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Farmer Innovation in Rural Ghana

Determinants, Impacts and Identification

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von

Justice Akpene Tambo

aus
Kpando, Ghana

Referent: Prof. Dr. Joachim von Braun

Korreferent: Prof. Dr. Robert Finger

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Abstract

Innovation is essential for agricultural and economic development, especially in today's rapidly changing global environment. While farmers have been recognised as one of the key sources of innovation, many studies on agricultural innovations continue to consider farmers as adopters of externally-driven technologies only. This thesis, in contrast, analyses the innovation-generating behaviour among rural farmers. Specifically, the study looks at the determinants, impacts and identification of farmer innovation. The study is based on primary data obtained from a survey of 409 smallholder farm households in the Upper East region of northern Ghana. Additional data were collected through an innovation contest and a stakeholder workshop conducted in the region.

Employing recursive bivariate probit and endogenous treatment-regression models which control for selection bias, it was found that participation in Farmer Field Fora − a participatory extension approach with elements of the innovation systems perspective − is a key determinant of innovation behaviour in farm households. Other important determinants are education, climate shocks and risk preferences. These results are robust to alternative specifications and estimation techniques. The study also found no spillover effect of FFF on farmers' innovation capacity and discussed its implications.

Using endogenous switching regression and propensity score matching techniques, the effect of farmer innovation on household welfare was analysed. The results show that farmer innovation significantly improves both household income and consumption expenditure for innovators. It also contributes significantly to the reduction of food insecurity among innovative households by increasing household food consumption expenditure, reducing the length of food shortages, and decreasing the severity of hunger. However, the findings show that the positive income effects of farmer innovation do not significantly translate into nutritious diet, measured by household dietary diversity. The results also indicate that though households innovate mainly to increase production, their innovations indirectly contribute to building their resilience to climate shocks. Overall, the results show positive and significant welfare effects of farmer innovation.

Through an innovation contest that rewards farmers' creativity and a household survey, 48 outstanding innovations developed by smallholder farmers were identified in the study region. The innovations are largely extensive modification of existing practices or combination of different known practices in unique ways to save costs or address crop and livestock production constraints. While some of the identified innovations can be recommended or disseminated to other farmers, most of them may require further validation or research. The multi-criteria decision making analysis − based on expert judgement − is proposed as a simple and useful method that can be applied in prioritising high-potential innovations. Using this method, it was found that among the most promising innovations involve the control of weeds, pest and diseases using plant residues and extracts, and the treatment of livestock diseases using ethnoveterinary medicines.

In conclusion, this study provides empirical evidence that smallholder farmers develop diverse and spectacular innovations to address the myriad challenges they face. These innovations also contribute significantly to household well-being, hence, need to be recognised and promoted. An institutional arrangement that permits interactions and learning among stakeholders may be a potential option for strengthening farmers' innovation capacity.

Zusammenfassung

Innovationen sind essentiell für die wirtschaftliche und agrarwirtschaftliche Entwicklung, insbesondere um sich der rapide verändernden globalen Umwelt anzupassen. Während Landwirte im Bereich der Agrarwirtschaft als Hauptquellen von Innovationen anerkannt werden, nehmen viele Studien über Agrarinnovationen fortwährend an, dass sie externe Innovationen und Technologien lediglich adaptieren. Diese Arbeit analysiert im Gegenzug dazu das innovationsgenerierende Verhalten von ländlichen Kleinbauern. Die Studie basiert auf Primärdaten, die aus der Erfassung von 409 kleinbäuerlichen Haushalten aus der nordöstlichen Region Ghanas hervorgehen. Zusätzliche Daten wurden im Zuge eines Innovationswettbewerbes und eines Stakeholder Workshops in derselben Region gesammelt.

Die statistische Analyse durch Rekursive Bivariate Probit- und Endogene Treatment-Regressions-Modelle, die der Kontrolle von Selektivitätsfehlern dienen, ergab, dass die Teilnahme in einem Farmer Field Forum (FFF) – einem interaktiven Forum für Landwirte mit innovativen Elementen – eine Schlüsseldeterminante für innovatives Verhalten in ländlichen Haushalten ist. Weiterhin sind Bildung, klimatische Schocks und die Präferenz für Risiko von zentraler Bedeutung für innovatives Verhalten. Die Ergebnisse sind robust gegenüber verschiedenen Annahmen und alternativen Schätzungsmodellen. Sie zeigen außerdem, dass es keine Spill-Over-Effekte von FFF auf die Innovationskapazität der Bauern gibt.

Die Wirkung der Farmer-Innovationen auf die Haushaltswohlfahrt wurde mit Hilfe der Anwendung Endogener-Switching-Regressions und Propensity-Score-Matching Methoden analysiert. Die Ergebnisse ergaben, dass Farmer-Innovationen sowohl das Haushaltseinkommen, als auch die Konsumausgaben signifikant erhöhen. Zudem sinkt die Nahrungsmittelunsicherheit innerhalb innovativer Haushalte signifikant, was erhöhten Nahrungsmittelausgaben, einer reduzierten Dauer von Nahrungsmittelknappheiten und einem verringerten Schweregrad des Hungers zugrunde liegt. Die positiven Einkommenseffekte bewirken allerdings keine signifikante Verbesserung der Ernährungsweise die durch die Nahrungsvielfalt in Haushalten gemessen wurde. Auch wenn die getätigten Innovationen hauptsächlich der Produktivitätssteigerung dienen, tragen sie zu einer erhöhten Widerstandsfähigkeit bei Klimakatastrophen bei. Insgesamt, zeigen die Ergebnisse positive und signifikante Wohlfahrtseffekte auf innovative Haushalte.

Durch einen Haushaltssurvey und einen Innovationswettbewerb, bei dem Landwirte für ihre Kreativität belohnt werden sollten, wurden in der Region insgesamt 48 hervorragende Innovationen kleinbäuerlicher Betriebe identifiziert. Bei den Innovationen handelt es sich größtenteils um Modifikationen bereits existierender Praktiken oder aber um die Kombination aus mehreren bereits bekannten Praktiken in einer speziellen Art und Weise. Ziel der meisten Innovationen war es, Kosten zu sparen oder Restriktionen bezüglich der Ernte- und Vieh Produktion entgegen zu wirken. Einige der Innovationen können weiterempfohlen und verbreitet werden. Der Großteil jedoch bedarf weiterer Erforschung und Bewertung. Die Multi-Kriterien-Analyse des Entscheidungsprozesses, basierend auf der Beurteilung von Experten, gilt als einfache und nützliche Methode, die dazu verwendet wird hochpotenzielle Innovationen zu detektieren. Sie ergab, dass die aussichtsreichsten Innovationen sowohl die Kontrolle von Unkraut, Pflanzenkrankheiten- und Schädlingen durch die Verwendung von Pflanzenresiduen- und Extrakten beinhalten, als auch die Behandlung von Tierkrankheiten durch ethnoveterinäre Medizin.

Zusammenfassend, liefert diese Arbeit empirische Evidenz dafür, dass kleinbäuerliche Betriebe viele spektakuläre Innovationen entwickeln, um die unzähligen Herausforderungen denen sie täglich gegenüberstehen, zu bewältigen. Diese Innovationen tragen erheblich zum Haushaltswohlstand bei, sollten demnach also erkannt und gefördert werden. Ein institutionelles Arrangement, das Interaktionen und gegenseitiges Erlernen innerhalb der Gruppe der Akteure erlaubt, stellt eine lukrative Option dar, die Innovationstätigkeit von Kleinbauern zu fördern.

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Abbreviations

ACDEP	Association of Church Development Projects
AE	Adult Equivalent
AGRA	Alliance for a Green Revolution in Africa
AIS	Agricultural Innovation Systems
ATT	Average Treatment Effect on the Treated
AU	African Union
CCADP	Comprehensive Africa Agriculture Development Programme
CGIAR	Consultative Group on International Agricultural Research
ESR	Endogenous Switching Regression
ETR	Endogenous Treatment-Regression
FAO	Food and Agriculture Organization
FFF	Farmer Field Fora
FFS	Farmer Field School
FIML	Full Information Maximum Likelihood
FP	Farmers Practice
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
HDDS	Household Dietary Diversity Score
HHS	Household Hunger Scale
ICM	Integrated Crop Management
IMR	Inverse Mills Ratio
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
KNE	Kassena Nankana East
KNW	Kassena Nankana West
MCDM	Multi-Criteria Decision Making
METASIP	Medium Term Agriculture Sector Investment Plan
MIHFP	Months of Inadequate Household Food Provisioning
MoFA	Ministry of Food and Agriculture
NARI	National Agricultural Research Institutes
NGO	Non-Governmental Organization
OLS	Ordinary Least Squares
PAR	Participatory Action Research
PCA	Principal Component Analysis
PSM	Propensity Score Matching
RBP	Recursive Bivariate Probit
RTIMP	Root and Tuber Improvement and Marketing Programme
TLU	Tropical Livestock Unit
UNDP	United Nations Development Programme
WASCAL	West Africa Science Center for Climate Change and Adapted Land Use

General Introduction

"At the present time, every intelligent farmer is an experimenter…..this cumulative body of experience of the best farmers is capable of yielding better results than similar work which might be undertaken at an experimental station…..An experimental station, which is necessary constituted for scientific research, cannot touch many of the most vital problems of farming."

---- Liberty Hyde Bailey 1896 (quoted by Hayami and Ruttan, 1985, p.57)

1.1 Background and Research Problem

There is a renewed emphasis on agriculture because of its important role in economic development. Agricultural development remains fundamental for feeding the growing world population and meeting the millennium development goals of cutting poverty and hunger in half by 2015 (World Bank, 2007). The 2008 World Development Report and the 2009 L'Aquila Food Security Initiative all put a spotlight on agricultural development as essential in reducing poverty, tackling food insecurity and ending hunger. The global food price crises in 2007-2008 and 2010-2011 which worsened food insecurity further placed the importance of investment in agriculture in the limelight. In Africa – where agricultural productivity is low but contributes largely to gross domestic product (AGRA, 2013) − there have been several initiatives in recent years aimed at enhancing agricultural development in the continent. For instance, the Comprehensive Africa Agriculture Development Programme (CCADP) initiative of the African Union (AU) and the establishment of the Alliance for a Green Revolution in Africa (AGRA) in 2004 have been aimed at boosting agricultural investment and productivity in Africa. The AU declaration of 2014 as the year of agriculture and food security further buttresses the importance of agriculture in the continent.

This renewed focus on agriculture has contributed to increased food production in the last decade. Despite this achievement, nearly 850 million continue to be hungry and food insecure and about one-quarter of them live in sub-Saharan Africa (SSA) (FAO et al., 2013). Most of these undernourished people are smallholders, who live in rural areas and on less than US$1.25 a day and derive their livelihoods from agriculture (McIntyre et al., 2009). Unfortunately, the challenges of food price volatility, climate change, increased demand for bioenergy, soil degradation, population growth, rural-urban migration, etc. may exacerbate this situation (Godfray et al., 2010; Foley et al., 2011). Climate change, in particular, poses serious threats to agricultural production and has major implications for rural poverty and food security (World Bank, 2009; Thornton et al., 2011; Wheeler and von Braun, 2013). Conversely, agriculture contributes to climate change through greenhouse gas emissions and natural resource degradation. The challenge of meeting the increasing global food demand must, therefore, occur while simultaneously tackling environmental problems stemming from agriculture (Godfray et al., 2010; Foley et al., 2011). This calls for innovations and sustainable agricultural practices.

The important role of agricultural innovations in food security and poverty reduction has been universally accepted (The Worldwatch Institute, 2011). The Green Revolution in Asia and Latin America, for instance, helped to significantly increase income and alleviate poverty among adopters of the introduced innovations, albeit with some environmental problems (David and Otsuka, 1994; Conway and Wilson, 2012). Agricultural innovations may be technological such as improved crop varieties or institutional such as farmer field schools and contract farming. These innovations may be induced by challenges such as factor scarcities, climate shocks and other production constraints, as well as economic opportunities and public policies (Hayami and Ruttan, 1985). It could also emerge through networks of actors and organizations (World Bank, 2011).

Farmers are not only recipients of introduced knowledge or technologies (Reij and Waters-Bayer, 2001). It is well acknowledged that agricultural innovations can emerge from multiple sources including farmers (Biggs, 1990), which is generally referred to as farmer innovation. Farmers have been developing or improving innovations to fit them into their local conditions and adapt to global changes (Sanginga et al., 2008). With the advancement of research and development, however, the attention has largely been on technologies developed by research institutions and universities, and farmers' innovative practices are often neglected or under-valued. There is much evidence on the positive livelihood effects of introduced technologies, but the scope of these impacts is often limited. For instance, adoption of these externally-promoted innovations by smallholders is hindered by a number of constraints such as incompatibility with farming system, unawareness, unavailability or unaffordability (Chambers et al., 1989; Letty et al., 2011; Tambo and Abdoulaye, 2012). There are increasing calls for better support for the innovative practices of farmers as well as strengthening their capacity to be able to experiment, develop and adapt innovations to suit the constantly changing global conditions.

Farmer innovation has gained increased attention in recent years, because of its potential for sustainable food production and in reducing rural food insecurity. There have been many initiatives aimed at promoting farmer innovation processes. Notable among them are two Dutch government funded projects in the late 1990's: *Promoting Farmer Innovation* (PFI) in Kenya, Tanzania and Uganda, and *Indigenous Soil and Water Conservation 2* (ISWC2) in Burkina Faso, Cameroon, Ethiopia, Tanzania, Tunisia, Uganda and Zimbabwe. A multi-stakeholder partnership programme, PROLINNOVA (promoting local innovation in ecologically-oriented agriculture and natural resource management), has led the identification and promotion of farmers' innovations in Africa, Asia and South America. The Honey Bee Network has also documented and disseminated thousands of grassroots innovations scouted in India and many parts of the world over the past two decades (Gupta et al., 2003). Since the late 1980's, several workshops and conferences have also been organised to discuss and promote farmer innovation approaches. These meetings have resulted in books related to farmer innovation such as *Farmer First* (Chambers et al. 1989); *Beyond Farmer First* (Scoones and Thompson, 1994); *Farmer First Revisited* (Scoones and Thompson, 2009); *Farmer Innovation in Africa* (Reij and Waters-Bayer, 2001) and *Innovation Africa* (Sanginga et al., 2009).

While these initiatives have resulted in increased knowledge on the concept and significance of farmer innovation, many important issues remain unanswered. For instance, there is still the challenge of how to involve many stakeholders in stimulating the innovative behaviour among farmers, and how to incorporate farmer innovation into research and development programmes. Thus, robust studies on farmer innovation are necessary to be able to argue for increased support for farmer innovation.

There is an emerging literature on farmer innovation approaches, particularly in developing countries. One strand of the literature has focussed on the determinants of farmer innovation and has shown that socio-economic variables such as ethnicity, age and wealth explain farmers' innovativeness (Reij and Waters-Bayer, 2001; Nielsen, 2001). However, these studies are qualitative or anecdotal and also ignore important factors such as institutional arrangements, shocks and risk attitude that may induce innovation behaviour.

Another important aspect of farmer innovation is its impacts on household welfare. While there are numerous empirical studies suggesting positive welfare impacts of externally-developed innovations, little is known about that of farmers' innovations. Once again, the few available studies are only anecdotal and based on subjective outcomes as indicated by the innovators. Rigorous impact assessment studies are needed to make arguments for increased government and donor supports for the promotion of farmer innovation. As argued by Waters-Bayer et al. (2009), GRAIN (2009) and The Worldwatch Institute (2011), it is possible that the farmers' innovations may be making even more impacts in poor people's livelihoods than the externally-driven technologies and might form the necessary basis for food security. However, without adequate evidence of the potential performance of farmer innovativeness, it is difficult for decision-makers to make policies and investments that promote farmer innovation (Letty et al., 2011b).

The various initiatives for the promotion of farmer innovation have identified several outstanding innovations. Some of these innovations have been verified through scientific research or joint experimentation involving farmers, researchers and extension agents. Some of the innovators have even been assigned patent rights, and their innovations have been converted into marketable products. Not all innovations developed by farmers are technically and economically effective or socially acceptable. Validating the identified innovations is, therefore, important in identifying those that have high potential for further improvement and dissemination. However, farmers have developed several innovations and thorough validation of these innovations is very expensive (Bentley, 2006). Methods that will ensure easy verification of identified innovations will be useful in efforts to recommend best-bet innovations to other farmers.

It is against these backdrops that this thesis – in three independent but related chapters – looks at the determinants, impacts, and identification and validation of farmer innovation processes. First, taking inspiration from the induced innovation and innovation systems' theories, we analyse the factors that are necessary in building farmers' capacity to innovate.

In particular, we examine if participation in Farmer Field Fora (a participatory extension method), risk attitude, shocks and socio-economic conditions of farmers could explain farm households' innovation behaviour. Secondly, we estimate the impacts of farmers' innovation behaviour on several welfare indicators such as farm income, household income, food consumption expenditure, consumption expenditure, and food and nutrition security. We also analyse the role of farmer innovation in building households' resilience to climate shocks. Finally, we investigate the potential of innovation contest and household survey in scouting farmers' innovations. We also examine the potential of using multi-criteria analysis in prioritising high-potential innovations for further improvement, scientific validation or dissemination.

1.2 Research Objective

Given the research gaps indicated above, this study aims to examine the determinants and welfare impacts of innovation-generating behaviour in rural farm households. This is essential for the formulation of policies aiming at building farmers' capacity to innovate, ensuring sustainable food production and reducing rural poverty. Specifically, the study aims to address the following research questions:

1. What determines the innovation-generating behaviour in farm households?

2. Do farmers' innovations contribute to household welfare?

3. How can innovations developed by farm households be identified and prioritised for further scientific validation or improvement?

The research was conducted in northern Ghana, a region highly vulnerable to climate change and food insecurity. The study was carried out under the West Africa Science Center for Climate Change and Adapted Land Use (WASCAL), a research-focused programme funded by the German Federal Ministry of Education and Research (BMBF), which aims at enhancing human and environmental systems resilience to climate change and variability.

1.3 Conceptual framework

The conceptual framework in Figure 1.1 is offered to analyse the determinants and outcomes of farmer innovation. The various factors hypothesised to influence farmer innovation are motivated largely by the induced innovation and innovation systems perspectives. Climate change, which manifests in decreasing and erratic rainfall as well as frequent extreme events (droughts and floods), may induce farmers to innovate in order to adapt. The scarcity of factors of production such as land and labour could also lead to the development of input-saving innovations. Households facing other production constraints (e.g. pests and diseases) at the farm level will need innovative solutions, and this could induce innovativeness. Institutional arrangements that provide opportunities for interactions among different actors in the agricultural sector could enhance farmers' innovativeness. Farmer innovation could also be triggered by the presence of an enabling environment (e.g. infrastructure) and policies such as property rights as well as market opportunities. Conversely, inappropriate policy environment may undermine farmers' creativity and incentive to innovate. The conditioning factors of farmers' innovative behaviour include various household socio-economic and farm characteristics.

There are interlinkages between the different drivers of farmer innovativeness. For instance, climate change could trigger pests and diseases or socio-economic problems which will induce households to be innovative; hence, climate change may not be the proximate driver of innovation.

The innovativeness of households in response to such challenges and opportunities could improve farm productivity, which may translate into increased farm income and improved food and nutrition security. Labour- or input-saving farmers' innovations may result in resource reallocation, which could have indirect effect on household income. Farmer innovation could also contribute to household consumption expenditure and building resilience to climate shocks through increased production and income.

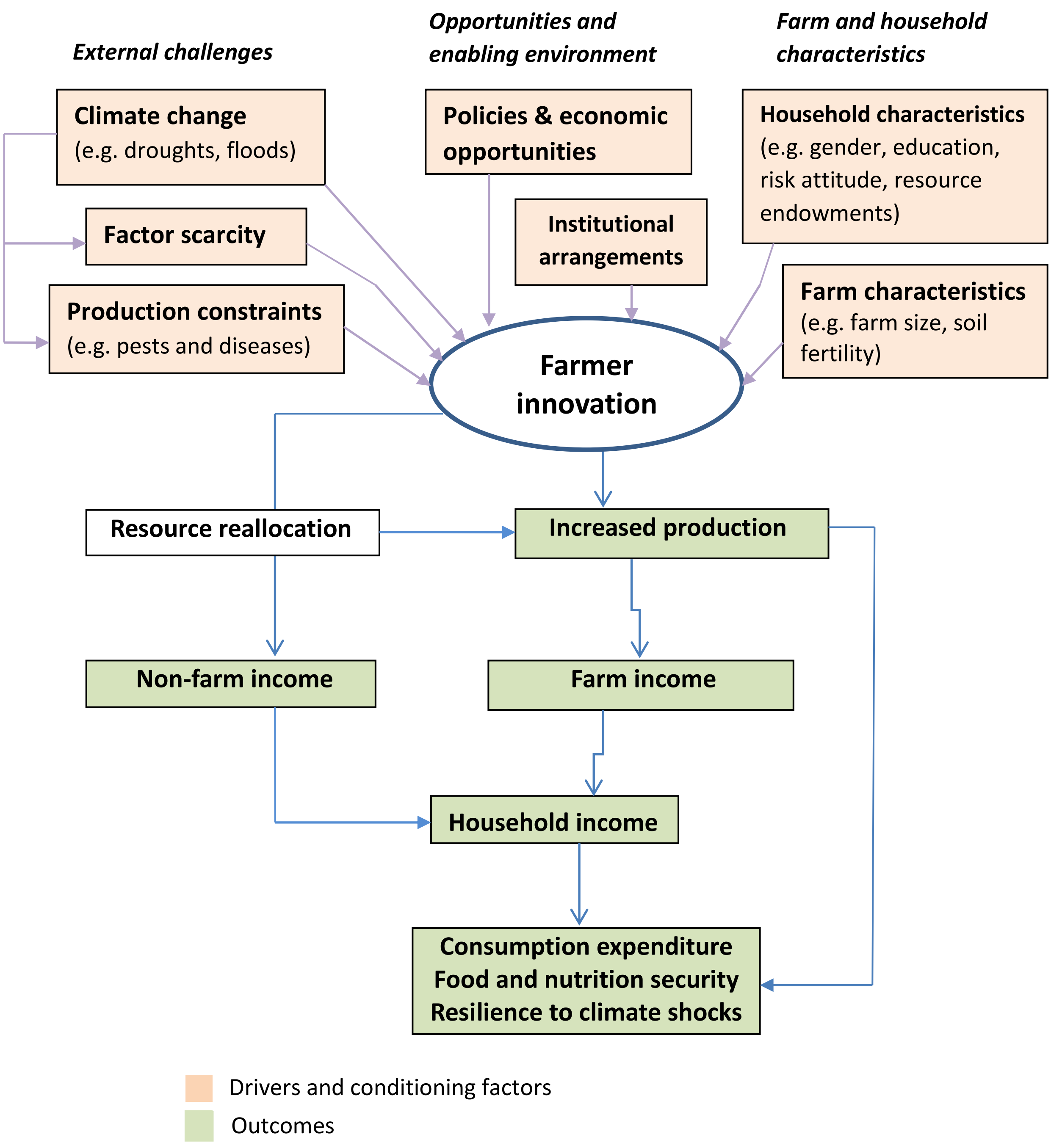


Figure 1.1: Conceptual framework for analysis
Source: Own presentation

1.4 Farmer innovation

Farmer innovation is the basis for evolution in agriculture and is essential for the development of local farming systems (Bunch, 1989; Sumberg and Okali, 1997). It is the process through which farmers adapt numerous technologies and practices to different conditions. It empowers farmers and lead to the creation of local or indigenous knowledge (Sumberg and Okali, 1997). Farmers' innovations are argued to contribute to improved rural livelihoods and food security (Reij and Waters-Bayer, 2001; Saad, 2002). The importance of farmer innovation for agricultural and rural development and the growing recognition of the need for increased participation of farmers in agricultural research have stimulated interest in the subject in recent decades.

While there is a growing level of interest in farmer innovation, the literature provides no clear or consensus definition of the concept "farmer innovation". Different studies and research programmes have used varied definitions. For instance Waters-Bayer et al. (2009, p.239) defined local (farmer) innovation as "the process through which individuals or groups within a given locality discover or develop and apply improved ways of managing the available resources – building on and expanding the boundaries of their indigenous knowledge". Wettasinha et al. (2008, p.4) regarded farmer innovation as "the process by which people in a given locality discover or develop new and better ways of doing things– using locally available resources and on their own initiative without pressure or direct support from formal research or development agents". Waters-Bayer and Bayer (2009) added that farmer innovation includes modifying or adapting existing knowledge, which can be local or external initiatives. They further indicated that the innovations are new to a particular locality, but not necessarily new to the world. To differentiate from traditional knowledge, GebreMichael (2001) considered farmer innovation as something new that has been started within the lifetime of a farmer, and not something inherited from parent or grandparents. Finally, Saad (2002, p.3) referred to "activities that farmers engage in independently of the formal research sector" as farmer innovation. The common element running through most of these definitions is that farmer innovation relates to experiment, adaptation and invention, and not adoption of introduced technologies. Also, it is initiated by farmers, and not external agents.

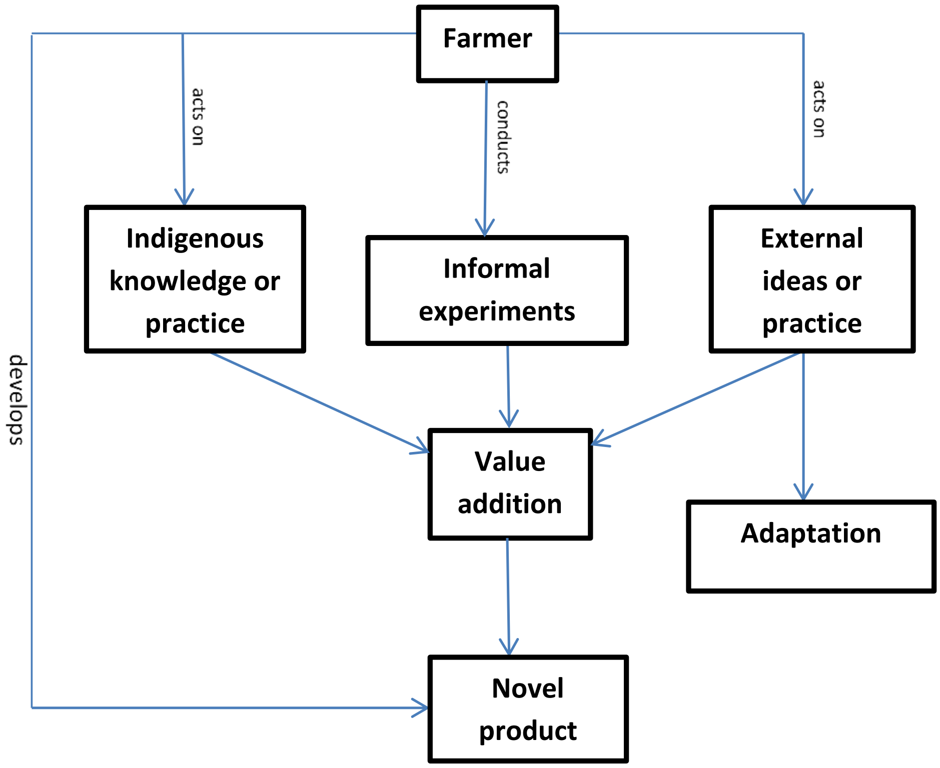


Figure 1.2: Farmer innovation process
Source Prolinnova-Ethiopia (2006), modified by author

Figure 1.2 presents the various aspects of farmer innovation. It shows that a farmer innovator is someone who: conducts informal experiments based on his own ideas; is testing various indigenous and or external ideas or practices; is modifying and adapting technologies brought from outside to local conditions; is improving or adding value to external and local practices to solve problems; or has developed a novel product such as new technologies or better ways of carrying out farming activities. Thus, in this thesis, farmer innovation is defined as a new or modified practice, technique or product that was developed by an individual farmer or a group of farmers without direct support from external agents or formal research. A key aspect of farmer innovation process is experimentation, which involves the process of trying, testing, generating or evaluating a technique or practice by an innovator (Saad, 2002; Sumberg and Okali, 1997). Hence, in the innovation literature, farmer innovation is sometimes referred to as farmers' experiments (Sumberg and Okali, 1997), folk experiments (Bentley, 1995) or lay experimentation (Saad, 2002).

Farmers innovate in several domains to suit the complex and diverse farming systems; hence, these innovations can be considered as farming system innovations. Most of the farmers' innovations identified by previous studies are technical in nature with very few institutional innovations. Commonly observed topics of farmers' innovations include new crop and variety, soil fertility, soil conservation, time of planting, planting methods, crop spacing and density, land preparation, intercropping, weed and pest management, animal husbandry and farm tools (Bunch, 1989; Sumberg and Okali, 1997; Kummer 2011; Leitgeb et al., 2014). The most frequently cited farmer innovation domain in the literature is related to the testing and development of planting materials (Sumberg and Okali, 1997).

The ideas for farmer innovation are largely based on innovators' own knowledge or are inspired by other farmers (Kummer, 2011; Leitgeb, 2014), which suggests that farmers possess innovation-generating abilities. The innovation literature suggests several factors as potential motives for or drivers of farmers' decisions to innovate. A farmer may innovate out of curiosity, coincidence, peer pressure or interest in increasing production or solving problems (Millar, 1994; Nielsen, 2001; Leitgeb, 2014). Sumberg and Okali (1997) cites perception of a problem, soil infertility, price change, commitment to farming, method of crop propagation, life cycle of crop, promotional activities (e.g. extension programmes) and degree of commercialization as some of the factors influencing farmers' innovation processes. Bentley (2006) also notes that economic changes, such as increased demand for certain products, improved roads, input prices, tax and subsidy, as well as response to environmental disasters, may drive farmers to experiment. While some authors argue that farmer innovators may differ from non-innovators in terms of personal characteristics such as gender, age, wealth and devotion to farming (Reij and Waters-Bayer 2001), others claim that there is no specific group of farmers who innovate, and most socio-economic variables do not affect farmers' innovativeness (Sumberg and Okali, 1997; Nielsen, 2001).

Farmer innovators determine the success or failure of their innovations by comparing with own experiences, other farmers and information from experts, or through side-by-side comparison with other part of their farms (Kummer, 2001). Most of the farmers' innovations reported in the literature are often minor modification of existing farming systems, and adaptation of practices and technologies to solve location-specific problems

(Lyon, 1996; Nielsen 2001). Some of them are novel techniques or practices. The frequently cited outcomes of farmers' innovations include increased knowledge, improved productivity, better income and food security, and labour and capital saving (Bentley, 2006; Kummer, 2011; Leitgeb et al., 2014). Using robust estimation techniques and data from rural Ghana, this thesis aims to add new empirical insights into the drivers and impacts of farmer innovation.

1.5 The Ghanaian Context

As is typical for many African countries, agriculture plays a key role in Ghana's economy. It accounts for about 22% of Ghana's gross domestic product (GDP) in comparison to the service and industrial sectors which account for 49.5% and 28.6%, respectively (GSS, 2014). The economy of Ghana is still largely agrarian despite the declining share of agriculture in GDP since the 1980's. The agricultural sector employs nearly half of the country's total labour force, and as much as 76% of rural households derive their livelihood from agriculture (GSS, 2013). With rural population constituting about half of the total population of Ghana (GSS, 2013), and with about 45% of the poor being food crop farmers (Curtis, 2013), agriculture remains important in the country's poverty reduction and development efforts.

Agriculture in Ghana is predominantly subsistent smallholder farming with about 90% of farm sizes being less than 2 hectares (MoFA, 2013). A wide range of crops are grown across the various agro-ecological zones in the country. These include staples such as cereals (e.g. maize, rice, millet, and sorghum); root and tubers (e.g. cassava, cocoyam, yam, sweet potato); vegetables (e.g. tomato, pepper, okro, onion); fruits (e.g. pineapple, citrus, banana, pawpaw, and mango); and industrial crops (e.g. cocoa, oil palm, coconut, coffee, rubber). Among the most widely cultivated crops include cocoa, maize and cassava (MoFA, 2013). The production of cereals and root and tubers are important for household food supply while the industrial crops are essentially for export earnings. While Ghana's agriculture is dominated by crop production, many farm households also engage in livestock production.

Recognising the importance of agriculture to the country's economy, successive Ghana governments have over the years developed several policy frameworks aimed enhancing growth in the agricultural sector. Some of the policy initiatives in the past two decades include: the Medium Term Agricultural Development Program (MTADP, 1991-2000); the Accelerated Agricultural Growth and Development Strategy in 1996; the Food and Agriculture Sector Development Policy I (FASDEP I) in 2002, which was revised into FASDEP II in 2007; the Ghana Poverty Reduction Strategy (GPRS I) 2003-2005; the Ghana Poverty Reduction Strategy II 2006-2009 (GPRS II); and recently the Medium Term Agriculture Sector Investment Plan (METASIP, 2011-2015) (Asuming-Brempong and Kuwornu, 2013). The interventions of the various policies include liberalization of input and output markets, investment in research, development and effective dissemination of improved technologies, irrigation development, crop diversification, development of mechanization services, improved access to markets and financial resources, value chain development, human resources development and strengthening of farmer-based organizations (Kolavalli et al., 2010).

The various policies produced mixed results, but overall, they contributed to improved performance of the agricultural sector. The sector recorded mostly positive growth (albeit irregularly) in the past two decades. Until the past few years, the agricultural sector experienced accelerated growth than the non-agricultural sectors (Breisinger et al., 2008). These reforms also resulted in some significant impacts such as improved income and food security, reduction in rural poverty, and reduction in rural-urban migration, particularly in northern Ghana (Asuming-Brempong and Kuwornu, 2013). The increased investment in agricultural research also yielded some successes such as the development and dissemination of several improved technologies by various research institutions in the country (Curtis, 2013).

Despite the achievements of the agricultural sector in the last two decades, there are still a number of challenges facing the sector. The sector is still characterised by low productivity, and much of the growth in agriculture is attributed to land expansion (Kolavalli et al., 2010). Average yield of crops are estimated to be less than half of achievable yields (Asuming-Brempong et al., 2006). The causes of the low productivity include, among other things, limited extension services, lack of support for innovation in smallholder farming and low adoption of agricultural technologies (Aryeetey, 2005; Asmah, 2011; Curtis, 2013). The top-down approach to research and technology dissemination has been identified one of the main causes of the poor adoption of technologies in Ghana, hence, the need for participatory research (MoFA, 2010). However, the various policies on investment in agricultural research and the promotion of agricultural innovations have largely focused on technologies developed by research institutions with little or no consideration of farmers' innovations. In the latest agricultural policy framework of Ghana (METASIP), there is increasing interest in using participatory research approaches for the promotion of agricultural technologies (MoFA, 2010). Thus, recognising and supporting farmer-focused approaches such as farmer innovation could play a key role in achieving the objectives of this new policy direction.

Agricultural extension services are essential for improving agricultural productivity in Ghana. Agricultural extension agents link researchers and farmers and provide valuable information and services related to new techniques of farming, input supply and access to credit (Buadi et al., 2013). The extension service providers in Ghana include the Ministry of Food and Agriculture (MOFA), public research and educational institutions, private firms and NGOs. Over the years, these extension service providers have used varied extension models ranging from top-down to decentralised approaches, and some of the models currently used in Ghana include Commodity approach, Training and Visit (T&V), Participatory approach and Farmer Field Schools (FFS) (MoFA, 2011).

The commodity approach, which was highly used prior to Ghana's independence in 1957 (Asuming-Brempong et al., 2006), is mainly employed by private firms and operates in the form of value chains or outgrower schemes. The firms provide agricultural services (e.g. input and advisory services) to farmers and in return, purchase their products which are usually export crops (MoFA, 2011). The T&V approach involves the transfer of information and technologies from researchers to farmers. Its limitations such as little recognition of farmers' knowledge and diversity of farming systems led to the adoption of participatory approaches (Okorley, 2007; MoFA, 2011). The participatory approaches focus on empowering farmers, and extension agents serve as facilitators who guide farmers to identify their production constraints and provide techniques necessary to address the identified constraints (MoFA, 2011). One of such participatory learning approaches is the FFS which was initiated in Ghana in 1996 by the Food and Agriculture Organization (FAO) and has since been incorporated into various agricultural projects in the country. It is useful in teaching farmers knowledge-intensive practices and encourages adoption of new technologies. A related concept to the FFS is the Farmer Field Fora (FFF) which was recently practiced in Ghana under the Root and Tuber Marketing Improvement Programme (RTIMP). The FFF encourages learning among stakeholders to address specific constraints and also aims to build farmers' capacity to generate location-specific innovations. An aspect of this thesis looks at the potential of the FFF in enhancing innovation capacity of farmers.

Studies have shown that there is a huge innovation potential among Ghanaian farmers. For instance, in a study in the Eastern and Brong Ahafo regions of Ghana, Sumberg and Okali (1997) found that farmers' experiment, particularly in the areas of new varieties, land preparation, and plant spacing and density. The outcomes of the experiments include novel techniques and major or minor modifications of existing practices. Millar (1994) argued that almost every farmer in northern Ghana experiments to some extent, and the experiments are driven by curiosity, problem-solving, adaptation and peer-pressure. Bruce et al. (2004) also reported that the high cost of fertilizer and veterinary drugs due to the removal of input subsidies in Ghana resulted in increased farmer experiments and innovations in the areas of ethnoveterinary medicines and soil fertility. Pineapple farmers in the Nsawam Municipal Assembly of Ghana are also noted to innovate and experiment through training received from NGOs and government agencies, observation, discussions, accidental discoveries and influence from large-scale commercial farms (AduAnkrah, 2014).

Over the years, there have been some efforts to promote farmer innovations in Ghana, but these have mostly been NGO-led initiatives. With the increasing concern for sustainable agriculture, and the recognition that farmers have innovation potentials, along with the low level of adoption of technologies developed by research institutions, some agricultural development organisations, facilitated by the Association of Church Development Projects (ACDEP), established the Northern Ghana LEISA Working Group (NGLWG) in the mid-1990s with the goal of recognising indigenous knowledge, supporting farmers' efforts to develop

Low-External-Input and Sustainable Agriculture (LEISA) technologies, and strengthening the partnership between farmers and formal research in northern Ghana (Bruce et al., 2004). In 2003, the NGLWG together with two southern Ghana NGOs started the Prolinnova Ghana Network (Bruce et al., 2004; Karbo, 2008). In more recent years, however, the main activity of Prolinnova is concentrated in northern Ghana, with ACDEP as the coordinating institution (Prolinnova, 2014). Among the aims and achievements of the Prolinnova Ghana network include creating awareness of local innovations, identification, documentation and dissemination of several farmers' innovations, providing financial support to farmer innovators, and participatory innovation development (Karbo, 2008; Prolinnova Ghana, 2006; Avornyo et al., 2012).

Despite these achievements, there is still the challenge of mainstreaming the farmer innovation process into formal agricultural research in Ghana. Farmer innovations are hardly considered by formal research in Ghana (Tagoe, 2006). Providing robust assessments of farmer innovation will contribute to speeding up the process of supporting and institutionalising farmer innovation in Ghana, and this study aims to contribute to this process.

