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Educating Farmers To Be Environmentally Sustainable: Knowledge, Skills And Farmer Productivity In Rural Bangladesh

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Educating Farmers To Be Environmentally Sustainable: Knowledge, Skills And Farmer Productivity In Rural Bangladesh

Abstract

Farmer field schools (FFSs) in South Asia are designed to promote improved productivity among smallholder farmers. However, there is a dearth of research investigating the impact of non-formal learning on both female and male farmers' productivity in these schools in the region. With a population of over 162 million and a coastline of 580 km, Bangladesh has an agro-based economy highly susceptible to climate change. For over two decades FFSs, first introduced by the Food and Agricultural Organizations of the United Nations and the United Nations Development Program in 1990, have educated Bangladeshi farmers on cost-effective environmentally sustainable practices to combat the adverse effects of climate change. This study evaluates the impact of non-formal education in the Integrated Agricultural Productivity Project (IAPP), a cluster-randomized controlled FFS trial in Rangpur district supported by the government of Bangladesh, FAO and the World Bank, designed to improve food security in northern Bangladesh. The goal of this study is to examine the impact of FFS education on farmers' livelihood outcomes and to better understand the workings of such an education system. By comparing 15 treatment and 6 control groups comprising 623 individuals in 21 villages (J=21, N=623), using mainly cross-sectional data, this study measures the impact of IAPP education on farmers' knowledge, use of environment-friendly technologies and productivity. Along with the major outcomes, the study assessed literacy, resource status and schooling background – indicators responsible for farmers' overall success – utilizing a culture-specific approach to measurement. Multilevel, multivariate analysis and structural equation modeling were employed to examine the relationship between non-formal education in IAPP schools and farmers' performance at both school and program levels. Results indicate that IAPP education significantly improved performance in all three areas: knowledge, environmentally sustainable technology skills and productivity. Overall, the findings suggest that access to literacy, agricultural resources and information are critical factors for determining farmer success in these schools. The study highlights the importance of learning for adult farmers, especially women, from resource-poor backgrounds for sustainable technology skills and productivity outcomes. This research has direct implications for similar development programs for adult female and male learners in low-literacy and low-resource contexts.

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EDUCATING FARMERS TO BE ENVIRONMENTALLY SUSTAINABLE:

KNOWLEDGE, SKILLS AND FARMER PRODUCTIVITY IN RURAL BANGLADESH

Fatima Tuz Zahra

A DISSERTATION

in

Education

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EDUCATING FARMERS TO BE ENVIRONMENTALLY SUSTAINABLE:

KNOWLEDGE, SKILLS AND FARMER PRODUCTIVITY IN RURAL BANGLADESH

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Fatima Tuz Zahra

For Nanabhai and Ammu

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Finally, I am grateful to the Almighty for giving me the chance to work with the farmers in Bangladesh and the people who care for them. This world cannot do without farmers. I certainly cannot do without them nor my mentors, family and friends. May Allah bless you all.

ABSTRACT

EDUCATING FARMERS TO BE ENVIRONMENTALLY SUSTAINABLE:

KNOWLEDGE, SKILLS AND FARMER PRODUCTIVITY IN RURAL BANGLADESH

Fatima Tuz Zahra

Daniel A. Wagner

Farmer field schools (FFSs) in South Asia are designed to promote improved productivity among smallholder farmers. However, there is a dearth of research investigating the impact of non-formal learning on both female and male farmers' productivity in these schools in the region. With a population of over 162 million and a coastline of 580 km, Bangladesh has an agro-based economy highly susceptible to climate change. For over two decades FFSs, first introduced by the Food and Agricultural Organizations of the United Nations and the United Nations Development Program in 1990, have educated Bangladeshi farmers on cost-effective environmentally sustainable practices to combat the adverse effects of climate change. This study evaluates the impact of non-formal education in the Integrated Agricultural Productivity Project (IAPP), a cluster-randomized controlled FFS trial in Rangpur district supported by the government of Bangladesh, FAO and the World Bank, designed to improve food security in northern Bangladesh. The goal of this study is to examine the impact of FFS education on farmers' livelihood outcomes and to better understand the workings of such an education system. By comparing 15 treatment and 6 control groups comprising 623 individuals in 21 villages (J=21, N=623), using mainly cross-sectional data, this study measures the impact of IAPP education on farmers' knowledge, use of environment-friendly technologies and productivity. Along with the major outcomes, the study assessed literacy, resource status and schooling background – indicators responsible for farmers' overall success – utilizing a culture-specific approach to measurement. Multilevel, multivariate analysis and structural equation modeling were employed to examine the relationship between non-formal education in IAPP schools and farmers' performance at both school and program levels. Results indicate that IAPP education significantly improved performance in all three areas: knowledge, environmentally sustainable technology skills and productivity. Overall, the findings suggest that access to literacy, agricultural resources and information are critical factors for determining farmer success in these schools. The study highlights the importance of learning for adult farmers, especially women, from resource-poor backgrounds for sustainable technology skills and productivity outcomes. This research has direct implications for similar development programs for adult female and male learners in low-literacy and low-resource contexts.

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ABBREVIATIONS AND ACRONYMS

AEO: Agricultural Extension Officer

AKS: Agricultural Knowledge Systems

ANDA: Academic Network for Development in Asia

AT: Agricultural Technologies

AWD: Alternative wet-dry method

BBS: Bangladesh Bureau of Statistics

CF: Community Facilitator

DIME: Development Impact Evaluation

ESAT: Environmentally Sustainable Agricultural Technologies

FAO: Food and Agricultural Organizations of the United Nations

FF: Field Facilitator

FFS: Farmer Field School

IFPRI: International Food Policy Research Institute

IPA: Innovations for Poverty Action

IPM: Integrated Pest Management

IAPP: Integrated Agricultural Productivity Project

KESAT: Knowledge of Environmentally Sustainable Agricultural Technologies

LGED: Local Government Engineering Department

MOWCA: Ministry of Women and Children Affairs

NFE: Non-formal Education

OLS: Ordinary Least Squares

SAAO: Sub-Assistant Agricultural Officer

SES: Socio-economic status

SDGs: Sustainable Development Goals

UESAT: Use of Environmentally Sustainable Agricultural Technologies

USAID: The United States Agency for International Development

DEFINITION OF TERMS

Agricultural Technologies (AT): Agricultural technologies refer to tools, resources and processes required for production e.g., seeds, fertilizer, pesticides, irrigation methods and pest-management techniques (FAO, 2014, Farmer, 1981).

Environmentally Sustainable Agricultural Technologies (ESAT): ESAT is a term coined for this study to indicate the agricultural tools, resources and methods that are environment-friendly. A test was designed to test the adoption of a set of seven specific environmentally sustainable technologies by farmers in this study. In short, the technologies for which farmers were evaluated will be referred to as ESAT and the tool used to measure the use of ESAT is called the UESAT (Use of environmentally sustainable agricultural technology) test.

Integrated Pest Management (IPM): The World Bank's Operational Policy 4.09 defines integrated pest management as "a mix of farmer-driven, Global Integrated Pest Management ecologically based pest control practices that Facility seeks to reduce reliance on synthetic chemical pesticides." The practice involves (a) managing pests (b) relying on non-chemical pesticides to avoid negative impact on pest population and (c) applying pesticides, to increase production and minimize adverse environmental effects through crop, pest and beneficial organism management (Kelly, 2005; Yang et al. 2002). IPM requires a systematic knowledge of biological influences and effective knowledge of crop and environment management. (Prudent et al. 2006).

Farmer Field School (FFS): Farmer field schools are participatory learning platforms for rice farmers in low-income regions, providing information on innovative technologies for higher productivity (Quizon, Feder & Murgai, 2001).

Knowledge of Environmentally Sustainable Agricultural Technology (KESAT): KESAT stands for knowledge of environmentally sustainable agricultural technologies, which indicates agricultural practices employed to conserve natural resources and prevent soil erosion, water waste and excessive use of chemicals by addressing changes in nature due to natural and man-made causes. The tool for measuring KESAT is referred to as the KESAT test in this study.

Non-formal Education (NFE): Non-formal education takes place outside of formal schools in an organized manner to achieve targeted goals based on learner needs (Madhu, 2014).

Yield: Yield is measured as agricultural output per unit area of land.

CHAPTER 1: INTRODUCTION

"There are reasons why we need new technologies and knowledge: the climate is changing, our environment is changing, and so is our soil. We need to change, too." - Abdul Kareem[1] (Age: 37, Education: Passed 5th grade)

1. A. Background

Over 60% of Bangladesh's 163 million inhabitants subsist on agriculture, responsible for 47% i.e. almost half of the total national income, compared to 17.5% in India and 21% in Pakistan (BBS, 2015; World Bank Development Indicator, 2017). The agricultural industry has directly employed about 19 and 23 millions of people in 2000 and in 2010 respectively (World Bank, 2016). As such, the country is significantly impacted by global warming and declining soil fertility, which has not only led to a significant drop in crop yields but also changing knowledge of soil and water management (World Bank, 2015). Decreasing crop yields have spurred many males in rural societies to migrate to cities and foreign countries, seeking higher income employment resulting in more women taking charge of agricultural production to fill in this gap (Hadi, 2001; Karthiki, 2011; Mizanur, 2012; Rashid, 2013; Ullah, 2017).

The gradual but steady shift involving 105 million people in rural Bangladesh has had significant impact on agricultural knowledge distribution. Seminal research – focused on male farmers receiving training from extension services by government and nongovernment actors – suggested that agricultural productivity and knowledge are positively correlated with education (Bhati, 1973; Jamison & Lau, 1982). In recent times, farmer education has seen a shift from universal extension approaches to targeted participatory learning platforms like farmer field schools in order to address farmers' educational needs (Waddington et al., 2015; Van der berg 2007). However, these schools are still mainly accessible to male farmers and only a handful of female farmers.

The present study addresses the gap in current research on female and male farmers' participation in farmer education and its impact on farmer knowledge, climate-sensitive

[1] Pseudonyms are used for all participants of the study.

agricultural practices and productivity in a participatory farmer field school (FFS). With global warming and other adverse effects of climate change, agricultural methods are undergoing drastic changes to conserve resources and energy to improve production with limited natural resources in a densely populated country like Bangladesh. According to IPCC (2014), climate change is predicted to favor agricultural production in developed regions through "moderate warming" while it will affect the poorest regions more severely owing to resource limitations. This phenomenon will result in an increased number of malnourished people by 80-90 million people (Parry et al., 1999). Like any other country in the world, Bangladesh will need quality education – underscoring improved agricultural knowledge – for both male and female farmers, in alignment with the SDGs# 4 (quality education) and 5 (gender equality). Quality farmer education will help ensure food security for the poorest people in order to reach the zero hunger goal (i.e. SDG#2) by 2030. Especially, in the current state of increasing economic migration of educated males from rural to urban areas, women's farming knowledge and skills are more likely than ever to determine the future of agriculture in Bangladesh (Alam & Khuda, 2011).

1. B. Problem Statement

In 2016, the United Nations declared its 17 Sustainable Development Goals (SDGs), among which Goals 2 (Zero hunger), 4 (Quality education) and 12 (Responsible production and consumption) lay emphasis on food security, quality education, and sustainable production for the global population (United Nations, 2016). Most governments in developing countries have relied on universal extension services, in particular, for farmer education to increase yield[2]. Traditionally, extension has been a means for transferring knowledge about researched technologies to farmers for improving their livelihood skills and practices mainly through training and visits (T&V) by government extension agents (Anderson & Feder, 2007). When it comes to environmentally sustainable agricultural technology adoption, however, top down approach to extension, which does not engage farmers in designing their own learning experiences, pays little attention to the quality of education (relevant knowledge and information) and hence proved to be

[2] Yield is the average output from a unit area of agricultural land.

unsuccessful (Anderson, Feder & Ganguly, 2006). Like most public education programs, the focus in extension services remained on access and not so much on the quality of learning. Consequently, the education provided often does not match the specific needs of these people, current knowledge, personal objectives and local innovation (Vanclay, 2008; Robinson-pant, 2016; van Crowder et al., 1998).

Building on earlier evidence, this study takes a different approach by examining the effects of participatory farmer education program on learning, measured as knowledge, to fully capture the quality of farmer education on sustainable agriculture. Furthermore, this study explains the critical influence of knowledge acquired in farmer education programs on technology adoption and productivity of farmers. The present research suggests a reconsideration of the important yet under-theorized relationship between farmers' knowledge (learning), and technology adoption and productivity in an agricultural industry highly susceptible to climate change with a focus on women farmers' productivity. In this study, knowledge of environmentally sustainable agricultural technologies will be considered not only as an outcome of farmer education (Waddington et al., 2015; Crouch et al. 2017), but also as an influential factor in ensuring that the education in farmer field schools translates to improved productivity through the use of environmentally sustainable agricultural technologies. This study will offer a new understanding of why large-scale interventions must consider learning as a dynamic predictor of farmer success by measuring relevant agricultural knowledge.

Experimental research, focused on agricultural productivity, have mainly focused on male farmers and often neglects explaining the reasons for positive outcomes or simply assigns success of a program or policy to the treatment e.g. participation in FFS. Recently, however, a growing body of literature (e.g. Ajayi, 2007; Hothongcum Suwunnamek, & Suwanmaneepong, 2014; Karunamoorthi, Mohammed, & Jemal, 2011; Meijer et al. 2015; Moumeni-Helali & Ahmadpour, 2013; Siddiqui, Siddiqui & Knox, 2012) has investigated the influence of farmers' knowledge, attitude, perceptions, beliefs and behavior (KAPBB) on sustainable technology adoption and management. However, limited evidence exists for explaining productivity using a

KAPBB framework. The potential of non-formal education amongst adult farmers for unlocking productivity related knowledge, attitude and adoption behavior have remained under-explored to date.

