Aust. Cotton Grower, May-July 1987, 7-9.

Rahmato D. (2008). "Ethiopia: Agricultural Policy Review", in Taye Assefa (ed.), Digest of Ethiopia's National Policies, Strategies and Programs: Addis Ababa: Eclipse Printers.

Reed, M., Evely, A. C., Cundill, G., Fazey, I. R. A., Glass, J., Laing, A., … others. (2010). What is social learning? *Ecology and Society*. Retrieved from https://research-repository.st-andrews.ac.uk/handle/10023/1624

Regeer, B., Bunders, J., & Hedges, M. (2009). *Knowledge co-creation: interaction between science and society: a transdisciplinary approach to complex societal issues*. Den Haag: RMNO.

Regmi, A., & Meade, B. (2013). Demand side drivers of global food security. *Global Food Security*, *2*(3), 166–171.

Reid, R. S., Nkedianye, D., Said, M. Y., Kaelo, D., Neselle, M., Makui, O., … Kristjanson, P. (2016). Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *Proceedings of the National Academy of Sciences*, *113*(17), 4579–4584.

Renner, R., Schneider, F., Hohenwallner, D., Kopeinig, C., Kruse, S., Lienert, J., … Muhar, S. (2013). Meeting the Challenges of Transdisciplinary Knowledge Production for Sustainable Water Governance. *Mountain Research and Development*, *33*(3), 234–247. http://doi.org/10.1659/MRD-JOURNAL-D-13-00002.1

Rodenburg, J., Bastiaans, L., Weltzien, E., Hess, D. E. (2005). How can selection for *Striga* resistance and tolerance in sorghum be improved? Field Crops Research, 93: 34-50.

Rogers, E. M. and Shoemaker, F. F. (1971). Communication of Innovations: A Cross – Cultural Approach. 2nd Ed. The Free Press. New York.

Rogers, E.M. (2003). Diffusion of innovations (5th ed.). New York: Free Press.

Röling, N. (2010). The impact of agricultural research: evidence from West Africa. Development in Practice 20 (8), 959–971.

Rosenfield, P. (1992). The potential of transdisiplinary research for sustaining and extending linkages between the health and social sciences. *Social Science and Medicine, 35*(11), 1343-1357.

Sanginga, P. C. (Ed.). (2009). *Innovation Africa: enriching farmers' livelihoods*. London ; Sterling, VA: Earthscan.

Sasakawa Africa Association (2015). Take it to the farmer The Sasakawa experience in Africa. Sasakawa Africa Association, 4th Floor, The Nippon Foundation, Minato-ku, Tokyo.

Sasakawa Global (SG-2000). 2007. Proceedings of Conservation Agriculture Performance Workshop. Sasakawa Global 2000 and EIAR. Addis Ababa.

Sayer, J., & Cassman, K. G. (2013). Agricultural innovation to protect the environment. Proceedings of the National Academy of Sciences, 110(21), 8345–8348.

Schäpke, N., Omann, I., Wittmayer, J. M., van Steenbergen, F., & Mock, M. (2017). Linking transitions to sustainability: a study of the societal effects of transition management. *Sustainability*, *9*(5), 737.

Scholz, G., Dewulf, A., & Pahl-Wostl, C. (2014). An Analytical Framework of Social Learning Facilitated by Participatory Methods. *Systemic Practice and Action Research*, *27*(6), 575–591. http://doi.org/10.1007/s11213-013-9310-z

Scoones, I. (1998). Sustainable Rural Livelihoods: A framework for analysis. Institute of Development Studies Working Paper 72, 1998. University of Sussex: Brighton.

Scott, J. C. (2008). *Weapons of the weak: Everyday forms of peasant resistance*. Yale University Press.

Siarta, S., Blochb, R., Knierima, A., & Bachingerb, J. (2012). Development of Agricultural Innovations in Organic Agriculture to adapt to Climate Change–Results from a Transdisciplinary R&D Project in North-eastern Germany. In Producing and reproducing farming systems. New modes of organisation for sustainable food systems of tomorrow. 10th European IFSA Symposium, Aarhus, Denmark, 1-4 July 2012. International Farming Systems Association.