1.6 Research methods

1.6.1 Study area

The study was conducted in the Upper East region of northern Ghana, which is one of the study areas of the WASCAL research programme. The region has a population of 1046545, covers an area of 8.84 km^2, and is densely populated with 118 people per km^2 (GSS, 2012). It shares boundaries with two countries (Burkina Faso and Togo), and two other regions in northern Ghana (Upper West and Northern regions). The region is one of the poorest in Ghana, and majority of the households (76.4%) live in rural areas (GSS, 2012). Agriculture is the predominant economic activity in the area. More households (83.7%) in the Upper East region are involved in agriculture relative to other regions in the country (GSS, 2012). The region is located in the Sudan savanna agro-ecological zone. The farming system is mainly the systems of permanent cultivation on rain-fed land which is characterised by high population density, small land holdings, soil degradation, low labour productivity, predominance of annual and biannual crops and increasing cash crop production (Ruthenberg, 1971). Rainfall is erratic, unpredictable and unimodal, with about 600 to 900 mm rainfall per year and 90-140 growing days (Ker, 1995). There are a number of dams and dugouts in many villages which support farming in the region, particularly during the prolonged dry season. Many households engage in non-farm income earning activities such as artisanry, processing of shea butter and brewing of local beer. Seasonal labour migration from the region to southern Ghana is also common.

The survey communities consist largely of several dispersed compound houses. Each compound comprises mostly of a number of mud huts that serve as dwellings for various households (averagely 3 in the sampled households) from the same patrilineal family. The head of the compound is often the eldest male of the family. Each household in the compound makes production and consumption decisions independently; hence, farm household is the unit of our analysis. Farming is carried out on compound farms which are located near the homesteads and bush farms which are often far from the communities. The compound farms have higher contents of soil nutrients as it receives most of the nutrients in the form of livestock droppings and household wastes, hence, are cultivated permanently (Runge-Metzger and Diehl, 1993). The bush farms are cultivated for a few years, after which soil fertility is restored primarily through fallowing (Ker, 1995). Cereal-legume intercropping system is commonly practiced in the region. The major crops are millet, sorghum, maize, cowpea, rice and groundnut. Tomato and pepper are also cultivated in the dry season under irrigated farming. Many farm households also own livestock, mainly cattle, sheep, goats, chickens and guinea fowls.

1.6.2 Data collection

The data for this thesis was obtained through an innovation contest (designed and implemented by Tobias Wünscher with the assistance of the author in selected tasks), household surveys and a stakeholder workshop. The contest was used to identify high-potential farmer innovations in the region. In collaboration with local partners, the contest was implemented between August and November 2012 in all the nine districts of the region. Extension services and radio announcements were used to disseminate information on the contest. Workshops were held at each of the nine MoFA district offices to introduce the concept of farmer innovation and innovation contest, and explain the application processes to extension agents who were to serve as contact points for the contest application. The extension agents were given application forms which were purposely designed for the contest, and asked to search for farmer innovations in their assigned zones and assist the innovators to fill the application forms after verifying that they are the originators of the innovations. URA radio, a radio station located in the regional capital (Bolgatanga) was contracted to broadcast information on the contest. They developed a one-minute radio jingle on the contest in the various local languages and aired them daily for about two months. Farmers who have developed innovations were asked to contact extension officers to help them fill applications and submit them to the contest. An 8-member evaluation committee was then set-up to evaluate all the submitted applications. The innovations were ranked and the top three innovators were given certificates and prizes during the annual National Farmers' Day celebration.

The household survey was conducted between December 2012 and May 2013 in Bongo, Kassena Nankana East and Kassena Nankana West districts in the Upper East region. Part of this research aimed at examining the effect of a participatory extension approach, the Farmer Field Fora (FFF), on farmers' innovativeness; hence, this influenced the choice of the three districts and sampling strategy used in this study. The three selected districts are among the four districts in the Upper East region where the FFF programmes have been implemented. Using a stratified random sampling, we selected farm households from 17 communities (Figure 1.3) across the three districts. The sample included FFF participants, non-participants from FFF communities and non-participants from control communities. We first obtained a list of all the 24 villages in the three districts where FFF has been implemented between 2008 and 2011. Then we randomly selected 10 participating villages across the three districts. In each FFF, there were either 30 or 40 participants and we selected about 16-21 participants from each village, resulting in a total of 185 FFF participants. We also obtained a list of all households in each participating village and randomly selected 99 farmers across the 10 villages. Since these farmers are located in the same FFF villages, they may be potentially exposed to some of the effects of FFF. To obtain group of control farmers devoid of potential spillovers, we randomly selected seven villages from the three districts that are quite homogeneous with the FFF communities in terms of infrastructural services and socio-economic conditions but far enough to be influenced by the FFF activities. Out of these, we randomly selected 125 farm households from a household list obtained from the District Agricultural Offices. Thus, our final sample consists of 185 FFF participants, 99 non-participants from FFF communities and 125 non-participants from control communities, making a total of 409 farm households.

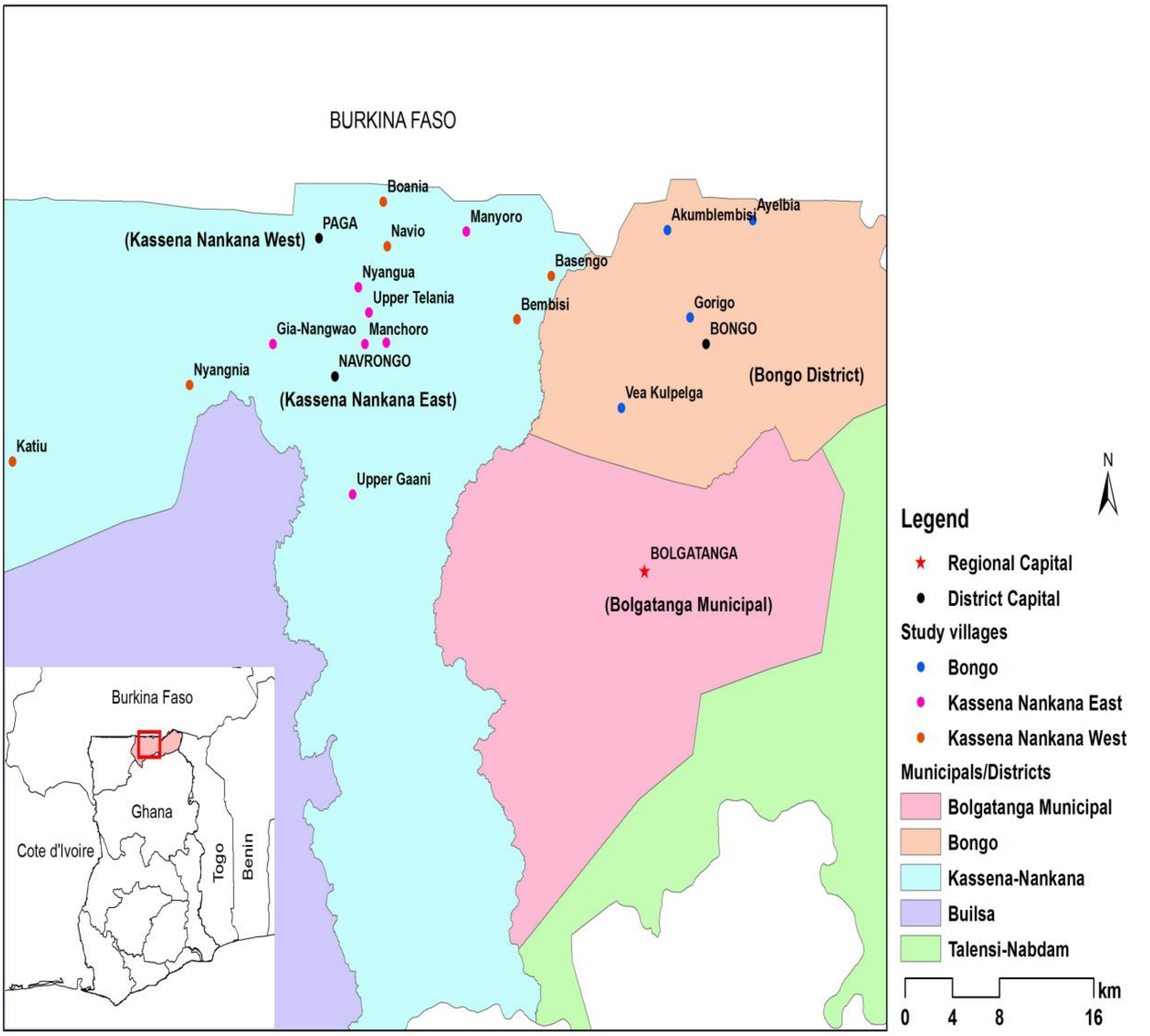


Figure 1.3: Location of the study communities
Source: Own presentation

The household survey was implemented in two phases by experienced enumerators who were highly trained for this research. Interviews were conducted with the aid of pre-tested questionnaires and were supervised by the author. Most of the interviews were conducted in the local languages: *Gurini, Kasem* and *Nankane*. The first phase of the survey was conducted between December 2012 and March 2013. The questionnaire used in this phase captured data on household and plot characteristics, crop and livestock production, off-farm income earning activities, innovation-generating activities, access to infrastructural services, information and social interventions, household experiences with shocks, climate change adaptation strategies and risk preferences. In second phase, which was implemented just after the end of the first phase, the same households were revisited and interviewed to obtain data on various food security indicators. In this phase, the survey was conducted simultaneously in the three districts so that the households' subjective responses to food insecurity are not influenced by differences in survey periods.

The final data collection process involved a participatory stakeholders' workshop which was held on 10 May 2013 at the Water Resources Commission of Ghana office in Bolgatanga. Twelve agricultural experts and stakeholders with extensive knowledge of farmer innovations and farming systems in the region were invited from research institutions, MoFA, NGO's and farmer organizations to prioritise the innovations obtained through the contest and household survey. The workshop activities included identification of criteria to evaluate the innovations, weighting of each criterion and assigning scores to the innovations using the weighted criteria.

1.7 Outline of the study

The remainder of the thesis is organised into three main chapters that address the formulated research questions in section 1.2. In chapter 2, the determinants of farmer innovation are analysed. Inspired by the induced innovation and innovation systems theories, various socio-economic, institutional and shock-related factors that explain farmers' decision to innovate are identified. We particularly focus on the potential of FFF in explaining farmers' innovativeness. Recursive bivariate probit and endogenous treatment regression estimation methods are employed to account for selection bias. Several robustness checks are also conducted using different specification of farmer innovation and estimation techniques such as propensity score matching. Moreover, spillover and heterogeneous effects of FFF participation on innovation are assessed in this chapter.

Chapter 3 analyses the impact of farmer innovation on household welfare. Using the agricultural household model as a theoretical model, we estimate the effect of farmer innovation on several outcome indicators, including consumption expenditure, farm and household income, food security and resilience to climate shocks. The potential endogeneity of innovation is addressed using endogenous switching regression estimation technique. The chapter also presents the subjective outcomes of farmer innovation as indicated by the innovators.

Chapter 4 presents the methods used in identifying and prioritising farmers' innovations. A brief review of some past and current initiatives and institutional arrangements for the promotion of farmer innovation are provided. The use of contest in scouting farmer innovations is presented. The multi-criteria decision making analysis, which was used in prioritising the identified innovations, and the results obtained are also presented. This chapter also describes some of the outstanding innovations identified in the study region.

Finally, chapter 5 concludes the thesis. The chapter provides a summary of the results, policy implications and directions for future research.

What determines innovation capacity in farm households? Insights from rural Ghana

"If I hear it, I forget it. If I see it, I remember it. If I discover it, I own it for life." A Chinese proverb

2.1 Introduction

Innovation is essential for agricultural and economic development (Hayami and Ruttan, 1985; World Bank, 2011). The need to overcome challenges and harness opportunities has induced the development of several innovations in agriculture (Hayami and Ruttan, 1985; Goldman, 1993). However, the focus of research and development has mainly been on externally-driven innovations which are generated by universities and research institutions. There is a mounting body of evidence on the positive impacts of these innovations. However, externally-driven innovations are often promoted in Africa using the transfer-of-technology (ToT) model, which considers farmers as recipients of knowledge only. This has led to the development of technologies that are inappropriate for farmers' conditions (Röling, 2009a; Reij and Waters-Bayer, 2001; Letty et al., 2011). Hampered by a number of constraints, smallholders often cannot benefit from these technologies which are may be unavailable, expensive for resource-poor farmers or require complementary inputs (e.g. fertilizer) which can increase environmental problems (Chambers et al., 1989; Tambo and Abdoulaye, 2012).

Over the years, farmers have also been recognised as innovators (i.e., generators of new practices) and experimenters, rather than mere adopters of introduced technologies. In fact, farmers have been innovating long before the emergence of formal research and development (Biggs and Clay, 1981), and there are even claims that some of the technologies developed by scientists were actually based on ideas and practices of local farmers (Rhoades, 1989; Röling, 2009b). In the face of increasing global challenges, rural farmers are becoming more innovative (Sanginga et al., 2009). They engage in informal experimentation, develop new technologies and modify or adapt external innovations to suit their local environments (Reij and Waters-Bayer, 2001). Farmer innovation processes are claimed to be relatively inexpensive, easily accessible, locally appropriate and highly disseminated (Waters-Bayer and Bayer, 2009). Thus, farmer innovation could complement the highly promoted external innovations in addressing increasing challenges in agriculture, and also contribute to sustainable intensification efforts.

There has been some attention on promoting farmer innovations in recent years. For instance, the establishment of Prolinnova – a global learning network seeking to promote local innovation in ecologically-oriented agriculture and natural resource management – in 1999 has facilitated the identification and promotion of farmer innovation in several developing countries. While there is increased interest in promoting farmer innovation, little attention has been paid to what determines the innovation-generating practices of farmers. The plethora of studies on innovative behaviour of farmers has focussed on adoption with little consideration for innovation generation. The few studies on the determinants of farmer innovativeness (e.g. Reij and Waters-Bayer, 2001; Nielsen, 2001; Kummer, 2010) are also either qualitative or only found in the grey literature. In this paper, we attempt to address this gap in the innovation literature using econometric techniques. Thus, the main objective of this paper is to assess the determinants of innovation-generating behaviour in farm households. This is essential for policy efforts aiming at promoting farmer innovation, strengthening innovation capacity of farm households, and sustainable intensification.

In examining the determinants of innovation generation[1], we rely on elements of the induced innovation hypothesis and the innovation systems perspective. The induced innovation hypothesis considers challenges and opportunities as key drivers of innovation, whereas the innovation systems approach argues that innovations emerge through networks of actors and organizations. We focus particularly on farm households' participation in Farmer Field Fora (FFF), a participatory platform for enhancing innovation capacities, as a measure of the innovation system approach. To account for the possible selection bias from the non-random nature of the FFF participation, endogenous treatment-regression and recursive bivariate probit models are used in estimating the determinants of farmers' innovative behaviour. We also employ propensity score matching (PSM) method and alternative specifications to examine the robustness of the effect of FFF participation on

[1] Innovation generation, innovation capacity, innovation behaviour and farmer innovation are used interchangeably in this paper.

innovation generation. We also analyse spillover and heterogeneous effects of FFF participation on innovation generation. The analyses are based on farm household data obtained from rural northern Ghana, which is an interesting case study. On the one hand, northern Ghana is characterised with resource-poor farmers who face challenges of climate change, soil infertility, land degradation, pest and diseases, population pressure and food insecurity (Runge-Metzger and Diehl, 1993), and thus serves as an appropriate example for analysing the induced innovation hypothesis. On the other hand, there are FFF programmes in the region which can be used in studying the effects of innovation systems in building farmers' innovation capacity.

The contribution of this paper to the extant literature is twofold. First, we focus on the drivers of innovation generation instead of innovation adoption, which has been studied extensively. Secondly, there are many studies looking at the impact of farmer field schools (FFS) on outcome variables such as empowerment, technology adoption, household income and food security but with inconclusive findings (for a review, see Davis et al., 2012, Table 1). Within this vast literature, however, there is little, if any, on the innovation-generating effects of FFS. This study provides empirical evidence on the potential of FFF, a variant of FFS, in stimulating innovation-generating behaviour among farm households.

The remainder of this paper is structured as follows. Section 2 presents the theories and relevant concepts of the study. In section 3, we explain the methods. Here, we describe in detail the estimation approaches, the data used for the analyses and also some descriptive statistics. The results and discussion are presented in section 4. We first highlight the determinants of innovation generation and then present alternative estimation methods. We also present spillover and heterogeneous effects of FFF participation in this section. Finally, section 5 concludes this paper.

2.2 Theories and Concepts

2.2.1 The concept of farmer innovation

There are several definitions and classifications of innovation (for an overview, see Garcia and Calantone, 2002), and this is partly because research on innovation spans many disciplines. Nonetheless, innovation generally entails the implementation of new or significantly improved products, processes or methods (OECD, 2005). In agriculture, it is well acknowledged that innovations could emerge from many sources including farmers, and these are normally referred to as farmers' innovations (Biggs and Clay, 1981; Röling, 2009b). Farmer innovation is sometimes termed farmer-driven or farmer-led innovation, grassroot innovation, local innovation, folk or farmer experiment, etc. (Saad, 2002). Similar to innovation, there is no generally agreed definition for a farmer innovation or a farmer innovator. It is, however, different from the concept in the literature on adoption and diffusion of innovations in which adopters or the first group of adopters of introduced technologies are referred to as innovators (Rogers, 1962). Following Saad (2002) and Waters-Bayer et al. (2009), we define a farmer innovation to be a new or modified practice, technique or product that was developed by an individual farmer or a group of farmers without direct support from external agents or formal research. In our study, the term innovative behaviour goes beyond the final outcome and encompasses activities of the innovation process such as experimentation. Innovation processes or activities may be new to farmers in one community, but not necessarily new to farmers in other communities (Saad, 2002; Waters-Bayer and Bayer, 2009).

In this study, we focus on four categories of innovation-generating activities of farm households. These are: (i) developing new techniques or practices (hereafter, invention), (ii) adding value or modifying indigenous or traditional practices, (iii) modifying or adapting external techniques or practices to local conditions or farming systems, and (iv) informal experimentation. Thus, innovators are farm households who have implemented any of these four categories of innovation-generating activities during the 12 months prior to the survey. There are several factors that can trigger the implementation of these innovation-generating activities. These include shocks, scarcity of factors of production, opportunities, stakeholder interactions, or socio-economic factors. This study relies on two innovation theories (induced innovation and innovation systems) in explaining the drivers of farmer innovation, and these are discussed below.

2.2.2 Induced innovation

The induced innovation theory was initially suggested by Hicks (1932), and it posits that changes in relative prices of production factors are expected to induce development and implementation of new technology to save relatively more expensive factors. This hypothesis has been frequently tested in agricultural growth using varied methods. The empirical research began with Hayami and Ruttan (1970) who verified the theory by showing, for instance, that land shortages induce land-saving technologies. Several studies on agricultural growth have also sought to test this hypothesis, and the results have often been mixed. While numerous studies such as Kawagoe et al. (1986), Thirtle et al. (1998), Thirtle et al. (2002) and Piesse (2011) confirmed the hypothesis, the findings of some recent studies (e.g. Olmstead and Rhode, 1993; Liu and Schumway, 2006; Liu and Schumway, 2009) contradict the hypothesis.

The original idea of the theory was price-induced innovation, and there have since been many variants. Hayami and Ruttan (1985) extended the theory to include response by research scientists to resource endowments and economic change. There is also the induced innovation concept of Boserup (1965), which suggests that increasing population density can stimulate technological innovations that increase land use intensity. In recent years climate-induced innovation has emerged as a basis for understanding the potential role of climate change in stimulating innovation (Easterling, 1996; Sunding and Zilberman, 2001). Thus, the anticipation that farmers will be at risk from climate change encourages innovation. Empirical evidence seems to support this argument. Chhetri et al. (2012), for instance, show that climate change induces the innovation of location-specific rice varieties and climatically appropriate agronomic practices in Nepal. McSweeney and Coomes (2011) also found that climate-related shocks open opportunity for innovation among the rural poor in Honduras. The induced innovation hypothesis can also be used in explaining the generation of new innovations to address production constraints such as the random emergence of pests and diseases (Sunding and Zilberman, 2001).

Other authors argue that innovation in a region is not only determined by factor scarcities or constraints, but also by economic and market-related opportunities, agro-ecological conditions and government policies (Goldman, 1993; Sunding and Zilberman, 2001). This is evident in the unevenness of the impact of Green Revolution, with many success stories in regions with established irrigation and favourable agro-ecological conditions (Goldman, 1993).

Thus, proponents of induced innovation theory argue that innovation is driven by the need to overcome limitations such as factor scarcity, and take advantage of economic opportunities and public policies. It should be emphasised that existing empirical work examining the induced innovation theory has mainly focussed on modern technologies in agriculture, but this study, in contrast, examines innovative behaviour of farmers which has rarely been considered in the induced innovation literature. Also, this study is based on a cross-sectional household survey data; hence, we do not intend to test the theory. Rather, we take inspiration from the variants of the theory to examine if constraints to production such as climate, pest and diseases and labour shocks, and opportunities such as increased market access induce innovativeness in farm households.

2.2.3 Innovation systems

The innovation systems approach emerged as a result of the increasing recognition that the ToT model which views innovation as a linear process driven by the supply of research and development has not fulfilled expectations in terms of developing locally adapted innovative practices (Röling, 2009a; World Bank, 2011). An innovation systems can be defined as "comprising the organizations, enterprises, and individuals that together demand and supply knowledge and technology, and the rules and mechanisms by which these different agents interact." (World Bank, 2006, p.5). The concept is applied in many disciplines, and in agriculture, it is commonly refer to as the agricultural innovation systems (AIS). The AIS is a recent concept that builds on two earlier innovation frameworks: national agricultural research systems (NARS) in the 1980s and agricultural knowledge and information systems (AKIS) in the 1990s (World Bank, 2006; Rajalahti, 2009).

The innovation systems approach acknowledges the role of education, research, and extension in supplying new knowledge and technology to the farmer, but in addition, it recognises the farmer as part of a complex network of heterogeneous agents who engage in innovation processes, and also looks at the actions and interactions that link these agents to each other, along with the formal and informal institutions and policy environments that influence these processes (Spielman, 2005). Hence, the approach argues for strengthening the interactions between actors of the innovation process. It emphasizes highly on building innovative capacity and acknowledges the important role of an enabling environment for innovation generation (Rajalahti, 2009).

The concept has often been criticized for the limited understanding and challenges of operationalising its principles as well as doubts on whether it can deliver significant impacts (Hall, 2007; Sanginga et al., 2009). However, there is a rapidly growing literature trying to evaluate the impact of using the AIS framework in developing countries. For instance Kaaria et al. (2008), Mapila and Makina (2011) and Mapila et al. (2012) empirically showed that agricultural interventions driven by the AIS framework impact positively on women's empowerment, income, and assets accumulation of rural households in Malawi and Uganda.

2.2.4 Farmer Field Fora

Our empirical analysis of the potential of the innovation systems perspective in explaining farmer innovativeness is based on the FFF of the Root and Tuber Improvement and Marketing Programme (RTIMP) in Ghana. The RTIMP used the FFF as a platform for mutual learning among stakeholders, particularly farmers, extension agents and researchers, in the root and tuber value chain. The aim of FFF is to "build the capacities of farmers to become experts in the development of technologies and managerial practices to solve specific problems within the agro-ecological context of farming" (Gbadugui and Coulibaly, 2013, p. 2). It is a variant of the well-known Farmer Field School (FFS), a participatory extension model. Unlike FFS which gives little or no attention to farmer-developed innovations (Reij and Waters-Bayer, 2001), FFF provides an opportunity for farmers to experiment with their own innovations, thereby strengthening their decision-making and innovation capacity.

The FFS approach was first introduced in Indonesia in the late 1980's by the FAO to help farmers deal with pesticide-induced pest problems in irrigated rice, but it has since spread to at least 78 countries and is highly promoted by many development agencies (Braun et al., 2006). Though it was mainly introduced to promote integrated pest management (IPM) practices in rice farming, it contents and methods have been adapted to suit the different farming activities and even with the inclusion of non-farm topics in Africa (Braun et al., 2006; Davis et al., 2012).

The RTIMP-FFF in Ghana, which started in 2006, aims at improving farmer innovation and productivity of root and tuber crops (cassava, yam, cocoyam, sweet potato and *Frafra* potato) in major production districts of the country. In each participation district, the FFF was developed for the most important root or tuber crop. This study is based on the sweet potato FFF in 10 communities in three northern districts of Ghana. The main actors include researchers, extension agents, business advisors, farmers and processors, and they are all placed on an equal footing. During a participatory rural appraisal, the farmers determine the theme of the FFF, thereby ensuring that their priorities are addressed. The thematic areas normally selected by the farmers include improved crop varieties, integrated pests management (IPM), improved cultivation practices and integrated soil fertility management. There are also discussion sessions on non-farm topics. Each forum consists of a group of 30 to 40 farmers together with other key actors who meet regularly (usually weekly) in the field during a growing season. They engage in comparative experimentations using three plots: farmers practice (FP), integrated crop management (ICM) and participatory action research (PAR), with the assistance of a facilitator who stimulates critical thinking and discussions, and ensures active participation. The participating farmers experiment with their own innovations or test new ideas on the PAR plots. Conventional and improved farming practices are implemented on the FP and ICM plots, respectively.

It should be noted that the RTIMP-FFF does not include all relevant stakeholders as required by the innovation systems model. Nevertheless, it has some elements of the model, hence, could be considered as a “partial innovation systems” framework. This is typical of most studies adopting the innovation systems framework (Sanginga et al., 2009).

2.3 Methods

2.3.1 Empirical strategy

We are interested in estimating the determinants of innovation-generating behaviour in farm households. This can be specified as:

$$FI_i = \beta_0 + \beta_1 X_i + \beta_2 \mathrm{II}_i + \beta_3 FFF_i + \beta_4 R_i + \beta_5 V_i + \varepsilon_i \qquad (1)$$

where the dependent variable *FI* (farmer innovation) indicates innovation-generating behaviour in household *i*. We use four different measures of the dependent variable to check if the results are sensitive to the indicator employed. The first (*innovation_binary*) is a binary variable which is equal to one if the household has implemented any of the four categories of farmer innovation (see section 2.3) in the past 12 months; and 0 otherwise. The second (*innovation_count*) is a count variable that indicates the number of different innovation-generating activities implemented by a household in the past 12 months. In the third and fourth measure of *FI*, we consider the varied importance of each of the four categories of farmer innovation and constructed an innovation index using weights. In the third measure of *FI* (*innovation index 1*), we followed Filmer and Pritchett (2001) and used principal component analysis (PCA) to assign weights to each of the four innovation categories, and constructed a household innovation index. The final indicator (*innovation index 2*) also involves the construction of a household innovation index but relies on weights obtained through expert judgements. A stakeholder workshop was organised and 12 agricultural experts in the study region assigned weights to the four innovation categories based on their relative importance. They assigned weights of 0.4, 0.2, 0.3 and 0.1 for invention, adaptation of exogenous ideas, modification of traditional practices and experimentation, respectively.

Variable *Xi* is a vector of household socio-demographic and economic variables that are commonly found in the agricultural innovation adoption literature (e.g. age, gender and education of the household head; household size and dependency ratio; access to services and the wealth position of the household). It also includes variables capturing land rights and soil fertility status of plots. The vector *II* contains variables motivated by the induced innovation hypothesis. It includes idiosyncratic shocks experienced by the household during the past 5 years (e.g., climatic stress, pests and diseases, and labour shocks), change in household size, and access to market opportunities. The variable FFF is equal to one if a household member participated in a FFF and zero otherwise, and we use it as a proxy for the innovation systems perspective.

Variable *R* represents household risk behaviour. Following the seminal study by Binswanger (1980), we conducted a simple experiment using the ordered lottery selection design with actual payments to elicit households' risk preferences. In the design, each respondent was presented with a choice of six lotteries (A-F), and was asked to select one. Once chosen, a coin was tossed to decide the payoff. A higher payoff could only be obtained at the cost of a higher variance. For instance, option A is the safe option, offering an actual payment of 3 GH¢ while option F has the highest payoff of 8 GH¢ but with 50% probability of no payment. Table A1 in appendix 2 shows the structure of the experiment, but it was actually presented to respondents in the form of photographs of money. This design is most suitable and generates accurate result when the respondents are mostly illiterate or less skilled in mathematics, as in our case (Harrison and Rutström, 2008). We also include village fixed effects (*V*) to control for unobserved heterogeneity in the sample villages. Finally, $\mathcal{E}$ is the random error term.

A usual problem of estimating equation 1 is the potential endogeneity of the FFF participation variable; hence, applying binary and count data regression models or ordinary least squares might yield biased estimates. There are two potential sources of endogeneity. First, there is placement endogeneity stemming from the non-random selection of FFF participating communities. Thus, if communities with more innovative farmers were selected to participate in the FFF, then the impact will be overestimated. Secondly, within the FFF communities farmer participation is voluntary, i.e. farmers self-select to participate. Thus, participating farmers may differ systematically from non-participants in unobserved characteristics such as entrepreneurship and risk behaviour which might lead to biased estimates of the effect of FFF on innovation. Due to the endogeneity issues, participants and non-participants are, therefore, not directly comparable.

To deal with these problems, we exploited our sampling frame and also used instrumental variables approach. First, in our sampling strategy, the non-participants sample was drawn from both FFF participating and non-participating villages, and this helps in reducing the problem of placement endogeneity. Though non-participants in FFF villages might potentially be affected by spillovers, we believe that participation enhances innovation-generating capacity and exposure alone does not confer this skill, and this is later proven to be true when we look at the spillover effect of FFF participation. The non-participation villages were also drawn from the same agro-ecological zone and districts as the participation villages and are likely to be the next group of FFF villages in any future scaling up. Secondly, we use village fixed effects to account for unobservable heterogeneity between villages. Furthermore, we control for risk attitude of farmers which is one of the key characteristics of innovative behaviour which, however, is often not captured in agricultural innovation studies (Feder *et al*., 1985). Finally, we employ two instruments and estimate equation 1 using recursive bivariate probit (RBP) and endogenous treatment-regression (ETR) models to further remedy the endogeneity problems. In the RBP and ETR models, we first estimate a selection model, expressed as:

$$FFF_i = \delta_0 + \delta_1 X_i + \delta_2 R_i + \delta_3 V_i + \delta_4 Z_i + \mu_i \qquad (2)$$

where *FFF, X, R* and *V* are defined as in equation 1. The vector *Z* consists of the two instruments: initial sweet potato cultivation and initial membership of farmer group[2]. We argue that these two variables affect FFF participation but do not directly affect innovation-generating behaviour. In the study region, sweet potato is a minor crop which is cultivated by almost every household, albeit irregularly and on a very small scale. Since participation in FFF is voluntary, every farmer could volunteer to join but we expect farmers who cultivated sweet potato at least two continuous cropping seasons prior to the FFF to show more interest in participating. Similarly, villages with regular sweet potato producers were more likely to be selected. Discussions with the FFF facilitators also indicated that, although not encouraged, extension officers responsible for registering interested participants appear to

[2] 'Initial' implies before the start of FFF in the participating villages and recent situation in non-participating villages. They are based on recall data.

have given preferences to farmer group members because they believed they were more likely to be committed to participate actively in the programme.

One could argue that these instruments may be endogenous to innovation-generating behaviour. To address this challenge, we use lagged variables to capture sweet potato cultivation and farmer group membership. That is, whether a farmer – before the start of FFF – (i) cultivated sweet potatoes on a regular basis, and (ii) was member of a farmer group. These are likely to be exogenous to recent innovation-generating decisions. Moreover, discussions with farmers indicate that the motivation for cultivating sweet potato regularly and joining farmer groups has nothing to do with innovation generation. Prior to FFF, the farmer groups were not active or engaging in any collective action that could induce innovation generation. Also, regular cultivation of sweet potato seems unrelated to innovation as almost all the innovation-generating activities observed are not connected to sweet potato production. Following Di Falco et al. (2011) and Fischer and Qaim (2012), we also estimated a placebo regression to test the exogeneity of our instruments. Using data from only non-participating villages, we examined the effect of the two instruments and other covariates on the innovation-generating decision of households not exposed to FFF. We expect significant effects of the two instruments if they are endogenous to the innovation-generating decision of households. The result (see Table A2 in appendix 2) indicates that there is no direct effect of the two instruments on the outcome variable; hence, both variables are valid instruments. We will show in the results section that the two instruments also significantly affect FFF participation.

As already indicated, we use four different measures of the dependent variable to check if the results are robust to different specifications of innovation generation. We therefore require estimation techniques that account for the different measures of the dependent variable and the endogeneity of the FFF participation variable. Consequently, we use three different econometric techniques. In the first model, (*innovation binary)*, we estimate a maximum likelihood RBP with instruments because both the outcome and endogenous FFF participation variables are binary. In the second model (*innovation count)*, the outcome is a count variable so we employ a Poisson regression with endogenous treatment effects

(PRETE). Finally, linear regression with endogenous treatment effects (LRETE)[3] was used in estimating model 3 (*innovation index 1)* and model 4 (*innovation index 2)*. For robustness checks, we also compute naïve models of equation 1 without accounting for the potential endogeneity of FFF participation.

2.3.2 Data and descriptive statistics

The empirical analysis is based on data for the 2011-2012 agricultural season obtained from a household survey in the districts of Bongo, Kassena Nankana East and Kassena Nankana West in the Upper East region, one of the poorest administrative regions of Ghana. The districts fall within the Sudan savanna agro-ecological zone, which is characterised by systems of permanent cultivation on rain-fed land with high population density, small land holdings, soil degradation, low labour productivity, predominance of annual and biannual crops and increasing cash crop production (Ruthenberg, 1971; Runge-Metzger and Diehl, 1993). Agriculture is the main income source and a cereal-legume cropping system is predominant in the study region. The major crops are millet, sorghum, maize, cowpea, rice and groundnut. Most households also rear livestock. The area is characterised by a prolonged dry season and erratic rainfall; hence, many of the inhabitants migrate to southern Ghana to seek employment opportunities or engage in irrigated vegetable farming during the dry season.

The sample included FFF participants, non-participants from FFF communities (hereafter, exposed farmers) and non-participants from control communities (hereafter, control farmers). We interviewed 409 households from 17 villages using a stratified random sampling. We first obtained from the district RTIMP project officers, a list of all the 24 villages in the three districts where FFF has been implemented between 2008 and 2011. Then we randomly selected 10 participating villages across the three districts. We interviewed about 16 to 21 participants from each of these villages, resulting in a total of 185 FFF participants. We also obtained a list of all households in each participating village and randomly sampled and interviewed 99 exposed farmers across the 10 villages. Since these exposed farmers are located in the same FFF villages, they may be potentially exposed

[3] Models fit by PRETE and LRETE are referred to as ETR models (StataCorp, 2013).

to some of the effects of FFF. To obtain a group of control farmers devoid of potential spillovers, we randomly selected seven villages (from the same three districts) that have similar infrastructural services and socio-economic conditions but not in close proximities to the FFF communities. Out of these, we randomly selected 125 farm households from a household list obtained from the District Agricultural Offices. Thus, our final sample consists of 185 FFF participants and 224 non-participants (99 exposed and 125 control farmers), making a total of 409 sample farmers.

Data collection was conducted by experienced enumerators who were highly trained for this research. Interviews were conducted with the aid of pre-tested questionnaires and were supervised by the author. The questionnaire captured data on household and plot characteristics, crop and livestock production, off-farm income earning activities, innovation-generating activities, and access to infrastructural services, information and social interventions. The respondents were mainly FFF participants or household heads in the presence of other available household members.

Table 2.1 outlines the description of the variables used in the regression and their mean values. The table shows that about 41 percent of the sampled households conducted at least one innovation-generating activity in the past 12 months. The explanatory variables consist of household and farm characteristics, FFF participation, variables motivated by the induced innovation theory and risk preference. The explanatory variables also include village dummies to control for village fixed effects and the two instrumental variables, initial regular sweet potato cultivation and initial membership of farmer group.

Table 2.1: Description and descriptive statistics of variables

Variable	Description	Mean	SD
Dependent variable (farmer innovation)			
Innovation_binary	Household has conducted innovation-generating activities (Binary)	0.41	0.49
Innovation _count	Number of innovation activities conducted by household (Count)	0.59	0.79
Innovation index 1	Household innovation index based on weights obtained through PCA	0.00	1.00
Innovation index 2	Household innovation index based on weights assigned by experts	0.13	0.21
Household and farm characteristics			
Age	Age of household head	49.42	14.88
Gender	Gender of household head (dummy, 1=male)	0.86	0.35
Household size	Number of household members	6.64	2.59
Dependency ratio	Ratio of members aged below 15 and above 64 to those aged 15-64	0.89	0.79
Education	Education of household head (years)	1.67	1.10
Land holding	Total land owned by household in acres	4.56	4.15
Livestock holding	Total livestock holding of household in Tropical Livestock Units (TLU)	2.92	3.41
Assets	Total value of non-land productive assets in 100 GH₵*	4.54	6.92
Off-farm activities	Household has access to off-farm income earning activities	0.76	0.43
Credit	Household has access to credit	0.26	0.43
Road distance	Distance to nearest all-weather road in km	0.54	0.84
Social group	Household member belongs to a non-farm group	0.40	0.49
Land right	Proportion of plots in which household has full user rights	0.86	0.25
Soil fertility	Proportion of plots with infertile soil	0.37	0.44
Innovation systems			
FFF participation	Household member participated in FFF	0.45	0.50
Induced innovation			
Climate shock	Household suffered from droughts or floods in the past 5 years	0.91	0.29
Pest and disease shock	Household farm affected by pests or diseases in the past 5 years	0.82	0.39
Labour shock	Death or illness of a household member one year prior to survey	0.60	0.49
Household size change	Change in household size (between 2008 and 2012)	-0.35	2.13
Market opportunities	Household has improved access to markets in the past 5 years	0.50	0.50
Risk aversion category			
Extreme	Household is extremely risk averse	0.40	0.49
Severe	Household is severely risk averse	0.22	0.42
Intermediate	Household is intermediate risk averse	0.14	0.34
Moderate	Household is moderately risk averse	0.04	0.20
Slight to neutral	Household is slightly risk averse to risk neutral	0.11	0.32
Neutral to preferring	Household is risk neutral to risk preferring	0.09	0.30
Instruments			
Sweet potato	Household cultivates sweet potato regularly prior to FFF	0.69	0.38
Farmer group	Household member belongs to farmer group prior to FFF	0.33	0.43

* The exchange rate at the time of the survey was 1 euro = 2.5 GH₵

Figure 2.1 presents the share of households that implemented innovation-generating activities and compares the results between participants and non-participants. Informal experimentation, which was implemented by 25 percent of the sampled households, constitutes the most practiced activity. A similar trend is observed when we compare the innovation activities of FFF participants and non-participants. This is expected as experimentation is the first stage of most innovation processes. The figure also shows that relative to non-participants, FFF participants implemented more innovation-generating activities in each of the the four categories which seems to suggest that FFF participation enhances innovation capacity. In the next section, we analyse this relationship using econometric techniques. Land preparation, method of planting, cropping pattern, soil fertility, new crops and varieties, soil and water conservation and animal husbandry are the major domains of the farmers' innovations. Examples of the farmer innovations include: informal trials or introduction of new crops or varieties in a community; testing and modification of planting distance and cropping pattern; using plant extracts as insecticide; new formulations of animal feed and new herbal remedies in the treatment of livestock diseases (ethnoveterinary practices); developing and using new farming tools; storage of farm products using local grasses; and new methods of compost preparation.