Many poor farmers, half of them being women whose contribution in agriculture are often overlooked, play a crucial role in making sustainable agricultural decisions and efficiently managing natural resources. This research acknowledges women – often ignored by the extension services (Galie, Jiggins & Struik, 2013; World Bank, FAO & IFAD, 2009) – as "real farmers" for their daily contribution in agriculture (FAO, 2014), thereby providing theoretical and practical insights into the rapid socio-economic changes currently experienced in rural agro-economy-based societies. Due to the economic migration of males in rural areas, women are increasingly undertaking the roles of household heads, making important economic and production decisions on a regular basis (Mizanur, 2012; Rashid, 2013; Ullah, 2017).

This research addresses the knowledge, technology adoption and productivity of both female and male farmers, thereby providing theoretical and practical insights into what needs to change for improved education on sustainable agriculture for all farmers. The study measures all kinds of educational training such as non-formal (e.g. extension, FFS, etc.) and formal education to explain farmer performance. Hence, this dissertation will contribute to the research literature on farmer education by examining whether and to what extent participatory non-formal education supports farmer knowledge, skills and productivity compared to formal education.

This dissertation examines the role of non-formal education in Integrated Agricultural Productivity Project (IAPP) in enhancing knowledge acquisition and adoption of environmentally sustainable agricultural technologies (ESAT) for higher productivity among Bangladeshi farmers. This research focuses on three performance outcomes: knowledge, use of environmentally sustainable agricultural technologies and productivity.

This research seeks to answer the following questions:

1. Are farmers with FFS training more productive compared to those without FFS training? (source of data: baseline and endline surveys, administered before and after the program)
2. Do FFS educated farmers use environmentally sustainable technologies with greater frequency compared to those without FFS training? (source of data: baseline and endline surveys, administered before and after the program implementation respectively)
3. Do FFS educated farmers have greater knowledge of environmentally sustainable technologies compared to those without FFS training? (source of data: endline survey administered in 2016)

In addition, the research will explore the relationship between all three major outcomes to explain how an FFS program works.

1. C. Brief history of Agricultural Knowledge Systems and Farmer Field Schools

In the wake of Second World War, development of infrastructures and technical support replaced more traditional knowledge sharing venues such as agricultural fair, demonstration lands etc. (Laurent, Certh, & Labarthe, 2006). This historical change led to the formation of the Agricultural Knowledge Systems (AKS) for managing information and production in the agricultural sector (Röling 1988), differently managed in different countries (Arnon, 1989), mostly through extension services. The agricultural extension services were supported by public funds or additional taxes on sale of produces and land in countries in the South – mostly free of charge – and the North – sometimes free of charge (ANDA, 1991). These services were designed to connect farmers with ongoing agricultural research to raise productivity and overall output by providing information on new technologies and production methods. Extension services provided information on land preparation; seeding, planting and cultivating; fertilizers, pesticides and herbicides; new methods of harvesting and crop preparation; and organized marketing (Orivel, 1983). However, the investment in these services decreased significantly since 1980s because of international free trade negotiations, with shrinking government support for these services (van den Ban, 2000).

About the same time, farmer field schools (FFSs) were introduced as participatory educational training programs for farmers in the rice-producing countries in the developing regions in the late 1980s. These schools trained farmers to use the latest agricultural technologies (such as organic fertilizer, proper land and water management to conserve natural resources, etc.) for achieving food security in low-income areas by engaging farmers in active problem solving in addressing their issues at hand (Quinoz, 2003; Trip et al. 2005; Mancini & Jiggins, 2010). FFSs started out with providing relevant information and resources for increasing farmer productivity to feed impoverished population in rural areas --as promoted by the Green revolution in the 1960s[3] originating in India (Hardin, 2008)-- but also emphasized sustainable use of land and other resources to address climate change (Quinoz, 2003). All these made FFS schools more effective compared to traditional extension services in raising the knowledge and productivity levels in farming communities functioning in a changed environment by using participatory and hands-on approaches to learning.

After its first wave in Indonesia, FFSs made its way to South Asian countries including India and Bangladesh (Kenmore, 1991; Quizon et al., 2001) with the aim to improve excessive use of pesticides in rice-intensive agricultural systems in Asia (van den Berg & Jiggins, 2007). As a result, FFSs in Bangladesh are a fitting site to explore the impact of non-formal learning on farmers' productivity, knowledge and adoption of sustainable technologies for three main reasons. First, Bangladesh, a country of over 161 million people, has an agro-based economy, with over 60% of its population involved in an agricultural industry, highly susceptible to climate change (World Bank, 2015). Second, a steady rise in temperature due to global warming has adversely disrupted crop and livestock production, with a significant drop in crop yields in South Asia and other economies relying primarily on rain-fed crops (FAO, 2014, IPCC, 2007). The realities of the farmers at this site, needing to adopt new technologies and information and to address the changing natural environment for sustained production, are similar to that of farmers

[3] Green revolution, started in India in by Norman Borlaug to address famines and was later adopted in other parts of the world for similar reasons, was heavily criticized for heavy use of chemicals destroying soil fertility (Farmer, 1986; Hardin, 2008)

in other poor countries affected by global warming. Third, for over two decades, FFSs in Bangladesh have educated mostly male farmers about new agricultural technologies, adoption and dissemination for ensuring food security (Braun et al., 2006). It is therefore critical to find out how women farmers in a contemporary FFS are responding to this education with increasing migration of rural men to urban areas.

1. D. The Integrated Agricultural Productivity Project

The Integrated Agricultural Productivity Project (IAPP), supported by the government of Bangladesh, Food and Agricultural Organization (FAO) of the United Nations and the World Bank is a special kind of FFS to ensure food security in northern Bangladesh. Despite higher government subsidies to agriculture the output level has been consistently low in Bangladesh (World Bank, 2013). IAPP aims to improve productivity by promoting use of sustainable agricultural technologies such as improved seeds, farm-yard manure, integrated pest management, land and water management through hands-on demonstration and participatory learning (Integrated Agricultural Productivity Project, n.d; World Bank, 2013)[4].

FFSs usually are groups of 20-25 farmers who meet weekly or bi-weekly to discuss critical challenges faced during a major crop cycle and research solutions with support from experts and extension agents in real time. At IAPP, both male and female farmers participate in these meetings. As Tripp et al. (2005) spoke about the general form of learning in FFSs, in these meetings "[farmers] are encouraged to make observations of important processes and relationships, such as the habits of harmful insects and the actions of natural enemies…to ask questions… seek answers" (p. 206). At IAPP schools, the scope of this discussion covers all aspects of farming including irrigation, soil and water management, pest control, beneficial insect management, fertilizer production, crop management and so on.

IAPP schools are among the most widely known FFSs in Bangladesh focused on improving household level productivity and imparting education on employing sustainable agricultural technologies to both female and male farmers for the first time in Bangladesh.

[4] Integrated pest management employs natural predators to combat pests by understanding the cycle, origin and natural enemies of pests.

Therefore, these schools are a suitable site for examining the impact of non-formal education on knowledge and adoption of sustainable technologies that are likely to improve farmer productivity. IAPP aims to increase productivity by promoting use of sustainable agricultural technologies such as healthy seeds, farm-yard manure, integrated pest management, and land and water management through hands-on demonstration related to water conservation and soil acidity control.

1. E. Significance of the study

This dissertation examines whether farmer field school (FFS) education has any impact on farmer performance in the areas of productivity, knowledge and use of environmentally sustainable agricultural technologies (i.e. KESAT and UESAT). Further, this study will examine the effect of knowledge or KESAT on the two other outcomes, productivity and UESAT for understanding the system of farmer education better to better inform the evaluation design of future interventions. The study will be significant in informing farmer education in low-income settings to achieve the maximum impact in the areas of outcomes discussed in this research.

The relationship between learning (measured as knowledge), and technology adoption and productivity in farming communities is not a common topic of research in farmer education. It is common knowledge that schooling doesn’t always guarantee learning, especially for the marginalized groups in low-resource environments, who face many system-level barriers to learning such as lack of access to education materials and functional relationships with educators (WDR, 2018). However, no visible attempts were made by education researchers to study the impact of farmer education on learning as a result of participatory farmer field schooling. Bringing together the existing evidence base on the positive outcomes of context-specific FFS education in the areas of productivity, knowledge and adoption of sustainable farming technology, separately recorded in various studies (Guo, et al., 2015; Najjar, Spaling & Sinclair, 2013; Yang, et al., 2008) this study offers a new way to understand farmer productivity and technology adoption as an outcome of learning (measured as knowledge) in an FFS.

This dissertation project has the potential to inform current agricultural education policy and program design in rural Bangladesh through a context-driven, multi-disciplinary approach to impact evaluation in the following ways. First, this research evaluates non-formal education in FFSs for farmers in Bangladesh to measure outcomes (e.g. knowledge and adoption) that directly address the climate related changes in Rangpur. Second, unlike traditional evaluation studies of FFSs, this dissertation combines various distinct theoretical paradigms, i.e. human capital theory (HCT), juxtaposed against adult learning theories, gender equity lens and alternative ways to understand farmer productivity in order to address participation of low-literacy level and resource-poor farmers as well as growing involvement of women in local agriculture. Third, this research aims to address the different ways non-formal education intersects with the socio-economic and individual backgrounds of the low-income female and male-headed farming households. All these aspects of this evaluative study have significant implications for improving learning environment for the low-income and low-literacy level farmers, who need to make climate-smart decisions, by maximizing the utilization of limited resources available to them.

1. F. Organization of the dissertation

The rest of this dissertation is organized as follows. Chapter 2 develops a conceptual framework that underlies the theoretical and empirical work on farmer education. Chapter 3 explains the design, empirical specification and testable hypotheses and Chapter 4 elaborates on the context of this study. In Chapter 5, the key findings on the empirical analysis and in Chapter 6 discussion of the major findings are presented and the implications are highlighted. In the final chapter, a brief summary of findings and a few recommendations are discussed.

The study has the following objectives as regards to what extent non-formal education in Integrated Agricultural Productivity Project (IAPP) contributes to adult farmer outcomes in terms of: 1) higher productivity; 2) adoption of environmentally sustainable technologies with greater frequency; and, 3) more knowledge of environmentally sustainable agricultural technologies when compared to those without the non-formal educational training. The significance of the study lies in a context-specific, program and school level approach to impact evaluation. This research accounts for individual, household and community characteristics to most accurately represent the above outcomes of the study at school levels as well as present a holistic picture of how FFS education generates positive outcomes, interrelated to each other.

CHAPTER 2: LITERATURE REVIEW

Theoretical perspectives in the fields of education, international development, and economics have provided lenses through which to understand the relationship between farmer education and agricultural productivity. Strikingly, despite existing scholarship confirming education's significant effects on agricultural technology (AT) adoption and productivity at different times and locations, mechanisms by which education affects farming practices and farm productivity through knowledge creation have remained underexplored. Seminal research on this topic maintained that formal education raises farmer productivity as literate farmers benefit from having greater knowledge and access to sources of information, resources, and technologies (Jamison & Moock, 1984; Jamison & Lau, 1982; Lockheed, Jamison & Lau, 1980). This study investigates the process of farmer education taking place in a non-formal learning environment to generate similar or better outcomes for sustainable development.

Recently, the rice-producing Asian countries have seen a departure from the traditional approach to extension education, in which extension personnel provide general instructions to farmers by visiting their homes, to more participatory forms of learning. Examples of participatory approaches to knowledge dissemination for sustainable farming include farmer participatory research (FPR) (Escalada & Heong, 1993), and the farmer field school (FFS) (Kenmore, 1991; van de Fliert, 1993), where participatory learning groups rely on interpersonal communication and group interaction to learn about new agricultural knowledge and practices (van de Fliert, Pontius and Roling, 1995). In particular, FFSs are characterized by their emphasis on education rather than instruction. FFSs impart non-formal education about new agricultural technologies for enhanced productivity using participatory learning techniques (FAO, 2014; Davis et al, 2012; Guo et al. 2015; Quizon et al. 2001). Considering the special emphasis on formal education in seminal studies and more recent evidence on the relevance of FFSs, it can be said that, both of these kinds of education – formal education and non-formal training in FFSs – can be complementary in preparing farmers for success (Mancini & Jiggins, 2010).

This study bridges the findings from both old and new research to offer a fresh way to examine the role of non-formal education in knowledge acquisition of environmentally sustainable technology, along with its impact on farming practices and productivity. By concretely measuring knowledge, this study paves the way to quantify non-formal learning that took place in a specific farmer field school in rural Bangladesh with the goal of better explaining the returns on farmer education.

2. A. Human Capital Theory

This study combines two theoretical paradigms in examining the role of farmer education in learning about productivity in rural Bangladesh: first, both traditional (Becker, 1993; Schultz, 1964, 1975) and new approaches to human capital theory (HCT) (Klees, 2016); and second, a framework of gender equity. Human capital theory has been central to estimating returns on investment in education, arguing that better educated laborers earn more by being more productive (Becker 1993; Schultz, 1964, 1975). Previous studies by economists drew upon this theory to predict productivity based on formal schooling and cognitive skills in a modernizing environment (Jamison & Moock, 1984; Jamison & Lau, 1982; Lockheed, Jamison, & Lau, 1980). They found that cognitive skills learned in schools, such as literacy and numeracy skills, positively influenced farm production in Nepal when new land and water management technologies were introduced during the Green Revolution. Recent studies of rural households in Bangladesh have shown insignificant effects of formal schooling, i.e. numbers of years in school, on production efficiency (Coelli et al., 2002; Wadud and White, 2000). Drawing on evidence collected at a global level, more recent studies synthesized the impact of multiple FFSs in various countries that point toward non-formal education’s positive impact on farmer performance (Van den berg 2007; Waddington et al. 2013). It is common knowledge that learning that takes place outside of schools, i.e. non-formal education, differs from what is learned in formal settings (Wagner 2014; BNFE, 2013). Hence, this dissertation examines to what extent non-formal education compared to formal education matters for a positive impact on knowledge, technology adoption and productivity in a changing environment.