Siebenhüner, B. (2004). Social learning and sustainability science: which role can stakeholder participation play? Int J Sustain Dev 7:146–163.

Simtowe, F. (2006). Can risk-aversion towards fertilizer explain part of the non-adoption puzzle for hybrid maize? Empirical evidence from Malawi.

Singh, S. J., Haberl, H., Chertow, M., Mirtl, M., & Schmid, M. (2012). *Long term socio-ecological research: Studies in society-nature interactions across spatial and temporal scales* (Vol. 2). Springer Science & Business Media.

SLIM (2004). Facilitation in Policy Processes: Developing New Professional Skills, Policy Briefing No. 4, May. http://slim.open.ac.uk (Social Learning for the Integrated Management and sustainable use of water at catchment scale).

Solomon, D. (1999). Micro Credit through Community Based Organisations. The Experience of ACCORD in Ethiopia. Conference on Poverty in Africa, Centre for the Study of African Economics, University of Oxford, UK.

Spielman, D. J. & Birner, R. (2008). How Innovative is Your Agriculture?: Using Innovation Indicators and Benchmarks to Strengthen National Agricultural Innovation Systems. World Bank.

Spielman, D. J., Byerlee, D., Alemu, D., & Kelemework, D. (2007). Policies to promote cereal intensification in Ethiopia: A review of evidence and experience. Retrieved from http://core.ac.uk/download/pdf/6337681.pdf

Spielman, D. J., Davis, K. E., Negash, K. E., & Gezahegn Ayele, M. (2008). *Rural Innovation Systems and Networks*. IFPRI Discussion Paper 00759. International Food Policy. www. ifpri. org. Retrieved from http://core.ac.uk/download/pdf/6388520.pdf

Spielman, D. J., M. Negash, K. Davis, and G. Ayele. (2006). The smallholder farmer in a changing world: The role of research, extension and education in Ethiopian agriculture. Ethiopian Strategy Support Program (ESSP) Policy Conference Brief No. 12. Addis Ababa, Ethiopia: International Food Policy Research Institute (IFPRI) and Ethiopian Development Research Institute (EDRI).

Star, S.L. and Griesemer, J.R. (1989). 'Institutional Ecology, 'Translations' and Boundary Objects: Amateurs amd Professional in Berkeley's Museum of Vertebrate Zoology, 1907-39' Social Studies of Science, 19: 387-420.

Stauffacher, M., Flüeler, T., Krütli, P., Scholz, R. (2008). Analytic and Dynamic Approach to Collaboration: A Transdisciplinary Case Study on Sustainable Landscape Development in a Swiss Prealpine Region. Systemic Practice and Action Research 21, 409-422.

Stellmacher, T. (2007). The historical development of local forest governance in Ethiopia. From imperial times to the military regime of the Derg. In: Afrika Spectrum 42(3). GIGA Institute of African Affairs, Hamburg.

Stellmacher, T. (2015). Socio-economic Change in Rural Ethiopia. Understanding Local Dynamics in Environmental Planning and Natural Resource Management. Peter Lang. Frankfurt.

Stellmacher, T., Grote, U. (2011). Forest coffee certification in Ethiopia: Economic boon or ecological bane? ZEF Working Paper Series, No. 76.

Stokols, D. (1999). Evaluation of the transdisciplinary process: Research plan for the Transdisciplinary Core Research Project. In F. M., Leslie (Ed.), Proposal to establish the UCI Transdisciplinary Tobacco Use Research Center, Funded by the National Institutes of Health (NIDA/ NCI), 1999–2004. Irvine, CA: University of California.

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., *et al.*,*(*2003). Evaluating transdisciplinary science. *Nicotine and Tobacco Research, 5,* S-1, S21–S39.

Suchman, L. (1994). Working relations of technology production and use. *Computer Supported Cooperative Work*, *2*, 21–39.