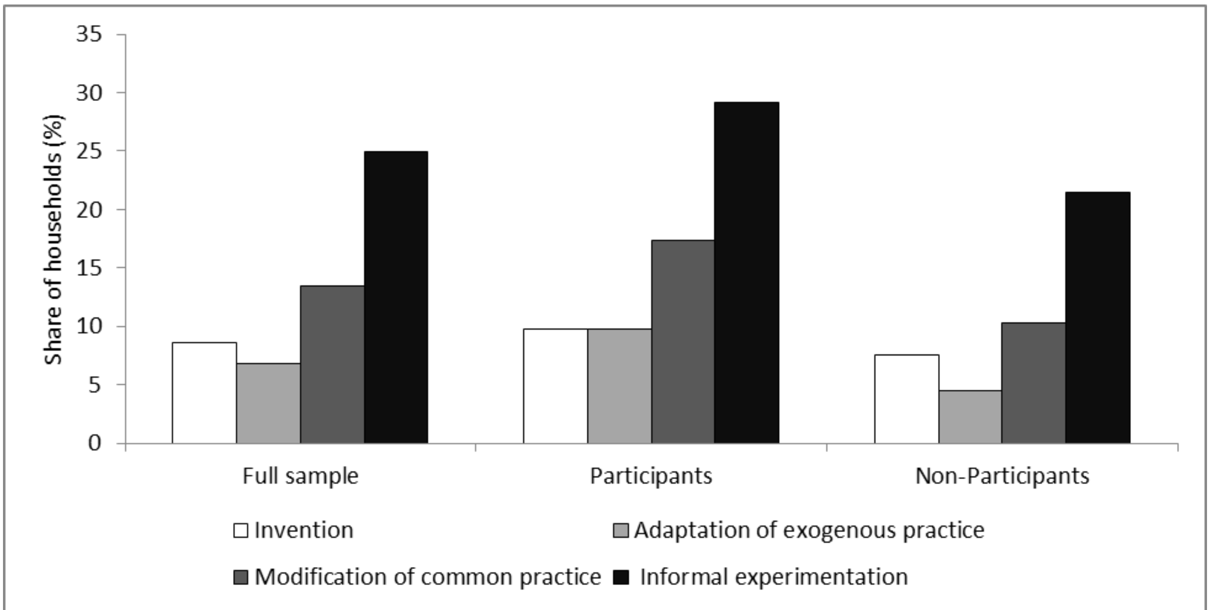


Figure 2.1: Share of households that implemented innovation-generating activities

When asked about the main motivation for conducting these innovation practices, the farmers indicated curiosity, increase in production and reduction in production costs, among others, as shown in Table 2.2. These are in line with the findings of other related studies (e.g. Millar, 1994; Nielsen, 2001; Kummer, 2011). The two most important motives are curiosity (34.9%) and increase in production (24.3%). Out of curiosity, farmers innovate (particularly experiment) to find out whether an idea they perceive will work or a practice they have seen outside their community will fit into their farming systems, or not. As mentioned, most of the innovations identified were yield-related so it is not surprising that increase in production is a key motive for innovation. Other important motives include cost-saving and improved food security.

Table 2.2: Motivation or reason for innovating

Motivation	Proportion of households (N=168)
Curiosity	34.9
Coincidence	1.7
Reduced inputs used	3.8
Labour saving	9.4
Reduced expenses	5.5
Increased production	24.3
Increased income	3.8
Food security	7.7
Improved quality	3.0
Environmental reasons	1.3
Increased safety	3.0
Market demands	1.3

2.4 Results and Discussion

In this section, we look at the econometric results on the determinants of innovation generation. We check for robustness using alternative specifications and estimation methods. Finally, we analyse the spillover and heterogeneous effects of FFF participation on innovation generation.

2.4.1 Determinants of farmers' innovation-generating behaviour

As already indicated, different econometric models (RBP and ETR) are used to deal with the endogeneity problems and also to account for the distribution of the four dependent variables. We instrumented for the FFF participation and the first stage regression results on the determinants of FFF participation are presented in Table A3 in appendix 2. The two excluded instruments (initial farmer group membership and initial sweet potato cultivation) are highly significant in all models, which suggests the relevance of the instruments. The other variables that determine FFF participation are household size, social group membership and off-farm income[4]. The results of the estimated models on the determinants of innovation generation are presented in Table 2.3. The Wald tests of independent equations indicate that there is a significant correlation between the error terms of the selection and the outcome equations in two of the models suggesting that there is a potential selectivity bias; hence, the use of treatment effect models is justified.

The results indicate that the robust determinants of innovation capacity, irrespective of the type of indicator employed, are FFF participation, years of education of household head, size of land holding, household experience of climate shock, change in household size and risk preferences. A key variable of interest, FFF participation, which is used to capture the innovation systems perspective, is highly significant in all the four models. Participation in FFF is found to increase the probability of generating innovations by 22.3 percentage points, and FFF participants are also likely to implement 0.41 more innovation-generating activities than non-participants. There are three possible pathways through which FFF participation may influence innovation capacity. First, FFF provides opportunity for farmers to test their innovations in the presence of other stakeholders, and this builds their self-esteem and empowers them to innovate due to the recognition and appreciation of their ideas by others. Second, FFF may enhance the analytical and problem-solving skills of participants which are essential for innovation. Finally, the FFF graduates form vibrant farmer groups for continuous group discussion and learning which may facilitate further innovative activities. This result suggests that the concept of innovation systems, which facilitates active interactions among key stakeholders, has a potential for strengthening farmers' innovation capacity. This result also adds to evidence of the positive effects of FFS participation on adoption of agricultural innovations (e.g. Erbaugh et al., 2010; Friis-Hansen and Duveskog, 2012; Lilleør and Larsen, 2013).

Education is another important determinant of innovation capacity as shown by its significant positive effect in all the four models. An additional year of education of the

[4] We do not discuss this result because it is not a main objective of this paper

household head increases household innovation practices by 2.6 percent. The significant and positive effects of both FFF participation and education confirm the important role of human capital formation in innovation processes.

Table 2.3: Determinants of innovation capacity

	Innovation (binary)	Innovation (count)	Innovation index 1	Innovation index 2
	RBP[b]	PRETE[c]	LRETE[d]	LRETE[d]
FFF Participation	0.223 (0.107)**	0.409 (0.168)**	0.655 (0.201)***	0.134 (0.039)***
Age	-0.003 (0.002)	-0.003 (0.003)	-0.004 (0.003)	0.000(0.001)
Gender	-0.084 (0.069	-0.143 (0.133)	-0.187 (0.140)	-0.013 (0.029)
Household size	-0.004 (0.011)	0.005 (0.020)	-0.000 (0.022)	-0.001 (0.005)
Dependency ratio	-0.010 (0.030)	-0.040 (0.058)	-0.055 (0.061)	-0.018 (0.013)
Education	0.013 (0.006)**	0.026 (0.011)**	0.035 (0.013)***	0.008 (0.003)***
Land holding	0.019 (0.007)***	0.017 (0.010)*	0.026 (0.013)**	0.005 (0.003)*
Livestock holding	-0.010 (0.008)	-0.016 (0.015)	-0.015 (0.017)	-0.006 (0.004)
Assets	0.002 (0.004)	0.006 (0.006)	0.000 (0.000)	0.000 (0.000)
Off-farm activities	0.041 (0.057)	0.140 (0.112)	0.160 (0.116)	0.041 (0.024)*
Credit access	0.057 (0.055)	0.087 (0.095)	0.149 (0.113)	0.016 (0.024)
Road distance	0.025 (0.030)	0.011 (0.056)	0.042 (0.062)	-0.001 (0.013)
Social group	0.004 (0.050)	-0.017 (0.091)	-0.083 (0.101)	-0.014 (0.021)
Land right	-0.054 (0.099)	0.057 (0.182)	0.081 (0.197)	0.038 (0.0415)
Soil fertility	-0.004 (0.059)	-0.009 (0.111)	-0.022 (0.118)	-0.022 (0.025)
Climate shock	-0.174 (0.085)**	-0.265 (0.144)*	-0.469 (0.173)***	-0.086 (0.037)**
Pest and disease shock	0.116 (0.065)*	0.165 (0.124)	0.192 (0.128)	0.020 (0.027)
Labour shock	-0.081 (0.050)	-0.085 (0.091)	-0.041 (0.099)	-0.011 (0.021)
Household size change	-0.019 (0.011)*	-0.037 (0.020)*	-0.061 (0.023)***	-0.008 (0.005)
Market opportunities	-0.012 (0.030)	-0.033 (0.054)	-0.030 (0.060)	-0.033 (0.013)
Severe risk averse (RA)	0.060 (0.062)	0.150 (0.118)	0.126 (0.122)	0.021 (0.026)
Intermediate RA	-0.008 (0.075)	-0.014 (0.149)	-0.008 (0.147)	-0.001 (0.031)
Moderate RA	0.217 (0.119)*	0.301 (0.193)	0.344 (0.244)	0.082 (0.051)
Slight to neutral RA	0.084 (0.077)	0.225 (0.139)	0.339 (0.159)**	0.088 (0.033)***
Neutral to risk preferring	0.190 (0.082)**	0.314 (0.136)**	0.463 (0.167)***	0.105 (0.035)***
Village fixed effects	Yes	Yes	Yes	Yes
Constant	0.309 (0.698)	-0.607 (0.735)	0.130 (0.457)	0.094 (0.096)
No. of observations	409	409	409	409
Wald (Chi^2)[a]	0.863	-	5.28**	6.22**

***, **, * represent 1%, 5%, and 10% significance level, respectively. Values in parentheses are standard errors

[a] We do not report the Wald (Chi^2) for the PRETE model because the first stage regression failed to completely converge

[b] We report the average marginal effects which were obtained using the stata command, margins with the option predict (pmarg1) force

[c] The PRETE model was estimated using *etpoisson* command in stata 13. Average treatment effects (ATE) are reported

[d] The LRETE model was estimated using *etregress* command in stata 13. The values are both ATE and average treatment on the treated (ATT) since we did not interact FFF participation variable with any of the outcome covariates (Statacorp 2013).

Two of the variables motivated by the induced innovation theory – change in household size and climate shocks – are statistically significant, albeit the latter with a sign contrary to our expectations. While arguments of the induced innovation hypothesis would predict households that are affected by climate-related shocks to be innovative and to overcome the adverse effects of the shock, our results suggest otherwise. This is, however, plausible as affected households may have lost their economic capabilities to implement innovations. Also, coping with such shocks may involve reallocating household resources (e.g. to non-farm employment), resulting in decreased agricultural production, hence, the less likelihood of generating innovations.

Among the four wealth-related factors included in the models, only size of land holding is a significant determinant of innovation generation. Most large land holders have several plots, hence, have the leverage to carry out experiments on some of them. There is no active land market in the study region so it is possible that the statistical significance of the land holding variable may be related to the opportunity for experimentation, rather than wealth. Finally, the results show that compared to risk averse farmers, risk neutral and risk preferring farmers are more likely to be innovative. This is expected since innovations generally involve risk (Feder et al., 1985).

As a robustness check, we also estimate three naïve models of the determinants of innovation capacity (Table A4 in appendix 2) and compare the results with the RBP result in Table 2.3. First, we estimate a probit model (model 1) which ignores self-selection and placement bias. This is the preferred model assuming FFF participation is exogenous, hence, allows us to examine if the two-stage approach used above significantly changes the result of other exogenous variables of interest. The result shows that FFF participants are 12.7 percentage points more likely to generate innovations than non-participants, thus indicating a downward bias if FFF participation is treated as exogenous. The direction and significance level of the other covariates, however, does not differ largely from those in Table 3. In model 2, we control for placement bias but assume no self-selection into FFF. Here again, we find that the innovation-generating effect of FFF (13.2 percentage points) seems to be underestimated. Finally in model 3, we assume random village placement of FFF but account for potential self-selection into FFF. The result shows that FFF participants are 23 percentage points more likely to implement innovation-generating activities relative to non-participants, which suggests a slight upward bias. The results from these three models[5] suggest that the positive and significant effect of FFF on innovation-generating behaviour is consistent and robust, but without controlling for self-selection and placement bias, the effect appears to be over-or underestimated.

2.4.2 Propensity Score Estimation of FFF Participation

The preceding results show that FFF participation significantly influences innovation-generating behaviour in farm households irrespective of the measure of farmer innovation employed. For a further robustness check on the FFF participation result, we use an alternative estimation strategy, PSM which is a non-parametric technique suggested by Rosenbaum and Rubin (1983). It involves matching FFF participants with non-participants that are similar in terms of observable characteristics (Caliendo and Kopeinig, 2008). Though it accounts for only observables, it is less restrictive as it does not impose any functional form assumption. We also try to minimize the bias stemming from unobserved heterogeneity by controlling for risk attitude.

In the PSM approach, a probit regression was estimated using several covariates, which are similar to those in the first stage regression of the ETR models, to obtain household's propensity to participate in FFF. We then use the propensity scores obtained in the first stage to match participants and non-participants of FFF. The matching algorithm used is kernel matching with a bandwidth of 0.3 but for robustness check, radius matching with a calliper of 0.05 and nearest-neighbour matching are also employed[6]. We conducted a matching quality test (Rosenbaum and Rubin (1985) to check if the balancing property is satisfied. Based on the kernel matching[7], the test result (Table A5 in appendix 2) shows that in contrast to the unmatched sample, there are no statistically significant differences in covariates between participants and non-participants of FFF after matching. Thus, the balancing requirement is satisfied. Using the PSM, we compute the average treatment effect on the treated (ATT) which is average difference in innovation capacity between FFF

[5] We also performed robustness checks using the other three specifications of the dependent variable. We obtained results very similar to Table A4 in appendix 2.

[6] For a review of the different matching techniques, see Caliendo and Kopeinig (2008)

[7] The other two matching estimators also yield similar results of matching quality, but are not reported for brevity

participants and non-participants. Here again we find that the result (Table 2.4) is robust irrespective of the matching algorithm or how the outcome variable is measured. Using the kernel matching, for instance, the results show that the rate of innovation generation by FFF participants is 13.4 percent higher relative to matched non-participants. Overall, the results confirm the positive and significant effect of FFF participation on innovation capacity in farm households.

Table 2.4: PSM estimation of the effect of FFF participation on innovation generation

Matching algorithm[a]	Outcome	ATT	SE
Kernel matching	Innovation _binary	0.134***	0.051
	Innovation _count	0.239***	0.083
	Innovation index 1	0.268***	0.104
	Innovation index 2	0.054**	0.022
Radius matching	Innovation _binary	0.123**	0.055
	Innovation _count	0.235***	0.088
	Innovation index 1	0.255**	0.111
	Innovation index 2	0.054**	0.023
Nearest neighbour	Innovation _binary	0.178***	0.055
	Innovation _count	0.308***	0.089
	Innovation index 1	0.357***	0.112
	Innovation index 2	0.071***	0.024

***, **, * represent 1%, 5%, and 10% significance level, respectively

[a]ATT estimates of kernel matching and radius matching were obtained by implementing 'psmatch2' command in Stata. ATT estimates of nearest neighbour matching were obtained using the 'teffects nnmatch' command with bias adjustment option in Stata 13.

We also conducted tests on the sensitivity of estimates to unobservable factors (Rosenbaum, 2002). Running *mhbounds* for binary outcome variables (Becker and Caliendo, 2007), for example, we obtained a critical value of gamma, Γ= 1.40 for kernel matching (model 1) which indicates that the ATT of 0.134 would be questionable only if matched pairs differ in their odds of FFF participation by a factor of 40 percent.

2.4.3 Spillover effect

In this section, we test whether FFF participation has spillover effects by comparing the innovation capacity of participants with that of the exposed group (Table 2.5, Model A) and the innovation capacity of the exposed group with the control group (Table 2.5, Model B). The FFF programme does not reach all farmers, but programme promoters believe that the knowledge gained will be transmitted from participants to other farmers. It is expected that if there is a strong spillover effect, there will be no significant effect of FFF participation on innovation capacity in Model A. Similarly, in Model B, we expect the exposed group to carry out significantly more innovative activities than the control group if there is a spillover effect. In both models, the dependent variable is the number of innovation activities implemented by households so we employ a Poisson regression. However, we take the potential endogeneity of FFF participation in Model A into consideration by estimating a PRETE model. The main variable of interest, Treatment, takes values of 1 and 0 if the household is a FFF participant or belongs to the exposed group, respectively (Model A); and 1 and 0 if the household belongs to the exposed or control group, respectively (Model B).

Table 2.5: Spillover effect of FFF participation on innovation generation

	Model A		**Model B**	
	Coefficient	**SE**	**Coefficient**	**SE**
Treatment	0.781***	0.263	0.508	0.535
Age	-0.007	0.007	-0.010	0.008
Gender	-0.376	0.271	-0.234	0.294
Household size	-0.021	0.041	0.073	0.050
Dependency ratio	0.063	0.103	-0.294*	0.174
Education	0.046**	0.023	0.037	0.029
Land holding	0.040	0.032	0.024	0.019
Livestock holding	-0.003	0.031	-0.015	0.036
Productive assets	0.001	0.014	0.007	0.012
Off-farm activities	0.164	0.211	0.660**	0.321
Credit access	0.073	0.188	0.120	0.276
Road distance	0.096	0.121	-0.057	0.139
Social group	-0.106	0.188	0.025	0.248
Land right	-0.116	0.372	-0.107	0.441
Soil fertility	0.000	0.212	0.128	0.318
Climate shock	-0.550**	0.251	0.193	0.498
Pest and disease shock	0.344	0.235	0.209	0.329
Labour shock	-0.189	0.177	0.087	0.252
Household size change	-0.055	0.038	-0.119**	0.057
Market opportunities	-0.027	0.110	-0.282*	0.147
Severe Risk Averse (RA)	0.284	0.243	0.223	0.287
Intermediate RA	0.057	0.274	-0.280	0.387
Moderate RA	0.349	0.396	0.238	0.593
Slight to neutral RA	0.256	0.276	0.389	0.337
Neutral to risk preferring	0.491*	0.257	0.117	0.409
Village fixed effects	Yes		Yes	
Constant	-0.44	0.796	-1.074	1.182
No. of observations	284		224	

***, **, * represent 1%, 5%, and 10% significance level, respectively

The highly statistical significance of the Treatment variable in Model A indicates that relative to the exposed group, participating households are more likely to implement innovation-generating activities, implying that there is no strong spillover effect of FFF on innovation capacity. Similarly, the result in Model B shows that exposed farmers are not significantly more innovative than control farmers, which further suggests that there is no spillover effect. Similar results were obtained in IPM-FFS studies by Rola et al. (2002), Feder et al. (2004a) and Tripp et al. (2005) in Philippines, Indonesia and Sri Lanka, respectively. This finding is plausible because FFF strengthens the analytical and problem-solving skills of participants, and the mere location of non-participating households in FFF villages or interactions with other FFF graduates does not confer these skills. Another possible explanation is the low level of intensity of the programme. Only one FFF with 30 to 40 participants (out of about 200 potential participants) was implemented in each participating village. This low intensity is argued to be an important determinant of successful application and dissemination of FFS principles (FAO, 1999 in Feder et al. 2004b).

This result also validates the inclusion of the exposed group into the group of non-participants in our initial analyses as part of our attempt to minimise the endogeneity problems. It is possible that FFF may have spillover effects on other outcome objectives of the programme such as innovation adoption and farm productivity, but this is not the focus of this paper. It should also be stressed that the innovation effect of FFF appears to be independent of the crop it focuses on since most of the innovations reported by the farmers were unrelated to sweet potato production.

2.4.4 Heterogeneous effect

The previous results show that FFF participation has a significant effect on innovation-generating behaviour in farm households. This is however an average effect which may be unevenly distributed among FFF participants. Consequently, we look at whether the innovation-generating effect of FFF is homogeneous among FFF participants. Using data on FFF participants only, we estimated a Poisson regression in which the dependent variable is the number of innovation-generating activities implemented by a household. The explanatory variables are similar to the previous models but we included two new variables which are of particular interest. The FFF programme was introduced in different years

(2006-2012) across the participating villages so the first variable, year of FFF participation, allows us to estimate if the length of time since participating in the programme matters. On the one hand, past participants may have ample opportunities to implement innovation activities which may result in positive effects, but on the other hand, the number of years since a household participated may result in a decline in knowledge which will hinder innovation generation (Feder et al., 2004b). Secondly, we test if the intentional inclusion of female participants has an effect on innovation generation. Participation in FFF was voluntary, but it was ensured that at least one-third of the participants in each forum were females, and in most cases there were equal number of male and female participants.

Table 2.6: Heterogeneous effect of FFF participation

	Coefficient	SE
Year of FFF participation	-0.167	0.133
Female participant	-0.413*	0.230
Age	-0.006	0.009
Household size	-0.024	0.050
Dependency ratio	0.019	0.120
Education	0.017	0.026
Land holding	0.027	0.040
Livestock holding	-0.054	0.037
Productive assets	0.012	0.019
Off-farm activities	-0.088	0.241
Credit access	0.224	0.206
Road distance	0.158	0.147
Social group	0.060	0.219
Land right	0.014	0.436
Soil fertility	-0.062	0.248
Climate shock	-0.550*	0.291
Pest and disease shock	0.398	0.285
Labour shock	-0.224	0.212
Household size change	-0.022	0.046
Market opportunities	0.163	0.122
Severe risk averse (RA)	0.463	0.297
Intermediate RA	0.165	0.355
Moderate RA	0.807*	0.423
Slight to neutral RA	0.310	0.346
Neutral to risk preferring	0.692**	0.291
Village fixed effects	Yes	
Constant	0.093	0.901
No. of observations	185	

***, **, * represent 1%, 5%, and 10% significance level, respectively

The result in Table 2.6 indicates that the year of FFF participation does not significantly influence innovation capacity of participants. This is interesting as it implies that there is no decline in innovation-generating capacity of households with time. Thus, FFF enhances the capacity of farmers for continuous innovation. We also find negative and significant (albeit weak) effect of female participation, suggesting that female participants are less likely to implement innovation-generating activities relative to male participants. This is probably due to the limited rights of women in making major farming decisions in northern Ghana (Apusigah, 2009) or the fact that some of the female participants were traders or processors who were not actively involved in farming. The result also shows that the innovation effect of FFF participation is greater for risk neutral and risk loving households. This variable is also statistically significant in the previous results and confirms the importance of risk preference but often excluded in most innovation studies (Feder et al., 1985). Overall, most of the variables included in the model are either weakly significant or not significant statistically, and this suggests that there is little heterogeneity in innovation-generating behaviour among FFF participants.

2.5 Conclusion

Innovation is essential for agricultural and economic development and global change further increases its importance. While there is increased interest in promoting farmer innovation as a complement to externally-driven technologies, little attention has been paid to what determines the innovation capacity of farmers. Using cross-sectional data from 409 farm households and econometric techniques, this study analyses the innovation-generating activities among rural farmers in northern Ghana. We specifically look at the determinants of innovation capacity in farm households using inspiration from two innovation theories: induced innovation and innovation systems.

This study has shown that resource-poor farmers are capable of implementing innovation-generating activities. The innovations range from experimenting with new ideas, modifying or adding value to existing or external practices to complete discovery of better farming practices. Controlling for selection bias, we found that participation in FFF, a participatory extension approach with elements of the innovation systems concept, is a key determinant of innovation capacity in farm households. This is possible because participants are likely to be empowered and also gain problem-solving and analytical skills which are essential for innovation. This result is robust to alternative specifications and estimation techniques. Innovation capacity also increases significantly with education level of household heads, another human capital related determinant.

In contrast to the innovation adoption literature where poor farmers are often found to be significantly constrained in adopting new technologies, our findings seem to suggest that wealth does not to play a key role in innovation-generating decisions of farmers. We also found little evidence that shocks induce innovativeness. Climate shocks rather appear to reduce the probability of generating innovation. A possible explanation is that coping with such shocks may involve reallocating household resources (e.g. to non-farm employment), resulting in decreased agricultural production, hence, the less likelihood of generating innovations. This study also attempted controlling for farmers' risk attitudes and found that it is a very important determinant of innovation capacity in farm households. There appears to be no spillover effect of FFF on innovation generation, and this has implications for the cost-effectiveness of the programme. Farmers have, however, extended the knowledge acquired from participating in FFF to other farming activities and there is a possibility of positive spillover effects on other outcome indicators such as farm productivity. Moreover, we found that earlier FFF graduates are equally innovative as recent ones, suggesting that the programme has long-term benefits. Therefore, further studies on FFF will be needed before a concrete conclusion on the cost-effectiveness of the programme can be drawn.

Policy efforts aiming at strengthening farmers' innovation capacity should provide platforms for active interaction between stakeholders as argued by the innovation systems theory. The innovation platform (IP) of the Forum for Agricultural Research in Africa (FARA) is a good example. An IP facilitates interactions between actors who have a common interest in innovation generation (Nederlof et al., 2011). This does not imply that promoting FFF or its variants will definitely induce innovation-generating behaviour in farmers. There are reports that some FFSs have rather been used as means to facilitate the transfer of technologies to farmers (Röling, 2009a). The innovation potential of FFF, therefore, likely hinges on how it is implemented in the field.

While the FFF programme is implemented throughout Ghana, this paper is based on only sweet potato FFFs in northern Ghana. Further studies are needed on other root and tuber FFFs to check if the innovation effect of FFF applies to other cropping systems in the country. The RTIMP, which initiated the FFF programme in Ghana, ends in 2014 and there are concerns about the sustainability of the programme. Typical of many FFSs, a large share (69%) of the funding for the programme was provided by an external partner, the IFAD. This study provides some insights on the positive effect of FFF, but there is the need for further evaluations if there is any consideration to adopt the method in future agricultural innovation projects in the country or even the national agricultural extension system.

Farmer innovation is a continuous process, but this study is based on cross-sectional data which does not allow the analyses of these dynamics and is further challenged by endogeneity problems. While we have tried to address these issues by using robust estimation techniques, a more rigorous analysis will require the use of panel data; hence, future research in this direction will be useful in corroborating the findings of this study. There are increasing attempts to promote farmer innovations and this study has illustrated some useful pathways. To further strengthen arguments in support of farmer innovations, studies on the livelihood impacts of these innovations are also needed.

Appendix 2

Table A1: Risk preference elicitation set-up

Choice	High pay-off	Low pay-off	Risk aversion class
A	3	3	Extreme
B	4	2.5	Severe
C	5	2	Intermediate
D	6	1.5	Moderate
E	7	1	Slight to Neutral
F	8	0	Neutral to Preferring

Table A2: Placebo regression

	Probit Model	
	Coefficient	SE
Sweet potato	-0.122	0.340
Farmer group	0.204	0.479
Age	-0.021*	0.012
Gender	-0.300	0.435
Household size	0.165**	0.079
Dependency ratio	-1.149***	0.351
Education	0.062	0.043
Land holding	0.076*	0.044
Livestock holding	0.712*	0.407
Assets	-0.105	0.065
Off-farm activities	0.000	0.000
Credit access	-0.093	0.419
Road distance	-0.394	0.429
Social group	0.137	0.167
Land right	0.510	0.654
Soil fertility	-0.377	0.504
Climate shock	-1.408	1.262
Pest and disease shock	0.753	0.563
Labour shock	-0.084	0.356
Household size change	-0.111	0.091
Market opportunities	-0.161	0.231
Severe risk averse (RA)	0.197	0.391
Intermediate RA	-0.869	0.645
Moderate RA	1.613**	0.810
Slight to neutral RA	0.051	0.614
Neutral to risk preferring	-0.125	0.677
Village fixed effect	Yes	
Constant	0.780	2.107
No. of observations	125	

***, **, * represent 1%, 5%, and 10% significance level, respectively

Table A3: First stage regression[a]

	Innovation (binary)		Innovation index 1		Innovation index 2	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Sweet potato	1.321***	0.26	1.339***	0.254	1.373***	0.256
Farmer group	1.248***	0.237	1.285***	0.234	1.268***	0.236
Age	-0.004	0.007	-0.004	0.007	-0.003	0.007
Gender	-0.138	0.288	-0.165	0.282	-0.151	0.284
Household size	0.080*	0.045	0.079*	0.045	0.086*	0.045
Dependency ratio	0.194	0.126	0.205	0.122	0.207*	0.124
Education	-0.005	0.029	-0.004	0.029	-0.003	0.029
Land holding	-0.024	0.039	-0.024	0.038	-0.028	0.038
Livestock holding	0.036	0.041	0.042	0.042	0.042	0.042
Assets	-0.004	0.017	-0.004	0.017	-0.007	0.017
Off-farm activities	-0.498**	0.241	-0.481**	0.237	-0.505**	0.241
Credit access	0.139	0.225	0.071	0.223	0.098	0.223
Road distance	0.115	0.159	0.084	0.165	0.102	0.166
Social group	0.935***	0.229	0.934***	0.225	0.963***	0.228
Severe	0.071	0.264	0.097	0.263	0.088	0.264
Intermediate	-0.089	0.282	-0.064	0.282	-0.082	0.284
Moderate	-0.303	0.545	-0.259	0.528	-0.236	0.535
Slight to neutral	-0.047	0.325	-0.06	0.321	-0.053	0.319
Neutral to preferring	0.060	0.360	0.033	0.343	0.029	0.347
Village fixed effects	Yes		Yes		Yes	
Constant	-8.537	1645	-8.478	3329	-8.602	1980

***, **, * represent 1%, 5%, and 10% significance level, respectively

[a] We do not report the first stage regression for the PRETE model because it failed to converge

Table A4: Determinants of innovation generation, naïve estimates[a]

	Model 1		Model 2		Model 3	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
FFF Participation	0.127***	0.048	0.132**	0.059	0.230***	0.078
Age	-0.003*	0.002	-0.003*	0.002	-0.002	0.002
Gender	-0.065	0.069	-0.09	0.069	-0.063	0.067
Household size	0.001	0.011	-0.002	0.011	-0.002	0.01
Dependency ratio	-0.004	0.031	-0.006	0.031	-0.01	0.03
Education	0.012*	0.006	0.013**	0.007	0.012*	0.006
Land holding	0.019***	0.007	0.020***	0.007	0.018***	0.007
Livestock holding	-0.008	0.008	-0.01	0.008	-0.008	0.008
Assets	0.001	0.004	0.002	0.004	0.002	0.003
Off-farm activities	0.038	0.057	0.037	0.057	0.041	0.055
Credit access	0.032	0.055	0.066	0.055	0.017	0.054
Road distance	0.032	0.027	0.024	0.03	0.04	0.027
Social group	0.000	0.048	0.01	0.05	-0.009	0.047
Land right	-0.039	0.098	-0.061	0.101	-0.035	0.094
Soil fertility	0.001	0.059	-0.012	0.06	0.005	0.057
Climate shock	-0.140*	0.084	-0.175**	0.087	-0.136*	0.081
Pest and disease shock	0.065	0.065	0.113*	0.066	0.067	0.063
Labour shock	-0.063	0.05	-0.089*	0.051	-0.057	0.048
Household size change	-0.022*	0.012	-0.020*	0.012	-0.020*	0.011
Market opportunities	0.004	0.031	-0.011	0.031	0.001	0.03
Severe Risk Averse (RA)	0.054	0.062	0.061	0.062	0.05	0.06
Intermediate RA	0.004	0.075	-0.016	0.076	0.002	0.073
Moderate RA	0.221*	0.12	0.223*	0.122	0.206*	0.116
Slight to neutral RA	0.079	0.077	0.079	0.078	0.074	0.075
Neutral to risk preferring	0.199**	0.083	0.193**	0.084	0.183**	0.082
Village fixed effects	No		Yes		No	
Constant	-0.031	0.562	0.335	0.701	-0.198	0.566
No. of observations	409		409		409	

***, **, * represent 1%, 5%, and 10% significance level, respectively

[a] Average marginal effects are reported

Table A5: Test of matching quality (kernel matching)

	Unmatched			Matched		
	Participants	Non-participants	t-test	Participants	Non-participants	t-test
Age	47.03	51.81	3.20***	47.11	48.82	0.39
Gender	0.89	0.82	2.12**	0.89	0.88	-0.15
Household size	6.90	6.38	2.05**	6.86	6.61	-0.16
Dependency ratio	0.92	0.86	0.89	0.92	0.90	-0.05
Education	2.77	2.39	0.91	2.78	2.65	0.10
Land holding	4.51	4.60	-0.21	4.50	4.39	0.05
Social group	0.46	0.34	2.50**	0.46	0.41	-0.46
Livestock holding	3.02	2.56	1.37	3.03	2.63	-0.03
Assets	4.67	4.41	0.36	4.67	4.69	-0.12
Off-farm activities	0.76	0.75	0.05	0.76	0.77	-0.21
Credit access	0.32	0.19	3.10***	0.33	0.25	-0.13
Road distance	0.42	0.64	-2.55**	0.43	0.46	-0.04
Extreme risk averse (RA)	0.36	0.44	-1.66*	0.36	0.39	0.70
Severe RA	0.22	0.22	-0.17	0.22	0.23	-0.18
Intermediate RA	0.14	0.13	0.17	0.14	0.14	0.06
Moderate RA	0.05	0.03	0.90	0.05	0.04	-0.36
Slight to neutral RA	0.13	0.10	0.85	0.13	0.12	0.00
Neutral to risk preferring	0.11	0.08	1.30	0.11	0.08	-0.26
Median bias		9.10			3.10	
Pseudo R-squared		0.08			0.00	
p-value of LR		0.00			1.00	

***, **, * represent 1%, 5%, and 10% significance level, respectively

Beyond adoption: the welfare effects of farmer innovation in rural Ghana

3.1 Introduction

Despite increased food production in the last half-decade, nearly 850 million people (12% of global population) continue to be hungry and food insecure, and many more are micronutrient deficient (Godfray et al., 2010; FAO et al., 2013). Majority of these people live in developing regions, especially sub-Saharan Africa (FAO et al., 2013). Food insecurity is attributed to a set of complex factors of which climate change is recognised as an important driver (von Braun, 2007; Godfray et al., 2010). Climate change poses serious threats to agricultural production and has severe implications for rural poverty and food security (World Bank, 2009; Thornton et al., 2011). For instance, climate change affects all the four facets of food security, i.e. availability, access, utilization and stability (Wheeler and von Braun, 2013). Smallholder farmers are the mainstay of food production and key to economic growth in developing countries, but they are also one of the most vulnerable to climate change (Easterling et al., 2007). Thus, the challenge of tackling smallholders' food insecurity problems must occur while simultaneously building their resilience to climate change.

The contribution of innovation to agricultural development and rural poverty reduction has been extensively documented (Hayami and Ruttan, 1985; de Janvry and Sadoulet, 2002). It is also generally agreed that agricultural innovations are essential in addressing the food insecurity and climate change challenges of the world (Brooks and Loevinsohn 2011; Lybbert and Sumner, 2012). Such innovations include: seed and agronomic innovations (e.g. improved varieties, fertilizer, and integrated pest management); mechanical innovations (e.g. plough); institutional innovations (e.g. farmer field schools, contract farming and microfinance); biotechnological innovations (e.g. herbicide-resistant crops, tissue culture banana and Bt crops); informational innovations (e.g. mobile phones); and innovations developed by farmers (i.e. grassroot or farmer innovation).

Over the years, there has been increased development and diffusion of technological innovations to farmers, and there are several projects and policy interventions facilitating the adoption of these introduced innovations. With the rapidly changing economic environment, however, local farmers do not only adopt but also generate innovations (Sanginga et al., 2008; Conway and Wilson, 2012). They also engage in informal experimentation, develop new technologies, and modify or adapt external innovations to suit their local environments. Such practices are claimed to play an important role in building their resilience to changing environments and addressing food insecurity challenges (Reij and Waters-Bayer, 2001; Kummer et al., 2012). Consequently, there is a growing recognition of the need to promote farmers' innovations and also strengthen their innovative capacities.

The increasing interest in the role of agricultural innovations in reducing poverty, hunger and malnutrition in the world has led to numerous micro-level studies on the impact of agricultural innovation on household welfare in developing countries. Many of these studies (e.g. Kijima et al., 2008; Minten and Barrett, 2008; Kassie et al., 2011; Amare et al., 2012; Asfaw et al., 2012) have shown that agricultural innovations have positive productivity, income, food security, and poverty reduction effects among adopters. These studies are, however, based on technologies developed and disseminated by National Agricultural Research Institutes (NARI), the Consultative Group on International Agricultural Research (CGIAR) centers and private seed companies, and there is little evidence on the contribution of locally developed farmers' innovations to household welfare. Considering the numerous challenges hindering poor smallholders adoption of these introduced technologies (Barrett et al., 2004), it is argued that innovation generation practices of farm households may have positive impacts on rural livelihoods and might form the basis for food security (Waters-Bayer et al., 2006; The Worldwatch Institute, 2011). Unfortunately, the few documents on the potential impacts of farmer innovation are only anecdotal, and a rigorous assessment is still lacking. Robust evidence is needed to be able to support increased arguments on the need for policy supports for grassroot or farmer innovation as a complement to introduced technological innovations.

Using survey data from 409 rural farm households in northern Ghana, this study attempts to fill the void on the welfare impacts of farmer innovation. Specifically, we assess the effect of farmer innovation on food and nutrition security, farm and household income, and consumption expenditure. On the one hand, farmers' innovation activities may improve productivity or save labour for non-farm activities and subsequently increase household income and food security. On the other hand, it is possible that the innovation activities may be unsuccessful or do not produce immediate result, hence, has negative effect on household income and food security in the short run. To estimate the treatment effects of farmer innovation, we employ endogenous switching regression which accounts for potential non-random selection bias. We complement the regression results with analysis of farmers' perceived outcomes of their innovations.

This paper contributes to several aspects of the existing literature on the impact of agricultural innovations. Firstly, to the best of our knowledge, this is the first paper to quantitatively and rigorously estimate the impact of farmer innovation on household welfare. Previous studies have focussed largely on externally introduced technologies. Secondly, in measuring household welfare, many studies have used either household income or consumption expenditure as an indicator. However, considering the limitations of both indicators (Deaton, 1997), we took advantage of our unique dataset and employ both measures. This allows us to check the robustness of our findings on the well-being effects of farmer innovation. Thirdly, there are several and varied measures of food security in the literature. For robustness check, we use three different subjective or perception-based measures, in addition to the conventional food consumption expenditure indicator. Finally, in addition to these standard welfare outcome indicators, we also analyse the effect of farmer innovation on household resilience to climate shocks. Farmers may innovate in order to improve farm productivity, but these innovations may enhance their resilience to shocks. Using a resilience framework suggested by FAO (2010), we constructed a unique household resilience index and assess the contribution of farmers' innovation to resilience to climate shocks.

Unlike the technological innovation literature, we do not analyse the impact of a single innovation or bundle of innovations. Rather, we consider innovation-generating behaviour in farm households. Farmers innovate in diverse ways (ranging from yield to marketing-related) in order to address different challenges; hence, we study the impact of the propensity to generate an innovation instead of specific innovations. Thus, we treat the farmers' innovations as farming system innovations which can take several forms. We consider farmer innovation to be a new or modified practice, technique or product that was developed by an individual farmer or a group of farmers without direct support from external agents or formal research. It also includes the process of experimenting with own ideas or external practices.

The rest of the paper is organised as follows. The next section presents the theoretical model. Here, we look at the agricultural household model. The endogenous switching regression model that is used in estimating the welfare effects of farmer innovation is described in section 3. Section 4 presents the choice of outcome indicators and how they are measured, followed by a presentation of the data and descriptive statistics in Section 5. The empirical results are discussed in section 6, while the last section summarises and concludes the paper.