Evidence from studies driven by human capital theory supports the view that transition from traditional methods to technology-based modernization of the agricultural sector creates a "dynamic" environment (Schultz, 1964, 1975). Based on this approach, economists have shown that workers with formal schooling possess comparative advantages over non-schooled ones in accepting new agricultural technologies such as high yielding varieties of rice (Bartel and Lichtenberg, 1987; Foster & Rosenzweig, 1995; Orivel, 1983). The concept of the dynamic environment, in which new technologies are a must, is relevant to farmers in rural Bangladesh, who need informed knowledge to address the various extreme effects of climate change such as flooding, infestation by new pests and prolonged dry seasons. As such, this research extends the concept of dealing with a dynamic environment from a formal to a non-formal education setting to address the contribution of non-formal farmer education toward learning new agricultural practices.

The HCT framework is often used in farmer education studies because its underlying theory is straightforward and easily comprehensible. That investment in human development through education increases one's chance at being productive is an appealing concept. As a result, HCT has remained an attractive theory to economists of neoclassical background since the 1960s as well as policy makers, who are taken by its simplicity in explaining the direct causal relationship between education and productivity. However, some critical assumptions made in HCT often do not hold. In his most recent work, Klees (2016) demonstrates the difficulty of accepting HCT and ROR (rates of return) as feasible ways of measuring the impact of education on earning. Klees's work concerning economic efficiency, income and productivity are highly relevant to this study.

First, Klees explains that the foundational idea of HCT is efficiency, embedded in the economic theory of the market economy, which in turn is assumed to be an ideal system in which "supply and demand by profit maximizing small firms and utility maximizing consumers...operate with perfect information" (2016, p. 647). He argues that by making this assumption about a perfect market economy, HCT undermines equity with its overemphasis on efficiency, especially since the concept of efficiency does not hold in a real world with many deviations from the perfect invisible hand of supply and demand. In this research, when measuring the efficiency of farmers with regard to improved productivity, it is important to identify additional factors such as community, household and individual conditions that influence productivity. Receiving relevant education such as FFSs may not always translate to greater outcomes, especially because farmers with access to limited resources may suffer due to various social and economic constraints.

Second, the relationship between education and earnings, which HCT treats as a measurement of productivity, is assumed to be causal as it is understood in most economic studies. However, Klees (2016) points out that there is no direct causal relationship between education and earnings as other factors are at play:

> *For many years, economists simply assumed that the association between education and earnings was causal, so that, for example, if a high school graduate earned $20,000 a year and a college graduate $50,000, the whole difference of $30,000 was taken as due to the impact of education. This was obviously nonsensical since there are many other factors that could be causing that difference in earnings such as ability, motivation, and socio-economic status. (p. 648)*

In the same vein, Hanushek (1980) explains that the estimated rates of return for years of schooling, particularly in regression estimates on earnings, are often arbitrary as they vary with sample, time and model specification. Hanushek's work, therefore, reflects Klees's argument that "the estimated impacts of education on earnings are basically arbitrary" (p. 653). This study takes these theoretical drawbacks of HCT into consideration and juxtaposes Schultz's HCT with Klee's criticism of HCT to address questions about the effects of non-formal education on knowledge, skills and productivity of farmers. Hence, this research uses an alternative approach to HCT as a framework to understand returns on non-formal education investment, keeping in mind the specific pitfalls of HCT while interpreting the results.

Due to limited availability of resources and low levels of literacy, farmers in rural Bangladesh need personalized resources to succeed, depending on factors such as gender, access to information and education. Therefore, in this study, special attention is paid to gender equity, access to resources and limited generalizability of the findings to other samples, times and places (Ashby, Klees, Pachico, & Wells, 1980, Klees, 2016). It is important to note that the model specifications employed in this research is reflective of the socio-economic and cultural realities of Bangladeshi rural households.

2. B. Gender equity in farming

About 40% of agricultural labor force in Bangladesh is comprised of women today as their participation increased by almost 100% between 1999 and 2006 (Burham, 2014; Jaim & Hossain, 2011). It is not surprising that, in Bangladesh, women participating in agriculture come mainly from marginalized and landless households (Naved, Khan, Rahman & Ali, 2011). While increased participation of women in agricultural production is a positive development, women's access to resources and education have been severely limited and there exist many challenges in ensuring productive and income-generating sources for rural women (Agarwal, 1994; Samanta, 1999).

Women are marginalized in rural societies due to inequitable socio-cultural, religious and economic conditions. For instance, Alidou and Niehof (2013), point out that in Benin, even though women farmers are playing a significant role in cotton production, only a few of them are involved in farm management due to existing gender stereotypes barring women from assuming managerial positions. Their study revealed that given organizational and societal constraints, a male farmer is 21 times more likely to become a manager – someone who possesses the authority to make major decisions – compared to a female farmer. The authors also suggest these few women who became managers at these farms had "open-minded husbands" who identified differently from the general pool of men in Benin (p. 331). The authors explained that men are more open to allow women to work when it is economically beneficial for them.

Even in participatory learning environments, individual backgrounds like gender, ethnicity, age, religion or culture suppressed and weakened the voices of less outspoken groups in rural India (Mancini & Jiggins 2008; Gujit & Shah 1998; Waddington et al. 2014). These results align with the reality of female farmers in Rangpur, where female participation in farm management is vastly restricted by gender and cultural norms. Therefore, gender is included as an important indicator for predicting farmer performance in this study.

Despite many challenges, women's participation in agriculture is becoming more common than ever due to the high rate of economic migration of men in rural Bangladesh. Increased autonomy of women is often a result of men's labor migration (Hadi, 2001; Karthiki, 2011; Mizanur, 2012) as the impact of men's labor migration is likely to persevere even after men return to their homes (Yabiku, Agadjanian & Sevoyan, 2010). This shift concerning the impact of current economic migration on women's improved autonomy in rural Bangladeshi societies, is likely to continue. Under the changing circumstances, it is possible that women farmers will experience increased economic, social and physical empowerment – necessary for the overall empowerment of women (Olawoye, 1996). Considering all the above evidence, this research adopts a gender equity approach – considering women's contribution in farming outcomes and related socio-economic and individual backgrounds, which influence their contribution.

From a policy perspective, the National Women's Development Policy, formulated by the Ministry of Women and Children Affairs, aims to give full control of "the property earned through own labor, inheritance, debt, land and market management" to women in order to address the issue of gender inequality in Bangladesh (MOWCA, 2011). However, in reality, the gender gap in agriculture is still very wide. For instance, despite giving women access to assets, it was not confirmed that they will retain control over the asset or receive income from the asset (Srabonia, Malapit, Quisumbing & Ahmed, 2014). For instance, BRAC's "Targeting Ultra Poor" program revealed that women did not retain control of the assets transferred to them (Das et al., 2013). As women are the ones in charge of food and nutrition in most households, these kinds of systemic barriers to women's development are responsible for food insecurity and malnutrition in the region despite increasing per capita income (Smith et al., 2003; von Grebmer et al. 2009). However, evidence exists to demonstrate that women's participation in vegetable cultivation led to improved nutrition and income for families in rural Bangladesh (Burham, 2014). In this study, vegetable production in kitchen gardens is therefore considered as a measurement of women farmers' active contribution in agricultural production.

2. C. Learning theories

While educators mainly focus on finding ways to improve the ability of learners to apply and retain learned skills, policy makers emphasize measurable outcomes, often in the form of economic performance (WDR, 2018). However, human development around the world needs an integrated approach to consider both quality of learning and related outcomes. Wagner (2018) in his book *Learning as Development* suggested identifying the state of learning equity by measuring the quality of learning for the most marginalized population in order to close the widening gap between rich and poor countries.

This section highlights both the educational process and the learning outcomes as two sides of the same coin when considering learning. A combination of learning theories can be applied to understand the learning process and related outcomes of non-formal education in FFSs, namely, adult learning theory highlighting participatory forms of learning, Freire's theory of learning based on his work *Pedagogy of the Oppressed* and the theory of adult education participation (AEP) (Knowles, 1980; Freire, 1970, 1980; Cookson, 1986), where learners actively participate in generating knowledge and are in charge of their own learning.

In 1980, Knowles specified the ways adult learners differ from child learners, mainly in the domains of self-concept, learning experience, readiness to learn, orientation and motivation. Transitioning from a dependent entity to a self-directed independent learner, adult learners accumulate experiences that guide their learning to fulfill the tasks or responsibilities in specific social roles (Knowles, 2011). In order to address their current roles, these learners have to find solutions to problems encountered in real life, understood as the "immediacy" for action, that changes their orientation to learning, making adults' motivation to learn more intrinsic compared to children (Knowles et al., 1984, p. 12; 2011). Similar to what Knowles had proposed, in today's extension culture, participatory learning in farmer field schools requires self-directed and self-motivated learners. Since adults are motivated intrinsically, the education they receive needs to align with their purposes. For instance, in their research, Togbe et al. (2015) explain that a small group of farmers in an experimental participatory program in Benin improved their knowledge and ability to deal with pests and natural enemies, mainly motivated by their desire to reduce the cost of pest management.

While accounts of positive outcomes in FFSs are numerous the process of participation is often overlooked. Waddington et al. (2013), in a meta-analysis of 75 FFSs, found that only half of them reported participatory education while the other half did not clarify their teaching pedagogy. Despite the prevalence of these many FFS programs, it is still crucial to acknowledge that participation varies from one FFS to another. Farmers' participation varies within distinct FFSs just as they differ in formal schools, depending on connected psychological, social and contextual factors.

Building on D.H. Smith's (1908) interdisciplinary, sequential-specificity, time allocation, life-span learning model as a standard outline of critical independent variables to predict adult education participation, Cookson (1986) discussed six classes of variables determining AEP. They are external contextual factors, social background and social role factors, personality and intellectual capacity factors, attitudinal dispositions, retained information and situational variables. According to Cookson, this interrelated set of complex variables has practical significance for educators and practitioners. Drawing from the theoretical framework of AEP, this research on adult farmers' participation in non-formal FFS education makes an attempt to understand the process behind the outcomes. As a result, this study accounts for some of these individual learner-related variables such as cognitive skills, attitude, group affiliation, retained information (knowledge) and other socio-contextual variables.

Despite its popularity in current literature, there exists poignant criticism of the participatory approaches to sustainable development, which often seem to reinforce existing imbalance in power relations (Cooke, 2002; Rocheleau, 1994) between different groups while revealing but not alleviating power inequalities. The opposing viewpoints can explain why there are differing levels of outcomes from various participatory FFS programs fueled by existing socio-economic inequalities. The inequalities experienced by farmers range from restricted access to information, resources, or tools to social constraints against women's participation in agricultural decision-making. As a result, this study addresses the impact of varying levels of access to resources and social network as well as gender on farmer performance.

Aptly, Freire (1970) has emphasized relevant and effective education for disadvantaged adult learners. Similar to Freire's emphasis on the capacity to change by the adult learner through reflection and action, farmers in Bangladesh learn more effectively when they are given the chance to act based on reflection, guided by their real needs. James & Farmer (1980) pointed out the importance of identifying major generative themes in Freire's framework, which enables adult learners to reflect and act for increased freedom and worth – helping adults transition educationally from "old cultures" to "emergent" ones (p. 67). Like any groups of adult learners, underprivileged farmers in rural Bangladesh need to emerge from their livelihood and socio-economic challenges by identifying what works best for them. Therefore, it is expected that those farmers with high levels of outcomes in this study – especially pertaining to transitioning from old practices to the new environmentally sustainable agricultural technologies – were able to receive education aligned with their resources and needs, and vice versa.

2. D. Major impacts of Farmer Field School education

Van den Berg et al. (2007) highlighted the developmental and immediate impacts of FFS education in the technical, social and political domains of farmers' lives based on their synthesis of twenty evaluation studies on the impact of Farmer Field Schools (FFSs). Under the technical domain, they discussed knowledge about ecology, experimentation skills, improved crop management, pesticide reduction, yield improvement, profit increase and risk reduction as an immediate-term impact. They classified sustainable production, innovation, cost-effectiveness and related topics as developmental impacts. Although these are broad concepts, they present a general idea of the impact of FFSs in both short (immediate) and long (developmental) terms. In this section, two immediate impacts, farmer knowledge and adoption of environment-friendly technologies, and one developmental impact, productivity, are discussed as the desired outcomes of an FFS program.

2. D. 1. Knowledge of Environmentally Sustainable Agricultural Technologies

Economic studies are predominantly focused on learning about farmer productivity and efficiency (Birkhaeuser et al. 1991). However, only a handful of studies report on the FFS's impact on farmer knowledge of various types, essential for environment-friendly farming practices and production (Birkhaeuser et al. 1991; Crouch et al. 2017; Waddington et al., 2015). Most studies reporting on knowledge, however, have focused on the impact of knowledge on pest management (Godtland et al., 2004; Lund et al. 2010) and soil nutrient management (Siddique et al. 2012 & Tripp, Wijeratne, Piyadasa, 2005). By and large, the impact of FFS education on knowledge is confirmatory. For example, in a non-experimental study by Siddiqui, Siddiqui & Knox (2012), farmers' knowledge of pesticides, nutrient management and decision-making ability regarding eco-friendly farming increased as a result of an integrated pest management FFS program. Additionally, evidence (Larsen et al., 2002; Van den berg 2007) shows that improved farmer knowledge increases nutrient management, pest control and use of natural fertilizer, and reduces the use of pesticides (Godtland et al. 2004; Guo et al. 2015). Whereas most of these studies found impact of FFSs on knowledge, some found little evidence of FFSs' impact in Asia (Tripp, Wijeratne, Piyadasa, 2005; Feder, Murgai & Quizon, 2004).