Swaminathan, M. S., & Borlaug, N. E. (2010). *Science and sustainable food security: selected papers of M S Swaminathan*. Singapore ; Hackensack, NJ: World Scientific.

Takele, G. (1997). *Sasakawa Global 2000 in the Intensification of Agriculture in Ethiopia*, Paper Presented in the 13th International Conference of Ethiopian Studies, Koyoto: 12-17 December

Tefera, T., Tesfay, G., Elias, E., Diro, M., & Koomen, I. (2016). Drivers for adoption of agricultural technologies and practices in Ethiopia.

Tilahun T. (1999), Survey of the Ethiopian Economy: Review of the Post-Reform Developments(1992/1993 - 1997/98), Addis Ababa: Ministry of Economic Development and Cooperation.

Tilman, D. *et al*. (2001). Forecasting agriculturally driven global environmental change. *Science* **292**, 281–284.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, *418*(6898), 671–677.
Tisenkopfs, T., Kunda, I., šūmane, S., Brunori, G., Klerkx, L. and Moschitz, H. (2015). Learning and Innovation in Agriculture and Rural Development: The Use of the Concepts of Boundary Work and Boundary Objects. The Journal of Agricultural Education and Extension: Competence for Rural Innovation and Transformation, 21:1, 13-33, DOI:10.1080/1389224X.2014.991115.

Tress, B., Tress, G., & Fry, G. (2005). *Defining concepts and the process of knowledge production in integrative research*. Springer: Heidelberg, Germany.

Tsanuo MK, Hassanali A, Hooper AM, Khan ZR, KaberiaF, Pickett JA, Wadhams L.J., (2003). Isoflavanones from the allelopathic aqueous root exudates of Desmodium uncinatum. Phytochemistry 64, 265–273.University Press.

UBOS (Uganda Bureau of Statistics) (2007). Uganda National Household Survey, 2005/06: Report on the agricultural module. Kampala: UBOS

Ul-Hassan, M., Hornidge A-K, van Veldhuizen, L., Akramkhanov, A., Rudenko, I. and Djanibekov, N. (2011). Follow the Innovation: *Participatory Testing and Adaptation of Agricultural Innovations in Uzbekistan-Guidelines for Researchers and Practitioners*. Center for Development Research (ZEF), University of Bonn, Germany.

United Nations, Department of Economic and Social Affairs, Population Division (2007). World Population Prospects: The 2006 Revision, Highlights, Working Paper No. ESA/P/WP.202.

United Nations, Department of Economic and Social Affairs, Population Division (2010). Revision of World Population Prospects. U.N. Population Division of the Department of Economic and Social Affairs.

United Nations, Department of Economic and Social Affairs, Population Division (2015). 2015 Revision of World Population Prospects. U.N. Population Division of the Department of Economic and Social Affairs.

Valera, J.B. and Plopino, R.F. (1987). Philosophy and principle of extension. In An introduction to extension delivery systems by JB Valera, VA Martinez, and RF Plopino (editors) 1987. Island Publishing House, Manila. P. 51-61.

van de Ban AW and HS Hawkin 1988. Agricultural Extension. John Willey & Sons, New York, United States. P. 61-127.
Vazquez-Brust, D. A., Sarkis, J., & Cordeiro, J. J. (Eds.). (2014). *Collaboration for Sustainability and Innovation: A Role For Sustainability Driven by the Global South?* Dordrecht: Springer Netherlands. Retrieved from http://link.springer.com/10.1007/978-94-007-7633-3

Vissoh, P. V., Gèhounou, G., Ahandédé, A., Kuyper, T. W. & Rölling, N. G. (2004) Weeds as agricultural constraint to farmers in Benin: results of a diagnostic study. Netherlands *Journal of. Agricultural Sciences,* 52:305-329.

Vitousek, P. M., Naylor, R., Crews, T., David, M. B., Drinkwater, L. E., Holland, E., … others. (2009). Nutrient imbalances in agricultural development. *Science*, *324*(5934), 1519–1520.