3.2 Theoretical model

In order to assess the effect of farmer innovation on household well-being, the farm household model, which posits that households maximise utility subject to income, production and time constraints (Singh et al., 1986), is used as a framework. The model integrates in a single framework, the production, consumption and work decision-making processes of the farm household (Sadoulet and de Janvry, 1995). We draw largely from Fernandez-Cornejo et al. (2005) who expanded the model of Huffman (1991) to include technology adoption decisions. In our case, we focus on farmer innovation.

Following Weersink et al. (1998) and Fernandez-Cornejo et al. (2005), households are assumed to derive utility (*U*) from purchased consumption goods (*G*) and leisure (*L*), and the level of utility obtained from *G* and L is affected by exogenous factors such as human capital (*H*) and other household characteristics (*Z*). Thus:

$$MaxU = U(G, L; H, Z) \qquad (1)$$

Utility is maximised subject to:

Time constraint: $T = F(I_f) + M + L,\ M \geq 0$ (2)

Production Constraint: $Q = Q\left[X(I_f), F(I_f), H, I_f, R\right],\ I_f \geq 0$ (3)

Income constraint: $P_g G = P_q Q - W_x X^{'} + WM^{'} + A$ (4)

The total time endowment (*T*) of each household is allocated to leisure (*L*), working on the farm (*F*), or off-farm work (*M*). The level of farm output (*Q*) depends on the quantity of farm inputs (*X*), the innovativeness of farm household (I_f), *F*, *H*, and a vector of exogenous variables that shift the production function (*R*). *X* and *F* are functions of I_f since some of the innovative activities of the farmers are labour or input saving, hence, freeing some time and money for other uses. I_f in turn is determined by households' experience of shocks (*S*), social capital (S_c), household assets (*Ö*), risk preference, *H* and Z. Thus:

$$I_f = I_f(S, H, S_c, R, \ddot{O}, Z) \qquad (5)$$

Equation 4 depicts the budget constraint on household income where P_g denote price of goods purchased. Thus, $P_g G$ is the income available for purchase of consumption goods, and it depends on the price (P_q) and quantity (*Q*) of farm output, price (W_x) and quantity (*X*) of farm inputs, off-farm wages (*W*) and the amount of time spent working off-farm (*M*) and exogenous household income such as government transfers, pensions and remittances (*A*).

Substituting equation 3 into equation 4 yields a farm technology-constrained measure of household income:

$$P_g G = P_q Q\left[X(I_f), F(I_f)^{'}, H, I_f, R\right] - W_x X^{'} + WM^{'} + A \qquad (6)$$

The Kuhn-Tucker first order conditions can be obtained maximising Lagrangean expression ($\mathcal{L}$) over (*G, L*) and minimising it over (*λ, η*):

$$\begin{aligned} \mathrm{L} &= U(G, L; H, Z) \\ &+ \lambda\left\{P_q Q\left[X(I_f), F(I_f)^{'}, H, I_f, R\right] - W_x X^{'} + WM^{'} + A - P_g G\right\} \\ &+ \eta\left[T - F(I_f) - M - L\right] \end{aligned} \qquad (7)$$

where λ and η represent the Lagrange multipliers for the marginal utility of income and time, respectively.

Solving the Kuhn-Tucker conditions, reduced-form expression of the optimal level of household income (*Y**) can be obtained by (Fernandez-Cornejo et al. 2005):

$$Y^* = Y(I_f,\ W_x,\ P_q,\ P_g,\ A,\ H,\ Z,\ R,\ T) \qquad (8)$$

and household demand for consumption goods (G) can be expressed as:

$$G = G(I_f,\ W,\ P_g,\ Y^*,\ H,\ Z,\ T) \qquad (9)$$

Thus, the reduced forms of *Y** and *G* are influenced by a set of explanatory variables, including I_f. The main aim of this paper is to estimate the effect of I_f on household income, household consumption of goods and other related outcome variables such as food security.

3.3 Empirical model

As already indicated by the reduced form expression (equation 8), we are interested in estimating the effect of innovation generating-activities of farmers on household welfare indicators such as income. A simplified model from linearising this reduced form equation can be expressed as:

$$y = \varphi V + \delta I_f + \mu \qquad (10)$$

where y denotes income or other household well-being indicators such as food security and consumption expenditure. *V* is a vector of explanatory variables (other than farmer innovation) that influence the outcome variables, and it includes household, farm and contextual characteristics such as age, gender and years of education of household head, household size, farm size, access to credit, asset endowments, social network variables, risk preference and district dummies. I_f is a dummy for farmer innovation and the coefficient *δ*, measures the effect of farmer innovation on household well-being. This variable is potentially endogenous since innovation is not randomly assigned and farmers may decide whether or not to innovate (i.e. self-selection bias). In other words, innovative farmers may be systematically different from non-innovators, and these differences may obscure the true effect of innovation on household well-being. Thus, estimating equation 10 with ordinary least squares (OLS) regression technique may yield biased results.

Commonly suggested methods for addressing such biases include Heckman selection, instrumental variable (IV) and propensity score matching (PSM). Each of these methods, however, has some limitations. For instance, both Heckman selection and IV methods tend to impose a functional form assumption by assuming that farmer innovation has only an intercept shift and not a slope shift in the outcome variables (Alene and Manyong, 2007). Though PSM tackles the above problem by avoiding functional form assumptions, it assumes selection is based on observable variables, but there is likely to be unobserved heterogeneity because farmers' innate abilities, skills and motivation are likely to influence their innovative behaviour. PSM, therefore, produces biased result when there are unobservable factors that influence both innovative behaviour and the outcome indicators.

In order to address these issues, we use the endogenous switching regression (ESR) technique. This method is increasingly being applied in evaluating the impacts of decisions of farmers on farm performance or household well-being (e.g. Fuglie and Bosch, 1995; Di Falco et al., 2011; Kleemann and Abdulai, 2013; Negash and Swinnen, 2013; Noltze et al., 2013).

In the ESR method, separate outcome equations are specified for each regime, conditional on a selection equation. Thus in our case, we estimate separate household well-being indicators for innovators and non-innovators, conditional on the innovation decision:

$$I_f = \gamma K + \varepsilon \qquad (11)$$

$$y_1 = \varphi_1 V + \mu_1 \quad if\, I_f = 1 \qquad (12)$$

$$y_0 = \varphi_0 V + \mu_0 \quad if\, I_f = 0 \qquad (13)$$

where *K* is a set of all the explanatory variables already defined in equation 5. y_1 and y_0 represent a vector of welfare indicators for innovators and non-innovators, respectively. φ_1 and φ_0 are parameters to be estimated for the innovators and non-innovators regimes, respectively. When the error term of the selection equation (ε) is correlated with the error terms of the outcome equation of innovators (μ_1) and non-innovators (μ_0), then we have a selection bias problem. The error terms ε, μ_1 and μ_0 are assumed to have a joint-normal distribution with mean vector 0, and a covariance matrix specified as (Fuglie and Bosch 1995):

$$\operatorname{cov}(\varepsilon, \mu_1, \mu_0) = \begin{pmatrix} \sigma_\varepsilon^2 & \sigma_{\mu_1\varepsilon} & \sigma_{\mu_0\varepsilon} \\ \sigma_{\mu_1\varepsilon} & \sigma_{\mu_1}^2 & \sigma_{\mu_1\mu_0} \\ \sigma_{\mu_0\varepsilon} & \sigma_{\mu_1\mu_0} & \sigma_{\mu_0}^2 \end{pmatrix} \qquad (14)$$

where var(ε)=σ_ε^2, which is assumed to be 1 since γ is only estimable up to a scale factor (Maddala 1983); var (μ_1) = $\sigma_{\mu_1}^2$, var (μ_0)= $\sigma_{\mu_0}^2$, cov (μ_1, ε)= $\sigma_{\mu_1\varepsilon}$, cov ($\mu_0$, ε)= $\sigma_{\mu_0\varepsilon}$, and cov ($\mu_1$, μ_0)= $\sigma_{\mu_1\mu_0}$. The expected values of the error terms μ_1 *and* μ_0 can be expressed as (Fuglie and Bosch 1995):

$$E(\mu_1 | I_f = 1) = \sigma_{\mu_1\varepsilon}\lambda_1 \qquad (15)$$

$$E(\mu_0 | I_f = 0) = \sigma_{\mu_0\varepsilon}\lambda_0 \qquad (16)$$

where λ_1 and λ_0 are the inverse mills ratios (IMR) evaluated at γK. Equations 12 and 13 can then be specified as (Maddala, 1983):

$$y_1 = \varphi_1 V + \sigma_{\mu_1\varepsilon}\lambda_1 + \xi_1 \quad if\, I_f = 1 \qquad (17)$$

$$y_0 = \varphi_0 V + \sigma_{\mu_0\varepsilon}\lambda_0 + \xi_0 \quad if\, I_f = 0 \qquad (18)$$

Thus, estimates from the selection equation are used to compute λ_1 and λ_0 which are then added to the outcome equations to correct for selection bias, and this can be estimated using a two-stage method (Maddala, 1983). However, we use the full information maximum likelihood (FIML) estimation approach (Lokshin and Sajaia, 2004), which estimates the selection and outcome equations simultaneously[8]. This is more efficient than the two-step procedure. If $\sigma_{\mu_1\varepsilon}$ and $\sigma_{\mu_0\varepsilon}$ in equations 17 and 18 are statistically significant, we have endogenous switching. Otherwise, we have exogenous switching.

While the FIML ESR model is identified through non-linearities of λ_1 and λ_0 (Lokshin and Sajaia, 2004), a better identification requires an exclusion restriction. That is, we need at least one variable that affects farmers' innovation decisions but does not directly affect any of the households' well-being indicators. Taking inspiration from the agricultural innovation literature on the importance of information in farmers' innovation decisions, we use constraint in accessing information on agricultural innovations (hereafter, information constrained) as our identification strategy[9]. Information-related variables have been used for identification purposes in some previous studies on impact of agricultural innovations (e.g. Kabunga et al., 2011; Asfaw et al., 2012; Negash and Swinnen, 2013). We hypothesise that households that do not face constraints in accessing information on agricultural innovations are more likely to learn of existing or new farming practices and technologies and consequently experiment and adapt them to their local environments or develop novel applications. However, constraint in accessing information on agricultural innovations is not directly related to the household well-being.

Following Di Falco et al. (2011) and Asfaw et al. (2012), the admissibility of the information constrained variable as a valid instrument is established by performing a falsification test: if a variable is an appropriate selection instrument, it will affect innovation decision but it will not affect the welfare outcomes of non-innovating households. The results (see appendix 3) indicate that the information constrained variable is a statistically significant determinant of farmer innovation (Table A1) but not any of the welfare indicators of non-innovative households, except the resilience indicators (Table A2). Thus, the information constrained variable can be regarded as a valid selection instrument for the income, consumption expenditure and food security models, but not the two resilience models.

[8]The models were estimated using the *movestay* command in Stata.

[9] Households were asked to indicate the ease of accessing information about agricultural innovations on a Likert-type response categories ranging from "very easy" to "very difficult". Households that responded "difficult" to "very difficult" are considered to be information constrained.

In this study, we are interested in how innovation decisions affect the well-being of farm households. The coefficients from the ESR model can be used to derive the expected values of well-being, which are then used in estimating the unbiased average treatment effect on the treated (ATT). The ATT compares the well-being of innovators with and without innovation, and this is our parameter of interest. For an innovative household with characteristics K and V, the expected value of well-being is given as:

$$E(y_1 \left| I_f = 1) = \varphi_1 V + \sigma_{\mu_1 \varepsilon} \lambda_1 \right. \qquad (19)$$

The expected value of well-being of the same household had it chosen not to innovate is:

$$E(y_0 \left| I_f = 1) = \varphi_0 V + \sigma_{\mu_0 \varepsilon} \lambda_1 \right. \qquad (20)$$

Thus, the change in well-being as a result of innovation is:

$$ATT^{ESR} = E(y_1 | I_f = 1) - E(y_0 | I_f = 1) = V(\varphi_1 - \varphi_0) + \lambda_1 (\sigma_{\mu_1 \varepsilon} - \sigma_{\mu_0 \varepsilon}) \qquad (21)$$

As indicated, our selection instrument is not valid for the resilience models; hence, we need a different instrument. Due to inability to find another instrument that satisfies the validity conditions, we cannot estimate the resilience models using the FIML ESR approach. Therefore, we employ the propensity score matching (PSM) technique[10]. Using this method, we compute the ATT:

$$ATT^{PSM} = E[R_1 \mid I_f = 1,\ P(K)] - E[R_0 \mid I_f = 0,\ P(K)] \qquad (22)$$

where R_1 *and* R_0 refer to resilience scores for innovators and non-innovators*;* I_f and *K* have been defined above; and *P(K)* indicates the probability of a household innovating given characteristics *K*, which is obtained from a probit regression.

[10] See chapter two for a description of the PSM method.

3.4 Choice of outcome measures

Farmers implement various innovations within their farming systems which may contribute to household welfare. We evaluate the effect of these innovations on a number of welfare outcomes, such as farm and household income, consumption expenditure, food security and resilience to climate shocks. Below, we explain these outcome measures in detail.

3.4.1 Farm and household income

Most of the innovative practices of farm households are yield-related, hence, are expected to affect productivity and consequently farm income. We therefore measure the effect of innovation on farm income. However, farmer innovation may result in resource reallocation which could have indirect effect on household income. For instance, a household involved in labour-saving innovations could have surplus labour for non-farm activities and earn extra income. To capture these potential indirect effects, we also analyse the effect of farmer innovation on total household income, which comprises farm and off-farm income. Gross farm income consists of revenue from sale of crops, livestock and livestock products as well as home consumption of farm produce valued at local market prices. All production costs (e.g. seed, fertilizer, pesticide, hired labour, animal feed, veterinary, etc.) incurred by households 12-month prior to the survey were then deducted from the gross farm income to derive the farm income. Off-farm income includes wages and salaries from agricultural and non-agricultural activities, profits from off-farm self-employment, pensions, remittances, rental income, and income from other off-farm sources. The farm and total household income were expressed in annual per adult equivalent[11] (AE) basis.

3.4.2 Household consumption expenditure

While household income can be used as a measure of household well-being, consumption expenditure is often preferred because it is less prone to seasonal fluctuations and measurement errors, hence, more reliable (Deaton, 1997). We therefore took advantage of our two survey rounds to obtain household consumption data in the second period. It is

[11] We use the OECD adult equivalent scale which is given by: $1+0.7(A-1)+0.5C$, where A and C represent the number of adults and children in a household, respectively.

expected that innovative practices of households will in result in increased yields or outputs, and thus, more consumption of farm products or more income from sales of products for the consumption of other goods. Also, the resource allocation effects of innovation may also induce changes in consumption expenditure.

Household consumption expenditure consists of different sub-components, including food consumption, housing, energy, transportation, communication, health and educational expenses; expenditures on other consumer durables and non-durables; and transfer payments made by households. The survey questionnaire captured the value of household consumption out of purchases, home production and all items received in kind. The non-purchased goods were valued at local market prices. A 7-day recall period was used to capture food expenditure, and a 30-day recall period was used for frequently purchased items or services and non-durable goods; while a 12-month recall period was used for durable items and transfer payments. All the recall periods were standardised to one year, and the different sub-components were aggregated to obtain total household consumption expenditure, which was expressed in per AE terms.

3.4.3 Food and nutrition security

There is no unified measure of food and nutrition security, and this is partly due to its complexity and multidimensionality (Pinstrup-Andersen, 2009; Barrett, 2010). Many studies have used different measures ranging from caloric intake, dietary quality and anthropometric estimates in order to capture the key dimensions of food security: availability, accessibility, utilization and stability. Most of these measures are, however, relatively time-consuming and costly to implement (de Haen et al., 2011). In this study we employ a standard food security measure − food consumption expenditure, as well as three other indicators which are relatively quick and easy to measure. These are food gap/deficit, Household Hunger Scale (HHS) and Household Dietary Diversity Score (HDDS).

The food consumption expenditure forms part of the total household consumption expenditure discussed above. Farmer innovation is expected to affect household food consumption since most inhabitants in the study area are subsistence farmers. The food gap/deficit is a subjective measure of food security, and it refers to the number of months in the past 12 months that households have difficulty satisfying their food needs due to depletion of own food stocks or lack of money to purchase food. This measure is also known as the months of inadequate household food provisioning (MIHFP) (Bilinsky and Swindale 2005). Farming in the study region is mainly rain-fed and rainfall is highly erratic. This results in pervasive seasonal food insecurity so smoothing food consumption throughout the year is a huge challenge for most households.

Another perception-based measure of food insecurity we employed is the HHS, which is suitable to use in highly food insecure areas (Ballard et al., 2011), as in our case. The HHS is a subset of the Household Food Insecurity Access Scale (HFIAS) developed by Food and Nutrition Technical Assistance (FANTA) project of the US-AID, but unlike the HFIAS, the HHS has been validated for cross-cultural use (Ballard et al. 2011). The HHS is related to food access dimension of food security, and it is based on three questions. That is, how often in the past 30 days: 1) was there no food of any kind in the house; 2) did a household member go to sleep hungry; and 3) did a household member go a whole day without eating. The response to each question was coded: 0=never; 1=rarely or sometimes[12]; and 2=often. The sum of these responses yields the HHS score, which ranges from 0 (no hunger) to 6 (severe hunger). Households were interviewed in April 2012 which is around the peak period of the lean season in the study area, and hence, an appropriate period to use the HHS, which measures severe level of food insecurity.

Finally, we use a dietary diversity indicator, the HDDS as another measure of the access facet of food and nutrition security. We assess whether the potential improvement in food production or household income through innovation translates into better nutritional quality of diets. The HDDS, which was also developed by the FANTA project, is obtained by simply summing the total number of 12 food groups consumed by household members in the home during the past 24 hours (Swindale and Bilinsky, 2006). The food groups include cereals, roots and tubers, legumes and nuts, vegetables, fruits, fish and seafood, eggs, meat and poultry, milk and milk products, oils and fats, sweets, and miscellaneous such as

[12] For data collection, “rarely” and “sometimes’’ categories were separated as recommended by Ballard et al. (2011).

spices[13]. As suggested by Swindale and Bilinsky (2006), we made sure that there were no special occasions such as funeral within the sampled households that might influence their food consumption pattern during the 24-hour period.

3.4.4 Resilience to climate shocks

The study region is characterised by frequent droughts and floods that adversely affect farming, the primary source of livelihood for majority of the households in the area. Given the rapidly changing climate, these adverse shocks are expected to become more pervasive. Resilience building is, therefore, necessary for farm households to be able to withstand any future climatic shocks. Resilience can be defined as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" (IPCC, 2007, p.37). While farmers may innovate in order to increase productivity, these innovations may enhance their resilience to shocks. We therefore assess if innovation behaviour of farm households indirectly contribute to building their resilience to climate shocks.

In measuring resilience to climate shocks, we adapted the resilience tool proposed by FAO (2010). This tool was originally designed to measure resilience to food insecurity, but it can serve as a useful framework for analysing households' capacity to absorb unpredictable shocks and stresses such as climate shocks. The advantage of this tool is that it considers short term actions that help households to cope in case of shocks but also long term actions which contribute to resilience building over time (FAO, 2010). The resilience tool consists of six components: income and food access, access to basic services, safety nets, assets, adaptive capacity and stability (Table 3.1). Each of the six components has a specific set of indicators which can confer resilience. Household-level data on these indicators were obtained from the field survey. We expect farmer innovation to contribute to household resilience mainly through the income and food access, assets, adaptive capacity and stability components.

[13] We use a disaggregated set of food groups which were then combined into 12 food groups to generate the HDDS (Swindale and Bilinsky 2006).

Table 3.1: Indicators of the climate resilience score

Component	Indicators	Units
Income and Food Access	Household income per AE	GH¢
	Household Food Insecurity Access Score (HFIAS)	Index, 0 to 27
	Household Dietary Diversity Score (HDDS)	Index, 0 to 12
Access to Basic Services	Distance to source of water	Km
	Distance to health service	Km
	Distance to all-weather road	Km
	Access to electricity	Dummy
	Access to telecommunication	Dummy
	Access to credit	Dummy
Safety Nets	Number of safety nets programmes household participates in	Count
	Group membership	Dummy
Assets	Value of productive assets	GH¢
	Livestock holding	TLU
	Land holding	Acres
Adaptive capacity	Diversity of income sources	Count
	Dependency ratio	Ratio
	Available adaptation strategies to climate shocks	Count
	Household receives early warning system notices	Dummy
	Knowledge of climate change	Dummy
	Household has savings with a bank or saving group	Dummy
Stability	Number of household members that have lost their jobs	Count
	Income change of household	Ordinal, 1 to 3
	Capacity to keep up in the future	Ordinal, 1 to 4

The indicators of each resilience component are measured on different scales; hence, standardization is needed so that the values of all the indicators range from 0 to 1. We followed the method used in the Human Development Index (UNDP, 2006) to standardize the values of the indicators. During standardization, we took into account fact that some of the indicators increase whiles others decrease with resilience. That is, we considered the functional relationship between resilience and the indicators. We therefore employed two methods of standardization so that resilience increases with an increase in the value of each indicator. For indicators that increase with resilience (e.g. per capita income, value of assets, and diversity of income sources) we standardized by:

$$\tau_{s\tan d} = \frac{\tau_{ij} - \tau_{\min}}{\tau_{\max} - \tau_{\min}} \qquad (23)$$

While indicators that decreases with resilience (e.g. HFIAS, distance to basic services) was standardized using:

$$\tau_{s\tan d} = \frac{\tau_{\max} - \tau_{ij}}{\tau_{\max} - \tau_{\min}} \qquad (24)$$

where τ_{ij} is the value of the indicator *j* for household *i*; stand, min and max are the standardized, minimum and maximum values of the indicator τ, respectively.

After standardization, we need to assign weights to each indicator. For robustness check, we use two weighting approaches: equal and unequal weights. In the former case each indicator contributes equally to the resilience score. We averaged the different sub-components to derive a score for each major component. The six components were then averaged proportionally to obtain the overall household resilience score. In the unequal weighting approach, we followed Alinovi et al. (2010) and used a two-stage factor analysis procedure. In the first stage, separate indices for each component were computed using an iterated principal factor method. In the second stage, a factor analysis was performed on the interacting components indices obtained in the first stage to derive the household resilience score.

3.5 Data and Sample Characteristics

The empirical analysis is based on data for the 2011-2012 agricultural season obtained from a household survey conducted within the research programme—West African Science Service Center for Climate Change and Adapted Land Use (WASCAL)—funded by the German Federal Ministry of Education and Research (BMBF). Data collection took place in Bongo, Kassena Nankana East and Kassena Nankana West districts in Upper East region, one of the poorest administrative regions of Ghana. Part of this research aims at examining the effect of a participatory extension approach, the Farmer Field Fora (FFF) on farmers' innovativeness; hence, this influenced the sampling strategy used in this study. Descriptions of the study area and the sampling design are presented in chapter one of this thesis. Overall, our sample consists of 409 farm households (101, 156 and 152 from Bongo, Kassena Nankana East and Kassena Nankana West districts, respectively) randomly selected from the three districts.

Data collection was conducted by experienced enumerators who were highly trained for this research. Interviews were conducted with the aid of pre-tested questionnaires (see appendix A and B) and were supervised by the author. Due to the bulky nature the questionnaire and the potential differences in perceived food insecurity across the three districts as a result of different survey days, the data collection took place in two phases. The first phase was conducted between December 2012 and March 2013. The questionnaire used in this phase captured data on household and plot characteristics, crop and livestock production, off-farm income earning activities, innovation-generating activities, access to infrastructural services, information and social interventions, household experiences with shocks, climate change adaptation strategies and risk preferences[14]. The second phase of the survey took place just after the end of the first phase and was conducted simultaneously in the three districts so that the households' subjective responses to food insecurity are not influenced by differences in survey days. In the second phase, the same households were revisited and all but one household were re-interviewed. Thus, the sample size in the second phase is 408. The second phase was used to obtain data on the food security indicators (HHS, HDDS and food consumption) as well as household consumption expenditure.

[14] We measured households' subjective risk preferences using the Ordered Lottery Selection Design with real payoffs (Harrison and Rutström 2008).

Table 3.2: Definition of variables in the regression

Variable	Description	Mean	SD
Treatment variable			
Innovation	Household implemented innovation practices in the past 12 months	0.41	0.49
Explanatory variables			
Age	Age of household head	49.42	14.88
Gender	Gender of household head (1=male)	0.86	0.35
Household size	Number of household members	6.64	2.59
Dependency ratio	Ratio of members aged below 15 and above 64 to those aged 15-64	0.89	0.79
Education	Education of household head (years)	1.67	1.10
FFF participation	Household member participated in Farmer Field Fora (FFF)	0.45	0.50
Land holding	Total land owned by household in acres	4.56	4.15
Livestock holding	Total livestock holding of household in Tropical Livestock Units (TLU)	2.92	3.41
Assets value	Total value of non-land productive assets in 100 GH¢[b]	4.54	6.92
Off-farm activity	Household engages in off-farm income earning activities	0.76	0.43
Credit access	Household has access to credit	0.26	0.43
Road distance	Distance to nearest all-weather road in km	0.54	0.84
Group membership	A household member belongs to a group	0.64	0.48
Climate shock	Household suffered from droughts or floods in the past 5 years	0.91	0.29
Pest and disease shock	Household farm affected by pests or diseases in the past 5 years	0.82	0.39
Labour shock	Death or illness of a household member one year prior to survey	0.60	0.49
Risk averse	Household is risk averse	0.40	0.49
Information constrained	Household faces agricultural information constraints	0.49	0.50
Bongo District	Household is located in Bongo District	0.25	0.43
KNW District	Household is located in Kassena Nankana West District	0.37	0.48
KNE District	Household is located in Kassena Nankana East District	0.38	0.49
Outcome variables			
Farm income	Total farm income per adult equivalent	317.57	448.42
Household income	Total household income per adult equivalent	531.69	768.68
Consumption expenditure	Total household consumption expenditure per adult equivalent	779.08	627.29
Food consumption	Total food consumption expenditure per adult equivalent	453.83	330.66
Food gap/deficit	Number of months of inadequate household food provisioning	2.85	1.68
HHS	Household Hunger Scale Score	1.13	1.27
HDDS	Household Dietary Diversity Score	7.14	1.96
Resilience score_1	Household resilience score using equal weighting of indicators	0.48	0.08
Resilience score_2	Household resilience score using unequal weighting of indicators	0.50	0.20

[a] The exchange rate at the time of the survey was 1 euro = 2.5 GH¢

Table 3.2 outlines the description of the variables used in the regression and their mean values. The explanatory variables were motivated by literature on agricultural innovation adoption, and they include household and farm characteristics (e.g. age, gender and years of education of the household head, household size, dependency ratio, farm size and risk attitude) as well as institutional and access related variables (e.g. FFF participation, and access to credit, information and motorable roads). We also include district dummies to control for district fixed effects. The table shows that an average household has 7 people with high dependency ratio. Majority of the households are male-headed, and household heads are mostly middle-aged with very low level of education. Households generally have about 5 acres of land, and many households have been affected by shocks, particularly climatic shocks. Majority of the households are credit constrained, and about half of them also face agricultural information constraints.

The summary statistics of the outcome variables, which are presented in the lower part of Table 3.2, indicate that the average farm income per AE is almost 318GH¢, and this contributes about 60 percent to total household income per AE. Similarly, the average food consumption expenditure of nearly 454GH¢ accounts for about 58 percent of average total consumption expenditure. On average, households experience about 3 months (April to June) of inadequate food provisioning. The average HHS of about 1.13 suggests that severe food insecurity or hunger is not pervasive in the study region. The average resilience score of 0.33 to 0.48 (out of a maximum of 1) indicates that the sampled households are weakly resilient to climate shocks. The table also shows that about 41 percent of the sampled households implemented at least one innovation generating-activity in the past 12 months, and this is our treatment variable. Table 3.3 shows the different domains in which the farmers innovated.

Table 3.3: Domains of innovations implemented by farm households

Domain	Proportion of households (%)
Crops and crop varieties	51.19
Method of planting	19.64
Soil fertility	17.26
Animal Husbandry	12.50
Weed control	7.74
Land preparation	7.14
Cropping pattern	6.55
Pests and Diseases control	5.95
Storage	4.17
Agroforestry	4.17
Farm tool/equipment	1.19
Soil and Water Conservation	1.19
Others	1.79

Most of the farmer innovations involve informal experimentation or minor modification of common or external practices. There are also few innovations that are major modification of current practices or even completely novel. Majority of the innovations are related to crop varieties and agronomic practices, as shown in Table 3.3. The main domain is related to crops and crop varieties, and this consists of introduction of new crops or crop varieties into a community and experimentation of different variety of crops to select the best ones that suit the farming system. The important agronomic innovations include new or modification of land preparation and planting methods as well as cropping patterns (e.g. new methods of intercropping or planting with reduced seed rate); soil fertility measures such as new methods of compost preparation or methods to prevent soil nutrient loss; and weed, pest and disease control methods such as the use of biopesticides. Some of the innovations are related to livestock production, and they include new formulations of animal feed and applying herbal remedies in the treatment of livestock diseases (i.e. ethnovertinary practices). Other minor domains of the farmers' innovations are related to storage, farm tool, agroforestry, and soil and water conservation.

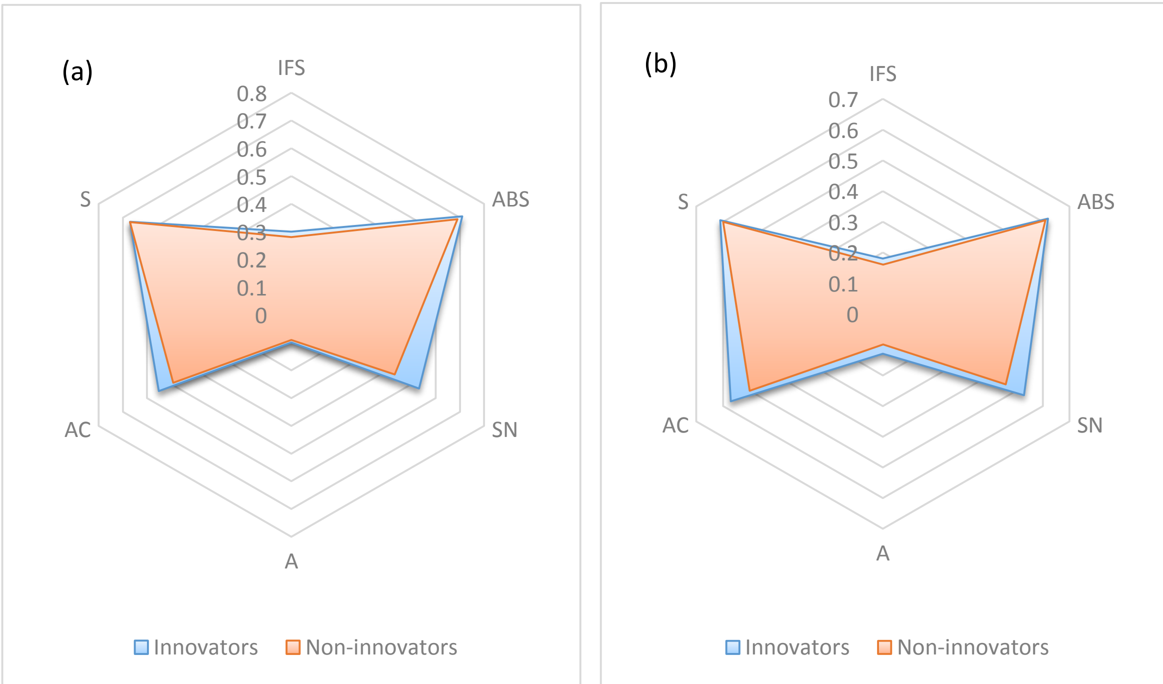
Table 3.4 presents descriptive statistics of the variables in the regression, disaggregated by innovation status. There are remarkable differences between innovators and non-innovators with respect to some of the household characteristics and well-being indicators. The heads of innovative households appear to be significantly younger and more educated than non-innovators. Innovative households also tend to be less risk averse and less agricultural information constrained but are likely to own more land. There are also significant differences in terms of FFF participation and group membership between the two groups, and the KNW District appear to have significantly higher number of innovative farmers. As expected, innovative households have significantly higher farm income, which further results in significantly higher total household income. They also seem to have fewer days of insufficient food and are more resilience to climate shocks. Average consumption expenditure is slightly higher for innovative households but the difference in means is not statistically significant.

Table 3.4: Descriptive statistics of variables in the regression

	Innovators (N=168)		Non-innovators (N=241)		
Variable	Mean	SD	Mean	SD	t-Stat[a]
Explanatory variables					
Age	46.80	14.22	51.63	15.59	-3.19***
Gender	0.86	0.35	0.85	0.36	0.30
Household size	6.57	2.20	6.65	2.84	-0.31
Dependency ratio	0.87	0.75	0.90	0.81	-0.38
Education	3.31	4.37	2.04	3.88	3.09***
FFF participation	0.54	0.50	0.39	0.49	3.06***
Land holding	5.20	5.60	4.11	3.37	2.47**
Livestock holding	3.04	3.47	2.79	3.41	0.74
Assets value	5.33	6.80	3.97	7.28	1.92*
Off-farm activity	0.80	0.40	0.73	0.45	1.66*
Credit access	0.29	0.46	0.22	0.42	1.55
Road distance	0.54	0.89	0.55	0.87	-0.01
Group membership	0.74	0.44	0.57	0.50	3.69***
Climate shock	0.88	0.32	0.93	0.26	-1.68*
Pest and disease shock	0.84	0.37	0.81	0.39	0.78
Labour shock	0.58	0.50	0.61	0.49	-0.66
Risk averse	0.34	0.47	0.44	0.50	-2.13**
Information constrained	0.36	0.48	0.59	0.49	-4.64***
Bongo District	0.21	0.41	0.27	0.45	-1.51
KNW District	0.44	0.50	0.32	0.47	2.42**
KNE District	0.35	0.48	0.40	0.49	-1.05
Outcome variables					
Farm income	399.88	538.64	259.96	362.77	3.14***
Household income	624.81	761.69	466.51	768.41	2.06**
Consumption expenditure	827.00	624.71	745.88	628.22	1.29
Food consumption	478.10	376.01	437.02	294.84	1.23
Food gap/deficit	2.62	1.53	3.00	1.76	-2.30**
HHS	1.02	1.10	1.21	1.37	-1.47
HDDS	7.30	1.97	7.02	1.94	1.40
Resilience score_1	0.50	0.01	0.46	0.01	4.70***
Resilience score_2	0.55	0.01	0.47	0.01	4.17***

[a] test of mean difference between innovators and non-innovators characteristics.
***, **, * represent 1%, 5%, and 10% significance level, respectively

The results of the major components of the resilience framework—using equal and unequal weighting approaches—are presented in Figures 3.1a and 3.1b, respectively. The two figures show that the component score for innovators and non-innovators are almost similar irrespective of the weighting method employed. Innovators and non-innovators have identical scores in terms of access to basic services and stability but differ marginally with respect to safety nets and adaptive capacity. The figures also indicate that households in the study region are moderately resilient in terms of access to basic services, safety nets, adaptive capacity and stability but are weakly resilient with respect to income and food access, and assets.



Note: IFS=Income and Food Access; ABS=Access to Basic Services; SN=Safety Net; A=Assets; AC=Adaptive Capacity; S=Stability

Figure 3.1: Resilience by innovation groups using**:** (a) equal weights (b) unequal weights

3.6 Impact of farmer innovation

In this section, we present the results of the effect of farmer innovation on household well-being. We first look at the outcomes of innovation practices as subjectively stated by the innovative farmers before presenting the econometric results.

3.6.1 Subjective outcome of farmer innovation

To corroborate the results from the regression analysis, all the innovators were asked about the outcomes observed from their innovative practices, and their subjective responses are summarised in Figure 3.2. The figure shows that increased production is the major outcome of the farmers' innovations. Most of the innovative practices listed by the farmers are yield-related (e.g. crops and crop varieties, soil fertility, and pest and disease control); so, it is not surprising that increased production is the most mentioned outcome. Increased income and improved food security are also important outcomes observed by the farmer innovators. These two outcomes may stem from the increase in production, and together, they point out the potential positive well-being effects of farmer innovation. Another positive effect of the farmers' innovations is labour saving, and thus, reduction in production costs and freeing of labour for off-farm employment. Some farmers implement informal experiments in order make better farming decisions, and others discover innovations out of curiosity or serendipity; hence, this explains the significant number of innovators asserting increased knowledge or satisfaction as outcomes of their innovations. A few of the farmers indicated that their innovations were unsuccessful, and this is expected since innovation generally involves decision making under uncertainty, which can result in positive or negative outcomes. Similar subjective outcomes were obtained by Kummer (2011) and Leitgeb et al. (2014) in studies on farmer experimenters in Austria and Cuba, respectively.

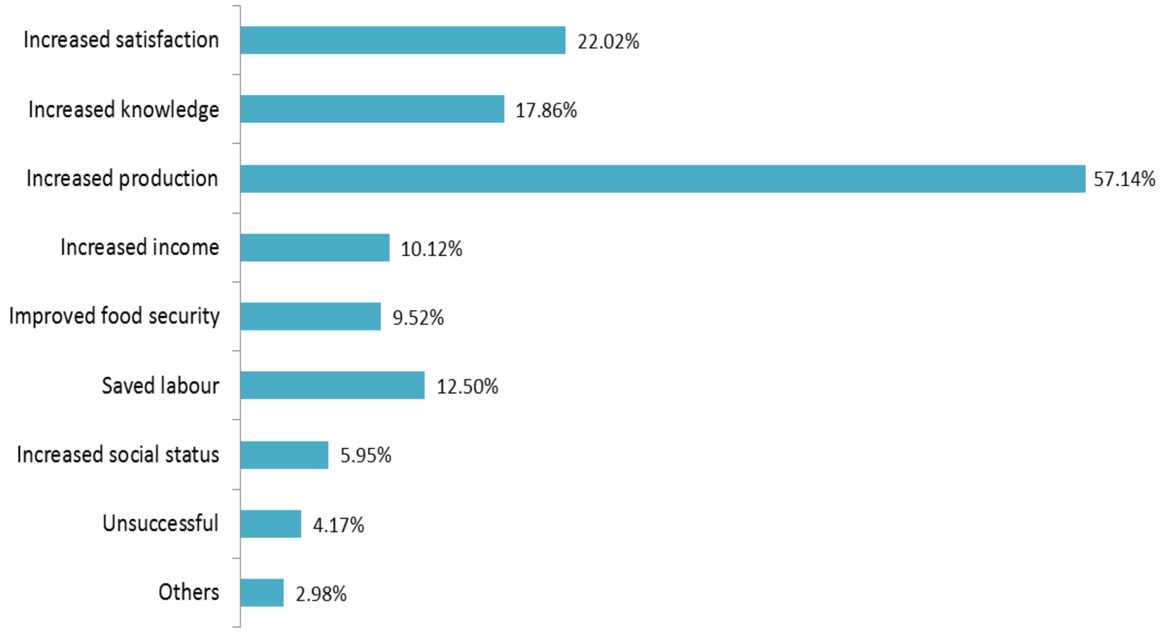


Figure 3.2: Subjective outcome of farmer innovation

3.6.2 Econometric results

The descriptive results in Table 3.4 revealed significant differences in some of the well-being indicators between innovators and non-innovators. Also, analysis of farmers' perceptions in the previous section shows potential positive effects of farmer innovation. To properly analyse the impacts of farmer innovation, we use an econometric technique, the FIML ESR. The FIML ESR model involves a selection equation and separate outcome equations for innovators and non-innovators which are estimated simultaneously. The selection equation is about the determinants of innovation decision, and the results are shown in Table A1 in the appendix. Our exclusion restriction variable, information constrained is statistically significant in all the models, thus satisfying the instrument relevance condition. The negative coefficient confirms our expectation that information-constrained households are less likely to innovate[15]. We now look at the results for each of the outcome indicators.