Although knowledge is likely to have a positive influence on environmentally sustainable agricultural technology adoption based on the current evidence, whether improved knowledge will bring about the same results in the context of rural Bangladesh still remains to be answered. If an FFS education has a positive effect on farmer knowledge, it will be useful to know about the other indicators beside FFS schooling that influence knowledge. Recent evidence suggests that the impact of FFSs on farmer knowledge and other outcomes vary at individual levels. In view of that, impact studies consider socio-economic status and community characteristics-related variables (Feder et al., 2004; Guo et al. 2015), likely to determine the impact of FFSs on individual farmers and the overall success of the program. Previously, Jamison and Moock (1984), in their study on

Nepali farmers, also tested farmer knowledge on cropping practices, recommended by the extension office. They argued that similar to numeracy, literacy and abstract reasoning, knowledge is an outcome of farmers' family and economic backgrounds. Moreover, knowledge is seen to play the role of an intermediate variable between these background variables and economic performance. Their argument indicates that farmers' background primarily influences knowledge, which determines desired outcomes, such as climate resilient technology adoption (Mariyono et al. 2013; Lund et al. 2010; Van den berg 2007) and productivity (Godtland et al. 2004, Waddington et al., 2015), as evidenced in more recent times.

Evidence shows that knowledge of environment-friendly agricultural practices is not only responsible for their adoption, but also for changing the mindsets of farmers toward sustainable practices. Conventionally, when it comes to environment-friendly farming practices, FFS education in Asian countries has led to the reduced use of insecticides (Van der Berg et al. 2007) in countries, such as Vietnam, Bangladesh and Sri Lanka (Tripp, Wijeratne, Piyadasa, 2005; van den Berg et al. 2002; FAO, 1993; Larsen et al., 2002; Pincus, 2000). Similarly, an integrated crop management (ICM) program in Indonesia (Mariyono, Luther & Bhattari, 2013) and Bangladesh (ICM, 2011) influenced farmers' expectations for reduced use of pesticide and improved yield. Considering the impacts knowledge has on farmer performance, Crouch et al. (2017), in their most recent report on climate-smart agricultural policies and evaluation, argue about a process through which both knowledge and agricultural investment influence farmer productivity (See Figure 2.1). They advocate for a Bayesian network[5] of farming knowledge, investment and incentives that allows to predict high or low yield. Their model demonstrates the importance of knowledge in determining the success of FFS programs both in the short and the long term, especially since evidence indicates retention of knowledge by farmers long after participating in FFS programs (Rola, Jamias & Quizon, 2002).

[5] "A Bayesian network can be represented (putting it colloquially) as a sort of flow chart without feedback loops, in which the key nodes are probabilities. A conditional probability distribution quantifies the effect of variables on each other."- Crouch et al. (2017, p. 9)

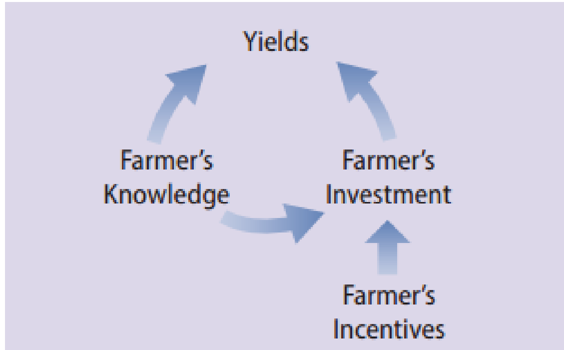

Figure 2. 1: Bayesian network of farming yields, farmer's knowledge, farmer's investment and farmer's incentives by Crouch et al. (2017)

Considering the existing evidence presented above, several relevant indicators and outcomes of knowledge were operationalized for examination in this study. Additionally, given different research goals various studies have described agricultural knowledge in different ways. As a result, it is deemed necessary to formulate a particular definition of knowledge for the sole purpose of measuring farmers' learning in this present research. Knowledge is defined as a finite set of information on the use of environmentally sustainable agricultural technologies promoted by the IAPP schools and is termed as *knowledge of environmentally sustainable agricultural technologies*, or KESAT. For this study, farmer knowledge in a few explicit areas such as pest management and cultivation methods – representative of the education in IAPP schools – is measured, which is hypothesized to have a strong impact on productivity and adoption of environmentally sustainable agricultural technologies.

2. D. 2. Environmentally Sustainable Agricultural Technologies

Like new knowledge, adoption of new technologies is considered an intermediary outcome, influencing direct outcomes such as productivity (Waddington et al. 2013). Education plays a significant role in driving the adoption of environmentally sustainable farming techniques by farmers as they learn to identify and abandon harmful practices. Especially, FFSs facilitate learning about new climate resilient technologies for addressing low productivity in vulnerable regions of the world. For instance, in Asia, studies support evidence of positive impact of FFSs in areas such as efficient pest management in Indonesia, Sri Lanka and other places (Feder et al., 2004; Lund et al., 2010; Van den Berg & Jiggins, 2007) and cost reduction in pest management in Philippines (Sanglestsawai, Rejesus, & Yorobe, 2015; Yorobe, Rejesus, & Hammig, 2011). Additionally, there are positive evidence of FFS's influence on the reduced pesticide usage from China (Mangan and Mangan, 1998), Indonesia (Kartaatmadja, Soejitno, & Wardana, 1997), Philippines (Price, 2001), Thailand (Praneetvatakul & Weibel, 2003) and Vietnam (Huan et al., 1999).

There are many factors that impact these technology adoptions other than farmer education. Largely, farmers adopt technologies that fit their local needs and resolve existing issues e.g. adoption of high density planting and beneficial insects (Prudent et al. 2006). While studying cotton farmers in Benin, Prudent et al. (2006) explained factors responsible for adoption failures. He explains that time consuming laborious methods like tilling were rejected by the cotton farmers. In addition to rejection of laborious technologies, self-perceived self-sufficiency, unwillingness to deal with uncertain outcomes of new technology adoption, lack of input, high price of input and lack of unavailability of labor or land could be responsible for adoption failures. In sum, new improved practices that seem productive to scientists and economists may not appeal to resource poor farmers (Munshi, 2007, Duflo, Kremer & Robinson, 2008) if misaligned with existing resources, needs and abilities.

While farmer abilities can significantly influence technology adoption, often, individual-level characteristics, such as gender, state level interventions or existing policies are responsible for contradictory outcomes. For example, in western Iowa, a survey involving female farmers revealed that women reported a higher concern about soil and water conservation compared to men even when they demonstrated considerably low-level of knowledge (Druschke and Secchi, 2014). Moreover, individuals' adoption behavior changes in response to policy changes. For instance, in the late 1980s, a few selected pesticides were banned and subsidies on these pesticides were removed as the incident successfully discouraged pesticide usage among the local farmers (Braun & Duveskog, 2008).

Since climate smart technologies are needed in many parts of the world, the expectation is that these technologies will diffuse to reach a larger audience beyond the farmers in a specific program. Technology diffusion is expected due to the nature of rural societies: formed in clusters of small and tight knit social networks—making these communities ideal sites for diffusion. However, one of the major critiques of FFS education has been that FFSs fail to diffuse knowledge beyond the farmers in the program, especially among female farmers (Guo et al., 2015). Tripp, Wijeratne and Piyadasa (2005) argue that by and large, *environmentally sustainable agricultural technologies* or ESAT pushed by FFSs such as bio-pesticides, coordinated irrigation or sowing and (drought or flood) resistant varieties of crop are not adopted as large scale techniques even when they are applied by the farmers in a program.

The lack of diffusion may be explained by the small size of the farming population and high cost of training at FFSs. For example, in Sri Lanka, Tripp et. al's (2005) evaluated an FFS by the FAO that trained 12,000 farmers – less than 2% of the total 700,000 rice farmers – in the country. Therefore, only a small number of farmers benefitted from the hands-on practical training in the FFSs and reduced their insecticide usage. Correspondingly, the high cost of training i.e. about 20 dollars per farmer, or the opportunity cost of attending these trainings when farmers hold multiple jobs are identified as possible reasons for technology diffusion failures (Ooi, Praneetvatakul, Walter-Echols & Waibel, 2005 & Banu & Bode, 2003). In Bangladesh, Ricker-Gilbert et al. (2008) reports that FFS per capita costs are ten times over those of comparable extension approaches, which include extension agents' visits and demonstration field days. The cost that they estimated includes both opportunity cost and trainer's time.

Considering these challenges impacting farmer performance in technology adoption, in this study, farmers are tested for the use of seven specific technologies, of which only two are resource intensive[6]. The seven ESATs chosen to evaluate farmer performance in this study

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[6] Some of these technologies, even though, had existed locally since a long time e.g. use of organic manure, their usage were replaced by heavy use of expensive chemical fertilizers brought about by the Green Revolution of the 1980s.

includes climate resilient land, water and crop management techniques, and their use is referred to as the *use of environmentally sustainable agricultural technologies* or UESAT.

2. D. 3. Farmer productivity

Impact of FFS education on productivity has been debated over the past several decades starting in the late 90s. An extensive literature exists on the measurement of FFS's influence on farmer performance related to productivity in Asia (e.g. Feder et al., 2004; Quizon et al., 2001, Tripp et al., 2005; Van den Berg, 2004; Van den Berg & Jiggins, 2007). These studies provide conflicting reviews on the impact of FFSs on productivity. Van de Berg's (2004) review demonstrated fairly authoritative and extensive positive influence of FFSs, mostly in the area of pest management, but also improved productivity in a few cases, validating "remarkable, widespread and lasting developmental impacts" (p.3). However, in their longitudinal study of FFSs in Indonesia, Feder et al. (2004) discovered that FFSs did not impact yield[7] or pesticide use. As recorded in existing literature (Ooi et al., 2005 & Banu & Bode, 2003), one of the main reasons for such failure is fiscal unsustainability of large scale extension services like FFSs as the cost is often too high for program sustainability.

Considering the inconclusive impact of FFSs on productivity worldwide, it is clear that there are multiple factors underlying the successes or failures of FFSs in improving yield beside financial considerations. In their study, Jamison and Moock (1984) recognized that farmers with seven or more years of education were more productive than those with less years of education. On the other hand, Lockheed, Jamison & Lau (1980) earlier determined the threshold for household head's education to be four years spent in a formal school. The differences in the number of years of formal schooling of the household heads are possibly a result of differences in the quality of basic education in various places. More recent results from Northern Nigeria also show that schooling not only enhances productivity, but also encourages adoption (Alene & Manyoung, 2005). However, there exists contrary evidence regarding how formal education affects traditional methods as opposed to new methods of production. Alene & Manyoung (2005)

[7] Yield, often used as a measurement of farmer productivity, is output per unit area of land.

found that four years of formal education improved cowpea production by 25.6% for new technologies, but it had no effect on traditional production practices. The authors observed that farmer education – both formal and non-formal – has “a higher payoff” for farmers who adopted an innovative agricultural practice.

In tandem with formal education, the latest evidence indicates that various socio-economic and individual characteristics e.g. gender and access to resources have significant influence on productivity. Despite existing evidence that confirms otherwise (Davis et al., 2012), in their recent study, Cai, Shi & Hu (2016) found that among tomato farmers in China, being wealthy and male along with possession of literacy skills and availability of larger land for production were critical indicators for predicting better yield due to participation in an FFS. Considering these diverse findings, it is safe to speculate that individual characteristics and household level socio-economic status are likely to determine the prospective beneficiaries of FFS education (Cai, Shi & Hu, 2016; Hall, Scoones & Tsikata, 2017). Hence this study includes gender, access to resources and literacy beside formal education as key indicators for predicting productivity in order to better understand farmer success in FFSs.

Concerning measurement of productivity, researchers have embraced diverse approaches in keeping with their different research objectives. Representative of many earlier studies, Jamison and Moock (1984) in their study on Nepali farmers measured the effect of education in wage employment by measuring the correlation between schooling and earning. This method was proposed by Schultz (1961) during his presidential address to other economists at the American Economic Association Annual Meeting. Further, in a more recent review of seven FFSs in Indonesia, Feder et al. (2004) looked at the differences in outcomes in the pre and post intervention periods by measuring yield (kg/hectare). On the other hand, Godtland (2004) measured potato yield in Peru as a ratio of output and input. There are also studies, which have looked at both knowledge and productivity outcomes as categorical variables, in an attempt to directly identify farmers who are knowledgeable and productive from those who are not. And others have made use of log transformation (Rahman, 2003) and continuous variables (Alene & Manyoung, 2007) to measure farm productivity.

This study adopts an innovative approach to measuring productivity by considering output per household member actively involved in agricultural production in order to fully capture the impact of FFS education on household-based farm productivity. The IAPP schools were designed to increase household level productivity. Hence it was deemed fitting to examine the impact of the program by considering average productivity of individuals in household-based farms, contributing in the production process.

2. E. Additional major factors influencing farmer performance

2. E. 1. Literacy and numeracy skills

Evidence of a positive relationship between literacy skills and farmer productivity has prevailed over time (Jamison & Moock, 1984; Cai, Shi & Hu, 2016). In this section, the different forms of literacy, representing the two major streams of literacy development theories, are discussed for a concise explanation of the nature of literacy skills and practices relevant to rural farming communities in Bangladesh. Literacy development theories can be mainly categorized into two major streams: a) the dominant stream, which underscores the functional use of literacy skills following some basic stages of development and b) the less dominant stream, which is about context-sensitive literacy practices. The former is outcome-focused while the latter emphasizes the process. However, in real life situations, some of these core literacy approaches may overlap by making way for a hybrid form to explain literacy in real-life situations. A few related theories of literacy development highlight some keys issues relevant to this study.