Waibel, H. (1986). *The Economics of Integrated Pest Control in Irrigated Rice*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-71319-4

Walker, A. & Walker, J. (1998). "Challenging the boundaries of sameness: leadership through valuing difference", Journal of Educational Administration, Vol. 36 Iss: 1, pp.8 – 28.

Wals, A. E. J. (Ed.). (2009). *Social learning towards a sustainable world: Principles, perspectives, and praxis*. The Netherlands: Wageningen Academic Publishers. Retrieved from http://www.wageningenacademic.com/doi/book/10.3920/978-90-8686-594-9.

Wang, C., Tan, Z. X., Ye, Y., Wang, L., Cheong, K. H., & Xie, N. (2017). A rumor spreading model based on information entropy. *Scientific Reports*, *7*(1). https://doi.org/10.1038/s41598-017-09171-8.

Welsh, A.B. & Mohamed K.I. (2011). Genetic Diversity of Striga hermonthica Populations in Ethiopia: Evaluating the Role of Geography and Host Specificity in Shaping Population Structure. International Journal of Plant Sciences, Vol. 172, No. 6. (pp. 773-782).

Wenger, E. (2000). Communities of practice and social learning systems. *Organization*, *7*(2), 225–246.

Wenger, E., McDermott, R., & Snyder, W. (2002). Cultivating communities of practice: a guide to managing knowledge. Harvard Business School Press.

Wennink, B. (Ed.). (2006). Farmers' organizations and agricultural innovation: case studies from Benin, Rwanda and Tanzania. Amsterdam: Royal Tropical Institute (KIT).

William, T. O., Spycher, B., & Okike, I. (2006). *Improving livestock marketing and intra-regional trade in West Africa: determing appropriate economic incentives and policy framework*. Nairobi, Kenya: International Livestock Research Institute.

Wolfram Mauser, Gernot Klepper, Martin Rice, Bettina Susanne Schmalzbauer, Heide Hackmann, Rik Leemans and Howard Moore, (2013) *Transdisciplinary global change research: the co-creation of knowledge for sustainability*, Environmental Sustainability, 5:420– 431)

Wood, S. A., Jina, A. S., Jain, M., Kristjanson, P., & DeFries, R. S. (2014). Smallholder farmer cropping decisions related to climate variability across multiple regions. *Global Environmental Change*, *25*, 163–172. https://doi.org/10.1016/j.gloenvcha.2013.12.011

World Bank (1997). Implementation completion report republic of Ethiopia peasant agricultural development project I (credit 1956-et). Agriculture Technical Group 2 Africa Regional Office. http://documents.worldbank.org/curated/en/769831468273905351/pdf/multi-page.pdf

World Bank (2006). Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems. The International Bank for Reconstruction and Development, The World Bank.

World Bank (2008) *World development report 2008: agriculture for development*. Washington, DC: The World Bank).

World Bank (2015). Doing Business 2016: Measuring Regulatory Quality and Efficiency. Washington, DC: World Bank Group.

World Bank (2015). *World Development Report 2015: Mind, Society, and Behavior.* Washington, DC: World Bank. doi: 10.1596/978-1-4648-0342-0.

World development report (2008). Agriculture for Development, The World Bank Washington, DC.

Wright Morton, L., Eigenbrode, S. D., & Martin, T. A. (2015). Architectures of adaptive integration in large collaborative projects. *Ecology and Society*, *20*(4). https://doi.org/10.5751/ES-07788-200405

YE, W. (2012). School Power and Democratic Citizenship Education in China. Experiences from three secondary schools. In Mitchell, R. C., & Moore, S. A. (Ed.), *Politics, participation & power relations transdisciplinary approaches to critical citizenship in the classroom and community*. Rotterdam; Boston: SensePublishers.

Yirga, C. and Alemu, D. (2016). Adoption of Crop Technologies among Smallholder Farmers in Ethiopia: Implications for Research and Development. Ethiopian Journal of Agricultural Science. Ethiop. J. Agric. Sci.. 1-16.

Zerfu, E. (2010) *In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendations for Improvement*. IFPRI Discussion Paper 01041.Washington, DC: International Food Policy Research Institute (IFPRI).