3.6.2.1 Farm and household income effects

The second-stage estimates of the FIML ESR models for the farm and household income equations are presented in Table 3.5. The table shows how each of the explanatory variables affects the two income measures. ρ_1 and ρ_0, the correlation coefficients between the error terms of the selection and outcome equations reported at the bottom part of the table, provide an indication of selection bias. A statistical significance of any of them suggests that self-selection would be an issue if not accounted for. In all the two income models in Table 3.5, the correlation coefficients for the innovators (ρ_1) and non-innovators (ρ_0) equations are both negative but only the ρ_1 coefficients are statistically significant, suggesting that there is self-selection among innovators. Thus, farm households with lower than average farm and household income are less likely to innovate, while the non-innovators are not better or worse off than a random farm household. The significance of the likelihood ratio tests for independence of equations also indicates that there is joint dependence between the selection equations and the income equations for innovators and non-innovators.

The results show that household size and livestock holding significantly affect the farm income of both innovators and non-innovators. An increase in household size results in a decline in farm income while larger livestock holding contributes positively to farm income. There are differences between what determines farm income among innovators and non-innovators, and this justifies the use of the ESR model. For example, gender of household head, dependency ratio, land holding and labour shock are significantly associated with the farm income of non-innovators, but the effects are insignificant among innovators.

[15] The first-stage results on the determinants of farmer innovation are not discussed in this paper since a detailed analysis and discussion were presented in chapter two of this thesis.

Conversely, years of education of household head significantly influences the farm income of only innovators. The results for the household income model also indicate similar differences in the significance of the coefficients between the innovators and non-innovators equations. However, there are notable differences across the two income models. For instance, the value of household assets and off-farm job positively and significantly influence household income but not farm income. Thus, factors that significantly affect farm income may not necessarily influence household income, and this is expected since most of the households (76%) earn income from non-farm activities to supplement farm income.

Table 3.5: ESR results for farm and household income

	Farm income per AE (log)		Household income per AE (log)	
	Innovators	Non-innovators	Innovators	Non-innovators
Age	-0.004 (0.005)	-0.001 (0.004)	-0.004 (0.004)	0.003 (0.004)
Gender	0.298 (0.200)	0.307 (0.153)**	0.218 (0.154)	0.346 (0.153)**
Household size	-0.141 (0.032)***	-0.140 (0.021) ***	-0.133 (0.025)***	-0.135 (0.021) ***
Dependency ratio	-0.058 (0.090)	0.136 (0.065)**	-0.008 (0.069)	0.068 (0.065)
Education	-0.036 (0.019)*	-0.012 (0.016)	-0.009 (0.015)	0.012 (0.016)
FFF participation[16]	0.240 (0.292)	0.390 (0.245)	0.093 (0.227)	0.189 (0.245)
Land holding	0.002 (0.016)	0.069 (0.019)***	0.004 (0.011)	0.046 (0.019)**
Livestock holding	0.116 (0.023)***	0.070 (0.019)***	0.100 (0.018) ***	0.059 (0.019)***
Assets value	0.003 (0.010)	0.002 (0.008)	0.023 (0.008)***	0.033 (0.008)***
Off-farm activity	0.012 (0.166)	-0.156 (0.122)	0.446 (0.129) ***	0.277 (0.122)***
Credit access	-0.225 (0.154)	0.095 (0.129)	-0.091 (0.114)	0.229 (0.129)*
Road distance	-0.194 (0.077)	-0.061 (0.068)	-0.039 (0.059)	-0.067 (0.068)
Group membership	-0.029 (0.175)	-0.042 (0.134)	0.045 (0.141)	-0.003 (0.133)
Climate shock	-0.089 (0.218)	-0.258 (0.223)	-0.211 (0.164)	-0.255 (0.224)
Pest and disease shock	-0.142 (0.186)	0.020 (0.139)	-0.137 (0.146)	-0.043 (0.139)
Labour shock	-0.071 (0.138)	-0.331 (0.115)***	-0.219 (0.107)**	-0.279 (0.115)**
Risk averse	0.087 (0.141)	0.096 (0.107)	-0.058 (0.111)	0.121 (0.138)
KNW District	0.343 (0.204)*	-0.058 (0.160)	0.443 (0.157) ***	-0.126 (0.160)
KNE District	0.316 (0.211)	0.135 (0.162)	0.473 (0.164) ***	0.179 (0.161)
Constant	6.816 (0.529)***	5.782 (0.425)***	6.573 (0.437) ***	5.646 (0.426) ***
$ln\sigma_1, ln\sigma_0$	-0.032 (0.106)	-0.239 (0.050)***	-0.416 (0.108)***	-0.241 (0.048)**
ρ_1, ρ_0	-0.912 (0.057)***	-0.203 (0.181)	-0.581 (0.194) ***	-0.156 (0.174)
LR test of indep. eqns.		18.13***		7.55***
Number of observations		409		409
Log likelihood		-693.486		-675.499

***, **, * represent 1%, 5%, and 10% significance level, respectively

[16] In all the models, we use the predicted probability of FFF participation since FFF participation is potentially endogenous.

Table 3.6: Treatment effects of farmer innovation

Outcome	Innovation decision		ATT
	Innovating	Not innovating	
Farm income per AE (log)	5.69	5.30	0.39***
Household income per AE (log)	6.09	5.75	0.34***
Consumption expenditure per AE (log)	6.54	6.24	0.30***
Food gap/deficit (months)	2.59	3.71	-1.12***
Household Hunger Scale (HHS) Score	1.03	1.53	-0.50***
Food consumption expenditure per AE (log)	5.98	5.67	0.31***
Household Dietary Diversity Score (HDDS)	7.30	8.02	-0.72***

***, **, * represent 1%, 5%, and 10% significance level, respectively

The estimates of the treatment effects of farmer innovation on farm and household income are presented in Table 3.6. The predicted farm and household income per AE from the ESR models are used to compute the ATT. The ATT measures the mean difference between the actual income of innovators and what they would have earned if they had not innovated. The results show that farmer innovation has a positive and statistically significant effect on both farm and household income of the innovating households. Innovation increases per adult equivalent farm and household income of innovators by about 39 and 34 percentage points respectively, and these effects are statistically significant. These results confirm the farmers' subjective reports of the positive income effects of their innovations. These findings also support the results of numerous studies (e.g. Amare et al., 2012; Noltze et al., 2013) on the significant contribution of agricultural innovations to household income.

3.6.2.2 Consumption expenditure effects

Table 3.7 shows the estimation results of the consumption expenditure model. The results show that household size and dependency ratio significantly reduce consumption expenditure of both innovators and non-innovators, but the effect is more pronounced for innovators. The value of household assets also significantly increases consumption expenditure for both groups, but the coefficients for other wealth-related variables (e.g. livestock holding and off-farm activity) are not statistically significant. The positive and significant coefficient of the district dummies in both innovation regimes suggests that farm households in the KNE and KNW districts have higher consumption expenditure than those in Bongo district. This is expected since Bongo district is recognised as one of the poorest districts in the Upper East region of Ghana (Akudugu and Laube, 2013).

Table 3.7: ESR results for consumption expenditure

	Innovators		Non-innovators	
	Coefficient	SE	Coefficient	SE
Age	-0.001	(0.003)	-0.001	(0.002)
Gender	0.086	(0.118)	0.083	(0.084)
Household size	-0.147***	(0.019)	-0.098***	(0.012)
Dependency ratio	-0.168**	(0.054)	-0.072*	(0.036)
Education	0.027*	(0.011)	-0.001	(0.010)
FFF participation	0.042	(0.171)	0.215	(0.144)
Land holding	0.012	(0.009)	0.010	(0.011)
Livestock holding	-0.005	(0.014)	0.007	(0.011)
Assets value	0.014*	(0.006)	0.014**	(0.004)
Off-farm activity	0.004	(0.098)	0.017	(0.067)
Credit access	-0.119	(0.088)	-0.007	(0.072)
Road distance	0.098*	(0.048)	-0.005	(0.037)
Group membership	0.272*	(0.109)	-0.007	(0.082)
Climate shock	-0.386**	(0.135)	0.171	(0.121)
Pest and disease shock	0.262*	(0.109)	0.002	(0.082)
Labour shock	-0.145	(0.081)	-0.021	(0.063)
Risk averse	-0.157	(0.082)	-0.027	(0.067)
KNW District	0.393**	(0.121)	0.353***	(0.088)
KNE District	0.432***	(0.127)	0.494***	(0.099)
Constant	6.648***	(0.319)	6.335***	(0.289)
$ln\sigma_1, ln\sigma_0$	-0.564***	(0.115)	-0.821***	(0.129)
ρ_1, ρ_0	0.911***	(0.063)	-0.412	(0.499)
LR test of indep. eqns.			8.14***	
Number of observations			408	
Log likelihood			-458.21	

***, **, * represent 1%, 5%, and 10% significance level, respectively

The results also show some differences between innovators and non-innovators with respect to some of the variables. For instance, climate shock has a negative and significant effect on the expenditure of innovative households, but the effect is positive and insignificant for non-innovators. The statistical significance of the correlation coefficient (ρ_1) suggests that there is selection effect; hence, unobserved factors affect both the innovation decision and household consumption expenditure. Thus, farm households who choose to innovate have above average consumption expenditure per AE, while those who choose not to innovate are not better or worse off than a random farm household.

The result for the treatment effect of farmer innovation on consumption expenditure per AE is presented in Table 3.6. The ATT result shows that farm households who innovated significantly increased their consumption expenditure per AE by 30 percentage points as a result of their innovations. This positive consumption effect may stem from the revenue increase or cost reduction potential of farmers' innovations. This also implies that the positive income effects of farmer innovation reported earlier translate into increased household consumption.

3.6.2.3 Food and nutrition security effects

As already indicated, four different measures of food security are used in the estimation of the effect of farmer innovation on food and nutrition security. The second stage results for all the four indicators are presented in Tables 3.8 and 3.9. The correlation coefficient (ρ_1) in the food gap and food consumption expenditure models are statistically significant while those of the HHS and HDDS models are not significant, suggesting heterogeneous results depending on the food security indicator employed. The estimated coefficients of the determinants of the four food security measures further highlight the presence of heterogeneous sample and effects. For instance, the included covariates largely influence the various food security indicators differently. Similarly, the variables that explain food security of innovators do not affect that of non-innovators, and vice versa. Only the location variables are statistically significant in all the four models. Similar to the results in the consumption expenditure model, the coefficients of the district dummies suggest that households located in KNE and KNW districts are more food secure compared with households in the relatively poor Bongo district. Among the key determinants of household food security are gender, dependency ratio, value of household assets, pest and disease shock, labour shock and risk attitude.

Table 3.8: ESR results for food gap and household hunger scale

	Food gap /deficit		Household Hunger Scale (HHS)	
	Innovators	Non-innovators	Innovators	Non-innovators
Age	0.002 (0.013)	-0.006 (0.008)	-0.001 (0.007)	0.003 (0.006)
Gender	-0.255 (0.450)	-0.950 (0.299)***	0.061 (0.259)	-0.445 (0.240)*
Household size	-0.003 (0.072)	0.021 (0.043)	0.048 (0.042)	0.007 (0.035)
Dependency ratio	0.278 (0.206)	0.174 (0.128)	-0.043 (0.114)	0.238 (0.103)**
Education	0.023 (0.043)	-0.017 (0.032)	0.000 (0.026)	0.005 (0.026)
FFF participation	-0.326 (0.667)	0.166 (0.485)	-0.445 (0.396)	-0.419 (0.389)
Land holding	0.056 (0.042)	-0.056 (0.039)	-0.001 (0.022)	-0.031 (0.032)
Livestock holding	-0.101 (0.064)	0.041 (0.037)	-0.021 (0.030)	0.051 (0.030)*
Assets value	0.008 (0.026)	-0.037 (0.016)**	-0.025 (0.013)*	-0.011 (0.013)
Off-farm activity	0.181 (0.377)	-0.139 (0.243)	0.183 (0.214)	-0.266 (0.196)
Credit access	0.039 (0.372)	-0.067 (0.253)	-0.017 (0.185)	0.117 (0.206)
Group membership	0.431 (0.469)	0.118 (0.265)	-0.219 (0.258)	0.132 (0.232)
Climate shock	-0.811 (0.555)	-0.132 (0.421)	-0.215 (0.285)	-1.085 (0.372)***
Pest and disease shock	0.624 (0.447)	0.263 (0.271)	-0.577 (0.252)**	0.456 (0.226)**
Labour shock	-0.214 (0.319)	0.006 (0.226)	0.080 (0.177)	-0.374 (0.184)**
Risk averse	-0.082 (0.334)	0.265 (0.215)		
KNW District	0.102 (0.500)	-0.738 (0.317)**	-0.395 (0.254)	-0.032 (0.256)
KNE District	-0.515 (0.483)	-1.485 (0.312)***	-0.493 (0.278)*	-0.595 (0.257)**
Constant	0.675 (1.251)	5.050 (0.874)***	2.192 (0.797)***	2.686 (0.767)***
$ln\sigma_1, ln\sigma_0$	0.834 (0.194)***	0.456 (0.072)***	0.012 (0.058)	0.233 (0.059)***
ρ_1, ρ_0	0.961 (0.077)***	0.361 (0.256)	-0.050 (0.560)	0.168 (0.405)
LR test of indep. eqns.		7.28***		1.94
Number of observations		409		408
Log likelihood		-989.31		-885.54

***, **, * represent 1%, 5%, and 10% significance level, respectively

The results indicate that female-headed households are more likely to have extra months of food inadequacy and their household members are more likely to experience hunger, but the coefficients are only significant for non-innovators. This is probably due to the fact that women in the study region have limited access to land and other resources needed to achieve food security (Apusigah, 2009). This is also in line with studies that found that female-headed households are more likely to be food insecure than male-headed households (Kassie et al., 2014). The value of household assets significantly reduces hunger and increases food consumption among innovators, while it significantly decreases the number of months of food shortages for non-innovators. This is plausible since households in the study region have a tendency of depleting their productive assets as a coping mechanism to food insecurity (Quaye, 2008). The results also show that innovative but risk averse households are more likely to realise a decrease in both food consumption expenditure and dietary diversity.

Table 3.9: ESR results for food consumption expenditure and household dietary diversity

	Food consumption expenditure per AE (log)		Household Dietary Diversity Score (HDDS)	
	Innovators	Non-innovators	Innovators	Non-innovators
Age	-0.001 (0.003)	0.000 (0.002)	-0.024 (0.011)**	0.003 (0.008)
Gender	0.061 (0.115)	0.095 (0.087)	0.227 (0.403)	0.355 (0.313)
Household size	-0.147 (0.019)***	-0.102 (0.012)***	0.046 (0.065)	-0.041 (0.044)
Dependency ratio	-0.133 (0.054)**	-0.030 (0.037)	-0.007 (0.179)	-0.105 (0.131)
Education	0.013 (0.011)	-0.003 (0.010)	0.000 (0.039)	-0.006 (0.035)
FFF participation	0.169 (0.167)	0.225 (0.146)	-1.226 (0.596)**	0.818 (0.505)
Land holding	0.009 (0.009)	0.004 (0.011)	0.043 (0.030)	0.075 (0.042)*
Livestock holding	-0.011 (0.013)	0.000 (0.011)	0.026 (0.046)	0.043(0.039)
Assets value	0.012 (0.006)**	0.004 (0.005)	0.025 (0.021)	0.026(0.016)
Off-farm activity	0.004 (0.098)	0.016 (0.070)	-0.261 (0.336)	1.052 (0.248)***
Credit access	-0.033 (0.085)	0.013 (0.074)	-0.462 (0.292)	-0.008 (0.262)
Road distance	0.031 (0.045)	-0.006 (0.039)	-0.143 (0.153)	0.050 (0.140)
Group membership	0.182 (0.110)*	-0.029 (0.081)	0.587 (0.379)	-0.068 (0.304)
Climate shock	-0.357 (0.130)***	0.145 (0.126)	0.051 (0.425)	-0.767 (0.490)
Pest and disease shock	0.265 (0.107)**	-0.052 (0.083)	0.022 (0.382)	0.187 (0.295)
Labour shock	-0.151 (0.079)*	-0.014 (0.066)	-0.707 (0.276)**	-0.299 (0.232)
Risk averse	-0.199 (0.081)**	-0.014 (0.066)	-0.496 (0.295)*	0.189 (0.242)
KNW District	0.485 (0.118)***	0.433 (0.091)***	2.465 (0.403)***	1.371 (0.326)***
KNE District	0.446 (0.123)***	0.510 (0.097)***	2.542 (0.428)***	1.605 (0.331)***
Constant	6.227 (0.316)***	5.875 (0.275)***	6.118 (1.158)***	5.169 (1.075)***
$ln\sigma_1, ln\sigma_0$	-0.636 (0.132)***	-0.782 (0.106)***	0.489 (0.096)***	0.471 (0.083)***
ρ_1, ρ_0	0.819 (0.120)***	-0.435 (0.370)	0.375 (0.298)	0.268 (0.479)
LR test of indep. eqns.		4.04***		3.55*
Number of observations		408		408
Log likelihood		-473.00		-1009.12

***, **, * represent 1%, 5%, and 10% significance level, respectively

The results for the treatment effects of farmer innovation on food and nutrition security are presented in Table 3.6. The results indicate that farmer innovation plays a key role in food insecurity reduction among innovators. The innovations of farm households help to reduce the length of food gap periods by one month. In other words, if households that innovated were not to innovate, they would have had an extra month of food insufficiency. Analogously, farmer innovation significantly reduces household hunger by 0.50 index points, and this amounts to about 33 percent reduction in the severe level of food insecurity for innovators. In addition, the innovations significantly caused an increase in food consumption expenditure per AE by about 31 percentage points for innovative households, which further confirms the positive food security effects of farmer innovation. The ATT estimate for the HDDS, however, suggests that farmer innovation does not increase household dietary diversity. Specifically, innovations significantly decrease dietary diversity by 0.72 index points (or about 9 percent) for innovators. This suggests that the high production and income benefits of farmer innovation do not necessarily translate into nutritious diets. Thus, the increased food consumption expenditure reported earlier is related to availability, and not diversity of food. In fact, the data on household expenditure indicates that a large share of the expenditure on food is devoted to cereal staples such as millet, maize and sorghum. Overall, farmer innovation improves food security for innovative households, and this corroborates the subjective outcomes reported by the innovators as well as anecdotal or qualitative evidences on the impact of farmer innovation (e.g. Reij and Waters-Bayer 2001; Sawadogo et al., 2001; Reij et al., 2009; Avornyo et al., 2011).

3.6.2.4 Climate resilience effects

Finally, we look at the contribution of farmer innovation to building households' resilience to climate shocks. As mentioned earlier, we use the PSM technique due to the failure to find a valid selection instrument. We also employ separate methods in computing household resilience score: equal weighting (Resilience_1) and unequal weighting (Resilience_2) of indicators. In the PSM, we use kernel matching algorithm with a bandwidth of 0.3, but radius matching (with a calliper of 0.05) and nearest-neighbour matching algorithms are also employed to check the robustness of our results. We first conducted a matching quality test to check if innovators are appropriately matched with non-innovators. The test result for kernel matching (Table A3 in appendix 3) shows that in contrast to the unmatched sample, there are no statistical significance differences in covariates between innovators and non-innovators after matching. Thus, the covariate balancing requirement of PSM is achieved, and we can now proceed to estimate the ATT.

The ATT results in Table 3.10 show that farmer innovation is positively and significantly associated with households' resilience to climate shocks. Using equal weighting of resilience indicators' approach, we find that farmer innovation improves innovative households' resilience to climate shocks by 5 percent. Similarly, the result of the ATT using unequal weighting approach implies that farmer innovators are about 6 percent more resilient to climate shocks than they would have been if they were not to innovate. These findings are consistent, irrespective of the matching algorithm or weighting approach employed. The small magnitude of the ATT values, however, suggests that there are other essential factors that enhance farm households' resilience to climate shocks.

Table 3.10: Effect of farmer innovation on resilience to climate shocks

Matching algorithm	Outcome	Innovation decision		ATT	ATT in %
		Innovate	Not-innovating		
Kernel matching	Resilience_1	0.494	0.470	0.024***	5.11
	Resilience_2	0.496	0.468	0.028***	5.98
Radius matching	Resilience_1	0.494	0.478	0.016*	3.35
	Resilience_2	0.496	0.475	0.020**	4.21
Nearest neighbour	Resilience_1	0.494	0.473	0.021*	4.44
	Resilience_2	0.496	0.473	0.023**	4.86

***, **, * represent 1%, 5%, and 10% significance level, respectively.

3.7 Conclusion

We have analysed the effect of farmer innovation on household welfare, measured by farm and household income, consumption expenditure, food security and resilience to climate shocks. With this, we contribute to the agricultural innovation literature since previous studies that look at the impact of agricultural innovations on household welfare have largely focused on externally promoted technologies. Using data from a recent field survey of rural farm households in northern Ghana and applying endogenous switching regression that controls for unobserved heterogeneity, we estimate the average treatment effects of farmer innovation on household well-being.

The results show positive and significant welfare effects of farmer innovation, confirming farmers' perceptions as well as the numerous anecdotal reports of the significant role of farmer innovation in the livelihoods of rural farm households. First, we found that farmer innovation significantly improves both farm and household incomes for innovators. Moreover, it significantly increases household consumption expenditure. Using both objective and subjective measures of food security, we also found that farmer innovation contributes significantly to the reduction of food insecurity among innovative households. Specifically, it significantly increases household food consumption expenditure, and contributes substantially to the reduction of the length of food shortages as well as decreasing the severity of hunger among innovative households. However, we found that the positive contribution of farmer innovation to production and income does not significantly translate into nutritious diet, measured by household dietary diversity. Finally, we found that though farmers innovate mainly to increase production, their innovations indirectly contribute to building household resilience to climate shocks.

Overall, the significant effect of innovation on both income and consumption and most of the food security indicators employed confirms the robustness of the positive effects of innovation on household well-being. The farmers' innovations could reduce production costs, increase revenue from crops and livestock production, minimise risks from climate and other external shocks and allow reallocation of labour to off-farm activities, resulting in the positive welfare outcomes observed. Our findings give credence to increasing assertions that farmer innovation has the potential of improving the livelihoods of rural households; hence, concerted policy efforts are needed to support and harness this potential. The significant contribution of farmer innovation to all the outcome indicators except dietary diversity suggests that further efforts are needed to ensure that the positive income effects translate into better nutrition for households in the study region. Thus, food security policies for the study region should go beyond food availability, and also focus on nutrition security.

It is important to emphasise that our findings do not imply the promotion of farmer innovation to the neglect of modern agricultural technologies. Our results only strengthen arguments for better support for farmer innovation as a complement to externally promoted technologies in efforts to reduce poverty and attain food security.

We do not perform separate analyses for the different innovation domains or practices, as the samples are limited. However, it will be interesting to assess which specific types of farmer innovations contribute largely to household well-being. Future research comprising large sample size will permit such analysis. Also, innovation is generally a dynamic process so further research involving panel data would be needed to study the long-term effects of farmer innovation. This research uses data from only a small region of Ghana; hence, extrapolating the findings to other settings should be done cautiously. Nonetheless, our study has shown that rural poor farmers who are resource-constrained go beyond adoption of externally introduced technologies and creatively implement location-specific and cost-saving innovations, which generally have positive welfare effects.

Appendix 3

Table A1: First stage results of the FIML ESR models

	(1)[a]	(2)	(3)	(4)	(5)	(6)	(7)
Information constrained	-0.421***	-0.483***	-0.260**	-0.272*	-0.390***	-0.268*	-0.434***
	(0.117)	(0.135)	(0.124)	(0.164)	(0.139)	(0.140)	(0.139)
Age	-0.006	-0.007	-0.008	-0.008	-0.008	-0.008	-0.008
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Gender	-0.174	-0.243	-0.124	-0.249	-0.163	-0.170	-0.176
	(0.196)	(0.200)	(0.199)	(0.190)	(0.201)	(0.200)	(0.203)
Household size	-0.024	-0.018	-0.031	-0.027	-0.018	-0.032	-0.018
	(0.029)	(0.030)	(0.031)	(0.028)	(0.029)	(0.032)	(0.030)
Dependency ratio	0.034	0.013	0.036	0.035	-0.002	0.033	-0.001
	(0.090)	(0.091)	(0.091)	(0.089)	(0.092)	(0.094)	(0.091)
Education	0.038**	0.035*	0.038**	0.039**	0.026	0.038**	0.030
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
FFF participation	0.238	0.183	0.352	0.400	0.213	0.337	0.154
	(0.301)	(0.308)	(0.305)	(0.321)	(0.300)	(0.313)	(0.309)
Land holding	0.059***	0.052**	0.031	0.052**	0.042**	0.035*	0.045**
	(0.023)	(0.024)	(0.022)	(0.022)	(0.020)	(0.021)	(0.021)
Livestock holding	-0.035	-0.031	-0.019	-0.018	-0.023	-0.023	-0.026
	(0.023)	(0.024)	(0.023)	(0.024)	(0.023)	(0.023)	(0.023)
Assets value	0.008	0.007	0.003	0.003	0.006	0.004	0.004
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Off-farm activity	0.167	0.123	0.048	0.141	0.112	0.057	0.102
	(0.162)	(0.164)	(0.162)	(0.162)	(0.164)	(0.164)	(0.164)
Credit access	-0.053	-0.005	0.078	-0.050	0.043	0.055	0.014
	(0.159)	(0.158)	(0.156)	(0.161)	(0.157)	(0.157)	(0.159)
Road distance	0.043	0.057	0.026			0.056	0.062
	(0.324)	(0.081)	(0.083)			(0.081)	(0.082)
Group membership	0.324*	0.300*	0.304*	0.242	0.311*	0.294*	0.306*
	(0.172)	(0.173)	(0.170)	(0.168)	(0.173)	(0.171)	(0.174)
Climate shock	-0.442*	-0.478**	-0.210	-0.263	-0.383*	-0.284	-0.397*
	(0.232)	(0.241)	(0.233)	(0.225)	(0.232)	(0.235)	(0.236)
Pest and disease shock	0.095	0.144	0.182	0.033	0.176	0.219	0.193
	(0.180)	(0.183)	(0.181)	(0.175)	(0.182)	(0.183)	(0.186)
Labour shock	-0.138	-0.104	-0.062	-0.103	-0.065	-0.096	-0.089
	(0.141)	(0.145)	(0.139)	(0.137)	(0.142)	(0.142)	(0.143)
Risk averse	-0.300**	-0.308**	-0.283**	-0.236*		-0.281**	-0.295**
	(0.135)	(0.138)	(0.135)	(0.136)		(0.136)	(0.138)
KNW District	-0.020	-0.041	0.020	-0.012	0.053	0.039	0.075
	(0.205)	(0.209)	(0.205)	(0.210)	(0.205)	(0.210)	(0.207)
KNE District	-0.184	-0.126	-0.299	-0.115	-0.159	-0.224	-0.107
	(0.212)	(0.216)	(0.222)	(0.205)	(0.207)	(0.225)	(0.215)
Constant	0.406	0.528	0.235	0.341	0.244	0.265	0.386
	(0.521)	(0.533)	(0.523)	-0.507	-0.513	-0.535	-0.533

***, **, * represent 1%, 5%, and 10% significance level, respectively. Values in parentheses are standard errors.

[a] Models 1 to 7 refer to first-stage estimates for farm income, household income, consumption expenditure, food gap, HHS, food consumption expenditure, and HDDS, respectively.

Table A2: Falsification test

	(1)[a]	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Information constrained	-0.010	0.046	0.059	0.124	0.056	0.050	0.001	-0.024***	-0.052***
	(0.095)	(0.090)	(0.098)	(0.085)	(0.158)	(0.094)	(054)	(0.006)	(0.020)
Constant	3.257	3.395	4.302	1.417	0.918	4.061	1.590	0.325	0.185
	(0.347)	(0.333)	(0.357)	(0.294)	(0.541)	(0.341)	(0.197)	(0.023)	(0.071)
Wald X2 /F-Stat	10.98***	13.66***	16.05***	64.05***	39.07***	15.74***	44.79***	33.66***	14.13***
No. of observations	242	242	241	241	241	241	241	241	241

***, **, * represent 1%, 5%, and 10% significance level, respectively. Values in parentheses are standard errors.
[a] Models 1 to 9 refer to farm income, household income, consumption expenditure, food gap, HHS, food consumption expenditure, HDDS, Resilience_1 and Resilience 2, respectively. Models 1–3, 6, 8, 9: Ordinary Least Squares. Model 4 and 7: Poisson Regression. Model 5: Negative Binomial Regression. We control for other variables but only report parameters for the variable of interest.

Table A3: Test of matching quality (kernel matching)

	Unmatched			Matched		
	Innovators	Non-innovators	T-test	Innovators	Non-innovators	T-test
Age	46.69	51.70	-3.31***	47.90	49.57	-0.36
Gender	0.86	0.85	0.46	0.85	0.84	-0.20
Household size	6.57	6.64	-0.28	6.57	6.64	-0.27
Education	3.33	2.00	3.25***	2.90	2.32	0.39
FFF participation	0.54	0.39	3.17***	0.53	0.46	0.50
Off-farm activity	0.80	0.73	1.65	0.78	0.77	-0.23
Climate shock	0.88	0.93	-1.86*	0.91	0.92	0.37
Pest and disease shock	0.84	0.81	0.93	0.84	0.83	-0.02
Labour shock	0.58	0.61	-0.56	0.57	0.59	-0.26
Risk averse	0.34	0.45	-2.25**	0.35	0.39	-0.13
Median bias		17.50			6.60	
Pseudo R^2		0.06			0.00	
p-value of LR		0.00			1.00	

***, **, * represent 1%, 5%, and 10% significance level, respectively.

Identification and prioritisation of farmers' innovations in northern Ghana[17]

4.1 Introduction

Agriculture is continuously undergoing changing conditions. Climate change, population pressure, new pests and diseases, bioenergy, food standards and food price volatility are among the numerous challenges and opportunities faced by farmers. There is a need to adapt quickly when challenges occur, and to respond readily when opportunities arise. This requires constant innovation (Waters-Bayer and Bayer, 2009; World Bank, 2011). While investments in public agricultural research and development are necessary, they are not sufficient to create a dynamic innovation capacity required in addressing the intensifying and increasing challenges confronting agriculture (Hall et al., 2006; World Bank, 2011). Similarly, farmers are involved in diverse farming systems under a wide range of agro-ecological conditions, which imply high costs of developing location-specific technologies (Biggs and Clay, 1981). Thus, diversity of farming systems requires site-specific innovation and not one-size-fit-all technologies, and this is a huge challenge for formal research (Waters-Bayer et al., 2009).

Over the years, farmers have been recognised as innovators and experimenters and not just adopters of introduced technologies. Farmers were innovating long before the emergence of formal research and extension services (Biggs and Clay, 1981; Waters-Bayer et al., 2009), and some of the technologies developed by scientists are claimed to have stemmed from ideas and practices of local farmers (Chambers et al., 1989; Rhoades, 1989; Röling, 2009b). Farmers modify existing technologies, invent new practices or experiment with new ideas to adapt to changes in their environment (Millar, 1994; Bentley, 2006). They often use locally available resources and generate low-cost innovation in many farming domains, including soil fertility, crop varieties, animal husbandry and marketing (Reij and Waters-Bayer, 2001).

[17] A version of this chapter has been published as: Tambo, J.A. and Wünscher, T. (2015) Identification and prioritization of farmers' innovations in northern Ghana. Renewable Agriculture and Food Systems 30(6):537-549

These innovation-generating activities of farmers are generally referred to as farmer innovation. Thus, farmer innovation involves a new or modified practice, technique or product that was developed by an individual farmer or a group of farmers without direct support from external agents or formal research.

Farmer innovation could play a critical role in addressing the numerous challenges facing agriculture. This is because the knowledge generated through the farmer innovation process leads to the creation of site-appropriate technologies, but more importantly, it increases farmers' capacity to adapt to changing conditions (Haile et al., 2001). Thus, supporting farmer-led innovations may help farmers to value their own knowledge and provide incentives for further exercising their ingenuity. Moreover, farmers generate different farming system innovations, and this is something difficult for scientific research to achieve (Röling, 2009b). Efforts to encourage farmers' innovativeness also reduce the responsibilities of formal research systems to manageable proportions (Biggs and Clay, 1981). It is therefore imperative to recognise innovative behaviour of farmers, design opportunities for them to innovate, and strengthen their innovative capacity (Röling, 2009b).

Unfortunately, the increased promotion of modern farming techniques coupled with the top-down technology transfer approach have resulted in under-valuation of farmer innovations. Farmers are, however, continuously innovating, and with increasing changing economic environments, added to the failure of many introduced technologies and the growing recognition of farmers' innovative capacities, there has been renewed attention to farmer innovation in recent decades (Reij and Waters-Bayer, 2001). There are now many programmes and non-governmental organisations (NGOs) supporting the promotion of farmer innovation in many developing countries.

The first step of promoting farmer innovation is the identification and documentation of these innovations. Identification can serve as an initial process of further experimentation and improvements of the innovations applicability through joint research or participatory innovation development involving farmers, scientists, and extension and development agents (Wettasinha et al., 2008). However, not all innovations developed by farmers are technically and economically effective or socially acceptable. For instance, farmers are more likely to adopt innovations that are affordable or less labour-intensive. Validating the farmers' innovations is, therefore, important in categorising those that have potential for improvement and dissemination.

The objective of this study is to identify farmer innovations in northern Ghana and prioritise them in order to recommend promising innovations for further scientific validation or research. The study was conducted in northern Ghana, where farming is the major economic activity. The region is characterised by pervasive food insecurity, poverty, soil infertility and environmental problems. Farmers in the region are continuously innovating to adapt to these challenges and changing conditions (Millar, 1994). An international NGO, Prolinnova (Promoting Local Innovation in Ecologically-Oriented Agriculture and Natural Resource Management), has been promoting farmer innovations in selected areas of northern Ghana in collaboration with local partners. They have identified and catalogued some farmer innovations, but many farmers in the region are not aware of this initiative due to limited dissemination efforts. This study was conducted within the research programme—West African Science Service Center for Climate Change and Adapted Land Use (WASCAL) —funded by the German Federal Ministry of Education and Research (BMBF). One aspect of the programme aims at identifying and supporting farmers' innovative practices.

Identification of farmer innovation is a tedious and difficult process (Reij and Waters-Bayer 2001). The commonly employed identification methods include household survey, focus group discussion, snow-balling, key informant interviews and field observation. In this study, we implemented an innovative farmer innovation contest, in addition to a household survey for the identification of the innovations. Farmers develop several innovations, and the validation of these innovations is very expensive and time-consuming (Bentley, 2006). We propose the multi-criteria analysis as a useful and cost-effective means of ranking alternative innovations before suggesting high-potential or best-bet innovations for further scientific validation or joint experimentation.

The remainder of this paper proceeds as follows. The next section provides a brief review of some past and existing initiatives and institutional arrangements for the promotion of farmer innovation. Section 3 presents the methods, and it includes the methods used in scouting the innovations as well as the validation approach. In section 4, we present the results of ranking of the identified innovations and also describe some of the high-potential innovations. Lastly, the conclusion of the paper is provided in section 5.

4.2 Identification and promotion of farmer innovation: a review[18]

In recent years, there has been growing recognition of the importance of locally developed innovations. Consequently, there are several projects and initiatives promoting local innovation processes. In this section, we describe some notable institutional arrangements and research programmes that have supported the identification and promotion of farmer innovation. We focus mainly on the aims, types of innovations and the methods used by the various initiatives in scouting and disseminating the innovations.

4.2.1 Indigenous Soil and Water Conservation (ISWC 2)

Indigenous Soil and Water Conservation (ISWC 2) was a Netherlands Government funded research programme implemented between 1997 and 2001 in Burkina Faso, Cameroon, Ethiopia, Tanzania, Tunisia, Uganda and Zimbabwe. The programme aimed at improving the effectiveness of indigenous and modern soil and water conservation (SWC) practices using joint experimentation approaches (Reij and Waters-Bayer, 2001). A key component of the programme was the identification of farmer innovators of SWC practices as a first step in a process of joint experimentation. The programme identified over 800 innovations in the seven participating countries. These innovations were identified by extension and development agents, students, scientists, teaching staff and farmers through field observation, farmer group and key informant interviews, contests and radio programmes. The identified innovations were documented in reports, database, photographs and videos and widely disseminated through farmer to farmer extension, radio programmes and

[18] This section relies largely on information obtained from the listed references in the bottom row of Table 1

workshops. Some of the innovations were further validated and improved in joint experiments involving farmers, scientists, and extension and development agents.

4.2.2 Promoting Farmer Innovation in Rainfed Agriculture (PFI)

Promoting Farmer Innovation in Rainfed Agriculture (PFI) was another research programme funded by the Government of the Netherlands, hence, had similarities with the ISWC 2 programme. It was implemented in Kenya, Tanzania and Uganda from 1997 to 2001 and was co-ordinated by the United Nations Development Programme (UNDP) Office to Combat Drought and Desertification (UNSO). The main aim of the programme was to stimulate farmer innovation in the field of land husbandry. The programme identified, verified and disseminated farmer innovations related to SWC. The innovations identified were mainly in the domains of water harvesting, organic matter production and gulley control. About 120 farmer innovations were identified in the three programme countries, and 18 of these innovations which were considered to promising or best-bet techniques have been extensively documented. The innovations were scouted by many actors such as village leaders, scientists, farmers and NGO field staff, through key informant interviews, field observations and participatory rural appraisal (PRA). Similar to the ISWC 2 project, the innovations identified were evaluated jointly by farmers, scientists and extension agents. The identified innovations were catalogued and disseminated through farmer networks, field visits and the media.

4.2.3 PROLINNOVA

PROLINNOVA is an NGO-initiated international network of multiple stakeholders with the interest of promoting local innovations in agriculture and natural resource management. The PROLINNOVA initiative started in 1999 and until 2012, it was mainly funded by the Dutch Ministry of Foreign Affairs. There are also several donors supporting specific activities in the participating countries. Currently, the network operates in about 20 countries (including Ghana) in Africa, Asia and South America. Local NGOs normally coordinate the activities of the network in partner countries. In Ghana, for instance, the network is coordinated by an NGO, Association of Church-Based Development Projects (ACDEP). Through a number of country-specific initiatives, Prolinnova focuses on recognising the dynamics of indigenous knowledge and enhancing farmers' capacity to develop and adapt innovations to local conditions. Such initiatives include identification and documentation of local innovations, strengthening the links between farmers, extension, researchers and other actors to enhance local innovation processes, participatory innovation development (PID), providing funding to promote local innovations through the Local Innovation Support Fund (LISF), and farmer-led documentation. Using field observation, key informant interviews, community sensitization and chain or snowball sampling methods, several local innovations have been identified and documented in each of the participating countries. Some of these innovations have been scientifically validated by students, researchers, and particularly through joint experimentation or PID involving key actors. The identified innovations are often disseminated through printed catalogues, brochures, posters, magazines, field visits, fora, featuring on radio and television programmes, award ceremonies to celebrate innovators and participatory videos.