The dominant stream, emphasizing the functional aspect of literacy, focused on improving various life outcomes, is supported by educational psychologists and major international and national literacy programs in governments, the UN and its agencies. In UNESCO’s Belem Framework for Action, literacy is treated as a human right with multiple objectives (such as economic, political, environmental and vocational) to be achieved in one’s lifetime (UIL, 2013). In the more recent days, literacy was seen as a set of reading and writing skills or even as a continuum of different skill-levels. However, earlier policy research in this stream often classified individuals as strictly literate and illiterate, suggesting that literacy can be absent in certain contexts, accruing serious criticism (Street, 1984; Wagner & Spratt, 1988). In agricultural settings, return on investment in literacy remains an under-researched area. Nevertheless, given strong evidence on the connection between literacy and other outcomes, it is logical to ask whether farmers can read or write or perform basic calculations as these skills are essential for knowledge acquisition in any current agro-based economies.

At the other hand of the spectrum is the New Literacy Studies (NLS), focusing on a tradition that considers literacy as a social practice embedded in the knowledge of reading, writing, identity and being in a specific context as opposed to “a neutral skill” (Street, 2003, p. 77; Street, 1984). For instance, Maddox (2008) advised that in Bangladesh, women’s literacy practices need to be understood as a process as they negotiate new gender roles and identities in rapidly transforming rural societies. Although many experts in the functional literacy tradition see NLS as being exclusively supportive of adult literacy practices (Madhu, 2014), NLS does not make any specific distinction between the sites of literacy as a social practice and admits to the effects of various settings on the nature of literacies (Street, 2003; Barton & Hamilton, 2000). Earlier, Scribner and Cole (1981) also demonstrated that there is a conflation between the impact of literacy and the impact of schooling – suggesting schooling and literacy do not always have the same outcomes – and that the effects of literacy are different depending on contexts because what is valued in one setting may not have much value elsewhere.

The two divergent views and theories of literacy pose an interesting challenge of choosing between the two streams to assess literacy skills. In this research, literacy is seen as a combination of both: basic skills in reading and numeracy, and social practices in the local context. Therefore, in this study farmers are assessed for their functional literacy skills, such as reading comprehension and numeracy skills, using context-specific test content. The test reflects literacy and numeracy practices in the daily lives of the local farmers.

2. E. 2 Social network

In rural Bangladesh, any social network consists of a large group of people involved in agriculture. As a result, farmers mainly find their information on relevant agricultural practices from their friends, neighbors or relatives who live in the same or adjacent villages. Especially, in the drought prone areas like Rangpur, partnership with one's neighbors for production purposes through sharing of electric motors, water sources or even labor is inevitable. In a developing country like India (Foster & Rosenzweig, 1995; Feder & Slade, 1986) neighbors are reported as a major source of information for farmers. Similarly, in Iran, potato farmers report accessing information through extension agents, model farmers[8], TV programs and other farmers in their neighborhood even though lack of literacy skills is identified as a challenge in procuring information (Bagheri, 2010). However, it was observed that farmers are more likely to seek information from agricultural extension agents regarding complex methods of production (Feder & Slade, 1986). Despite evidence on elite capture through exclusion of poor and women farmers from accessing these services (Feder, Anderson, Birner & Deininger, 2010) in Bangladesh, agricultural extension service is a major source of agricultural knowledge in places where access to information is fairly inadequate (Asadullah & Rahman, 2009; Rahman, 2003).

In conjunction with acquiring knowledge from external sources such as schools, non-formal trainings and extension services, knowledge is constructed across generations in local farming societies (FAO, 2014). Haug (1999) and Wallace (2007) explained that rural small–scale farming households experience knowledge and productivity as they form their own human capital in local communities by creating, sharing and integrating newly learned information. As access to useful information is one of the major challenges to new technology adoption, relationships within social networks provide encouragement to farmers to adopt new technologies (Beaman et al. 2015; Munshi, 2007). As a result, farmers integrate FFS knowledge with locally available information in various community and religious groups (Genius, Koundouri, Nauges, & Tzouvelekas 2013) to improve their production. This is what Rogers (1983), in his seminal work,

[8] Model farmers are those who are considered to be successful farmers in their local communities.

defined as "diffusion" or "a special type of communication, in that the message are concerned with new ideas" (p 5). This research addresses the practical reality of local farmers who obtain information and share information on new practices from friends, neighbors and relatives in an age of ubiquitous access to mobile phones.

2. E. 3 Attitude, perception and behavior

Attitude can be understood as human tendencies – based on previous experience or knowledge – to evaluate a particular situation as necessity arises and this tendency is believed to be quite malleable (Dasgupta & Greenwald, 2001; Schwarz, 2007). It was evidenced that changed attitude towards agro-environment and technology use in Pakistan and Iran (Siddiqui, Siddiqui & Knox, 2012; Moumeni-Helali & Ahmadpour, 2013) improved environmentally sustainable technology adoption and related knowledge. Often farmers' attitude, perceptions and behavior of sustainable agricultural technologies such as use of organic manure or water conserving methods of irrigation are determined by their different group affiliation, operating as channels of information. For instance, a study in Iran on farmers' attitude and perceptions demonstrated that participation in extension and use of agricultural information sources had significant positive correlations with farmers' perceptions of sustainable agriculture (Bagheri, 2010).

Similar to Bagheri's observation in a study on rural farmers in Bangladesh, Rahman (2003) found that farmers' perceptions of soil erosion, air and water pollution and negative effects of chemical usage on biodiversity were rather weak. This is still the reality in rural Bangladesh, where agro-chemicals are perceived as the most effective means for improved productivity as farmers' access to extension network is limited. This study, therefore, asks questions about attitude, perceived norms and behavior regarding the use of chemical and organic fertilizers that are expected to aid measurement of one's tendency in evaluating environment-friendly technology adoption. Farmers with positive attitude, perception and behavior are expected to demonstrate better adoption practices.

2. F. Conceptual framework

Based on the discussion above, a conceptual model (See Figure 2.2) was created to guide the methodology of this research project. The framework is designed to provide a system-level understanding of the impact of farmer education at IAPP schools on the three major outcomes: knowledge of environmentally sustainable agricultural technologies (KESAT), use of environmentally sustainable agricultural technologies (UESAT) and productivity (See Definitions).

Drawing from established literature (Van den Berg, 2007; Waddington et al., 2013), at a program-level, the conceptual framework represents immediate impacts (also known as intermediate outcomes) such as KESAT and UESAT and development impact (also known as direct outcome) such as productivity of FFS education (See Figure 2.2). Farmers' participation in IAPP, i.e. the treatment and any other form of participation in similar farmer groups are measured as predictors of success related to the three major outcomes. In addition to the treatment, at a school level, there are three categories of indicators that are hypothesized to determine the performance of farmers. Drawing from Klees' (2016) critical approach to HCT, this study describes the impact of education on farmer outcomes considering individual, household and community characteristics, which are likely to influence a farmer's performance related to KESAT and UESAT. Under individual characteristics one can look at the number of years spent in school, gender, literacy and numeracy skills, attitude, perceptions and behavior. Household characteristics consist of household head's education, educational backgrounds of household members, percent of male and female household members, agricultural expense, resources available for production, socio-economic status etc. Under community features, this study accounts for farmers' affiliation with different groups, social network and sources of information.

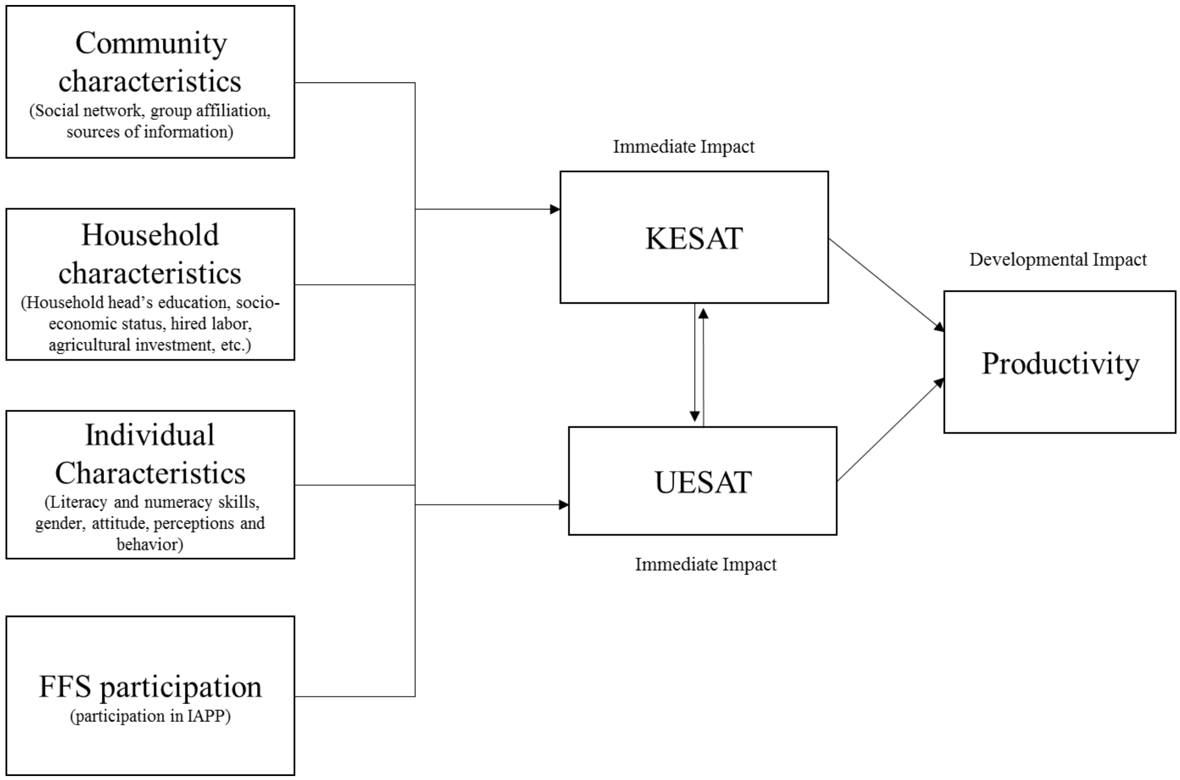

Figure 2. 2: Conceptual Framework for predicting the major outcomes of FFS education

Additionally, the model describes the presumed direction of the relationship between all of the above variables. In this study, variables under the various categories such as individual, household and community characteristics were measured to predict the outcomes of interest on the right side of Figure 2.2. In the framework, it is hypothesized that community, household and individual characteristics and farmers' FFS training are going to affect the outcome variables. Similarly, at a program level, FFS participation will enhance farmer's KESAT, which is likely to influence UESAT and vice versa, along with productivity of farming households. It is also hypothesized, based on existing evidence, that the individual characteristics e.g. reading comprehension and numeracy skills, age, gender or attitude and perception may have low to moderate impact on outcome variables. Additionally, individual characteristics are likely to identify the type of farmers who benefit most from an FFS program.

The conceptual framework is able to account for the statistical models employed in predicting the three major outcomes (knowledge, technology adoption and productivity) as well as to determine the relationships among them, examined in a mediation analysis. Among the key indicator variables, this research includes education and agricultural investment to predict productivity, reflecting Crouch et al.'s (2017) Bayesian network model. The indicator variables, representing individual, household and community levels, incorporated in the conceptual framework, are addressed in this research to measure their influence on the major outcomes, which is expected to provide useful information for similar future interventions. As demonstrated in the conceptual framework, the proposed models in this study includes key variables to individually estimate statistically significant relationships between the various individual, household and community level variables and the three major outcomes. Additionally, the model describes the direction of the relationships among all major outcomes.

2. G. Summary

This chapter focused on the theoretical foundations of the study, combining human capital theory with a gender equity framework, followed by brief discussion on several topics including adult education, gender inequality in agriculture and its effects, the three major impacts of farmer field school education and associated predictors. The chapter concluded with the conceptual framework, which will be employed as the methodological and analytical basis of this work.

CHAPTER 3: CULTURAL CONTEXT

This chapter describes the context of this research on farmer education to provide a nuanced understanding of the location, culture and practices at the project site in northwestern Bangladesh. In addition to conducting a quantitative impact evaluation of the IAPP program, data from observation and interviews with farming communities in Rangpur were collected with the intention to present a holistic and emic view (Hornberger, 1992) of the farming culture in Rangpur. The ethnographic work – not included in this dissertation – will come out as a separate publication. However, given the nature of my work, it is only appropriate that I share some necessary insights with my readers for a comprehensive understanding of farmer education in a rural setting. Following a general description of the country's poverty status, this chapter will highlight the socio-economic conditions, gender norms, women's participation in farming, sources of knowledge and resilience in the farming communities in rural Rangpur.

Bangladesh has recently achieved the lower middle income country status graduating from her earlier low-income status (WDI, 2016). The share of population in the country living in extreme poverty, with less than $1.90 a day based on 2011 purchasing power, has fallen from 33.7% in 2000 to 18.5% in 2010 (World Development Indicator, 2016) as 16 million people moved from extreme poverty. However, according to the latest "Bangladesh Development Update and Poverty" the country still remains the 64th poorest out of the 154 countries (World Bank, 2016a). Rangpur represents the largest concentration of the poorest population – with over 42% people living in poverty – in Bangladesh (Zutt, Kamal & Rader, 2010; Rukunujjaman, 2016). In order to understand how the national economy is affected by the agricultural sector, run largely by the rural population, one has to consider the share of population involved in this sector.

Over 60% of Bangladesh's 162 million inhabitants subsist on agriculture, responsible for 47% i.e. almost half of the total national income (BBS, 2015; WDI, 2016). Agricultural industry has directly employed 18.70 millions of people in 2000, which surged up to 22.74 million in 2010 (World Bank, 2016). As such, the entire country is significantly impacted by global warming and declining soil fertility, which has not only led to a significant drop in crop yields, but also changing knowledge of soil and water management (World Bank, 2015).