Appendices

Appendix 1: Focus Group Discussion (FGD) interviews conducted

Method	Designation	No. of Persons/events/meetings	Location	Date	Data gathered
Focus Group Discussions	MoA officials (DAs)	7	Bako district agricultural office	25th November 14	**Participant views on;** - Background information on farmers stemborer pest experiences on cereal crops - Type of stemborer pest control measures and effectiveness - Perceptions of the farmers on PPT and joint learning and implementation process involving other stakeholders: researchers and extension staffs - Farmers experiences, views and comments on PPT implementation activities and management practices from land preparation to harvesting of PPT crops with focus on; how different from the usual practices, new knowledge/skills gained, challenges faced, suggestions on changes to be made, incentives to be introduced to attract other stakeholders and sustainability of PPT. **Development Agents views on;** - Inputs requirements, dates and farms accessible to irrigation, - Stemborer pest infestation hot spots areas, and control methods used within the Woredas - Other actors in the Woredas/Kebeles whose contributions are
	Farmers	6	Jameshone Kebele Yayu Woreda	26th April 15	
	Experienced PPT farmers	10	Tolay district	30th April 15	
	Farmers and Development agents	3 DAs and 15 farmers	Jimma Arjo Agricultural office	4th April 2015	
	Farmers	10	Dhembi Gobuu	26th March 2015	
	Farmers	8	Sedan Kite	24rd March	
	Field visit Researchers (ZEF),	2 researchers 3 extension staff 15 farmers	Sedan kite and dembi gobbu villages, Bako Tibe	15th Feb 15	
	Demonstration plots establishment	**8** extension staffs 10 farmers	Jimma Arjo Wayu Kumba	21st Jan 2015	
	Demonstration plots establishment	12 farmers 3 extension staffs (MoA)	Jame Shono village, Yayu	16th January 2015	
	Development agents (MoA), officials from water and irrigation ministry	6	Bako agric office	11th Dec 2014	
	Demonstration plots establishment	Research, extension and farmers 11 officials (Researcher and Extension) 16 farmers	PPT Learning field- Dembi Gobu- Muri village)	28th November 14	
	Demonstration plots establishment	3 Researchers 7 extension staffs 14 farmers	Sedan Kite	5th Dec 2014	
	MoA officials (DAs)	7	Jimma arjo agricultural office	22 October 2014	
	Farmers meeting	6	Yayu ECFF offices	27th October 2014	
	Farmers meetings	8 (6 male and 2 female	Sedan Kite	25th November 2014	
	Farmers meeting	11(7 male 4 female)	Dembi Gobbu	24th November 2014	

					complementary and their ratings in terms of agriculture information delivery, access and effectiveness

Appendix 2: Key Informant (KI) interviews conducted/Participant Observations (PO)

Method	Designation	No. of Persons/events/meetings	Location	Date	Data gathered
Key informant interviews	Researchers (Maize Entomologists)	3	Bako Agricultural research	16th April 2015	The stakeholders experiences, perceptions and views on; - PPT and TDR implementation; challenges and opportunities, their roles and contributions to the processes - their current approaches and practices used in dealing with the stemborer pests problems and their effectiveness - the socio economic and contextual factors which may hinder the implementation or expansion of PPT and research results - incentives to foster fruitful interaction and effective earning and sustainable implementation of PPT - Key lessons learnt and way forward regarding PPT and TDR approaches
	Women affairs ministry	1	Bako agricultural office	16th April 2015	
	Experienced DA with PPT implementation	1	Tolay district	30th April 15	
	PPT farmer	1	Bako Tibe	23rd March2015	
	Crop protection officer	1	Bako Tibe	16th April 15	
	Information resource Center	1	Bako	16th April 2015	
	Tutor	1	Bako Agricultural college	31st March 15	
	PPT farmer	1	Dem	25th March 15	
	Agricultural extensionists	1	Min of Agri. Bako	20th March	
	Entomologist (icipe)	1	Addis Ababa	17th Feb 15	
	Extension staff	1	Yayu district	15th Dec 2014	
	Researchers (Maize Entomologists)	3	Bako Agricultural Research	27th November 14	
	Tutor	1	Bako agricultural college	5TH April 2015	
	Min of water and irrigation, and cooperatives	2	Bako agricultural office	27th March 15	
	Researchers	2	Matuu Agric Res Center	13th Dec 2014	
	Researchers (Weed scientist, Chemical Ecologist and Entomology)	3	Jimma Research Center and University	30th October 2014	
	Crop protection	1	Bako Tibe district	14th April 15	
	Extension expert	1	Bako Tibe district	14th April 15	
	Min of water and Irrigation	1	Bako Tibe district	14th April 15	
	Min of youth Affairs	1	Bako district	17th April 15	
	PPT farmers	6	Bako Tibe/Yayu districts	17th -28th April 15	
	Icipe researcher (social science)	1	Addis Ababa	5th May 15	