4.2.4 Grassroot innovations in India

The most comprehensive and institutional support for local innovations in the world is the Indian example. It all started with the Honey Bee Network, an informal movement of individuals, innovators, farmers, scholars, academicians, policy makers, entrepreneurs and NGOs, which was formed in the late 1980's to acknowledge grassroot innovations and traditional knowledge. It engages in the scouting and documentation of grassroot innovations in more than 75 countries, but largely in India. The innovations are identified by volunteers, members of the network and through scouting competitions. The network has a database of about 100000 documented grassroot innovations and traditional practices, and also publishes a newsletter in English and seven Indian languages to disseminate these innovations and activities of the network. The innovations include both farm and non-farm related innovations. The achievements of the network have induced the establishment of other institutions to further support and promote its activities. Notable among them are the Society for Research and Initiatives for Sustainable Technologies (SRISTI), the Grassroots Innovation Augmentation Network (GAIN), and the National Innovation Foundation (NIF). The SRISTI was established in 1983 to provide support to the Honey Bee Network activities, such as managing the database of innovations, newsletter publication and protecting innovations through intellectual property rights. The GAIN was set up in 1997 to provide incubation support to outstanding grassroot innovators and traditional knowledge holders by promoting linkage with scientific institutions, market research and funding organizations. Finally, the NIF was set up in 2000 by the Indian Department of Science and Technology as a national initiative to strengthen and provide institutional support to the activities of the Honey Bee Network and its partners. Among other things, it collaborates with research institutions to validate identified innovations and convert them into marketable products. It also organises a biennial competition to award outstanding innovators and traditional knowledge experts.

4.2.5 Find Your Feet

Find Your Feet is a development NGO working in India, Nepal, Malawi and Zimbabwe. They support rural families in finding sustainable solution to hunger, poverty and discrimination, and a key aspect of their work is to promote local knowledge and farmer innovation. As part of their work on acknowledging the creativity of smallholder farmers, they carried out a study on farmer innovation in 2011 in Rumphi District of northern Malawi, which was published with supports from the European Union and the Development Fund. The study sought to identify and document farmer innovations, recommend high-potential innovations for scientific validation and disseminate innovations among stakeholders. Employing focus group discussions and visits to renowned innovative farmers, they identified 16 innovators in the study region. The main domains of the farmers' innovations include livestock husbandry, pest control, soil fertility and water conservation. Some of the identified innovations were documented in a report which was extensively disseminated via national and international networks.

4.2.6 Organic Farmer Experiments

Our final case is a research project, Organic Farmer Experiments, which was funded by the Austrian Science Foundation and implemented by the University of Natural Resources and Life Sciences (BOKU) in three countries, Austria, Israel and Cuba between 2006 and 2008. The research, which was mainly conducted by doctoral students, aimed at obtaining empirical evidence on the processes of organic farmers' experiments. It focussed on the domains, motives, drivers, methods and outcome of farmer experiments and innovations by conducting comparative studies in the three project countries. Using key informant interviews and snowball sampling techniques, about 73 and 72 farmer experimenters were identified and interviewed in Austria and Cuba, respectively. Most of the experiments were related to crop production and animal husbandry. The farmer experimenters disseminated their innovations through farmer networks, field visits and publication in magazines or books. The outputs of the research project were disseminated through conference presentations and publications in journals and doctoral dissertations.

In summary, the six examples illustrated above indicate that there are concerted efforts to promote farmer innovation processes, but mainly in developing countries. Most of the promotional efforts are through externally-funded research projects or development initiatives of NGOs. The Indian case appears to be the only national initiative that is well institutionalised, hence, likely to be sustainable. These six examples identified numerous farmer innovations using varied identification methods. Some of the identified innovations have been validated and widely disseminated, but it is only the India example that often goes beyond validation to provide patent protection and convert the innovations into marketable products. Table 4.1 summarises the key issues in the six cases considered. In this paper, we contribute to the various initiatives aimed at scouting farmer innovation by highlighting the application of innovation contest in Ghana. We also make a methodological contribution to the farmer innovation literature by proposing multi-criteria analysis as an effective method that can be used in prioritising promising innovations.

Table 4.1: Summary of some of the initiatives supporting farmer innovations

	ISW2	PFI	PROLINNOVA	India	Find your Feet	Organic Experiments
Type of initiative	Research programme	Research programme	NGO-led multistakeholder network	National	NGO-led research	Research project
Period	1997 - 2001	1997 - 2001	1999 - ongoing	1988 - ongoing	2011	2006 - 2008
Participating countries	Burkina Faso, Cameroon, Ethiopia, Tanzania, Tunisia, Uganda and Zimbabwe	Kenya, Tanzania and Uganda	Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Mali, Niger, Nigeria, Mozambique, South Africa, Sudan, Senegal, Tanzania, Uganda, Cambodia, India, Nepal, Bolivia, Ecuador, Peru	India, but innovations scouted in more than 75 countries	Malawi	Austria, Israel and Cuba
Funders/Donors	Directorate General for International Cooperation (DGIS) of the Government of the Netherlands	Directorate General for International Cooperation (DIGS) of the Government of the Netherlands	DGIS, DURAS project, GFAR, Rockefeller Foundation, Misereor, CCAFS, country donors	Department of Science and Technology, Government of India	European Union and the Development Fund	Austrian Science Foundation (FWF)
Aim	Improve the effectiveness of both indigenous and modern soil and water conservation practices through a process of joint experimentation	Stimulate technical innovation, in the field of land husbandry, by farmers.	Promote local innovation in ecologically oriented agriculture and natural resource management	Strengthen grassroots technological innovations and outstanding traditional knowledge	Identify and document farmer innovations, recommend high-potential innovations for scientific validation and dissemination	Generate empirical knowledge on the processes by which organic farmers' local knowledge is created and communicated.
Concept of farmer/local innovator	Farmers who spontaneously try out new things, without the direct support of formal research and extension	Someone who have developed or are testing new ways of land husbandry that combine production with conservation	Discovering or developing new and better ways of doing things – using the locally available resources and on their own initiative, without pressure or direct support from formal research or development agents.	Someone who have developed technological innovations in any field of human survival without any outside help.	Developing new and better ways of doing things - using their own resources and on their own initiative	None

	ISW2	PFI	PROLINNOVA	India	Find your Feet	Organic Experiments
Main domains of innovation	Soil and water conservation	Land Husbandry	Agriculture and natural resource management	Grassroot innovations and traditional knowledge of any kind	Livestock husbandry; Pesticide and Fertiliser production and application; Water conservation and use	Organic farming
Scouting methods	Field observation, farmer group interviews, key informant interviews, contests and radio programmes	Key informant interviews, field observations and participatory rural appraisal	Field observation, key informant interviews, community sensitization and chain or snowball sampling methods	Scouting competitions, National innovation competition	Focus group discussions and visits to renowned innovative farmers	Key informant interviews and snowball sampling techniques
Documentation and dissemination methods	Reports, database, photographs and videos, farmer networks, extension, radio and workshops	Catalogues, farmer networks, field visits and media	Catalogues, brochures, posters, magazines, field visits, fora, featuring on radio and television programmes, award ceremonies to celebrate innovators and participatory videos	Database, newsletter	Reports disseminated through national and international networks	Farmer networks, field visits, conference presentation and publication in journals, magazines or books, and doctoral dissertations.
Validation	Few cases	Few cases	Yes	Yes	Intended	No
Commercialization	No	No	Very few cases	Yes	No	No
Key references	Reij and Waters-Bayer, 2001	Mutunga and Critchley, 2001; Reij and Waters-Bayer, 2001; Critchley and Mutunga, 2003;	Wettasinha et al., 2008; www.prolinnova.net	Gupta et al., 2003; www.sristi.org; www.sristi.org/hbnew; www.nif.org.in	Find Your Feet, 2012; www.find-your-feet.org	Kummer, 2011; Leitgeb et al., 2014

4.3 Methods

This study intends to identify outstanding farmer innovations and conduct stakeholder’s validation so as to prioritise the innovations with high potential for dissemination or further improvement through scientific research. In this section, we explain the methods employed in the identification and validation processes.

4.3.1 Identification methods

The review above shows that various projects and initiatives have used several methods in scouting farmers’ innovations. As already mentioned, we employed two of these methods: innovation contest and household survey.

4.3.1.1 Farmer innovation contest

Part of the innovations were identified through an innovation contest, which was implemented by Tobias Wünscher in the Upper East region of northern Ghana between August and November 2012[19]. The objectives of the contest included: identification of high-potential farmer innovations in order to motivate further research into innovation and possibly improve and disseminate to other farmers, acknowledging farmers’ creativity, creating awareness of farmer innovation among stakeholders and testing the effectiveness of the contest to unearth farmer innovations. The contest was implemented in collaboration with local partners, which include the Upper East Regional and District Offices of the Ministry of Food and Agriculture (MoFA), Savanna Agricultural Research Institute (SARI), University of Development Studies (UDS) and the Navrongo-Bolgatanga Catholic Diocesan Development Office (NABOCADO), a regional NGO which is part of the Prolinnova-Ghana network.

To create awareness among farmers in the region, we employed two channels: extension contacts and radio announcements to disseminate information on the innovation contest. First, a one-day workshop was held at each of the offices of the nine MoFA district offices in the region[20]. The purpose of the district workshops was to meet the extension officers,

[19] The author assisted in the organisation of the contest in selected tasks.

[20] Four new districts have since been carved out of the 9 districts, making a total of 13 districts in the region.

introduce to them the concept of farmer innovation and innovation contest, and explain the application processes and their roles. The extension officers were given application forms which were purposely designed for the contest (see appendix C), and asked to search for farmer innovations in their assigned zones and assist the innovators to fill the application forms after verifying that they are the originators of the innovations. The verification process involved randomly asking farmers in the communities to indicate and confirm the originator of an identified innovation.

We also contacted a radio station, URA radio, which has a wide coverage in the region, to broadcast information on the contest. We created a one-minute radio jingle in English which was also translated into four local languages, *Buli*, *Gurini*, *Kasem* and *Kusaal*. The jingles, which captured information on farmer innovation, application process and deadline, prizes to be awarded and a central phone number where farmers can call to get further details on the contest, were aired about 5 times daily for nearly 2 months. Farmers who have developed innovations were asked to contact extension officers in their zones to help them fill an application form for each of their innovations. The filled application forms had to be signed or thumb printed by the innovators confirming that they agree to participate in the contest and their innovations could be shared with other farmers or stakeholders. The farmers were given a deadline to submit their applications and when the date elapsed, we visited the various districts to collect the filled application forms. To acknowledge the extension officers who scouted the innovations and assisted the farmers to apply, they were paid 25 GH¢ for each correctly filled application form.

After receiving all the entries submitted to the contest, we formed an evaluation committee to help evaluate them. The evaluation committee members were representatives from our partners, including two farmer representatives. Overall, we had 8 committee members. They evaluated the innovations using four criteria: innovativeness or originality, economic potential, dissemination potential, and social and environmental sustainability. Scores for each criterion ranged from zero to three (0=none, 1=low, 2=middle, 3=high). The innovations were ranked based on their overall sum of scores from all the committee members. The best six innovations were then short-listed, and the innovators were visited by the evaluation committee members in order to get detailed information on processes involved in developing the innovations and their applications. The visit also allowed further confirmation of the original innovators of the reported innovations. Based on the field visits, the best three innovators to be awarded were selected and informed.

4.3.1.2 Household survey

To further identify farmer innovations in the region, we implemented a household survey in three out of the nine districts where the farmer innovation contest was held. The household survey took place in 17 communities in the Bongo, Kassena Nankana East (KNE) and Kassena Nankana West (KNW) districts between December 2012 and April 2013. The survey was part of a field study to obtain data on the determinants and impacts of farmer innovation. About 409 randomly selected farm households were interviewed by trained enumerators on (among other things) their innovation practices, which ranges from experimentation, modification of existing practices, adaptation of outside ideas and invention of new techniques. At the end of the survey, farmers who were found to have developed interesting and outstanding innovations, but who did not participate in the contest, were visited and interviewed with the aid of the application form used for the innovation contest. These innovations were to be included in a subsequent edition of the contest.

4.3.2 Validation and ranking of innovations

To validate the identified innovations in order to recommend promising ones for further scientific evaluation and dissemination, we convened a participatory stakeholders' workshop on 10 May 2013 at the Water Resources Commission of Ghana office in Bolgatanga, the administrative capital of the region. We invited 12 experts and stakeholders who have knowledge on farmer innovation and farming systems in the region. They were selected from research institutions, MoFA, NGO's and farmer organizations (see Table A1 in appendix 4 for the affiliations of the invited stakeholders). The purpose of the workshop was threefold: identify the criteria to evaluate the innovations, weighting of each criterion and assigning scores to innovation using the weighted criteria.

In a participatory and iterative approach, the stakeholders deliberated on the criteria to evaluate innovations. Several evaluation criteria such as problem-solved, acceptability, dissemination potential, research potential, economic viability, technical viability, affordability, flexibility and gender responsiveness were suggested, but criteria that are more relevant to the promotion of farmer innovation were given priority. Also, related criteria were merged into one so as to avoid double counting. The experts finally agreed to evaluate the innovations based on: originality/innovativeness, economic potential, environmental friendly and dissemination potential. These are related to the criteria used in evaluating the innovations during the innovation contest. All the experts agreed on the definitions of the four evaluation criteria. Originality refers to the extent to which an innovation differs from common or traditional practices in the region. In other words, originality implies the uniqueness or degree of 'newness' of the innovation. Economic viability was considered to be the cost-effectiveness of the innovation as well as the potential contribution to household income and food security. An innovation was regarded as environmentally sustainable if it does not negatively impact on the environment. Dissemination potential relates to the degree to which the innovation is likely to be adopted by farmers in the region. This includes social acceptability, gender responsiveness, the ease with which it can be replicated or modified, and the extent to which required resources are locally available, accessible and affordable.

To rank the identified innovations, we employ a multi-criteria decision-making (MCDM) analysis. MCDM is a decision analysis tool that is frequently used (particularly in climate change and energy policy research) in prioritising alternative options, and it has several functions, including criteria weighting which involves scoring all the innovations based on the relative importance of the agreed criteria (Bell et al., 2003). Following de Bruin et al., (2009), we adapted the method of MCDM for criteria weighting, based on expert judgement. First, all the experts agreed on the weights for the four evaluation criteria based on the relative importance of each criterion. The experts were then assigned into three groups of four members. To ensure equal representation, each group had at least an expert from MoFA, research institute, NGO or farmer association. Each group was asked to score all the innovations on a scale of 1 (very low) to 5 (very high) on the four evaluation criteria. The weighted summations of the scores for each innovation from each group were then averaged to obtain the overall score. Thus, the overall weighted sum of scores for each innovation was computed by:

$$I_j = \frac{w_o s_{ojg_i} + w_{e_p} s_{e_p jg_i} + w_{d_p} s_{d_p jg_i} + w_{e_s} s_{e_s jg_i}}{3} \qquad (1)$$

where:

I_j = weighted sum of scores for innovation *j*

w_o, w_{ep}, w_{dp} and w_{es} = weights assigned to originality, economic potential, dissemination potential and environmental sustainability criteria, respectively.

s_{ojg_i} = score assigned to originality criterion for innovation *j* by group *i*

$s_{e_p jg_i}$ = score assigned to economic potential criterion for innovation *j* by group *i*

$s_{d_p jg_i}$ = score assigned to dissemination potential criterion for innovation *j* by group *i*

$s_{e_s jg_i}$ = score assigned to environmental sustainability for innovation j by group *i*

The innovations were then ranked based on the overall weighted sum of scores.

4.4 Results and discussion

We identified 48 farmer innovations in the study region: 29 through the innovation contest and 19 from the household survey. Applications to the innovation contest were obtained from six out of the nine districts of the Upper East region. Bolgatanga municipality had the highest number of applicants (8). The top three innovations were: storing of onion seeds using a local herb, *Barakuk*; using onion residues to control striga; and designing an integrated aquaculture-agriculture system. The three innovators were given certificates and prizes during the annual National Farmers' Day celebration which was held on 2 November 2012. The prizes were motor tricycle, motor cycle and water pump for the first, second and third ranked innovators, respectively. Using the household survey, 6, 8 and 5 innovators were identified in the KNE, KNW and Bongo Districts, respectively. Overall, the average age of the innovators was 45.53, and about 30 percent of them were women. Nearly all the innovations were developed by individuals (only 2 applications by groups) and were largely technical innovations.

The categorization of the innovations is presented in Table 4.2. It shows that most of the innovations were related to animal husbandry and crop management, and this is consonant with the findings of the Organic Farmer Experiments research project reported earlier. Animal husbandry innovations were mainly new formulation of animal feeds and the discovery of ethno-veterinary medicine for the treatment of livestock diseases. The crop management innovations included the use of local and low-cost resources such as plant extracts to control weeds, pests and diseases. Other important categories of innovations were storage, processing and SWC. Similar to the findings of Bentley (2006), a large share of the identified innovations were developed to save production costs such as pesticide, storage and veterinary costs, by blending different ideas. Most of the innovations have been adopted by other farmers located in the same or nearby communities of the innovators. Such claims of high adoption rates by the innovators have also been reported by Critchley and Mutunga (2003). The high rate of adoption is due to the fact that farmer innovations are often adapted to local conditions and are relatively inexpensive. This finding suggests that farmer innovations could be disseminated with little support from formal research, and this has positive (e.g., cost-saving) implications for the promotion of agricultural innovations. This also supports Biggs (1981) arguments on the potential role of farmer innovations in the reduction of the tasks of formal agricultural research.

The identified innovations also relate with those found by Millar (1992), who studied farmer experimenters in northern Ghana and categorised the innovations based on the driving factors into curiosity, problem-solving, adaptive and peer pressure experiments. For instance, innovations numbered 33, 1, 6 and 36 in Table 3 can be considered as examples of these four types of experiments, respectively.

Table 4.2: Categories of identified innovations

Category	Number of innovators
Animal husbandry	21
Crop Management	12
Storage	8
Processing	2
Water and soil conservation	2
Soil fertility	2
Tree/Forest Management	1

4.4.1 Ranking of innovations

As mentioned, we used MCDM analysis—based on expert judgement—to score the 48 identified innovations on the criteria: originality, economic potential, dissemination potential and environmental sustainability. The innovations were evaluated on these criteria using scores of 1 (very low) to 5 (very high). The average scores on the innovations on the four criteria are 2.51, 3.47, 3.08 and 3.18 for originality, economic potential, dissemination potential and environmental sustainability, respectively. Thus, the innovations score highest on economic potential but low on originality. The low average score on originality can be explained by the fact that most of the identified innovations are modifications and value additions to known practices in the study region and not complete novelties.

Based on the relative importance of the agreed evaluation criteria to the concept of farmer innovation, the experts assigned weights of 40%, 25%, 20% and 15% for originality, economic potential, dissemination potential and environmental sustainability, respectively. The weighted sums of scores were computed and used in prioritising the innovations. Thus, an innovation with very high dissemination potential but low originality will rank lower than one with average originality and low dissemination potential, due to the criteria weighting. The results of the ranking are presented in Table 4.3. From the ranking, the most promising innovations include: suppression of striga emergence using dried onion leaves; reduction of Guinea keets mortality using sorghum malt and pepper solution as a dewormer; and planting common wireweed (*Sida acuta*) in a semi intensive system to protect birds from hawks. Among the innovations with least potential include: control of *Digitaria* spp. using a mixture of diesel, water and weedicide; control of nematode using a mixture of salt solution and fungicide; and mixing millet seeds with contents of dry cell batteries to prevent attack by worms.

The ranking results also show that the three top-ranked innovations by the evaluation committee in the innovation contest do not attain the same rank in the MCDM approach. For instance, onion seed storage using *Barakuk* and suppression of striga with onion residues were judged first and second best innovations in the contest but ranked fourth and third in the MCDM analysis, respectively. The difference in the ranking positions is due to criteria weighting which was not implemented in the contest. Also, in the contest, the committee members evaluated the innovations independently, but the MCDM approach was participatory. Moreover, the MCDM analysis involved more and diverse experts with knowledge on innovations and farming systems in northern Ghana.

The use of MCDM analysis to rank the identified innovations is not devoid of limitations. The choice of evaluation criteria and assigning of weights can be criticised for being subjective (Belton and Stewart, 2002). Nonetheless, it is a useful method which can be applied in the first stage of validating farmer innovations. It is easy to implement, and it also considers stakeholders' preferences. Initially, this study also intended to quantitatively estimate the costs and benefits of the identified innovations; but, similar to the observation by Critchley and Mutunga (2001) in a study on farmer innovations in East Africa, we found that there were insufficient data to permit such analysis. Thus, the MCDM analysis employed in this study can be used as a good qualitative evaluation approach in cases where quantitative analysis are impossible, or to first prioritise innovations before undertaking comprehensive evaluations such as scientific validation.

Table 4.3: Ranking of farmer innovations based on criteria weighting

No.	Innovation	Originality	Economic potential	Dissemination potential	Environmental sustainability	Weighted sum
		40%	25%	20%	15%	
1	Suppression of striga emergence using dried onion leaves	4.67	3.67	3.33	4.67	4.15
2	Reduction of Guinea keets mortality using sorghum malt and pepper solution as a dewormer	3.67	4.33	4.33	4.33	4.07
3	Common wireweed (S*ida acuta*) in a semi intensive system to protect birds from hawks	4.00	4.00	4.00	4.00	4.00
4	Storage of onion seed and treatment of livestock wounds using *Barakuk*	4.33	3.67	3.33	3.00	3.77
5	Integrated aquaculture-agriculture	3.33	4.67	2.33	4.33	3.62
6	Multiplication of sweet potato vine under artificial shade	3.33	4.00	3.33	4.00	3.60
7	Planting *Yookat* herb on termite hills to prevent and control termites	3.67	3.67	3.33	3.33	3.55
8	Using salt solution as a seed dresser	3.33	3.67	3.33	3.00	3.37
9	Reducing mortality rate in newly hatched chicks using *Gbenatu*, mango, and fig bark extracts	3.33	4.00	3.00	2.67	3.33
10	Treatment of Alopecia using a mixture *Sa-ire* plant and *Se-iriko* clay	3.00	4.33	3.33	2.00	3.25
11	Treatment of fowl pox using a mixture of *Baleer*, *Gbandang* and *Norag Kombri* herbs	3.33	3.67	3.00	2.33	3.20
12	Bicycle tube pieces with *Ku-enka* for storage of seed and grain	3.33	3.33	2.67	3.33	3.20
13	Unique compost preparation using animal droppings and crop residues	2.33	3.67	3.33	4.33	3.17
14	Storage of seed using *Barakuk*	2.67	4.00	3.33	2.67	3.13
15	Exposure of guinea fowl eggs to early evening sunlight to improve hatchability	2.33	3.67	3.67	3.67	3.13
16	Treatment of intestinal worms of Guinea fowls using honey and mahogany bark extracts	3.00	3.67	2.67	3.00	3.10
17	Control of vegetable pests using *Gloriosa spp.* fruit extract	3.00	3.33	3.00	3.00	3.08
18	Treatment of animal eyes using *Yaae* roots or bark	3.00	3.67	3.33	2.00	3.08
19	Organic Manure preparation from a mixture of rice husks and animal droppings	1.67	4.33	3.33	4.33	3.07
20	Preparation of silage using fresh maize, sorghum stalks/leaves and salt	2.00	4.00	3.33	4.00	3.07
21	Brooder house for poultry	2.33	4.00	3.33	3.00	3.05
22	Treating Newcastle disease in poultry using *Goa* bark extracts	3.00	3.33	3.33	2.33	3.05

Table 4.3 (continued)

No.	Innovation	Originality	Economic potential	Dissemination potential	Environmental sustainability	Weighted sum
		40%	25%	20%	15%	
23	Storing Bambara beans using boiled aqueous extract of shea tree	2.67	3.33	3.67	2.67	3.03
24	Storage of seed using neem-seed oil	1.67	4.00	3.33	4.33	2.98
25	Using neem extracts as fertilizer, insecticide and pesticide	2.00	3.33	3.33	4.33	2.95
26	Using a mixture of *Periga*, *Kuka* and *Anriga* bark extracts as a dewormer for livestock	2.33	4.00	3.67	1.67	2.92
27	Guinea fowl production in a semi-intensive system	2.33	3.33	3.00	3.67	2.92
28	Neem oil to control crop pests and soil nematodes	1.33	4.00	3.33	4.67	2.90
29	Treatment of sick puppies by ear tipping	2.67	2.67	3.33	3.33	2.90
30	Kenaf seed for hatching eggs	2.33	3.33	3.00	3.33	2.87
31	Hatching of Guinea Fowl eggs using cotton and rag	2.00	3.33	3.33	3.67	2.85
32	Seed preservation using pungent pounded pepper or groundnut/neem seed oil	2.67	3.00	2.33	3.67	2.83
33	Cultivation of Southern Ghana crops in Bolgatanga municipality	2.33	2.67	3.33	3.67	2.82
34	Neem leaves to spray pepper and tomato against pests and diseases	1.67	4.00	3.00	3.33	2.77
35	Yogurt production from cattle milk	1.67	3.67	2.67	4.00	2.72
36	Planting and eating of *Dawadawa* fruit against the traditional belief of dying	1.67	3.33	2.33	4.67	2.67
37	Using mahogany bark for the treatment of chicken diseases	2.00	3.33	3.00	2.67	2.63
38	Formulation of local fish meal	2.00	3.00	3.00	3.00	2.60
39	Livestock feed formulation using pito residues, and rice and wheat brans	1.33	3.33	3.00	4.00	2.57
40	Salt for controlling striga	2.33	3.00	3.00	1.67	2.53
41	Storage of cowpea seeds using wood ashes	1.00	4.33	3.00	3.00	2.53
42	Planting of anti-snake weed to drive away snake from farm	2.00	2.67	2.33	3.33	2.43
43	Salt to control termite in rice field	2.00	3.00	3.00	1.67	2.40
44	Ebony and mahogany bark extracts to treat poultry diseases	2.00	2.67	2.67	2.67	2.40
45	Onion to control poultry disease	2.00	2.33	2.67	2.67	2.32
46	Mixing millet seeds with contents of dry cell batteries to prevent worms attack	2.00	2.67	2.67	1.00	2.15
47	Control of nematode using a mixture of salt solution and fungicide	2.00	2.00	2.33	1.67	2.02
48	Control of *Digitaria spp* using a mixture of diesel fuel, water and weedicide	1.67	1.33	1.67	1.00	1.48

4.4.2 Case studies

In this section, we present the six most highly ranked farmer innovations and their respective innovators.

Case 1: Suppression of striga using onion residues

Striga is a parasitic weed that hampers cereal production in northern Ghana and other savanna regions of Africa, and there are several research efforts in the continent to address this challenge (Khan et al., 2011). Several approaches have been suggested to farmers to control the weed, including crop management practices, seed treatment and striga tolerant crop varieties. We present the case of Mr. Ramani Abe-bieli, a 33-year-old innovative farmer in Kuka Megogo near Missiga in the Bawku Municipality, who mixes dried onion leaves with seeds before planting to suppress the emergence of striga on his millet and sorghum farms. Ramani discovered this innovation serendipitously. He has a parcel of land where he cultivates millet and sorghum. The parcel was highly infested with striga which affected crop yield. He tried several measures to control the weed but was unsuccessful. In one cropping season, he decided to cultivate onion on the parcel instead of cereals. He harvested the onion and left the residues on the field. The following season, he cultivated the cereals again and realised that, unlike previous years, there was very little emergence of striga on the field. He then developed the idea that onion residues could help control striga. He further improved this innovation by processing the onion leaves and using it for coating seeds before planting to control striga in his fields. Ramani found that the innovation is less expensive compared to other seed treatment methods. He also claims that the innovation is effective as it has prevented the emergence of striga in his field and has subsequently been adopted by more than 50 farmers in his community.

Case 2: Reduction of Guinea keets mortality using ethnoveterinary medicine

Guinea fowl is an important bird reared by many households in the study region. One of the main causes of mortality, particularly in keets, is worms. Ethnoveterinary medicines are commonly used in treating worms and other diseases in birds. One of such example, which was highly ranked by the experts, is the innovation of Mr. Asaa Abagre, a 76-year-old livestock and poultry farmer in Googo village in the Bawku West district. He uses a mixture of sorghum malt and pepper solution as a dewormer for Guinea keets to reduce mortality. Sorghum is one of the major crops cultivated in northern Ghana, and malted sorghum is used in brewing a local beer known as *pito.* Asaa, however, uses it in addition to pepper solution to deworm his keets. The malt is sun-dried and pulverized into flour. He also dissolves 2 pepper fruits in the drinking water of the birds. The keets are confined and fed with the malt flour three times daily and allow to drink the water with pepper solution for one week. Asaa asserts that he has successfully reduced the mortality of his keets through this innovation.

Case 3: *Sida acuta* in a semi intensive system to protect birds from hawks

Mr. Samuel A. Anaba is a poultry farmer in Zaare near Bolgatanga, the capital of the Upper East region. He rears chicken and Guinea fowls in a semi intensive system. He has designed a unique way of protecting his young birds from hawks, which are a major cause of loss of young birds in his community. He broadcasts the seeds of common wireweed (*Sida acuta*) in front of his brooder house at the beginning of the rainy season. The chicks and keets are brooded in the brooder house for 4 weeks and then released into the *Sida acuta*. *Sida acuta* is a small shrub with many branches on the stem, and this serves as a hiding place for the birds and protects them from hawks. It also provides a good micro-climate for the birds. The birds also derive nutrients by feeding on the plant as well as insects, such as ants and worms, beneath the plant. Through this innovation, Samuel significantly reduces the mortality rate and cost of protecting his young birds and also supplements the mineral and vitamin requirements of the birds.

Case 4: Storage of onion seed and treatment of livestock wounds using Barakuk

Mr. John A. Akugre is a 56-year-old farmer from Tilli in the Bawku West District, and the first prize winner of the innovation contest organised in 2012 to identify farmer innovations, which was described above. Onion production is a major farming activity in his community. Onion seeds are difficult to store for longer periods and lose viability before the next planting season, and this is a major production challenge in his community. After several unsuccessful attempts to store the seeds, John experimented using *Barakuk*, a local plant herb to store the seeds. He collects the plant from the wild during the rainy season, dries, burns them into char and grind them into powder. The powdered herb is stored in clean containers. He mixes an amount of the herb with the onion seeds and fills a bottle with the mixture for storage in a cool, dry place. With this method, the seeds remain viable even after a year, and he obtains a high germination percentage. A large share of onion farmers in his community has subsequently adopted this innovation.

John also uses the *Barakuk* herb to treat animal wounds. The powdered *Barakuk* is mixed with melted shea oil. After cooling, the ointment is applied daily on a cleaned animal wound. John argues that the wound will be completely healed within a week, and the ointment is 90% effective in treating animal wounds. Thus, the use of Barakuk herb improves onion seed viability and saves cost of drugs for treating animal wounds. A limitation of the innovation is the seasonality and limited distribution of the *Barakuk* plant. However, the powdered *Barakuk* can be bottled and stored, and is still effective even after 2 years. John's innovations have been documented in brochures by Prolinnova-Ghana and disseminated among key stakeholders.

Case 5: Integrated aquaculture-agriculture

Mr. Joseph A. Abarike is an outstanding 55-year-old innovator and experimenter from Zuarungu in the Bolgatanga Municipality. He engages in crop and livestock production, and fish farming. He undertakes several innovative activities on his farm and is responsible for the innovations numbered 5, 33 and 38 in Table 3. He was awarded the third best innovator in the innovation contest. High cost of imported fish feed is a major challenge of fish farming in Ghana. To address this challenge and save costs, Joseph decided to formulate fish feed from local materials. He mixes rice bran, pito mash, soybean, fish waste, maize or millet flour and pulverised baobab leaves. He dries and stores the mixture in bags for feeding the fish. The different ingredients provide varied nutrients such as carbohydrate, protein, folic acid and other vitamins to the fish.

Another of Joseph's innovation, which actually won him the award, is the use of fish pond water as a liquid manure and insecticide. Apart from the fish feed, he also drops livestock droppings and neem leaves into his fish ponds. This promotes the growth of micro-organisms needed by the fish. The pond water is recycled and used as liquid fertilizer for the crops he cultivates around the ponds. The addition of the neem leaves also serves as a pesticide for the crops. This innovation reduces the amount of fertilizer and pesticide needed for his crops.

Joseph is also a curious experimenter. He cultivates several crops that are grown in southern Ghana and considered to be unsuitable for the climate in northern Ghana. To satisfy his curiosity, he carries planting materials of crops grown in southern Ghana anytime he travels to this region. Some of the crops, like avocado and cocoa, were unsuccessful but most of them, including banana, plantain, cassava, oil palm, pineapple, coconut, orange and cocoyam did very well on his farm. He multiplies the planting materials in order to increase production. He now sells the planting materials to other farmers in the region, and his household is able to prepare southern Ghana dishes with products from his own farm.

Case 6: Multiplication of sweet potato vine under artificial shade

Sweet potato is the most widely grown root and tuber crop in the Upper East region of Ghana. It is propagated using vine cuttings, which are generally obtained from young plants. To improve the amount and quality of vine cuttings, Mr. John Adjabui, a 46-year-old farmer from Wiaga in the Builsa district produces sweet potato vines under artificial shade instead of the usual method of growing them on the ground. He erects a shade of about 3m tall and covers it with millet stalks. He plants two-node cuttings under the shade with one of the nodes above the ground and supported with millet stalk to enhance upward growth. The vines grow, climb and spread on top of the shade. Within 4 months, the vines completely cover the shade. He cuts them for planting and sells the rest to other farmers. With this method, he obtains more vines because it prevents phototropism, and also there is no destruction by insects, such as beetles or termites, as in the case of growing completely on the ground. Additionally, there is an increase in vine length since the nodes do not touch the soil for rooting, which retards the length of vine. He is also able to produce vine cuttings throughout the year.

4.5 Conclusion

The aim of this paper was to identify innovations developed by smallholder farmers in northern Ghana, and prioritise the high potential ones for further scientific validation or dissemination. Using an innovation contest that rewards farmers' creativity, we identified 29 promising innovations. Additionally, 19 innovations were scouted through a household survey. Using expert judgement in a MCDM analysis, these 48 innovations were ranked, and among the most promising innovations were those involving the control of weeds, pest and diseases using plant residues and extracts, and the treatment of livestock diseases using ethnoveterinary medicines.

The study shows that farmers have added value to existing practices or externally introduced techniques to solve their production constraints, save costs and adapt to changing conditions. The innovations are related to diverse farming practices and largely involve the use of local resources. Most of the innovations are not necessarily new inventions. They are mainly extensive modification of existing practices or combination of different known practices in unique ways to address production constraints. Though these low-cost innovations have not been verified, they are increasingly spreading through farmer networks. The innovators are also pleased to share their innovations with other farmers and stakeholders as it builds their reputation and social capital. The claims of high adoption rate suggest that these innovations may have potential in addressing farmers' problems. Most of these innovations involve less use of external inputs, hence, have positive effects on the environment. The result from the MCDM analysis also indicate that most of these innovations have high economic and dissemination potential.

The paper also shows that contest can be a good instrument in unearthing farmers' innovations. Awards through the innovation contest may provide incentives for innovators, who may have kept their innovations in secrecy, to reveal their practices. The contest processes also create awareness of farmers' innovations. It facilitates stakeholders to appreciate the importance of farmer innovation and provides a platform for further improvements of the innovations through joint research. Thus, the contest strengthens the partnership between farmers and key actors such as extension officers and scientists. The contest may also inspire farmers to try out new things. As part of the WASCAL project, steps are currently under way to evaluate the potential of the contest in inducing farmers to innovate.

While some of the identified innovations can be recommended or disseminated to other farmers, most of them may require further validation or research. For instance, with the first ranked innovation on suppression of striga using onion residues, It would be essential to ascertain how it works and to what extent. That is, which component of the onion residues limits striga emergence, can this be found in other plant extracts and what amount will ensure a high success rate? Also, what value can be added to make it more effective, and is it cost-effective? Validating all these 48 innovations and the several innovations that have been identified by other research programmes will be costly and time consuming. We show in this study that MCDM analysis can be used as a first step in prioritising innovations that will need further validation and to suggest the high-potential innovations. The MCDM approach used in this study is based on expert judgement, which involves key stakeholders in agriculture. This provides an opportunity to further create awareness and promote farmer innovation processes.

There is the need for better support for farmers' innovations. As shown by the Indian example, such support may include validating the innovations, adding value, assigning patents and commercializing the products. The WASCAL project aims to go beyond identification of innovations to validate some of these innovations with relevant stakeholders in the region. For instance, discussions are currently ongoing with the SARI for scientific validation of storing onion seeds using *Barakuk* and suppression of striga using onion residues. Some of the identified innovations, particularly the ethnoveterinary medicines, have the potential to be converted to marketable products if proven to be effective. Achieving this will, however, require strong institutional support.

This case study from northern Ghana provides further evidence that smallholder farmers develop diverse and spectacular innovations to address the myriad challenges in crop and livestock production. Their efforts have to be recognised, and some of these innovations have high potential that needs to be validated and promoted. More efforts are needed to promote and institutionalise farmer innovation approaches.

Appendix 4

Table A1: Institutional affiliation of stakeholders and experts invited to the workshop

Ministry of Food and Agriculture, Upper East Regional Office, Bolgatanga
Ministry of Food and Agriculture, Bolgatanga Municipality, Bolgatanga
Ministry of Food and Agriculture, Kassena Nankana East District, Navrongo
Ministry of Food and Agriculture, Kassena Nankana West District, Paga
Ministry of Food and Agriculture, Bongo District, Bongo
Savanna Agricultural Research Institute (SARI), Bawku
Forest Research Institute of Ghana (FORIG), Bolgatanga
Water Resources Commission of Ghana, Bolgatanga
West African Science Service Center for Climate Change and Adapted Land Use (WASCAL), Bolgatanga
Navrongo-Bolgatanga Catholic Diocesan Development Office (NABOCADO), Bolgatanga
Upper East Vegetable Farmers Association, Bolgatanga

Conclusions

Agriculture is rapidly undergoing economic changes, with new challenges and opportunities. This calls for agricultural innovation, which is essential in meeting food demands and the challenges facing agriculture. There are varied sources of agricultural innovations, including farmers. However, investment in the development of agricultural innovations has focussed largely on scientific research by private and public research institutions, with neglect of innovative practices of farmers. These research institutions have developed numerous one-size-fits-all technologies which have had some great successes, but also with limited scopes (Macmillan and Benton, 2014). For instance, the diversity of farming systems requires context-specific innovations, and this is an enormous challenge for research institutions. Farmers are, however, able to develop innovations which are suitable for their local conditions, and reorient existing technologies and practices to new situations. There are increasing efforts to promote farmer-centred approaches to innovation development, but the literature on this subject is very limited. This study purports to contribute to the empirical research on farmer innovation by analysing the innovation-generating behaviour in rural farm households in Ghana.

This thesis addresses three objectives: (1) to examine the determinants of innovating-generating behaviour in farm households, (2) to assess the impact of farmer innovation on household welfare, and (3) to identify and prioritise high-potential farmers' innovations. The study is based on primary data obtained from a survey of 409 smallholder farm households in Bongo, Kassena Nankana East and Kassena Nankana West districts in the Upper East region of northern Ghana. Additional data were collected through an innovation contest and a stakeholder workshop conducted in the region.