Bangladesh, an agricultural economy-based state, is divided in seven administrative divisions. Among these divisions, Rangpur has the highest incidences of poverty. According to the Bangladesh Integrated Household Survey (BIHS) by IFPRI, in 2011–12, about 38.2 percent of people in rural Bangladesh lived below poverty level (USD 1.25 per day) (Ahmed et al., 2015). In Rangpur and more generally in rural Bangladesh, decreasing crop yields have prompted many men of rural societies to migrate to cities and foreign countries, seeking higher income employment resulting in more women taking charge of agricultural production to fill in this gap (Hadi, 2001; Karthiki, 2011; Mizanur, 2012; Rashid, 2013; Ullah, 2017).

The gradual but steady shift in agricultural population distribution involving over 100 million people in rural Bangladesh had a significant impact on agricultural knowledge distribution in rural areas. This is important because seminal research – focused on male farmers as the main beneficiaries of farmer education and extension services – suggested that agricultural productivity in low income countries were strongly influenced by education (Jamison & Lau, 1982; Lockheed, Jamison & Lau, 1980). Currently, in rural Rangpur, both men and women are actively involved in farming. As a result, farmer education offers a viable solution to improve food security and reduce the longstanding gender gap in women farmers' bargaining power and participation (Agarwal, 1994). However, despite increasing demands for participation in agriculture, women lack access to land and assets, restrained by property rights and education (Srabonia et al., 2014).

In the following section, I will briefly discuss the socio-economic configuration of rural Bangladesh, especially Rangpur, followed by a brief description of literacy practices, women's role in agriculture and resilience in farming communities.

3. A. Rural Bangladesh (Rangpur): Education, agriculture and socio-economic conditions

Located in the northwestern part of the country, Rangpur covers an area of about 23,0778 square kilometer with a population of 33,34,567 (See Figure. 3.1). Rangpur comprises 8 *upazillas* and 83 unions[9] with a population density[10] of about 1100 people per square kilometer, which is slightly less than the country's average of 1,236 people per square kilometer (LGED, 2017).

Figure 3. 1: Political Map of Bangladesh
(Source: www.mapsofworld.com)

Figure 3. 2: Map of Rangpur with 8 upazillas

Of the 83 unions and eight *upazillas*, this study covers only 21 villages in seven unions representing a total of six *upazillas*. The treatment villages belong to Rangpur Sadar and Gangachara *upazillas* and the control villages belong to Kaunia, Mithapukur, Taraganj and Badarganj (See Figure 3.2). The villages belonging to the treatment group in my study are situated in Haridebpur, Gajaghanta and Kolokondo unions, and those from the control group belong to Imadpur, Ekchali, Kalupara and Kursha unions.

[9] These are administrative units scaled as division-districts-upazillas-unions-villages.

[10] Population density (people per sq. kilometer of land area) is midyear population divided by land area in square kilometers.

The map below (See Figure 3.3) shows the land layout of the Haridebpur union in Rangpur Sadar upazilla – the union with the most treatment villages – in Rangpur, outlining large areas of agricultural land and interspersed freshwater bodies.

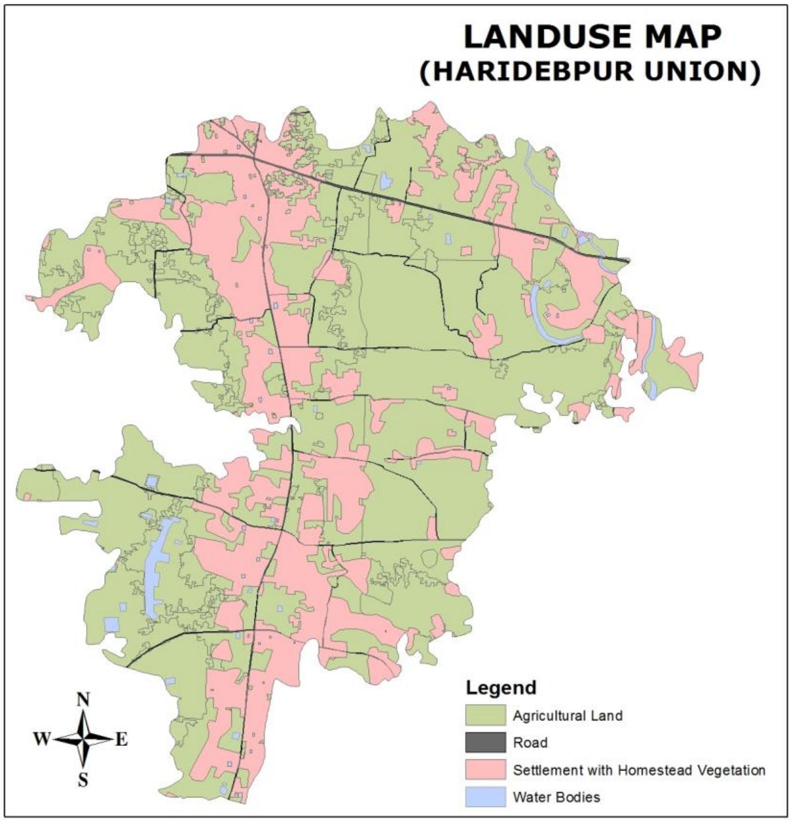

Figure 3. 3: Land use map of Haridebpur union

3. A. 1 Education

According to the latest national population census, over 80% of the population in Bangladesh live in villages (BBS, 2011). Among them 47% of these rural population ages 15 years or above report direct involvement with agricultural work with a literacy rate of 56.09 % for men and 46% for women. In Rangpur, the literacy rate is slightly higher than the national average with a 55% literacy rate. Nationally, about 36% of the population received elementary education, about 22% did not complete secondary education while 30% managed to earn some secondary degree and only about 6% of the population never experienced any formal schooling (BBS, 2011). Despite 92% of the population experiencing some form of elementary education, the low literacy rate is indicative of poor quality public education.

To support farmer education, the government of Bangladesh has different administrative bodies assisting extension programs. According to the National Agricultural Extension Policy (NAEP), the goals for these agencies are:

> *…to encourage the various partners and agencies within the national agricultural extension system to provide efficient and effective services which complement and reinforce each other, in an effort to increase the efficiency and productivity of agriculture in Bangladesh. To achieve this goal the policy includes the following key components: extension support to all categories of farmer; efficient extension services; decentralization; demand-led extension; working with groups of all kinds; strengthened extension-research linkage; training of extension personnel; appropriate extension methodology; integrated extension support to farmers; coordinated extension activities; integrated environmental support. (Ministry of Agriculture, 2006, p.5)*

In brief, these various governmental agencies are responsible for providing information and services to farmers by utilizing agricultural extension systems focused on research, collaborating with partner agencies, training extension agents and providing integrated support to farmers to enhance productivity. Of all agricultural extension agencies, the Department of Agricultural Extension (DAE) is the largest and advises farmers on crop production – offering its services in areas of agro-climatic issues, farmer's needs and market demands (Department of Agricultural Extension, n.d.).

The characteristics of various existing programs vary across regions although a majority of them have included women at a greater rate than ever before. One of the major nationwide programs is called *One House One Farm*, supported by the Government of Bangladesh, which focuses on women's abilities to raise domestic animals and contribute to farm production. Some current farmer field schools in Rangpur are Integrated Crop and Pest Management (ICPM) and Integrated Pest Management (IPM), providing extension services to both men and women in the areas of crop production, poultry and animal husbandry, and fisheries. Additionally, there are community learning centers by UNESCO and extension services by BRAC and RDRS, as well as other literacy and adult education initiatives that educate both female and male learners, majority of them belonging to the farming profession.

Although private extension services – financed by large corporations – are common, coordination between DAE and these private programs is either non-existent or very rare. Since the main target of any private companies is to sell their products and services to increase profit margins, privatization of the extension sector poses various challenges – of the many challenges, the major challenge being limited access to these private services by the majority poor and smallholder farmers (Uddin & Qijie, 2013). Despite the appeal of a demand-driven extension system proposed by the public private partnership proponents, the provision for a service charge in extension poses a critical challenge for resource-poor farmers. Additionally, it is increasingly evident that some private companies – selling chemical pesticides – incentivize farmers to use their products that are often environmentally detrimental.

Beyond the competition between public and private extension systems, any farmer education programs in rural Bangladesh is a complex site of learning as it involves adults with diverse educational backgrounds and with varying levels of exposure, for example, formal, informal and non-formal learning. One's educational experience varies according to different individual, family, community or gender associated characteristics. Based on the characteristics of a specific community, farmers' educational experiences differ as a result of varying levels of exposure to information and opportunities for learning.

Furthermore, various cultural practices related to gender norms and division of labor result in limited or varying access to information sources as well as educational opportunities. For instance, generally, men avail of the services offered through the extension programs in rural areas. Only in the recent past, these programs have started recruiting female extension agents and officers to support women farmers' education. All female extension agents I have met during my field work for formal and informal interviews were between the ages of 25-40, while older male extension agents – serving the extension office for lengthier durations – seemed to be the norm. Given the comparatively fresh recruitment of female extension agents and officers over the last decade, it can be said that the DAE intends to reach out to more female farmers to share relevant knowledge on farming.

3. A. 2. Agriculture

The agriculture sector comprises crops, forests, fisheries and livestock. The majority of the GDP from the agriculture sector is from crop with a 71 per cent contribution while forests account for 10 per cent, fisheries for 10 per cent and livestock for 9 per cent of the agricultural GDP (NAEP, 2006). Estimates from a 2009-2010 survey conducted by the Bangladesh Bureau of Statistics show that the major crops in the country are Aman rice, Aus rice, Boro rice, potato, wheat and jute, and minor crops are: cereals, pulses, oil seeds, spices and condiments, sugar crops, fibers, drugs and narcotics, fruits (perennial), flowers, vegetables (perennial), vegetables (summer), *Rabi* vegetables (winter), other food crops, tea, palm and other non-food crops (BBS, 2015). In Rangpur, however, the major crops are Aman rice, Aus rice, Boro rice, potato, corn, wheat and tobacco. Tobacco production is largely encouraged by tobacco companies, which incentivize the farmers with extension services and agricultural technologies to pursue and expand tobacco cultivation. Despite the popularity of tobacco production among farmers owing to its profitability, the local DAE has been discouraging its cultivation and associated heavy usage of pesticides and water.

Rangpur has been historically known as the most drought-prone and food insecure region in the country. The recent changes in climate have affected Rangpur in a unique manner. Between 2008 and 2013, the average rainfall has significantly increased during the monsoon and post-monsoon periods (May-September), while the months between November and March still remain mostly dry (See Table 3.1).

Table 3. 1: Rainfall (Millimeter) - Long term average

Station Name	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rangpur	43	37	77	735	1636	2432	2012	2465	1636	871	5	2

Source: Climate Information Management System by Bangladesh Agricultural Research Center

The amount of rain experienced in this region has drastically increased over the last decade as a direct result of drastic climate change. While on one hand, higher lands benefit from the radical increase in rainfall, on the other hand, lower lands experience both flash and persistent floods. Similarly, on one hand, the formation of flood plains along the Teesta River in Rangpur is seen as a boon and on the other hand, flooding has a negative impact on crop productivity. A recent study reports formation of such flood plains in Gangachara Upazilla, one of the treatment areas in my study (Islam & Sarker, 2017) which also experiences flooding in low-lying areas. Importantly, harvest has been negatively impacted in 2016 in this area due to flooding of a large extent of land area in 2016.

While one can have mixed reactions about how increasing rainfall and flooding affect Rangpur, the status of soil degradation due to increased use of chemical fertilizer and pesticides is unanimously considered a major threat to the agricultural sector in Rangpur. Based on observations at the project site, it was evident that there is a knowledge gap about the interconnected relationship between use of pesticides, food quality and safety among farmers. In Rangpur, one of the major threats to crop productivity has been the steady decline in soil fertility as a result of the growing use of chemical fertilizer and pesticides, fueled by incentives from local and international agencies to use harmful chemicals. Owing to this phenomenon, the soil been increasingly devoid of natural minerals and nutrients, which in turn compelled the farmers to resort to an ever-increasing use of some chemical fertilizers. For example, urea usage increased drastically between the years of 1981-1982 to 2011- 2012 (Figure. 3.4) compared to other chemical fertilizers such as TSP, SSP, DAP, MOP and Gypsum.

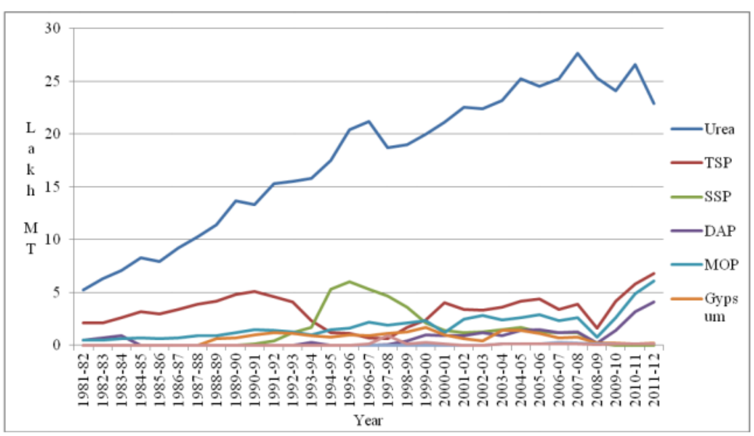

Figure 3. 4: Fertilizer use by different types in Bangladesh (1981-82 to 2011-12)

Source: IFPRI, 2013

Despite the fact that rural communities hold their own wisdom about maintaining the natural balance of soil composition, and government and international agencies such as the World Bank and FAO encourage organic methods for production, the after-effects of numerous modern extension interventions, which had earlier incentivized farmers to use chemicals and pesticides, still prevail. As a result, many disadvantaged farmers still believe that they need to use chemicals for bumper production, leaving their soil further deprived of nutrients and required minerals. This phenomenon gives rise to a second challenge in the form of increased acidity of the soil (Smithson, 1999). My examination of the IAPP program therefore includes adoption of a few major environmentally sustainable agricultural technologies (ESATs) – such as liming of soil and use of organic fertilizers (farm yard manure and vermicompost) – implemented by the program to train local farmers to address soil infertility and acidity issues.