Participant observations	Researcher	Field visits to the demonstration sites		7th Dec 14 on wards	Perceptions, attitudes, actions and motivations of different stakeholders during planning workshops and on-farm PPT implementation

Appendix 3: Planning workshops and farmers field days

Method	Designation	No. of Persons/events/meetings	Location	Date	Data gathered
PPT field day	Farmers Field day	over 100 attendants	Sedan Kite	8th April 15	Views, perceptions and comments on farm evaluation of PPT performance by new farmers and other stakeholder from neighboring villages and districts
	Farmers and other stakeholders	Farmers, researchers, MoA, donors and other guests with over 200 participants	Tolay	15th November 14	
	Farmers	Over 100	Jameshone Kebele Yayu Woreda	26th April 2015	
Planning Workshops	Stakeholders	2	Regional and Woreda/community levels	October 2014	The stakeholders (participants) joint view and understanding on; - the stemborer pest problem, how addressed before and how PPT can be used to address the problem - Opportunities and challenges for collaboration and learning across knowledge types, experiences of different stakeholders - Terms of engagement by different stakeholders on their commitment in the TD stakeholder engagement process and PPT implementation - New benefits of implementing PPT on farm which never existed before such as cereal crop intercropping, fodder availability during dry season etc.
	Development Agents	46	Bako tibe district agricultural office	4th Dec 14	

Questionnaire survey	Farmers	227	Bako, Jimma arjo and Yayu	November 2014-March 2015	- Socio-economic information of the smallholder farmers in the study area; Sources of incomes, types of crop and livestock owned and related production challenges, sources and types of fodder - Knowledge of stemborer pest infestations , effect on cereal yields, and management approaches

Appendix 4: Stakeholders during planning workshop, Disciplines and Institutional affiliation

Stakeholder	Organization/Region	Profession
Research scientists	Jima Agric Research center .	Entomologist
	Jima Agric Research center .	Weed scientists
	Jima University	Chemical ecologist
	Jima Plant H.Clinic	Entomologist
	Jima Plant H. clinic	Entomologist
	Metu Agric Research center .	Soil scientist
	Metu Agric Research center .	Researcher
	Bako Agric Research center .	Entomologist
	ECFF	Sociologist
	Icipe	Social Scientist
Extensionists/Agronomists	Jima zone agri. office	Crop protection
	ECFF/Yayu	Crop protection
	East Wolega zone agri.	Agronomist
	East Wolega zone agri.	Agronomist
	Jima zone agri. office	Agronomist
	MoA Federal leve;	Crop protection
	Jima Arjo district	Agronomist
	Jima Arjo distric	Agricultural Ext
	Jima Arjo district	Agricultural Ext
	Bako Tibe district	Agricultural Ext
	West Shawa zone agri.	Agricultural Ext
	Yayu district agri.	Agricultural Ext
	Yayu district agri.	Agricultural Ext
Others: Federal and regional MoA Administration, Media and Farmers	Iluababora zone agri.	Zonal administrator
	Oromiya agri. office	Regional Administrator
	Fana Broadcasting	Journalist
	Smallholder farmers	Smallholder Farming
	MoA Federal	Crop protection