The results show that farmers in the study region have enormous innovation potentials. About 41 percent of the sampled households conducted at least one innovation-generating activity in the past 12 months. The innovations range from experimenting with new ideas, modifying or adding value to existing or external practices to complete discovery of better farming practices. The farmers innovate in several farming domains such as land preparation, method of planting, cropping pattern, soil fertility, new crops and varieties, soil and water conservartion, and animal husbandry. The main motivations for conducting these innovative practices include satisfying curiosity, increase in production and reduction in production costs.

The determinants of farmer innovation were estimated using recursive bivariate probit and endogenous treatment regression models, which control for selection bias and account for the different measures of farmer innovation. Particular emphasis was placed on the potential of Farmer Field Fora (FFF), a participatory extension approach with elements of innovation systems, in explaining farmers' innovation behaviour. The results suggest that participation in a sweet potato FFF in the study region is a key determinant of innovation capacity in farm households. FFF participants were found to be 22 percentage points more likely to generate innovations than non-participants. This is plausible since FFF participants are likely to be empowered and gain problem-solving and analytical skills, which are essential for innovation. The implication of this finding is that the innovation systems framework, which facilitates active interactions among key stakeholders, may be a potential option for strengthening farmers' innovation capacity.

Spillover and heterogeneous effects of FFF on innovation capacity were also analysed. It was found that the mere location of non-participants households in FFF villages or interactions with other FFF graduates does not induce them to innovate. The policy implication is that any attempts to stimulate innovativeness in farmers though FFF programmes should not rely on the few participants to spread the knowledge gained, but should rather increase the intensity of the programme. However, it seems FFF participation has positive spillover effects on other farming activities because although the FFF studied is sweet potato-based, most of the innovations reported by the farmers were unrelated to sweet potato production. The results also show that there is little heterogeneity in the determinants of innovation-generating behaviour among FFF participants, and an interesting finding was that the number of years since participating in FFF does not significantly influence innovation capacity of participants. This suggests that the innovation-generating effect of FFF persists over time. Thus, FFF enhances the capacity of farmers to continuously innovate in several farming domains, and this has positive implications for the cost-effectiveness of the FFF programme.

Along with FFF participation, the probability of implementing innovations also increases significantly with education of household head, implying that human capital development is essential in inducing innovativeness in farmers. Contrary to the innovation adoption literature, little evidence was found that wealth affects smallholder farmers' decision to innovate. This finding suggests that resource-poor households are able to generate innovations, and this can be explained by the fact that farmer innovation mostly involved the use of locally available and less costly resources which are accessible to most households. Furthermore, the results suggest that households most affected by climate shocks are less likely to innovate. Thus, enhancing farmers' capacity to adapt to climate shocks may indirectly contribute to building their capacity to generate innovations. Finally, using a simple experiment to measure risk attitude, it was found that risk preferring farmers are more likely to be innovative than risk averse farmers, suggesting that some farmers have an innate capacity to develop innovations. Several robustness checks were performed and these results were found to be robust to different specifications of farmer innovation and estimation techniques.

To estimate the welfare effects of farmer innovation, the endogenous switching regression technique which controls for unobserved heterogeneity was employed. Household welfare was measured in terms of farm and household income, consumption expenditure, and food and nutrition security. Additionally, the potential contribution of farmer innovation to building households' resilience to climate shocks was investigated. The use of various household welfare outcomes, which is rarely done in the same study, enabled robust assessment of the welfare effects of farmer innovation.

Analysis of the determinants of the welfare indicators revealed heterogeneous results, and among the major findings was the confirmation of the problem of gender inequality in the study region. Women in the study region are noted to have limited access to land and other resources needed to achieve food security. The results indicate that non-innovative female-headed households are more likely to have extra months of food inadequacy and their household members are more likely to experience hunger. The fact that this result is only applicable to non-innovators implies that motivating female farmers to innovate will play an important role in reducing gender disparities in food security in the study region.

In terms of impacts, the results show that farmer innovation has a significant income and consumption effects. Farmer innovation increases per adult equivalent farm and total household income by about 39 and 34 percentage points respectively for innovators. Also, farmer innovation contributes significantly to per adult equivalent consumption expenditure by about 30 percent for innovative households. These positive income and consumption effects may be related to an increase in output or a reduction in production cost as a result of the farmers' innovations.

Using both subjective and objective measures of food security, the results indicate that farmers' innovations play a key role in food insecurity reduction among innovators. Farmer innovation contributes to the reduction of the length of food gap periods by one month. It also significantly reduces 33 percent of the severe level of food insecurity for innovators. Furthermore, the innovations significantly cause an increase in per adult equivalent food consumption expenditure by about 31 percentage points for innovative households. The results, however, suggest that farmer innovation does not increase household dietary diversity. In fact, farmer innovation rather decreases household dietary diversity. Thus, the increased food consumption expenditure reported earlier is related to food availability, and the positive income effects do not also translate into nutritious diets. Thus, food security policies for the study region should go beyond food availability, and also focus on nutrition security. The results also show that although most farmers innovate to increase production, the innovations may indirectly enhance their resilience to shocks. It was found that farmer innovation improves innovative households' resilience to climate shocks by about 3 to 6 percent. This may be as a result of an improved income and food access, an increase in assets, and a higher adaptive capacity.

Generally, the innovative farmers, albeit subjectively, confirm the results of the impacts of farmer innovation. They cited increased knowledge and satisfaction, increased production and income, labour saving and improved food security as the main outcomes of their innovative practices. Overall, the findings of the welfare effects underscore the importance of farmer innovation in rural livelihoods and support the numerous anecdotal evidences of the potential positive impacts of farmer innovation; hence, there is the need to promote and tap the potential of farmer innovation. However, the small magnitude of the effects on some of the welfare measures suggests that other activities are very important in improving farmers' livelihoods. Thus, farmer innovation should be promoted alongside other best farming practices.

To identify high-potential farmers' innovations, an innovation contest was implemented in the study region. The contest rewarded farmers for their creativity and also inspired them to be innovative. Additional innovations were scouted during the household survey. Overall, 48 outstanding innovations were identified. These innovations are largely extensive modification of existing practices or unique combinations of different practices. The study used the multi-criteria decision making analysis (MCDM) to prioritise the identified innovations, and some of the most promising innovations are those involving the control of weeds, pests and diseases using plant residues and extracts, and the treatment of livestock diseases using ethnoveterinary medicines. The innovations are relatively inexpensive and adapted to local conditions, and there are reports of high adoption among farmers in the region. This further implies that farmers' innovations have the potential to contribute to addressing important production constraints.

The study shows that contest can be a good instrument in unearthing farmers' innovations. Contest could be used to inspire farmers to try out new things, and the awards may provide incentives for innovators to reveal their innovative practices. The contest processes allow the appreciation of the importance of farmer innovation and provides a platform for building partnerships to improve and promote the innovations. Through the use of MCDM in prioritising the identified innovations, this study makes a methodological contribution to the farmer innovation literature. MCDM is a simple method that could be used as a first step in validating farmers' innovations before disseminating to other farmers or carrying out scientific evaluation. The MCDM used in this study is based on expert judgement, which involves key stakeholders in agriculture. This provides opportunity to further create awareness and promote farmer innovation processes.

In conclusion, this study has demonstrated that smallholder farmers go beyond adoption of externally-promoted technologies to experiment, and develop adaptive and remarkable innovations. These innovations contribute significantly to household welfare. There is, therefore, the need to recognise and empower farmers to develop and adapt innovations, and this study has shown that institutional arrangements such as FFF could be an essential pathway. Nevertheless, more research is needed to complement this study and increase the understanding of farmer innovation. Some of the limitations of this study and suggestions for future research are presented as follows.

The study shows that FFF programme is effective in building farmers' capacity to generate innovations, but it did not investigate the cost-effectiveness of the programme. There is a high cost of implementing FFF programmes, and the finding of no spillover effect of FFF on innovation generation also has cost-effectiveness implications. However, it appears the programme may have positive spillover effects on several farming activities. Moreover, with the finding that earlier FFF participants are equally innovative as recent participants, it seems the programme has long-term benefits. Therefore, a comprehensive study on the cost-effectiveness of the FFF extension model will be required to assess if the benefits of FFF in terms on innovation is worth the investment, or if an alternative extension method could achieve similar results at a relatively low cost.

In the analysis of the determinants and welfare effects of farmer innovation, all the innovators were lumped together irrespective of their innovations, and separate analyses were not performed for the different innovation domains or practices. This is due to data limitations. It will be interesting to assess the drivers of the various innovation domains and their respective household welfare impacts. Similarly, some farmers are either only adopters of introduced technologies, innovators or both, but this study focussed on only innovators and non-innovators. It will be useful to examine the heterogeneity in farmers' innovation behaviour. Future research comprising large sample size will permit such analysis.

The results from the farmer innovation contest show that about 30 percent of the innovations were developed by females, suggesting that women play an important role in the innovation-generating processes in the study region. However, in examining the determinants and impacts of farmer innovation, the gender analysis was based on comparing male- and female-headed households. For instance, it is possible that women living in male-headed households may have implemented some of the innovations that were reported by the male respondents. Gender-disaggregated data are required to analyse the gender dimensions of farmer innovation. Furthermore, the study found that education plays a key role in farmer innovation processes, and this has important policy implications. However, the indicator of education employed in the regressions is the number of years of education of household heads, which is overly simple. Future work should consider several measures of education, such as level of education of household head and other household members (e.g. spouse and children).

Finally, farmer innovation is a dynamic process, but this study is based on cross-sectional data which restricted the analyses to a one-year period. Further research involving panel data would be needed to provide a better understanding of the dynamics and long-term effects of farmer innovation.

References

AduAnkrah, D., Dorward, P.T. and Garforth, C.J. (2014) Pathways of Farmers Innovation, A Case Study of Pineapple Farmers in the Nsawam Municipal Assembly of Ghana. International Journal of Agriculture Innovations and Research 2: 2319-1473

AGRA (2013) Africa Agriculture Status Report: Focus on Staple Crops. Alliance for a Green Revolution in Africa (AGRA), Nairobi, Kenya

Akudugu, A.A. and Laube, W. (2013) Implementing local economic development in Ghana: Multiple actors and rationalities. ZEF Working Paper 113, Center for Development Research, University of Bonn

Alene, A. and Manyong, V. (2007) The Effects of Education on Agricultural Productivity under Traditional and Improved Technology in Northern Nigeria: An Endogenous Switching Regression Analysis. Empirical Economics 32: 141-159

Alinovi, L., D'Errico, M., Mane, E., and Romano, D. (2010) Livelihoods strategies and Household Resilience to Food insecurity: An Empirical Analysis to Kenya. Paper presented at the European Research for Development Conference, 28-30 June 2013, Dakar, Senegal

Amare, M., Asfaw, S. and Shiferaw, B. (2011) Welfare impacts of maize–pigeonpea intensification in Tanzania. Agricultural Economics 43:27–43

Apusigah, A.A. (2009) The gendered politics of farm household production and shaping of women's livelihoods in northern Ghana. Feminist Africa 12: 51-68

Aryeetey, E. 2005. Globalization, Employment and Poverty in Ghana. Working Paper. Institute of Statistical, Social and Economic Research, University of Ghana, Accra

Asfaw, S., Shiferaw, B. Simtowe, F. and Leslie, L. (2012) Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. Food Policy 37:283–295

Asmah, E.E. (2011) Rural livelihood diversification and agricultural household welfare in Ghana. Journal of Development and Agricultural Economics 3:325-334

Asuming-Brempong, S. and Kuwornu, J.K.M. (2013) Policy Initiatives and Agricultural Performance in Post-independent Ghana. Journal of Social and Development Sciences 4:425-434

Asuming-Brempong, S., Sarpong, D. B. and Asante, F. (2006) Institutional Bottlenecks of Agricultural Sector Development: The Case of Research and Extension Provision in Ghana. University of Ghana for the OECD Development Centre (Paris, France). Accra, Ghana

Avornyo, F.K., Lambon, J., Nchor, J. and Alenyorege, B. (2011) Action Research on Farmer Access to Innovation Resources (FAIR): The Ghana Experience. Prolinnova-Ghana, ACDEP Tamale, Ghana

Ballard, T., Coates, J., Swindale, A. and Deitchler, M. (2011) Household Hunger Scale: Indicator Definition and Measurement Guide. Washington, DC: FANTA-2 Bridge, FHI 360

Barrett, C., Moser, C., McHugh, O. and Barison, J. (2004) Better Technology, Better Plots, or Better Farmers? Identifying Changes in Productivity and Risk among Malagasy Rice Farmers. American Journal of Agricultural Economics 86:869-888

Barrett, C.B. (2010) Measuring food insecurity. Science 327:825–828

Becker, S. and Caliendo, M. (2007) Sensitivity analysis for average treatment effects. The Stata Journal 7:71-83

Bell, M., Hobbs, B. and Ellis, H. (2003) The use of multi-criteria decision-making methods in the integrated assessment of climate change: implications for IA practitioners. Socio-Economic Planning Sciences 37:289-316

Belton, V. and Stewart, T. (2002) Multiple Criteria Decision Analysis: An Integrated Approach. Kluwer Academic Publishers, Boston, MA

Bentley, J.W. (2006) Folk Experiments. Agriculture and Human Values 23:451-462

Biggs, S.D. and Clay, E.J. (1981) Sources of innovation in agricultural technology. World Development 9:321-336

Biggs, S.D. (1990) A multiple source of innovation model of agricultural research and technology promotion. World Development 18:1481-1499.

Bilinsky, P. and Swindale, A. (2005) Months of Inadequate Household Food Provisioning (MIHFP) for Measurement of Household Food Access: Indicator Guide. Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, DC

Binswanger, H.P. (1980) Attitudes toward Risk, Experimental Measurement in Rural India. American Journal of Agricultural Economics 62:395-407

Boserup, E. (1965) The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Growth. Aldine, Chicago

Braun, A., Jiggins, J., Röling, N., van den Berg, H. and Snijders, P. (2006) A Global Survey and Review of Farmer Field School Experiences', International Livestock Research Institute, Nairobi and Endelea, Wageningen

Breisinger, C., X. Diao, J. Thurlow, and R. M. Al-Hassan (2008) Agriculture for development in Ghana: New opportunities and challenges. IFPRI Discussion Paper No. 784. International Food Policy Research Institute, Washington, DC

Brooks, S. and Loevinsohn, M. (2011) Shaping agricultural innovation systems responsive to food insecurity and climate change. Natural Resources Forum 35:185-200

Bruce, J., Karbo, N. and Alebekiya, M. (2004) Building Multi-Stakeholder Partnerships to Promote Farmer Experimentation and Innovation in Ghana. IK Notes No. 74. The World Bank

Buadi D.K., Anamah, K.A. and Kwarteng, J.A. (2013) Farmers' perceptions of the quality of extension services provided by non-governmental organisations in two municipalities in the Central Region of Ghana. Agricultural Systems 120:20-26

Bunch, R. (1989) Encouraging farmers' experiments. In: Chambers et al. (eds.), Farmer First. Intermediate Technical Publications, London, UK

Caliendo, M. and Kopeinig, S. (2008) Some Practical Guidance for the Implementation of Propensity Score Matching. Journal of Economic Surveys 22:31–72

Chambers R., Pacey A. and Thrupp L.A. (1989) Farmers first: farmer innovation and agricultural research. Intermediate Technical Publications, London

Chhetri, N., Chaudhary, P., Tiwari, P.R. and Yadaw, R.B. (2012) Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal. Applied Geography 33:142-150

Conway, G. and Wilson, K. (2012) One Billion Hungry: Can we Feed the World? Cornell University Press, Ithaca, New York

Critchley, W. R. S. and Mutunga, K. (2003) Local innovation in a global context: documenting farmer initiatives in land husbandry through WOCAT. Land Degradation and Development 14:143-162

Curtis, M. (2013) Improving African Agriculture Spending: Budget Analysis of Burundi, Ghana, Zambia, Kenya and Sierra Leone. Curtis Research, Oxford, UK

David, C. C. and Otsuka, K. 1994. Modern Rice Technology and Income Distribution in Asia. Boulder, CO: Lynne Rienner Publishers

Davis, K., Nkonya, E., Kato, E., Mekonnen, D.A., Odendo, M., Miiro, R. and Nkuba, J. (2012) Impact of farmer field schools on agricultural productivity and poverty in East Africa. World Development 40: 402- 413

de Bruin, K.C., Dellink, R.B., Ruijs, A., Bolwidt, A. van Buuren, L., Graveland, J., de Groot, R.S., Kuikman, P.J., Reinhard, S., Roetter, R.P., Tassone, V.C., Verhagen, A. and van Ierland, E.C.

(2009) Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. Climatic Change 95:23-45

de Haen, H., Klasen, A. and Qaim, M. (2011) What do we really know? Metrics for food insecurity and undernutrition. Food Policy 36:760–769

de Janvry, A. and Sadoulet, E. (2002) World poverty and the role of agricultural technology: Direct and indirect effects. Journal of Development Studies 38:1-26

de Rouw, A. (2004) Improving yield and reducing risk in pearl millet farming in the African Sahel. Agricultural Systems 81:73–93

Deaton, A. (1997) The Analysis of Household Surveys: A Microeconometric Approach to Development Policy. Johns Hopkins University Press for the World Bank, Baltimore

Di Falco, S., Veronesi, M. and Yesuf, M. (2011) Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. American Journal of Agricultural Economics 93:829–846

Easterling, W,E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J-F., Schmidhuber, J., Tubiello, F.N. (2007) Food, fibre and forest products. In: Parry et al. (eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 273-313

Easterling, W.E. (1996) Adapting North American agriculture to climate change in review. Agricultural and Forest Meteorology 80:1-53

Erbaugh, M.J., Donnermeyer, J.F., Amujal, M. and Kidoido, M. (2010) Assessing the Impact of Farmer Field School Participation on IPM Adoption in Uganda. Journal of International Agricultural and Extension Education 17:5-18

FAO (1999) Technical Assistance to the Integrated Pest Management Training Project: Indonesia. Report No. AG: UTF/INS/072/INS, In: Feder et al. (2004) Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia. Review of Agricultural Economics 26:45-62

FAO (2010) Measuring Resilience: A Concept Note on the Resilience Tool. EC-FAO Programme on Linking Information and Decision Making to Improve Food Security. Food and Agriculture Organization of the United Nations, Rome

FAO, IFAD and WFP (2013) The State of Food Insecurity in the World 2013. The multiple dimensions of food security. Rome, FAO

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

Feder, G., Murgai, R. and Quizon, J.B. (2004a) The acquisition and diffusion of knowledge: the case of pest management training in farmer field schools, Indonesia. Journal of Agricultural Economics 55:221–243

Feder, G., Murgai, R. and Quizon, J.B. (2004b) Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia. Review of Agricultural Economics 26:45-62

Fernandez-Cornejo J., Hendricks, C. and Mishra, A. (2005) Technology adoption and off-farm household income: the case of herbicide-tolerant soybeans. Journal of Agricultural and Applied Economics 37:549–63

Filmer, D. and Pritchett, L.H. (2001) Estimating wealth effect without expenditure data—or tears: an application to educational enrolments in states of India. Demography 38:115–132

Find Your Feet (2012) Recognising the Unrecognised: Farmer Innovation in Northern Malawi. Find Your Feet, London

Fischer, E. and Qaim, M. (2012) Gender, agricultural commercialization, and collective action in Kenya. Food Security 4:441–453

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D. And Zaks, D.P.M. (2011) Solutions for a cultivated planet. Nature 478:337-342

Friis-Hansen, E. and Duveskog, D. (2012) The Empowerment Route to Well-being: An Analysis of Farmer Field Schools in East Africa. World Development 40:414–427

Fuglie, K. O. and Bosch, D. J. (1995) Economic and environmental implications of soil nitrogen testing: a switching regression analysis. American Journal of Agricultural Economics 77:891–900

Garcia, C. and Calantone, R. (2002) A critical look at technological innovation typology and innovativeness terminology: a literature review. The Journal of Product Innovation Management 19:110-132

Gbadugui, B.J. and Coulibaly, O. (2013) PRONAF's Farmer Field Fora (FFF). MEAS HRD Case Study Series, # 2. International Institute of Tropical Agriculture, Cotonou, Benin

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 327:812–818

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 327:812–818

Goldman, A. (1993) Agricultural Innovation in Three Areas of Kenya: Neo-Boserupian Theories and Regional Characterization. Economic Geography 69:44-71

GRAIN (2009) Nerica: another trap for small farmers in Africa. GRAIN Briefing, Barcelona

GSS (2012) 2010 Population & Housing Census: Summary Report of Final Results. Ghana Statistical Service (GSS), Accra, Ghana

GSS (2013) 2010 Population & Housing Census: National Analytical Report. Ghana Statistical Service (GSS), Accra, Ghana

GSS (2014) Gross Domestic Product 2014. Ghana Statistical Service (GSS), Accra, Ghana

Gupta, A.K., Sinha, R., Koradia, D., Patel, R., Parmar, M., Rohit, P., Patel, H., Patel, K., Chand, V.S. James, T.J., Chandan, A., Patel, M., Prakash, T.N. and Vivekanandan, P. (2003) Mobilizing grassroots' technological innovations and traditional knowledge, values and institutions: articulating social and ethical capital. Futures 35:975-987

Haile, M., Abay, F. and Waters-Bayer, A. (2001) Joining Forces to discover and celebrate local innovation in land husbandry in Tigray, Ethiopia. In: Reij, C. and Waters-Bayer, A. (eds.) Farmer Innovation in Africa: A source of inspiration for Agricultural Development. Earthscan, London

Hall, A. (2007) The Origins and Implications of Using Innovation Systems Perspectives in the Design and Implementation of Agricultural Research Projects: Some Personal Observations. UNU Merit Working Paper #2007-013, Maastricht

Harrison, G.W. and Rutström, E.E. (2008) Risk Aversion in the Laboratory. Research in Experimental Economics 12: 41-196

Hayami, Y. and Ruttan V.W. (1985) Agricultural Development: An International Perspective. Rev., exp. edn. Baltimore: Johns Hopkins University Press

Hayami, Y. and Ruttan, V.W. (1970) Factor Prices and Technical Change in Agricultural Development: The United States and Japan, 1880-1960. Journal of Political Economy 78:1115-1141

Hicks, J.R. (1932) The Theory of Wages. Macmillan, London

Huffman, W. (1991) Agricultural household models: Survey and critique. In: Hallberg, M. C., J. Findeis and D. Lass (eds.) Multiple Job-Holding Among Farm Families. Iowa State University Press, 79-111

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Kaaria, S., Njuki, J., Abenakyo, A., Delve, R. and Sanginga, P. (2008) Assessment of the Enabling Rural Innovation (ERI) approach: Case studies from Malawi and Uganda. Natural Resources Forum 32:53-63

Kabunga, N.S., Dubois, T. and Qaim, M. (2011) Impact of Tissue Culture Banana Technology on Farm Household Income and Food Security in Kenya. Courant Research Centre Discussion paper no. 8, Göttingen, Germany

Karbo, N. (2008) Nigeria PROLINNOVA Programme Development Inception Workshop: Sharing the Ghana Experiences. PROLINNOVA Working Paper 25

Kassie, M. Ndiritu, W.S. and Stage, J. (2014) What Determines Gender Inequality in Household Food Security in Kenya? Application of Exogenous Switching Treatment Regression. World Development 56:153-171

Kassie, M., Shiferaw, B. and Geoffrey, M. (2011) Agricultural Technology, Crop Income, and Poverty Alleviation in Uganda. World Development 39: 1784–1795

Kawagoe, T., Otsuka, K. and Hayami, Y. (1986) Induced Bias of Technical Change in Agriculture: The United States and Japan 1880–1980. Journal of Political Economy 94:523–44

Ker, A. (1995) Farming systems of the African savanna: a continent in crisis. International Development Research Centre (IDRC), Ottawa

Khan, Z.R., C.A.O. Midega, and J.A. Pickett. 2011. Striga weed in Africa: cultural control. Encyclopedia of Pest Management doi: 10.1081/E-EPM-120046898

Kijima, Y., Otsuka, K., and Sserunkuuma, D. (2008) Assessing the impact of NERICA on income and poverty in central and western Uganda. Agricultural Economics 38: 327–337

Kleemann, L. and Abdulai, A. (2013) Organic certification, agro-ecological practices and return on investment: Evidence from pineapple producers in Ghana. Ecological Economics 93:330–341

Kolavalli, S., Birner, R., Benin, S., Horowitz, L., Babu, S., Asenso-Okyere, K., Thompson, N.M. and Poku, J. (2010) Institutional and public expenditure review of Ghana's Ministry of Food and Agriculture. IFPRI Discussion 1020, Paper International Food Policy Research Institute (IFPRI), Washington, DC

Kummer, S. (2011) Organic farmers' experiments in Austria - Learning processes and resilience building in farmers' own experimentation activities. Doctoral thesis, University of Natural Resources and Life Sciences, Vienna

Kummer, S., Milestad, R., Leitgeb, F. and Vogl, C.R. (2012) Building resilience through farmers' experiments in organic agriculture: Examples from eastern Austria. Sustainable Agriculture Research 1:308-321

Leitgeb, F., Kummer, S., Funes-Monzote, F.R. and Vog, C.R. (2014) Farmers' experiments in Cuba. Renewable Agriculture and Food Systems 29:48-64

Letty, B., Noordin, Q., Magagi, M. and Waters-Bayer, A. (2011) Farmers Take the Lead in Research and Development. In: The Worldwatch Institute- State of the World 2011: Innovations that Nourish the Planet. The Worldwatch Institute, Washington DC

Letty, B., Shezi, Z. and Mudhara, M. (2011b) Assessing the impact of grassroots innovation in Agriculture. Paper presented at the 9th GLOBELICS International Conference. Buenos Aires Argentina in 15-17 November 2011

Lilleør, H.B. and Larsen, A.F. (2013) Beyond the field: Impact of Farmer Field Schools on food security and poverty alleviation. Study Paper No. 52, The Rockwool Foundation Research Unit, Copenhagen

Liu, Q. and Shumway C.R. (2006) Geographic Aggregation and Induced Innovation in American Agriculture. Applied Economics 38:671–682

Liu, Y. and Shumway, C.R. (2009) Induced Innovation in U.S. Agriculture: Time-series, Direct Econometric, and Nonparametric Tests. American Journal of Agricultural Economics 91:224-236

Lokshin, M. and Sajaia, Z. (2004) Maximum likelihood estimation of endogenous switching regression models. The Stata Journal 4:282–289

Lybbert, T.J., Sumner, D.A. (2012) Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. Food Policy 37: 114–123

Lyon, F. (1996) How farmers research and learn: the case of arable farmers of East Anglia, UK. Agriculture and Human values 13: 39-47

Macmillan, T. and Benton, T.G. (2014) Engage farmers in research. Nature 509:25-27

Maddala, G.S. (1983) Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press, Cambridge

Mapila, M.A.T.J. and Makina, A. (2011) Engendering rural livelihoods in Malawi through agriculture innovation systems. Journal of Sustainable Development in Africa 13, No.5

Mapila, M.A.T.J., Kirsten, J.F. and Meyer, F. (2012) The impact of agricultural innovation systems interventions on rural livelihoods in Malawi. Development Southern Africa 29:303-315

McIntyre, B.D., Herren, H.R., Wakhungu, J. and Watson, R.T. (2009) Agriculture at a crossroads - global report. International assessment of agricultural knowledge, science and technology for development (IAASTD), Washington, DC

Mckenzie, F.C. (2011) Farmer-Driven Innovation in Agriculture: Creating Opportunities for Sustainability. Doctoral thesis, The University of Sydney

McSweeney, K. and Coomes, O.T. (2011) Climate-related disaster opens window of opportunity for rural poor in northeastern Honduras. Proceedings of the National Academy of Sciences (PNAS) 108:5203-5208

Millar, D. (1994) Experimenting farmers in Northern Ghana. In: Scoones, I. and Thompson, J. (eds.) Beyond farmer first. Rural people's knowledge, agricultural research and extension pr actice. Intermediate Technology Publications, London

Minten, B. and Barrett, C.B. (2008) Agricultural technology, productivity, and poverty in Madagascar. World Development 36:797–822

MoFA (2010) Medium Term Agriculture Sector Investment Plan (METASIP) 2011-2015. Ministry of Food and Agriculture, Accra, Ghana

MoFA (2011) Agricultural Extension Approaches Being Implemented in Ghana. Directorate of Agricultural and Extension Services, Ministry of Food and Agriculture (MoFA), Accra

MoFA (2013) Agriculture in Ghana: Facts and Figures (2012). Ministry of Food and Agriculture (MoFA). Statistics, Research and Information Directorate (SRID), Accra, Ghana

Mutunga, K. and Critchley, W.R.S. (2001) Farmers initiatives in land husbandry. Promising technologies for the drier areas of East Africa. Technical Report No. 28. Regional Land Management Unit: Nairobi

Nederlof, S., Wongtschowski, M. and van der Lee, F. (eds.) (2011) Putting heads together. Agricultural innovation platforms in practice. Bulletin 396, KIT Publishers

Negash, M. and Swinnen, J.F.M. (2013) Biofuels and food security: Micro-evidence from Ethiopia. Energy Policy 61:963–976

Nielsen, F. (2001) Why do Farmers Innovate and Why don’t they Innovate More? Insights from a study in East Africa. In: Reij, C. and Waters-Bayer, A. (eds.), Farmer innovation in Africa: a source of inspiration for agricultural development. London: Earthscan, 92-103

Noltze, M., Schwarze, S. and Qaim, M. (2013) Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste. Ecological Economics 85:59–68

OECD (2005) Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition, The Measurement of Scientific and Technological Activities, OECD Publishing. Statistical Office of the European Communities, Luxembourg

Okorley, E. L. (2007) An Operational framework for Improving Decentralized Agricultural Extension: A Ghanaian Case Study. Doctoral dissertation. Institute of Natural Resources. Agricultural/Horticultural Systems & Management, Massey University, Australia

Olmstead, A.L. and Rhode, P.W. (1993) Induced Innovation in American Agriculture: a reconsideration. Journal of Political Economy 101:100–118

Piesse, J., Schimmelpfennig, D. and Thirtle, C. (2011) An error correction model of induced innovation in UK agriculture. Applied Economics 43: 4081–4094

Pinstrup-Andersen, P. (2009) Food Security: Definition and Measurement. Food Security 1:5–7

Prolinnova (2014) Prolinnova.net/Ghana. Accessed on 23rd June 2014

Prolinnova-Ethiopia (2006) Progress report. Unpublished report

Prolinnova Ghana (2006) Identifying & cataloguing farmer innovations. Inception Phase, Prolinnova Ghana, Accra, Ghana

Quaye, W. (2008) Food security situation in northern Ghana, coping strategies and related constraints. African Journal of Agricultural Research 3:334-342

Rajalahti, R. (2009) Agricultural innovation system approaches: The Way forward. World Bank, Washington DC

Reij, C. and Waters-Bayer, A. (eds.), (2001) Farmer innovation in Africa: a source of inspiration for agricultural development. Earthscan, London

Reij, C., Tappan, G. and Smale, M. (2009) Re-Greening the Sahel: Farmer-led innovation in Burkina Faso and Niger. In: Spielman, D.J. and Pandya-Lorch, R. (eds.), Millions Fed: Proven successes in agricultural development. International Food Policy Research Institute (IFPRI), Washington, DC

Reij, C., Tappan, G. and Smale, M. (2009) Re-Greening the Sahel: Farmer-led innovation in Burkina Faso and Niger. In: Spielman, D.J. and Pandya-Lorch, R. (eds.), Millions Fed: Proven successes in agricultural development. International Food Policy Research Institute, Washington, DC, 53-58

Rhoades, R. (1989) The role of farmers in the creation of agricultural technology. In: Chambers et al. (eds.) Farmers first: farmer innovation and agricultural research. Intermediate Technical Publications, London

Rogers, E.M. (1962) Diffusion of innovations. The Free Press, New York

Rola, A.C., Jamais, S.B. and Quizon, J.B. (2002) Do farmer field school graduates retain and share what they learn? An investigation in Iloilo, Philippines. Journal of International Agricultural and Extension Education 9:65–76

Röling, N. (2009a) Pathways for impact: scientists' different perspectives on agricultural innovation. International Journal of Agricultural Sustainability 7:83-94

Röling, N. (2009b) Conceptual and methodological developments in innovation. In: Sanginga et al. (eds.), Innovation Africa: enriching farmers' livelihoods. Earthscan, London

Rosenbaum, P. and Rubin, D. (1983) The Central Role of the Propensity Score in Observational Studies for Causal Effects. Biometrika 70: 41-55

Rosenbaum, P.R. (2002) Observational Studies. 2nd ed. New York, NY: Springer

Runge-Metzger, A. and Diehl, L. (1993) Farm household systems in northern Ghana. A case study in farming systems oriented research for the development of improved crop production systems. Nyankpala Agricultural Research Report No.9

Ruthenberg, H. (1971) Farming Systems in the Tropics. Clarendon Press, Oxford

Saad, N. (2002) Farmer processes of experimentation and innovation. A review of the literature. CGIAR system wide program on participatory research and gender analysis: Working Doc. No 21

Sadoulet E. and de Janvry A. (1995) Quantitative development policy analysis. John Hopkins University Press, Baltimore, USA

Sanginga, P., Waters Bayer, A., Kaaria, S., Njuki, J. and Wettasinha, C. (eds.), (2009) Innovation Africa: enriching farmers' livelihoods. London: Earthscan

Sawadogo, H. Hien, F., Sohoro, A. and Kambou, F. (2001) Pits for trees: how farmers in semi-arid Burkina Faso increase and diversify plant biomass. In: Reij, C. and Waters-Bayer, A. (eds.), Farmer innovation in Africa: a source of inspiration for agricultural development. London: Earthscan, 35-46

Scoones, I. and Thompson, J. (eds.), (1994) Beyond farmer first. Rural people's knowledge, agricultural research and extension practice. Intermediate Technology Publications, London

Scoones, I. and Thompson, J. (eds.), (2009) Farmer First Revisited. Innovation for Agricultural Research and Development. Practical Action Publishing, Warwickshire, UK

Singh I., Squire L. and Strauss J. (eds.) (1986) Agricultural household models: Extensions, applications and policy. The John Hopkins University Press, Baltimore, USA

Spielman, D.J. (2005) Innovation Systems Perspectives on Developing-Agriculture: A critical appraisal. ISNAR Discussion Paper 2, International Food Policy Research Institute (IFPRI), Washington, DC

Spielman, D.J. and Birner, R. (2008) How Innovative is Your Agriculture? Using Innovation Indicators and Benchmarks to Strengthen National Agricultural Innovation Systems. Agriculture and Rural Development Discussion Paper No. 41. World Bank, Washington, DC

StataCorp (2013) Stata treatment effects reference manual. Stata: Release 13. Statistical Software. College Station, TX: StataCorp LP

Sumberg, J. and Okali, C. (1997) Farmers' Experiments: Creating Local Knowledge. Lynne Rienner Publishers Inc., London, UK

Sunding, D.L. and Zilberman, D. (2001) The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector. In: Gardner, B., Rausser, G. (eds.) Handbook of Agricultural and Resource Economics. Volume 1. Chapter 4, pp. 207–261

Swindale, A. and Bilinsky, P. (2006) Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (v.2). Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, DC

Tagoe, R.F. (2006) Identifying and cataloguing farmer innovations. Field Notes, LEISA Magazine 22.3

Tambo, J.A. and Abdoulaye, T. (2012) Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. Mitigation and Adaptation Strategies for Global Change 17:277-292

The Worldwatch Institute (2011) State of the World 2011: Innovations that Nourish the Planet. The Worldwatch Institute, Washington DC

Thirtle C.G., Schimmelpfennig D.E. and Townsend R.E. (2002) Induced innovation in United States Agriculture, 1880–1990: Time Series Tests and an Error Correction Model. American Journal of Agricultural Economics 84:598–614

Thirtle, C.G., Townsend, R.E. and van Zyl, J. (1998) Testing the Induced Innovation Hypothesis: An Error Correction Model of South African Agriculture. Agricultural Economics 19:145– 157

Thornton, P.K., Jones, P.G., Eriksen, P.J. and Challinor, A.J. (2011) Agriculture and food systems in sub-Saharan Africa in a 4°C+ world. Philosophical Transactions of the Royal Society 369:117–136

Tripp, R., Wijeratne, M. and Piyadasa, V.H. (2005) What should we expect from farmer field schools? A Sri Lanka case study. World Development 33:1705-1720

UNDP (2006) Human development report 2006: Beyond scarcity: Power, poverty and the global water crisis. UNDP, New York

von Braun, J. (2007) The World Food Situation: New Driving Forces and Required Actions. Food Policy Report. International Food Policy Research Institute. Washington, DC

Waters-Bayer, A. and Bayer, W. (2009) Enhancing local innovation to improve water productivity in crop–livestock systems. The Rangeland Journal 31:231–235

Waters-Bayer, A., van Veldhuizen, L., Wongtschowski, M. and Wettasinha, C. (2009) Recognizing and enhancing processes of local innovation. In: Sanginga et al. (eds.), Innovation Africa: enriching farmers' livelihoods. London: Earthscan

Weersink, A., Nicholson, C. and Weerhewa, J. (1998) Multiple job holdings among dairy families in New York and Ontario. Agricultural Economics 18: 127-143

Wettasinha, C., Wongtschowski, M. and Waters-Bayer, A. (eds.), (2008) Recognising local innovation: experience of PROLINNOVA partners. Silang, Cavite, the Philippines: International Institute of rural Reconstruction / Leusden: PROLINNOVA International Secretariat, ETC EcoCulture

Wheeler, T. and von Braun, J. (2013) Climate Change Impacts on Global Food Security. Science 341: 508-513

World Bank (2006) Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems. World Bank, Washington, DC

World Bank (2007) World Development Report 2008: Agriculture for Development. World Bank, Washington, DC

World Bank (2009) World Development Report 2010: Development and Climate Change. World Bank, Washington, DC

World Bank (2011) Agricultural Innovation Systems: An Investment Source Book. World Bank, Washington, DC

www.find-your-feet.org. Accessed on 14th April 2014

www.nif.org.in. Accessed on 14th April 2014

www.prolinnova.net. Accessed on 10th March 2014

www.sristi.org. Accessed on 14th April 2014

www.sristi.org/hbnew. Accessed on 14th April 2014

Appendix A

Zentrum für Entwicklungsforschung
Center for Development Research
University of Bonn

Determinants and implications of farmer innovations/innovativeness in Northern Ghana

Household Survey Questionnaire

Department of Economic and Technological Change
Center for Development Research (ZEF), University of Bonn, Germany

The purpose of this survey is to improve our understanding of the role of farmer innovation in food security and climate change resilience in Northern Ghana. The data collected as part of this survey are for research purposes ONLY. We assure of full confidentiality.

Questionnaire No ______________ Date of interview __________________ Start time _______________

Name of enumerator _______________ Name of respondent _________________________ End time _______________

Household identification

District	*1) Bolgatanga* *2) Bongo* *3) KNM* *4) KNW*
Name of community/village	
Name of enumeration area	
I.D of household or telephone number of the household head	
Number of households in the compound	
Is the household head also the head of the whole compound?	*1=Yes* *0= No*
GPS readings (N)………………… (W)……………………. Altitude (m.a.s.l.)……………………	

SECTION 1: HOUSEHOLD INFORMATION

1. Household data- Note: Household refers to a group of people living together, sharing common cooking arrangements and pooling their incomes.