3. A. 3. Socio-economic conditions

A single source of income is not adequate for supporting a farm-based household year-round. Therefore, men in farming families have multiple occupations ranging from small business, government jobs, teaching, rickshaw driving, hired labor to other forms of manual labor. Females in a household are either NGO workers, teachers, students or home makers and spend all of their time outside of primary occupation in farming and household associated work. More or less, every family wants to ensure agricultural production provides for food for the family. However, small farmers and their families do not produce enough rice or other major crops like wheat and potatoes to last them year-round. And only those families who own large amount of land can afford to sell produces after securing their annual food stock.

Access to water, electricity and sanitation in rural Rangpur varies by economic conditions of households. Since farming requires regular access to water, many farming households install shallow or deep tube-wells depending on the geographical location of their houses or use neighbor's wells. The amount of money spent on accessing water is dependent on the location of a household, for instance, comparatively expensive deep-tube wells are needed in drier regions.

Additionally, access to sanitation and electricity are fairly common. While access to electricity is ubiquitous in Rangpur due to *Polly Biddut* (translation: Rural Electricity) Initiative, the power supply is interrupted at various times of day and night. The series of intermittent interruptions in power supply is referred to as *load shedding*. Sanitation is not completely affordable to small and poor farming households although there are existing initiatives by the government and local NGOs to support free toilet installation to maintain the health and hygiene of rural families. Often times, the human wastes from toilets are disposed of in nearby swamps, causing water pollution and problems related to mosquito infestation.

In the villages in Rangpur, most households are headed by men. Exceptions – families with female family members in charge of household and agricultural decisions – occur only when males in a family are either physically or mentally unable or have deceased. In these female-headed families, women are free to make decisions regarding their time and monetary investment in any areas of farm production as they deem appropriate. In male-headed households, women (mostly wives or mothers) members of the family still play a major role in the production related decision-making process. However, men consult with their female family members regarding agricultural decisions in the privacy of their house rather than in social spaces. In public settings, men are considered as decision makers although any important economic decision is made in consultation with all adults in the family.

The rest of this chapter will focus on literacy and numeracy practices, cultural norms, women's participation and resilience in farming communities.

3. B. Literacy, numeracy and knowledge sharing

Adult literacy and livelihood performances are intricately connected. One of the ways, literacy skills help an adult to navigate the real world is through knowledge and information acquisition relevant to their livelihoods.

3. B. 1. Literacy and numeracy skills and practices

According to the latest national population census, literacy is defined as the ability to be able to "write a simple letter" (BBS, 2011, p.2). The national literacy rate for men is 46.81% and the share of literate women is 42.59 % while the national share of literate adult population is 44.70 % (BBS, 2011). As mentioned above, the low literacy rate is indicative of poor quality basic education in most parts of rural Bangladesh. Successful farming households usually have household heads and multiple family members with higher levels of education[11].

Generally, in rural areas, literacy is understood as the ability to sign one's name on a piece of paper. However, functional literacy practices among farmers vary quite a bit depending on one's levels of literacy and numeracy skills. As for the state of literacy and numeracy skills among farmers, most of the time, these skills are called into practice when they read newspapers, news headlines (while watching news on TV) and brochures to find necessary information on specific farming technologies, instructions from a manual, political manifestos, advertisements on bill boards, and help children read along with other daily encounters with letters for different purposes.

Basic numerical competence is a critical skill that most farmers need or they know someone nearby who can help them with simple addition, subtraction, multiplication and percentage counting. Farming requires buying and selling of raw materials and produces as well as keeping track of quantity of rice or other crops harvested. Numeracy in Rangpur's context follows local methods of measurement. Men and women with some kind of exposure to primary education are able to conduct simple calculations, however, more men than women are likely to possess these skills if they are in their thirties, forties or at a later stage in their lives.

3. B. 2. Sources of information and knowledge sharing

Knowledge in agricultural settings is dynamic and the state of knowledge differs between people from one place and time to another depending on how effective they are in procuring and retaining knowledge, needed for making efficient farming decisions. IAPP was a public educational intervention making it possible for farmers to acquire knowledge through a limited

[11] About 38% of the skilled population involved in agriculture, fisheries or forestry finished primary school and 21 % completed secondary education, while about 29% of the population completed higher secondary education, only 3% finished college and about 1% completed their masters or graduate education. Only 8 percent of this skilled population did not complete their primary education (BBS, 2011).

number of training sessions as well as continued contact with the Community Facilitators (CFs) and government Sub-assistant Agricultural Officers (SAAOs). The SAAOs are the primary sources of knowledge for all farmers. Those in the program also had access to CFs, who were in frequent contact with farmers, helped implement new technologies and provided useful information in the monthly meetings during post-training period.

Both men and women in the treatment and control villages I visited seemed confident in reaching out to CFs and SAAOs. However, women, who had reported reaching out to extension agents were either elderly – about 50 years of age or above (when a woman is considered an elder citizen in the local community) – or household heads – or most likely both. Elderly women are comfortable calling up the SAAO or CF directly, however, this is not a widespread practice. Women usually seek help from their male neighbors or relatives when they do not have a male in the family to reach out for extension support.

It is very common among well-to-do male household heads to call SAAOs or speak with them during field visits. One of the farmers, Afsanur Miah in his fifties, who is also a chair of an IAPP group, stated his experience about working with the CFs and SAAOs in his village.

> *Specially, I want to talk about the CF in our area. I do not know what the CFs in other areas are doing. Our CF organized us, introduced savings and sharing [for the group]. After forming this group, we eventually formed a savings account. The savings has served some of our members during very difficult times. (July 2016)*

Besides getting information support from extension agents like SAAOs, AEOs and CFs, farmers also obtain information from TV and radios on weather and agricultural technologies. The most popular TV show on agricultural education – providing up-to-date knowledge about best farming practices for about three decades– is *Hridoye- Mati o Manush*, previously known as *Mati O Manush.*

3. C. Women in agriculture

Women's participation in agriculture is often interrupted by various cultural and economic factors. This section highlights the role and participation women in agriculture with a focus on cultural and social norms guiding their activities and contribution in a rural household-based farm.

3. C. 1. Role in agriculture and gender norms

The relationship between women in rural Bangladesh and agriculture has been a longstanding and indispensable one. In southeastern and eastern Asia, women constitute over 50% of the agricultural labor force (FAO, 2011). A well-established myth has been that, in Bangladesh, women exclusively contribute in post-harvest crop processing; this popular belief severely underestimates their contribution in farm productivity given women's continuous involvement in agricultural management and production activities (Rahman & Routray, 1998). In reality, rural women participate in all aspects of agriculture including planning, implementing and managing farm production despite "differences in property rights, education, control over resources (e.g., land), access to inputs and services (e.g., fertilizer, extension, and credit), and social norms" for men and women (Coppensteidt, Goldstein & Rosas, 2013, p. 1). However, women in Bangladesh are primarily considered as care-givers and home makers – they grow up learning to focus on caring for their families and accept their low levels of engagement in economic decision-making – following the established norms – leaving it up to the males of their family.

Although there are multiple factors at play, it is reasonable to say that the existing gender norms arise from the inherently patriarchal nature of rural societies and result in negative consequences for food security and nutrition for individual families as well as exclusion of women from commercial farming. Recent work suggests that there is a gender dimension to inequality reflected in women's poor access to education and health services in South Asia, contributing to chronic child malnutrition and food insecurity (Srabonia et al., 2014; Smith et al., 2003; von Grebmer et al., 2009). As a result, there is a direct price to pay for limiting women's educational and economic capacities as caregivers and nutrition manager of families. There is evidence (Coppensteidt, Goldstein & Rosas, 2013) that the gender gap in economic returns on commercial and contract farming is not closing despite improved GDP, and access to resources and agricultural input, while women continue to provide labor in the industry in greater numbers than ever before.

Women's role and participation in farming and related activities in a rural environment are heavily influenced by gender norms that are embedded in the social fabric of culturally Muslim[12] and historically male centric communities in Bangladesh, with regular opposition from conservative groups that feel threatened by women empowerment (Adams, 2015). The culture of gender divide in all spheres of life due to limited mobility of women, purdah associated practices and labor division often render existing development programs ineffective (Naved et al., 2011, Lamia, 2011). Due to these practices and norms, women's access and participation in farmer education is limited by heavy social restrictions involving women's behavior in public or social spaces. At the project site, I observed that women did not ask as many questions as men when they meet local agricultural authorities such as SAAOs and AEOs. Often, they passed their questions through husbands, brothers, sons and male neighbors to find out answers to their questions from officers.

Figure 3. 5: Photo of a farmer field school meeting with male and female farmers (July, 2016)

Often women are quiet learners, usually sitting at the periphery of an FFS meeting (Figure 3.5). Women learn but do not speak up often in these meetings. It is only possible to find

[12] Almost 89.1% of the population is Muslim, about 10% is Hindu and the rest 0.9% represent Buddhist and Christian beliefs (BBS, 2011).

out how much they have learned through one-on-one discussion. However, the reasons behind women's preference for this kind of quiet learning practices are linked to the unstated gender norms widespread in Bangladeshi rural societies.

Although the recent trend involves college educated females and males seeking employment in cities and thereby leaving villages, women's involvement in farming is determined mainly by their husband's and in-law's profession and wealth. Anyone who has lived in a Bangladeshi village can tell that young women coming from a middle- income background in villages are more likely to pursue a high school degree or college education than participating in a farmer education program. Women are typically expected to move in with their in-laws after marriage with a few exceptions[13]. As a result many young and old women chose farming by default because of marrying someone in the village. Women's physical participation in farmer education as productive adults is a more recent phenomenon, expanding the physical space of women's empowerment (Olawoye, 1996) – a phenomenon that clearly breaks away from a long standing gender norm where women's socio-economic conditions are determined by those of their husbands or fathers

3. C. 2. Purdah and participation

In the context of Bangladeshi societies, *purdah* is usually understood as a collection of norms and rules with regard to women's exclusion or restricted participation in any public activities, broadly demonstrated through confinement of women in household activities and covering of women in social spaces (Amin, 1997). However, many different interpretations and adoption of purdah practices in different communities prevail and are demonstrated in different ways – commonly employed to control women's economic and social activities, especially in rural areas.

Not surprisingly, majority of women farmers (who are Muslims or Hindus) are physically limited by their circumstances from showing up for farmer field school meetings. If they attend the

[13] One of the community facilitators in IAPP, in his early thirties, stated that his wife, whom he met in agricultural college, works as a teacher in a different village. While he lived with his parents, she lived close to her work place. This kind of phenomenon is quite rare and the CF pointed out to me that despite his expectations, he cannot ask his wife to leave her job and stay with him because she is educated and has ambitions for her own career.

meetings, it is expected that women will conform to “purdah” associated norms and speak sparingly, technically implying restricted participation access in an active conversation. When women participate in a discussion, it is not met with a lot of enthusiasm, especially among males in FFSs. This is not to say that there are not exceptions; in fact, the numbers of exceptions are on the rise according to both female and male farmers, even though women’s enthusiasm for participation is not received with the same level of eagerness by male-dominated, farming societies. For instance, women who have been vocal and active in IAPP were identified as “vocal women”, “leaders” but also as “the ones with the loud voice” or as “the talkative ones.” Male farmers describe some of these women as “strong” “talkative” and “too eager to learn” while women’s perceptions of female farmers who actively participate allude to the strength, leadership and enthusiasm of the women. In brief, participation of women is neither looked down upon by the rural communities surrounding these farmer field school meetings nor it is celebrated. At best, women’s enthusiasm to participate in farmer education is welcomed and at times is considered a matter of cheerful joke, exclusively made by some male farmers in the groups.

3. C. 3. Vegetable farming

As the main managers of a family’s dietary distribution, vegetable gardening is a space where women make all major decisions. However, female farmers, who tend to miss more FFS training sessions compared to men due to domestic responsibilities and established cultural norms, also tend to miss out on the opportunities to drastically improve their adoption and knowledge of environmentally sustainable farming methods. Through my observation, it was clear to me that households with female participants in the program tend to make smart choices regarding vegetable production for family consumption, using organic compost and fertilizer compared to households with male participants. Therefore, loss of female participants or lack of participation in FFSs can compromise the effectiveness of a participatory farmer education program by negatively impacting the most common sustainable production practice through vegetable farming in rural areas.

3. D. Resilience

Agriculture is a dynamic sector where education comes hand in hand with facing production challenges on a daily basis. What is unique about both female and male farmers is that they are resilient in the face of adversity. For example, Rownok Ara[14], a female farmer in her fifties describes her encounter with the “dhaner sheesh shada” (i.e. whitening of the rice seedling) disease in the following way:

> *I was checking the paddy field every day: going back and forth. Suddenly one or two of them were affected and I immediately applied pesticides. I did not make any delay at all. Even after that I was deeply saddened by what I saw later. O Allah! All of my field was affected. Each individual bunch of the rice seedlings was so thick! I planted them in line and after every ten lines I kept some space and yet they were affected. I asked Hamidur [a neighbor and relative] to bring me Phosphate but the rice came out even before I could apply it [phosphate]. I was perplexed to see the paddy. So much of it was affected. If this disease did not affect the paddy, I would’ve harvested a larger quantity of rice.*

Before she described to me her encounter with an increasingly common rice disease, where the tip of the rice seedling turns white, she expressed her gratitude that she could harvest 2/3rd of the rice despite this damaging disease. I have encountered many similar incidents during my field work in Rangpur.

The celebratory nature of the production culture among farmers in rural Bangladesh can be interpreted as a culture of resilience, especially when flood or dry seasons or the evolving nature of pests and disease negatively impact the production in these areas. Through a positive approach to challenges, these farmers live and build a culture of resilience in their communities despite various natural and man-made disasters.