Appendix 5: Perceptions on the informal and formal sources of information related to agriculture

To assess the perception on the level of importance and contribution of various formal and informal institutions as potential information sources of messages related with agriculture, a participatory ranking exercise was conducted by the Development agents, administrators and other ministries officials at the Woreda level. The meeting held at Bako MOA office with representatives from Jimma arjo, Yayu and Bako. After identifying and deliberating on the various formal and informal organization and institutional sources, they ranked them in terms of access (how reachable are these sources to the farmers when they are in need of them), frequency (based on the number of contacts made by farmers with these sources on monthly basis) and effectiveness (the rating of messages communicated from these sources in terms of successfulness when applying). The scale was on 1 to 5; where 1 was poor and 5 excellent. Table 2.1 below is a summary of the averages of from these rankings. The total number of participants was 26.

Access, frequency of contacts and effectiveness of information sources

Sources of agriculture information	Figures in averages where ; 1=poor; 2=fair; 3=Average; 4=Very good; 5= Excellent			
	Access	Frequency	Effectiveness	Overall
Formal				
Development Agents	4.4	4.3	4.0	**4.2**
Irrigation committee	3.2	2.9	3.2	3.1
Credit & savings association	3.1	3.1	3.2	3.1
Youth committees	3.0	2.5	2.7	2.7
Women committees	2.9	2.5	2.6	2.7
Agricultural colleges/Universities	2.1	2.1	2.3	2.2
Artificial insemination centers	2.3	2.4	2.4	2.4
National research centers	2.4	2.3	2.8	2.5
Seed multiplication centers	2.4	2.3	2.5	2.4
Agricultural produce collection centers	2.1	2.0	2.2	2.1
Agro-dealers/Traders	2.1	1.9	2.2	2.1
NGOs working in agriculture	2.3	2.3	2.5	2.4
Farmers cooperatives	3.3	3.4	3.4	3.4
Informal				
• *Iddir*	3.9	3.7	3.7	**3.8**
• *Iquib*	2.9	3.0	3.0	3.0
• *Debbo*	3.8	3.7	3.8	**3.8**
• *Maheber and Senbete*	2.9	2.4	2.4	2.6
Elders Council	2.4	2.5	2.4	2.4
Churches	3.6	3.4	3.3	3.4
Mosque	2.3	2.2	2.1	2.2

The results in table above show that the Ministry of Agriculture (represented by DAs at the village level) was ranked as very good when it comes to easily accessible, on frequent contact and provides reliable information on agriculture to the farmers. The MOA overally ranked very well in terms of information sources as compared to other sources. This was linked to their terms of employment of DAs which require them to be live closer to the farmers and have meetings with them on a regular basis. This is in agreement to what Davies et al. (2010), where they indicated that the Ethiopian government had made heavy investment on the public extension services provision whereby in each village there are at least 3 DAs each in charge of crop protection, animal health and natural resources management and also a health extension officer in charge of two neighboring villages. The rankings of other institutions such as; irrigation committee, credit and saving association, farmer cooperatives were on an average level. These sources provide crucial agricultural information linked with their mandate, but the work hand in hand with the MOA officials. The Information sources such as agricultural colleges, Agro-dealers, research centers were ranked fair. Although they are engaged in extension services provision, they are limited in terms of their mandates, geographical locations and even logistical support when compared with the MOA. The private sector players such as Agrodealers and NGOs were also ranked fair. Although they important and relevant and innovative approaches, they have limited role to play in extension services delivery (Davies et al., 2008).

The *Iddir* and *Debbo* as informal sources ranked average in terms of accessibility, frequency and reliability. Almost every household belong to one or more than one informal institutions. This makes them to be potentially useful for extension services information dissemination. Although their base functions are more of social support than in agricultural information dissemination, they are important social platforms to enhance this. *Maheber and Senbete* were ranked fair as agricultural information sources, because their functions are not directly linked to farming activities, but close to savings and access to credit or financial support.

The results from the table show that; both formal and informal sources in the extension sector service play an important role in the growth and expansion of the agricultural sector.