	Members of your Household *(first names)*	**Relation-ship to HH head** *(use codes below)*	**Gender** 1=Male 2=Female	**Age**	**Marital Status** 1= Married 2= Single 3= Divorced/ Separated 4= Widowed	**Education**		**Occupation**		**Migration** *(for those 7 years old more or)*	
						Highest level of formal education completed *(use codes below)*	**No. of years of formal education** *(Do not count Kindergarten)*	**Principal Occupation** *(use codes below)*	**Participate in farm work** *1=Yes 0=No*	Has this person ever lived outside this community for a year or more? *1=Yes 0=No*	In the past 12 months, how many months in total has this person been absent from the household?
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											

Relationship to HH head

1 = Self (Head)
2 =Wife or Husband
3= Son/Daughter
4= Father/Mother
5 =Sister/Brother
6 =Grandchildren
7= Grandparents
8=Mother inlaw/ father inlaw
9= Daughter inlaw/son inlaw
10= Adopted Child
11 =Not Related

Education

1=Never been to school
2=Primary
3=Middle/Junior High
4= Senior High/ Vocational
5= Tertiary e.g. Polytechnic, University Training College
6= Other e.g. Adult education, Koranic education

Occupation

1=Farmer
2= Civil servant (government)
3= Non agriculture wage labor
4=Agricultural wage labor
5= Self-employment outside farm
6=Student
7= Unemployed /idle
8= Too young for school (6 yrs & below)
9= Other (specify)____________

2. How many people were in this household 5 years ago?

3. Years of residency of household head in the community………………years

4. Number of years of farming of the head of household…………………years

5. Religion of the head of household *1) Christian 2) Moslem 3) Traditional 4) No religion 5) Other (specify)……………………*

6. Ethnicity of the head of household *1) Frafra 2) Kassena 3) Nankam 4)Bulis 5) Other (specify)………………………………….*

7. Who in the household decides on following? (a) Farm production activities (e.g. what to plant and output)…………….. (use codes below)

(b) How income earned should be used……………. (use codes below)

Codes: *(1) Husband alone makes decisions* *(2) Husband is major decision maker after consulting with wife* *(3) Wife is major decision maker after consulting with husband* *(4) Wife alone makes decisions* *(5) Other (specify)*

8. Have you had a major health incident in household in the last 12 months? *1) Yes 0) No*

9. How many days of agricultural labour did you lose due to the illness? *[due to illness or taking care of the ill]……………….*

10. Is there anybody in the household who is chronically ill (get sick very often)? *1) Yes 0) No*

11. Any death in the household **in the past 5 years** …. *1) Yes 0) No*

12. How many people in the household have lost their jobs in the last 12 months? ....

13. How do you compare the income situation of the household with 1 year ago? *1) Better off 2) Same 3) Worse off*

14. How likely is your household's capacity to keep up in the future? *1) Not likely 2) Somewhat Likely 3) Likely 4) Very Likely*

15. How do you compare your household **access to market opportunities** now and with 5 years ago? *1) Increased 2) Same 3) Decreased*

16. The nature of the household's residence

1	Main construction materials of walls	*1)Mud bricks/Mud 2)Burnt brick 3)Wood 4)Straw 5)Concrete 6)Metal sheet 7)Stone 8)Other(specify)*	
2	Floor	*1)Earth/Mud 2)Concrete 3)Stone 4)Wood 5)Bricks/stones 6)Tiles 7)Other(specify)*	
3	Roof	*1)Earth/Mud 2) Aluminium sheets 3) Wood 4) Straw/ thatch 5)Tiles 6)Concrete 7)Other (specify)*	
4	Ownership type?	*1) Own 2)Rent 3) Borrowed 5)Other (specify)*	
5	Source of lighting	*1) Electricity 2) Generator 3)Kerosene lamp 4) Candle 5)Torch 6)Other(specify)*	
6	Main source of water	*1) River/lake 2) Well 3)Borehole 4) Piped/tap water 5)Spring 6)Other(specify)*	

17. Access to infrastructure services

Distance to the nearest		**Km**
1	All-weather road	
2	Tarmac road	
3	Farm input market/shop	
4	Market in case you want to sell your farm products	
5	District capital	
6	Health facility	
7	Main source of water	

18. Is your main water source available throughout the year? *1) Yes 0) No*

19. If you have access to health facility, how would you rate the quality of service provided? *1= Poor 2= Acceptable 3= Good*

SECTION 2: LIVESTOCK OWNERSHIP, INCOME AND EXPENSES

For the last 12 months, please give the total numbers of livestock or animal products sold and the revenue, and the total cost of production.

Type of Livestock	Quantity in stock now (currently)	Quantity bought in the last 12 months	Quantity sold in the last 12 month	Units (if applicable)	Total Value: Amount received for sale (GH¢)	Total cost of production				
						Fodder/ Feed bought (GH¢)	Veterinary/ Medications (GH¢)	Hired Labour (GH¢)	Housing repairs/ maintenance (GH¢)	Other expenses (GH¢)
1. Cattle										
2. Goats										
3. Sheep										
4. Chickens										
5. Pigs										
6. Rabbits										
7. Donkeys										
8. Ducks										
9. Guinea fowls										
10. Fish										
11. Bees/honey										
12. Eggs										
13. Milk										
14. Cow dung										
15.Other (specify)										

SECTION 3: LAND RESOURCES

1. How many parcels of land do your household own? ………….

2. How much land (total acres) does your household own (add all parcels)………………….acres

3. Please tell me the about the land resources you owned and cultivated last year and their characteristics in the table below

Parcel	Total area of the parcel *(acres)*	Distance of parcel from homestead *(km)*	What ownership rights do you have for this parcel? *1) Lease 2) Inheritance* *3) Allocated by Tindaana* *4) Purchased 5) Rented* *5)Borrowed* *6)Sharecropping* *7)Other (specify)*	Will you be able to use this parcel during your lifetime? i.e. do you have full user rights? *1) Yes* *0) No*	What is the slope of the parcel? *1) Flat* *2) Moderate* *3) Steep*	How fertile is the parcel? 1) *Low fertility* 2) *Moderate fertility* 3) *High fertility*	Degree of soil erosion on the parcel? *1) No* *2) Moderate* *3) Severe*	Do you use irrigation on the parcel? *1) Yes* *0) No*
1								
2								
3								
4								
5								
6								
7								
8								
9								

Crop Codes
1= Maize 2= Millet 3= Sorghum 4= Paddy Rice 5= Cowpea 6= Groundnut 7= Sweet potato 8 = Frafra potato 9= Tomato
10= Onion 11= Okro 12= Cabbage 13= Carrot 14= Pepper 15= Watermelon 16= Local vegetable 17= Other __________________

SECTION 4: CROPS−PRODUCTION, INCOME AND EXPENSES

PART A: EXPENSES: Please tell me all the expenses you incurred on the crops you cultivated in the previous dry and rainy season

Input / **Parcel no.**	Crops Grown *Use codes below*	Crop variety *1= improved* *2= local*	Seeds/ Planting material		Fertilizer		Manure		Pesticide/ Herbicide/		Cost of irrigation (GH¢)	Cost of Ploughing (GH¢)
			Amount applied (unit)	Total cost (GH¢)	Amount applied (unit)	Total cost (GH¢)	Amount applied (unit)	Total cost (GH¢)	Amount applied (unit)	Total cost (GH¢)		
Dry season												
	a)											
	b)											
	c)											
	a)											
	b)											
	c)											
	a)											
	b)											
	c)											
Rainy season												
	a)											
	b)											
	c)											
	a)											
	b)											
	c)											
	a)											
	b)											
	c)											
	a)											
	b)											
	c)											

PART B: PRODUCTION AND INCOME: Please tell me all the output and sales of the crops you cultivated in the previous dry and rainy season

Output / Parcel no. [From previous table]	Crops *(Fill this column using the previous table)*	Area planted (acres)	Quantity harvested	Unit 1 = Bag/Sack 2 = Crate 3 = Bowl 4 = Basin 5 = Basket 6 = Bundles 7 = Pieces 8 = Other: ______	Quantity given out (gift or repayment of loan)	Quantity sold	Average price per unit (GH¢)	Total value from sale (GH¢)
Dry season								
	a)							
	b)							
	c)							
	a)							
	b)							
	c)							
	a)							
	b)							
	c)							
Rainy season								
	a)							
	b)							
	c)							
	a)							
	b)							
	c)							
	a)							
	b)							
	c)							
	a)							
	b)							
	c)							

PART C: LABOUR: Please tell me about all the labour you used in the previous dry and rainy season. Account for ALL activities on the farm

Labour / **Parcel no.** [From previous table]	**Family labour**			**Hired labour**					**Exchange labour**		
	No. of persons involved		Total no. of days worked	No. of persons involved		Total no. of days worked		Total cost for hired labour (GH¢)	No. of persons involved		Total no. of days worked
	Male	Female		Male	Female	Male	Female		Male	Female	
Dry season											
Rainy season											

(C2) What is the typical number of working hours per day by household members? ....hours

SECTION 5: OTHER INCOME SOURCES AND ASSETS

1. What was your household's income from the following sources during the last 12 months? *(include income of all household members).*
*[**Enumerator:** For some of the income sources (e.g. handicrafts and processing), ask of the costs incurred in securing the income and deduct it from the total value]*

Income source	**Total value (GH¢) in the past 12 months**
Wages and salaries for **non-agricultural** employment/business (e.g. civil service, masonry, carpentry etc)	
Wages for labour on other farms	
Income from machinery services for other farms (ploughing etc.)	
Revenues from leasing out land	
Pensions	
Gift	
Remittances from family members/friends who do not live in the household	
Sale of handicrafts (weaving, pottery etc)	
Sale of fodder/grass/fuel wood	
Sale of animal manure	
Sale of wild nuts/fruits (e.g. Shea, Dawadawa)	
Petty trade (net profit)	
Processing (e.g producing shea butter, pito brewing, making oil, parboiling rice, etc)	
Hunting	
Mining	
Fishing	
Other (specify) --	

2. What usable/repairable agricultural equipment and household assets do you have and what are their current market values?

Item	How many do you have in the HH at the moment?	In what year did you purchase this item? *(if more than 1, ask for the most recent purchase)* *[Indicate month, if bought in 2012]*	How much do you think you will earn (in GH¢) if you sell this item today? *(if more than 1, ask for the value of each and add them)*	Item	How many do you have in the HH at the moment?	In what year did you purchase this item? *(if more than 1, ask for the most recent purchase)* *[Indicate month, if bought in 2012]*	How much do you think you will earn (in GH¢) if you sell this item today? *(if more than 1, ask for the value of each and add them)*
Tractor				Motor-tricycle (motor king)			
Tractor drawn equipment				Motorcycle			
Water pump				Bicycle			
Sprinkler				Television			
Watering can				Radio			
Hoe				Car/Truck			
Machete, sickle, mower				Mobile phone			
Ox/donkey cart				Refrigerator			
Ox / donkey plough				Fan			
Knapsack sprayer				Iron			
Barn/Store for farm produce				Livestock Kraal			
Wheelbarrows				Other			
Irrigation pipe				Other			

SECTION 6: HOUSEHOLD INNOVATIVENESS

PART A: INNOVATION

1. (a) In the past 12 months (previous dry and rainy season), did you **develop or discover** anything that is **entirely new to your community**, on your own or jointly with other farmers **without direct external assistance**, within the following areas?

Activity	*1=Yes 0=No*	**Activity**	*1=Yes 0=No*
Land preparation		New methods of harvesting	
Method/time of planting		Processing	
Cropping pattern (e.g intercropping, crop rotation)		Storage	
Soil fertility (e.g. manure, composting, mulching)		Transportation	
New varieties and crops		New forms of marketing	
New methods of weed control		Financing/Insurance	
Tree/Forest management		New ways of organising	
Soil and water conservation		Irrigation	
Farm tool/equipment		New farm product	
Animal husbandry (new breed, feedstuff, house, medicine)		Other (specify)	

(b) Brief description of the innovation(s)………..

(c) What was the main reason/motivation for starting this innovation? .... (use codes on page 15)

(d) Where did the idea for the innovation come from? ……………………………………(use codes on page 15)

(e) What benefit/result have you obtained from this innovation? .... (use codes on page 15)

2. (a) In past 12 months (previous dry and rainy season), did you **modify, adapt** or **make any changes** in techniques, practices or technologies introduced by external agents such as extensionists, NGO, development agents etc, within the following areas?

Activity	*1=Yes 0=No*	**Activity**	*1=Yes 0=No*
Land preparation		New methods of harvesting	
Method/time of planting		Processing	
Cropping pattern (e.g intercropping, crop rotation)		Storage	
Soil fertility (e.g. manure, composting, mulching)		Transportation	
New varieties and crops		New forms of marketing	
New methods of weed control		Financing/Insurance	
Tree/Forest management		New ways of organising	
Soil and water conservation		Irrigation	
Farm tool/equipment		New farm product	
Animal husbandry (new breed, feedstuff, house, medicine)		Other (specify)	

(b) Brief description of the innovation(s)………..

(c) What was the main reason/motivation for starting this innovation? .... (use codes on page 15)

(d) Where did the idea for the innovation come from? ……………………………………(use codes on page 15)

(e) What benefit/result have you obtained from this innovation? .... (use codes on page 15)

3. (a) In past 12 months (previous dry and rainy season), did you **modify or make any changes** to traditional or common practices in the community, within the following areas?

Activity	*1=Yes* *0=No*	**Activity**	*1=Yes* *0=No*
Land preparation		New methods of harvesting	
Method/time of planting		Processing	
Cropping pattern (e.g intercropping, crop rotation)		Storage	
Soil fertility (e.g. manure, composting, mulching)		Transportation	
New varieties and crops		New forms of marketing	
New methods of weed control		Financing/Insurance	
Tree/Forest management		New ways of organising	
Soil and water conservation		Irrigation	
Farm tool/equipment		New farm product	
Animal husbandry (new breed, feedstuff, house, medicine)		Other (specify)	

(b) Brief description of the innovation(s)………..

(c) What was the main reason/motivation for starting this innovation? .... (use codes on page 15)

(d) Where did the idea for the innovation come from? ……………………………………(use codes on page 15)

(e) What benefit/result have you obtained from this innovation? .... (use codes on page 15)

4. (a) In the past 12 months (previous dry and rainy season), did you **experiment or test or conduct trials** of a new idea you thought of or saw somewhere to see if it will work on you own farm, within the following areas?

Activity	*1=Yes 0=No*	**Activity**	*1=Yes 0=No*
Land preparation		New methods of harvesting	
Method/time of planting		Processing	
Cropping pattern (e.g intercropping, crop rotation)		Storage	
Soil fertility (e.g. manure, composting, mulching)		Transportation	
New varieties and crops		New forms of marketing	
New methods of weed control		Financing/Insurance	
Tree/Forest management		New ways of organising	
Soil and water conservation		Irrigation	
Farm tool/equipment		New farm product	
Animal husbandry (new breed, feedstuff, house, medicine)		Other (specify)	

(b) Brief description of the experiment(s)………..

(c) What was the main reason/motivation for starting this experiment? .... (use codes on page 15)

(d) Where did the idea for the experiment come from? ……………………………………(use codes on page 15)

(e) What benefit/result have you obtained from this innovation? .... (use codes on page 15)

5. (a) In the past 12 months (previous dry and rainy season), have you participated in **joint experimentation or participatory innovation development** with external innovation actors (researchers, extension staff, university staff, NGO staff, etc)? *1=Yes* *0=No*

(b) If yes, briefly describe the joint experiment or innovation………………………

6. (a) Apart from things you tried in the past 12 months that have been listed above; did you try or discover any new thing **in the past 10 years**?
1=Yes 0=No

(b) If yes, which year? ………………………

(c) If yes, briefly describe the innovation………………………

7. Do you know of any **member of your compound** who has been trying new things in the past 5 years? *1=Yes 0=No*

8. Do you know of **any farmer in this community** who is creative and often tries new things? *1=Yes 0=No*

9. Has anyone in this community ever had problems because of trying out new things that are not known in the community? *1=Yes 0=No*

10. Do you think you might encounter some problem in this community if you try new things that are not known? *1=Yes 0=No*

PART B: ADOPTION

1. (a) In the past 12 months (previous dry and rainy season), did you adopt a new practice or technology in your farming activities which have previously been used by other farmers in the community, **without** any modifications? *1) Yes 0) No*

If yes,
(b) Brief description of the innovation(s)………..

(c) What was the main reason/motivation for adopting this innovation? .... (use codes on page 15)

(d) Where did the idea for the innovation come from? ……………………………………(use codes on page 15)

(e) What benefit/result have you obtained from adopting this innovation? .... (use codes on page 15)

2. (a) In the past 12 months (previous dry and rainy season), did you **adopt** any new technique, tool or farming practice that was recommended to you by extensionists, NGO, development agents, **without** any modifications? *1) Yes* *0) No*

If yes,

(b) Brief description of the innovation(s)………..

(c) What was the main reason/motivation for adopting this innovation? .... (use codes below)

(d) Where did the idea for the innovation come from? ……………………………………(use codes below)

(e) What benefit/result have you obtained from adopting this innovation? .... (use codes on page 15)

CODES

Reason/motivation for the innovation

1) Curiosity *2) Coincidence* *3) Reduce use of inputs* *4) Saving labour* *5) Reduce expenses*
6) Increasing production *7) Increasing income* *8) Food security* *9) Improving quality*
10) Environmental reasons *11) Increasing safety* *12) Market demands* *13) Other (specify)*

Source of idea

1) Own idea *2) Friends and Relatives* *3) Farmer-Based Organisation* *4) Extension (MoFA)* *5) Scientist* *6) Other innovators* *7) NGO*
8) Other (specify)

Benefit/outcome of the innovation

1) Obtained more knowledge *2) Increased satisfaction* *3) Gained reputation* *4) Saved or reduced labour*
5) Increased production *6) Increased income* *7) Improved food security* *8) Other (specify)*

SECTION 7: SOCIAL PROTECTION, CREDIT, SOCIAL NETWORKS AND AGRICULTURAL INFORMATION

PART A: SOCIAL PROTECTION PROGRAMS

1. How many months in the last 12 months did you have problems satisfying your household food needs................

2. Have you or any member of your household participated in the Farmer Field Fora (FFF) of RTIMP? *1) Yes 0) No*

3. Document any social protection assistance your household has received in the past 12 months in the table below.

Social Protection Program	Are you aware of the availability of this program in your district? *1= Yes 0=No*	If aware, did your household participate in this program in the past 12 months? *1= Yes 0=No*
1. Block Farming Programme?		
2. Northern Rural Growth Programme		
3. Other Agric project (e.g. RSSP, GSOP, WAAPP,)		
4. School feeding program		
5. Free food distribution		
6. Food for work		
7. Input (Fertilizer) Subsidies for Farmers		
8. School Funding (e.g. uniforms, books, fees)		
9. Conditional Cash Transfers		
10. Unconditional Cash Transfers (e.g. LEAP)		
11. Microfinance (Credit or Savings Programs)		
12. National Health Insurance Program		
13. Distribution of Bed Nets		
14. Immunization Programs		
15. Nutritional Supplements		
16: Other (specify)		

PART B: CREDIT ACCESS

1. How easy is it for your household to obtain credit? *1) Very easy* *2) Easy* *3) Difficult* *4) Very difficult*

2. Does anyone in this household receive credit (cash or input) from any source? *1= Yes* *0= No,* *if Yes, go to question 4*

3. If no, why? *1) No need* *2) Lack of guarantee* *3) Too risky* *4) Too expensive* *5) Not available* *6) No loan information*

4. How many credit applications did your household make in the last 12 months? ___________________

5. Document credit applications for the last 12 months and for what purpose they were used.

Credit applications	**Did you succeed?** *1= Yes 0 =No*	**If yes, what did you use it for?**	**If yes, what was the source of the credit?** (use codes below)	**Form** *(cash, good, input etc)*	**Total Amount** [estimate of credit amount given (GH¢)]	**If no credit was received, why not?** (use codes below)
1						
2						
3						
4						
5						
6						
		Uses of credit 1 Pay agricultural inputs 2 Pay education expenses 3 Pay health expenses 4 Other (specify)	**Credit Source** 1 Input Salesmen 2 Buyer of Harvest 3 Bank 4 Farmer association 5 Microfinance 6 NGO 7 Family/friend 8 Savings group 9 Money lender 10 Other (specify)	**Reasons for Denial** 1 Lack of collateral or guarantee 2 Did not have necessary documents 3 Prior debt 4 Lack of ability to repay 5 Other (specify)		

6a. Did you provide any credit (in-cash or kind) to relatives or friends in the past 12 months? *1= Yes* *0= No*

6b. If yes, what is the value of the credit you gave in GH¢…………………..

7. Does this household have any savings either at home or in a bank or with a savings group, etc.? *1= Yes* *0= No*

PART C: SOCIAL NETWORK

1. Is anyone in this household a member of any group or association? (e.g. farmer association, village council, faith-based association, etc)? *1) Yes* *0) No*

2. If yes, please fill in the table below with information about the group.

Type of group *(see codes below)*	Name of group/association	How long have you been a member? (*years*)	How many times did you participate in activities or meetings of this group in the past 12 months?	Have you received any service from this group? *1) Yes* *0) No*	If yes, what services have your household received from group? *(see codes below)*
Group: 1= Farmer Association 2= Women's Group/Youth Group 3= Village Council 4= Community Welfare Group 5= Faith-based Association 6= Other (specify)					Services: 1=Credit 2= Inputs 3= Training 4= Marketing 5=Welfare/Social Support 6= Other (specify)

3. In the past 2 years, did you or any member of your household participate in any farm demonstration/field days? *1) Yes* *0) No*

4. In the past 2 years, did you participate in informal meeting (wedding, social festivals)? *1) Yes* *0) No*

5. (a) Have you, or any member of the household, participated in training or capacity-building courses or workshops **in the past 5 years**? *1) Yes* *0) No*

(b) If yes, which course/workshop and organized by whom?

PART D: AGRICULTURAL INFORMATION

1. How easy is it for you to get good information about new agricultural technologies/practices? *1) Very easy* *2) Easy* *3) Difficult* *4) Very difficult*

2. Do you receive information/advice from extension officers? *1) Yes* *0) No*

3. If yes, in the past 12 months, how many contacts has your household had with an extension officer? ....

4. What kind of service or information did you obtain from your contacts with the extension officer?
1) Use of fertilizer *2) Irrigation* *3) New crop varieties* *4) Pest Infestation* *5) Crop disease* *6) Soil problems* *7) Weather problems*
8) General crop advice *9) Vaccination services* *10) Animal diseases* *11) Animal feed/nutrition* *12) Insemination services*
13) Marketing advice *14) Accessing credit* *15) Other (specify)*

5. Apart from extension services, do you use the following sources for information on agricultural production such as production techniques, new seeds, input use, market price, etc?

Source	*1)Yes 0) No*
Radio	
Television	
Neighbours/Friends/Relatives	
Farmer group	
Input dealer/Traders	
Research Scientists	
NGO (e.g. NABOCADO, ACDEP, CARE)	
Other (specify)	

6. Are you or any member of your household aware that you can apply for money from the Local Innovation Support Fund (LISF) of NABOCADO/ACDEP, if you want to experiment an innovation or further develop your innovation? *1) Yes* *0) No*

7. Are you aware of innovation support activities of NABOCADO/ACDEP? *1) Yes* *0) No*

8. (a) Did you hear of the 2012 Farmer Innovation Contest? *1) Yes* *0) No*

(b) If yes, from which source? *1) Radio* *2) Extension officer* *3) Other farmers* *4) Other (specify)*

SECTION 8: SHOCKS AND CLIMATE CHANGE

1. In the past 5 years, have the household's production and properties been affected by the following stresses or shocks?

Stress/Shock	*1=Yes 0=No*
Insect/Pest infestation	
Plant disease	
Drought	
Flood	
Fire	
Temperature variability	
Strong wind	

2. In the past 5 years, did your household suffer a reduction in asset holdings, household income, or consumption due to **high food prices?** *1=Yes 0=No*

3. Do you receive information on weather forecast or early warning to enable your household to respond to extreme climatic conditions in a timely fashion?
1=Yes 0=No

4. Are you aware or have you heard of climate change? *1=Yes 0=No*

5. Have you noticed any changes in climate (temperature and rainfall) over the last 20 years? *1=Yes 0=No*

6. Have you made any changes to your farming practices due to any long-term shifts you have noticed in temperature and rainfall changes and variability?
1=Yes 0=No

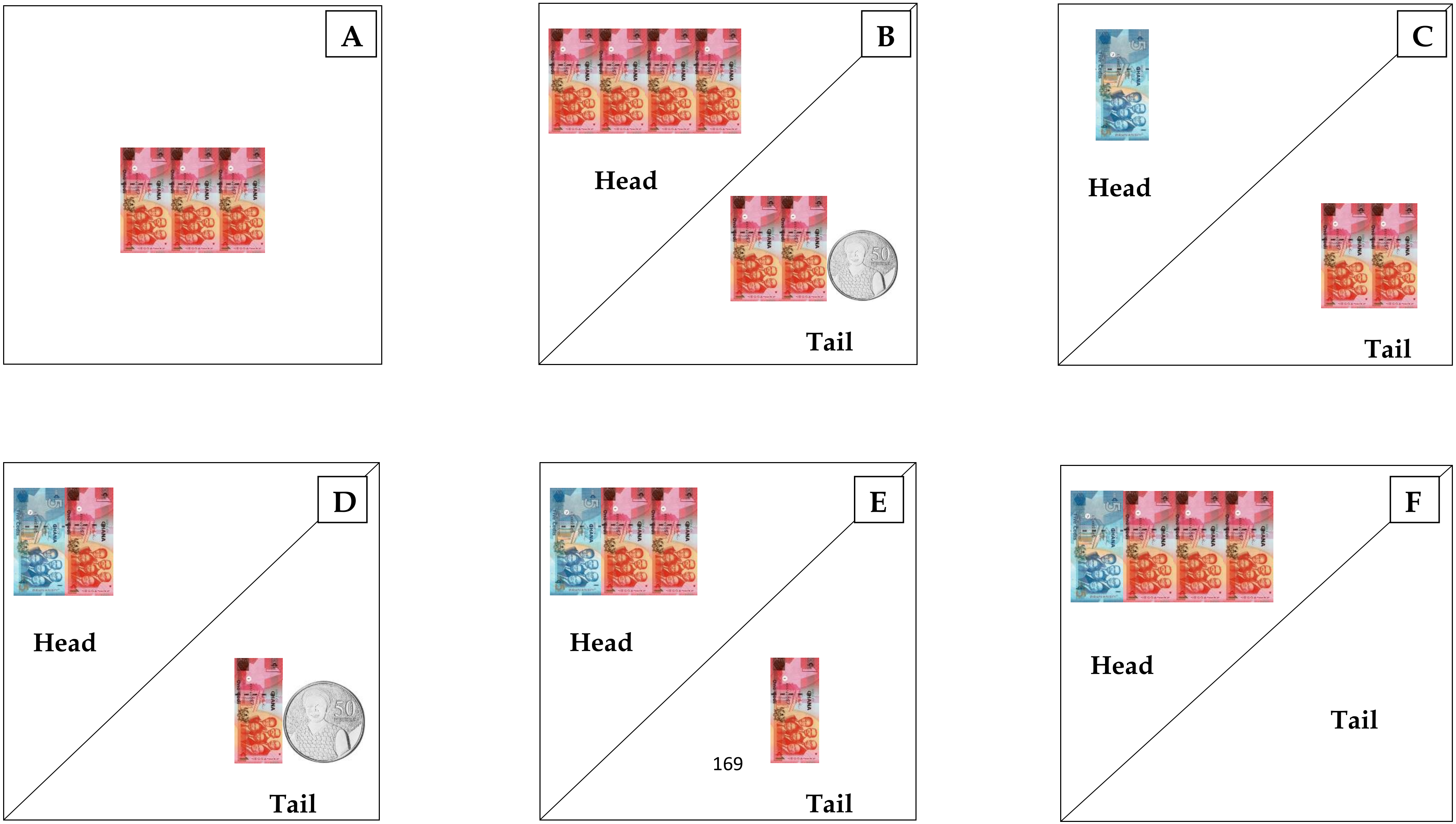
7. If yes, what adjustments have you made to these long term changes and variability?

Strategy	*1=Yes 0=No*	**Strategy**	*1=Yes 0=No*
Change planting dates		Change field location	
Use drought tolerant and early maturing varieties		Plant trees for shading	
Change crop type		Seek off farm employment	
Change crop variety		Change from crop to livestock production	
Mixed cropping(different crops)		Change from livestock to crop production	
Mix crop and livestock		Buy insurance	
Build a water harvesting scheme		Build a diversion ditch to cope with floods	
Use more irrigation		Other (specify)	
Soil and water conservation		Other (specify)	

SECTION 9: ORDERED LOTTERY SELECTION DESIGN

Now, I am going to present you with a choice of six lotteries, A to F. Option A offers you actual payment of 3 GH¢. If you decide to choose any of the options B to F, I will toss a coin and the amount you will earn depends on whether head or tail appears from tossing the coin. For instance, in B you can win 4 GH¢ if head appears and 2.5 GH¢ if tail appears. I will kindly ask you to pick the one which you prefer most.

Note: You cannot change the option you have chosen after I have tossed the coin.



Appendix B

Zentrum für Entwicklungsforschung
Center for Development Research
University of Bonn

WASCAL
West African Science Service Center on Climate Change and Adapted Land Use

Determinants and implications of farmer innovations/innovativeness in Northern Ghana

Household Survey Questionnaire-Phase 2

Center for Development Research (ZEF), University of Bonn, Germany

Name: Household Head: House no:

Previous respondent: Date: Mobile no:

Are you a regulator cultivator of sweet potato? *1) Yes* *0) No*

Prior to RTIMP-FFF, were you cultivating sweet potato? *1) Yes* *0) No*

SECTION 1: HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS) MEASUREMENT TOOL

No.	Question	Response options	
1	a) In the past month, did you worry that your household would not have enough food?	1=Yes 0=No	
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	
2	a) In the past month, were you or any household member not able to eat the kinds of food you preferred because of lack of resources?	1=Yes 0=No	
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	
3	a) In the past month, did you or any household member eat just a few kinds of food (a limited variety of foods) day after day due to lack of resources?	1=Yes 0=No	
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	

4	a) In the past month, did you or any household member eat food that you preferred not to eat because of a lack of resources to obtain other types of food?	1=Yes 0=No	|_|
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	|_|
5	a) In the past month, did you or any household member eat a smaller meal than you felt you needed because there was not enough food?	1=Yes 0=No	|_|
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	|_|
6	a) In the past month, did you or any household member eat fewer meals in a day because there was not enough food?	1=Yes 0=No	|_|
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	|_|
7	a) In the past month, was there ever no food at all in the household because there were not enough resources to get more?	1=Yes 0=No	|_|
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	|_|
8	a) In the past month, did you or any household member go sleep hungry because there was not enough food?	1=Yes 0=No	|_|
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	|_|
9	a) In the past month, did you or any household member go a whole day without eating anything because there was not enough food?	1=Yes 0=No	|_|
	b) If yes, how often did this happen?	1=Rarely (once or twice) 2=Sometimes (3 to 10 times) 3=Often (more than 10 times)	|_|

Did your household mortgage its standing field crops for current consumption in the past 12 months? *1) Yes 0) No*

How was the household's food consumption in the last month? *a) less than adequate* *b) just adequate* *c) more than adequate*

Are you worried that your household will lack food…..? *1) next week* *2) next month* *3) next 2 to 3 months* *4) in 4 months or later* *5) never*

SECTION 2: HOUSEHOLD DIETARY DIVERSITY SCORE (HDDS) MEASUREMENT TOOL

I would like to ask you about the foods and drinks you OR ANYONE ELSE IN THE HOUSEHOLD ate or drank yesterday during the day and at night IN THE HOME

[note for enumerator: **consider foods eaten by any member of the household , and exclude foods purchased and eaten outside of the home**]

No.	Food group	Examples	*1=Yes; 0=No*
1	CEREALS	bread, noodles, biscuits, cookies or any other foods made from millet, sorghum, maize, rice, wheat + *insert local foods e.g. banku, TZ, porridge or pastes or other locally available grains*	
2	VITAMIN A RICH VEGETABLES AND TUBERS	pumpkin, carrots, squash, or sweet potatoes that are orange inside + *other locally available vitamin-A rich vegetables(e.g. sweet pepper)*	
3	WHITE TUBERS AND ROOTS	white potatoes, white yams, cassava, or foods made from roots e.g. fufu	
4	DARK GREEN LEAFY VEGETABLES	dark green/leafy vegetables, including wild ones + *locally available vitamin-A rich leaves such as cassava leaves etc.*	
5	OTHER VEGETABLES	other vegetables (e.g. tomato, onion, eggplant) , including wild vegetables	
6	VITAMIN A RICH FRUITS	ripe mangoes, cantaloupe, dried apricots, dried peaches + *other locally available vitamin A-rich fruits*	
7	OTHER FRUITS	other fruits, including wild fruits	
8	ORGAN MEAT (IRONRICH)	liver, kidney, heart or other organ meats or blood-based foods	
9	FLESH MEATS	beef, pork, lamb, goat, rabbit, wild game, chicken, duck, or other birds	
10	EGGS		
11	FISH	fresh or dried fish or shellfish	
12	LEGUMES, NUTS AND SEEDS	beans, peas, lentils, groundnuts, seeds or foods made from these	
13	MILK AND MILK PRODUCTS	milk, cheese, yogurt or other milk products	
14	OILS AND FATS	oil, fats or butter added to food or used for cooking	
15	SWEETS	sugar, honey, sweetened soda or sugary foods such as chocolates, sweets or candies	
16	SPICES, CONDIMENTS, BEVERAGES	spices(black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages OR *local examples*	

Did you or anyone in your household eat anything (meal or snack) OUTSIDE of the home yesterday? *1=Yes 0=No*

SECTION 3: HOUSEHOLD CONSUMPTION EXPENDITURE

A. Food Consumption expenditure **(During the past 7 days)**

Food, Beverage and Tobacco	Value of consumption out of purchases (GH¢)	Value of consumption out of home produce (GH¢)	Value if received in-kind/free (GH¢)
Cereals			
Roots, Tubers, Plantain			
Legumes and Nuts			
Fruits			
Vegetables			
Meat, Fish and Egg			
Oils and Fats			
Dairy products			
Sweets, Spices, Condiments			
Alcoholic and non-alcoholic drinks			
Cigarettes and other tobaccos			
Food (actual)			

B. Housing, Energy, Transport and Communication Expenditure **(During the past 30 days)**

Housing, Energy, Water	Value of payment /purchase (GH¢)	Value if used own product (GH¢)	Value if received in-kind/free (GH¢)
Rent paid for rented house			
Imputed rent of owned house			
Imputed rent of borrowed house			
Repair and maintenance of house			
Electricity			
Firewood			
Charcoal			
Kerosene			
Batteries for torch, radio, etc.			
Water			
Transportation and Communication			
Tires, tubes, spares, repairs, etc.			
Petrol, diesel			
Taxi or bus fares			
Air time (units) for mobile phone			
Personal goods			
Soaps, matches, paste, cosmetics, etc.			

C. Education, Health, Clothing, etc. Expenditure **(During the past 12 months: May 2012 to April 2013)**

Education	Value of purchases/payment (GH¢)	Value if received in-kind/free (GH¢)
School fees including PTA		
Boarding and lodging		
Uniforms and shoes		
Books and stationary		
Other educational expenses		
Health		
Medicine		
Consultation fees and hospital charges		
Traditional Doctors fee/ medicine		
Clothing		
Men clothing and footwear		
Women clothing and footwear		
Children clothing and footwear		
Household appliances		
Kitchen utensils, basins and buckets		
Furniture items		
Bedding materials (e.g. bed sheet, mattress)		
Remittances and Donations		
Remittances, gift and other transfers		
Donations at funerals, wedding, church, etc.		

THANK YOU FOR YOUR TIME!

Appendix C

Application Form for Farmer Innovation Contest 2012

Name of extension officer:	
Telephone extension officer:	
Mofa district office which extension officer belongs to:	
Operational Area of extension officer:	
How did you get in touch with farmer?:	□ I knew farmer □ I was told about the farmer to have an innovation □ Farmer contacted me □ Field Survey
Date you met with farmer:	Day___, Month______, 2012

1. Name of applicant / group: ____________________________________

2. Application type (please tick as appropriate): □ Group □ Individual

3. Gender: □ Female □ Male

4. Contact (Phone No.): ____________________________

5. Contact Information (Location, address, House No. etc.)

6. Notes on applicant (any relevant information on applicant)

7. Age of applicant (average age of group members): _______________years

8. Total number of group members: _______________________

9. Number of male group members: ____________________

10. Number of female group members: __________________

11. Main Theme of Innovation
    - □ Animal husbandry
    - □ Crop Management
    - □ Tree/Forest Management
    - □ Processing
    - □ Storage
    - □ Marketing
    - □ Transport
    - □ Financing & Insurance
    - □ Soil fertility
    - □ Water and soil conservation

12. Type of innovation
    - □ Technical
    - □ Organizational
    - □ Social/institutional

13. Description of Innovation (please provide details of the innovation so that the selection committee members get a clear understanding of what the innovation does, how it is implemented, what the benefits are, etc.). Questions that should be addressed include:

    a) Please provide a name of the innovation

    b) Please provide a brief explanation of the innovation with a maximum of two sentences.

    c) What problem does the innovation address?

d) How is the innovation implemented? Please provide a detailed description with all steps involved (if space is not enough please attach additional sheets of paper or backside of this sheet)

e) What is the estimated direct benefit (effectiveness) of the innovation?

f) What were the obstacles in developing and using the innovation?

g) What was the cost of developing the innovation and what is the cost of applying the innovation (materials, labor, money)?

14. Why do you think what you describe is actually an innovation and not common or traditional practice. What makes the described activity different or new from other activities?

15. In what year did the applicant start to develop the innovation and since when is it functional?

Start to develop in year____________

Functional since_________________

16. Does the applicant believe his/her innovation can be further improved?

□ Yes, it could still be improved further

□ No, innovation is already optimized

17. Number of farmers known to have adopted the innovation?

____________number of farmers

18. How did you hear about the innovation contest?
    - □ Radio
    - □ Extension officer
    - □ Colleague
    - □ Other, please specify ___________________

19. How did you get in touch with the extension officer?
    - □ I called him directly
    - □ I called central phone number of innovation contest
    - □ I looked for him in operational area
    - □ I met him coincidentally
    - □ I went to MOFA district office to find him
    - □ (S)he contacted me
    - □ other, please specify ________________________________

20. What is your main motivation to participate in innovation contest
    - □ To win one of the prizes
    - □ To be known as the best farmer innovator 2012
    - □ To share my innovation with others
    - □ other, please specify

I hereby declare that what I have described as an innovation is something which I have developed myself (or my group has developed itself) and is not a practice which I (we) have copied from a neighbor or other farmers, or a practice which was recommended to me by the extension service, scientists or any other organization.

I hereby agree that the details of my innovation can be made public and can be shared with other farmers and stakeholders such as MOFA staff and scientists (e.g. on Farmer's Day, on the radio, in brochures and other media).

Location______________________ Date: ___________

Applicant's Signature: ___________________________