3. E. Summary

Bangladesh, one of the most densely populated countries in the world with over 162 million people, has an agro-based economy that engages over 60% of the total population despite various man-made and natural disaster associated threats to agricultural production. In this chapter, some important contextual information about rural Bangladesh, with a focus on

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[14] Pseudonyms were used instead of actual names to maintain anonymity of the participants in the study.

Rangpur, were highlighted in order to provide insights into the socio-economic configuration of rural lives followed by a brief description of literacy practices, role of women in agriculture and resilience of the farming community. The farmers in Rangpur – known for its extreme weather and hardships of local farmers – represent the most marginalized farming population in rural Bangladesh. Therefore, the challenges faced by the farmers in Rangpur, discussed in this chapter, are relevant to understanding the lives of small and marginalized farming populations in other countries and how they cope with various global warming and chemical induced environmental challenges as well as limiting gender norms.

CHAPTER 4: METHODOLOGY

4. A. Research design

This chapter provides a detailed description of the survey data, research objectives, population sample, model specification and data analysis procedure to explain the choice of methodology in this research. The data employed for answering the research questions in this study were obtained from the baseline and the endline surveys (See Table 4.1 for details).

Table 4. 1: Survey data source

Survey types	Duration	Additional information	Measurement of dependent variables
Baseline	1.5 hours (approx.)	Designed and implemented by DIME (World Bank) and IPA prior to the intervention in 2011	UESAT and yield
Endline	2.5 hours (approx.)	Adapted from the baseline survey by the researcher and administered by her team post-intervention in 2016	KESAT, UESAT, yield and productivity

The methodology of this study addresses the three main research questions at the school level:

1. Are farmers with FFS training more productive compared to those without FFS training? (using data from baseline and endline surveys for both cross-sectional and longitudinal data analysis)

2. Do FFS educated farmers have greater knowledge of environmentally sustainable agricultural technologies (KESAT) compared to those without FFS training? (using only the cross-sectional data from the endline survey)

3. Do FFS educated farmers use environmentally sustainable agricultural technologies (UESAT) with greater frequency compared to those without FFS training? (using data from baseline and endline surveys for both cross-sectional and longitudinal data analysis)

Additionally, in order to understand the impact of IAPP education at a program level, the study explores the relationship between the different outcomes KESAT, UESAT and productivity.

Mediation analysis is carried out to detect whether KESAT mediates the impact of the program on the other two outcomes.

This study tests the null hypotheses related to the above questions by considering two different groups of households: a) the treatment and b) the control groups[15]. These groups are comprised of households from 15 treatment and 6 control villages (clusters) respectively. A minimum detectable effect size (MDES)[16] of 0.478 was calculated for the current sample size (J=21) of treatment and control villages with an average cluster size of n=30 in each of the groups (for p=0.80 and α=0.05) (Dong & Maynard, 2016) (See Figure 4.1 for details). To determine the impact of farmer field school (FFS) education in Integrated Agricultural Productivity Project (IAPP) the study employs data from two different surveys (See Table 4.1).

1. The survey data collected by the World Bank prior to the intervention is referred to as the baseline data.

2. The survey data collected in 2016 by the researcher and her team of 11 enumerators and one field coordinator is referred to as the endline data.

In this study, the major outcomes or performance indicators are: productivity, use of environmentally sustainable agricultural technology (UESAT) test score and knowledge of environmentally sustainable agricultural technologies (KESAT) test score. Productivity is measured as a ratio of total output from land to the total number of household members actively involved in agricultural production (kg/n). UESAT and KESAT scores are measured as continuous variables and a dummy variable (iapp=0, 1) is created to represent the treatment, indicating farmers' participation in IAPP schools.

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[15] Overall, the quantitative data analysis procedure employing the above data comprises of hypothesis testing (e.g. t-test); bivariate and multivariate linear regressions accounting for robust cluster standard errors; multilevel random effects modelling; difference in difference estimation; and effect size calculation to discern the program outcomes. In addition, the analysis includes mediation analysis for explaining the process behind how the FFS education system generates different types of impact.

[16] MDES shows the smallest true detectable effect in standard deviations of the outcome for a given level of power and statistical significance. The estimation was done using the Power Up! MDES estimation tool.

Various socio-economic characteristics and individual characteristics are represented as index, continuous and categorical variables based on the guidelines in established literature (Alene & Manyoung, 2005; Feder et al., 2004; Crouch et al. 2017; Godtland, 2004; Lockheed & Lau, 1980) and contextual knowledge. Following the conceptual framework (See Figure 2.2, Chapter 2) – providing guidelines grounded in current evidence – this research analyzes the impact of the program by considering individual, household and community level characteristics due to their varying levels of impact on the three major outcomes of IAPP education examined in this study.

Model: MDES Calculator for Two-Level Cluster Random Assignment Design (CRA2_2)— Treatment at Level 2

Assumptions		Comments
Alpha Level (α)	0.05	Probability of a Type I error
Two-tailed or One-tailed Test?	1	
Power (1-β)	0.80	Statistical power (1-probability of a Type II error)
Rho (ICC)	0.15	Proportion of variance in outcome that is between clusters
P	0.50	Proportion of Level 2 units randomized to treatment: J_T / (J_T + J_C)
R_1^2		Proportion of variance in Level 1 outcomes explained by Level 1 covariates
R_2^2		Proportion of variance in Level 2 outcome explained by Level 2 covariates
g*	1	Number of Level 2 covariates
n (Average Cluster Size)	30	Mean number of Level 1 units per Level 2 cluster (harmonic mean recommended)
J (Sample Size [# of Clusters])	21	Number of Level 2 units
M (Multiplier)	2.60	Computed from T_1 and T_2
T_1 (Precision)	1.73	Determined from alpha level, given two-tailed or one-tailed test
T_2 (Power)	0.86	Determined from given power level
MDES	**0.478**	Minimum Detectable Effect Size

Figure 4. 1: Snapshot of MDES calculation for two level cluster random assignment design

The empirical work that follows focuses on the three performance indicators (UESAT, KESAT and productivity) for the cross sectional data analysis by employing the endline survey data. The baseline survey did not include any questions regarding farmer knowledge (KESAT). Hence, yield and use of environmentally sustainable agricultural technology (UESAT), only two of the three major outcomes, are considered for the panel data analysis, which utilizes both baseline and endline survey data. In case of productivity, treatment groups are expected to perform better compared to the control groups that did not receive the intensive educational training at IAPP schools. A special area of focus at IAPP schools was generating knowledge and implementing technologies regarding the use of organic fertilizer and natural methods for controlling pests, which was also highlighted in the IAPP curriculum. It is thus expected that UESAT and related KESAT score will be greater for the treatment villages and households compared to the ones in the control group.

4. A. 1. Research objectives

The objective of this research concerns the extent to which non-formal education in Integrated Agricultural Productivity Project (IAPP) contributes to adult farmers experiencing: 1) higher productivity; 2) UESAT with greater use frequency; and 3) greater level of related knowledge (KESAT) when compared to those without the educational training. Since IAPP recruited both female and male farmers, this study also examines productivity, UESAT and KESAT outcomes for both female and male farmers in Rangpur. The literacy rate for both men and women in Rangpur are the lowest in the country and the rate is even lower among women (See Chapter 3). As a result, this research also investigates if low or high levels of literacy significantly affect farmers' productivity, UESAT and KESAT. The following table (Table 4.2) summarizes the data collection and analysis process:

Table 4. 2: A summary of the data collection and analysis process

Research questions	Data Collection	Data Analysis
1. Do farmers in the IAPP Farmer Field School (FFS) demonstrate higher levels of productivity when compared to those without non-formal educational training? Productivity is measured as the average output from land for each active household member.	-Two different surveys administered to households in treatment and control groups before and after entering into the program. The baseline survey was conducted by Innovations for Poverty Action on behalf of the World Bank. The endline survey was administered by the researcher and her team.	-measurement of productivity -causal analysis using Stata and JmP - random effects multilevel modelling, structural equation modelling, and difference in difference estimation using Stata
2. Do farmers in the IAPP schools have higher UESAT score compared to those without the training? UESAT is measured as an aggregated score on a test measuring the use of 7 different types of ESATs.	-As above	-measurement of UESAT -causal analysis using Stata and JmP -multilevel modelling, difference in difference and structural equation modelling using Stata
3. Do IAPP farmers have greater KESAT score compared to those without the training? KESAT is measured as an aggregated score on a test consisting of ten questions on knowledge of selected ESATs from those promoted in IAPP.	-As above	-measurement of KESAT -causal analysis, random effects multilevel modelling and structural equation modelling using Stata and JmP

4. A. 2. Research setting, population and sample

The IAPP groups were established to increase productivity of farmers in three areas a) crop, b) fisheries and c) poultry and animal farming. Since this study focuses on only crop productivity, this section will highlight the implementation of this program through the Department of Agricultural Extension (DAE). Along with the DAE, the program office supported the creation of treatment groups of 25 male and female farmers in a total of 45 villages (N≈1,125) in Rangpur division. Among all groups in these villages, over half of them were focused on improving crop productivity of small farmers. The sample for this study, consisting of only 21 villages i.e.15 treatment and 6 control villages, was non-randomly selected from a larger set of randomly assigned villages (T_0=23) and all 6 long-term control villages (T_c=6).

In IAPP, field facilitators (FFs) from local communities were trained by the local agricultural extension office to work with the small farmers by meeting with them on a bi-monthly basis. The farmers received a ten day training session through the course of 6 months from the Sub-Assistant Agricultural Officer (SAAO) and the Agricultural Extension Officer (AEO), and continued meeting with the FFs post-training to ask questions and seek solutions for any ongoing issues. Occasional meetings were also held at the local agricultural extension office organized by the AEO, program managers and coordinator to ensure continued use of the new practices learned at IAPP schools by the farmers. Additionally, farmers were encouraged to create savings account for the future sustainability of these groups.

4. A. 2. 1. Baseline

The sample from the baseline survey, administered by the Innovations for Poverty Action (IPA) in Rangpur division, originally consisted of 55 villages randomized to 27 treatment and 28 control groups by the IAPP local office. In the baseline survey, a total of 1022 farmers were identified to be either in treatment or control groups (See tables 4.6 and 4.7). Of them, 468 (45.79%) were identified as people in the control groups from 28 villages and 554 (54.21%) from 27 treatment villages. However, the rest of the 1102 respondents were not assigned to any groups.

Table 4. 3: Assignment of farmer to treatment and control groups in the baseline

Groups	Villages	Farmers	Percent
Control	28	468	45.79
Treatment	27	554	54.21
Total	55	1,022	100

A total of 67 households in the baseline survey had female household heads while 2057 reported male household heads. This is not surprising given that the proportion of women in the baseline sample is very low in both the treatment (5%) and control (3.6%) villages. Only a portion of the sample consisting of 532 households was used for the panel data analysis, based on matches with the endline data. The baseline data contained information about farmer productivity and technology adoption, however, no data on knowledge was recorded. The endline survey collected data on all three major outcomes (See Table 4.1).

Table 4. 4: Proportion of females and males in the baseline survey

Gender	Treatment	Control	Neither
Female	27 (5%)	17 (3.6%)	67 (3.2%)
Male	527 (95%)	451 (96.4%)	2057 (96.8%)
Total	554	468	2124

4. A. 2. 2. Endline

A total of 15 of the 45 original treatment villages, and all 6 long-term control[17] villages of the 45 control villages, were selected for conducting a small-scale, in-depth impact evaluation of the IAPP schools using cross-sectional data from the endline survey. The treatment and long-term control villages in this study are located in six different *upazillas* (sub-districts) in Rangpur Division. The long-term control villages were located in four different *upazillas* and the treatment villages in two other *upazillas*. Due to the long distance between treatment and control villages, diffusion of knowledge – often times a desired outcome for farmer education programs – was deemed quite unlikely (See Figure 3.3, Chapter 3 for a map of the *upazillas*). The six *upazillas* where the survey was administered are: Gangachara, Rangpur Sadar, Mithapukur, Taraganj, Badarganj and Kaunia.

The treatment villages in the endline survey were exposed to the program between the 2015-16 fiscal year. This research examined farmers' KESAT and its relationship with farmer

[17] Due to the randomized phase-in design of the IAPP program, all villages in the control groups except these 6 control villages were eventually brought under the coverage of this intervention.

productivity and UESAT in relation to the major crops such as rice, wheat, corn, or potatoes in that year. As a result, this research chose to measure how much farmers have learned by assessing their knowledge (KESAT). This is also a necessary initial step to measuring the impact of FFS education on farmers' knowledge in a longer term study. A total of 623 households took part in the 2016 survey, with 324 households in the treatment and 299 households from the control villages. The following table shows the distribution of males and females in the treatment and control groups (See Table 4.3).

Table 4. 5: Gender distribution by treatment and control groups

Gender	Treatment	Control	Total
Female	112 *(0.65)*	59 *(0.35)*	171
Male	212 *(0.47)*	240 *(0.53)*	452
Total	324 *(0.52)*	299 *(0.48)*	623

Note: The shares of farmers from each category of gender are listed in parentheses

Of the total number of respondents a total of 171 females and 452 males were engaged. There were almost twice the number of males in treatment villages compared to females while the number of males was almost 4 times the number of females in the control villages. These numbers indicate the overall nature of male-centric production culture in rural Bangladesh.

It was seen that the highest proportion of farmers in the control (~48%) and treatment (~37%) villages had no formal education, while the next larger share of farmers had either primary or secondary/higher secondary education (See Table 4.4). This distribution also reflects the general distribution of formal education in rural Bangladesh according to the Bangladesh Bureau of Statistics (BBS, 2017). Grounded in this contextual evidence and previous literature on farmer education (Lockheed et al. 1980; Alene & Manyong, 2007), a threshold- based schooling dummy variable (HHedlevel) was introduced to represent household head's educational level. This was done, mainly, to separate household heads in farming households with formal education of 4 years or above from those with no formal educational background for understanding their influence on household-based farm productivity.

Table 4. 6: Household head's education by treatment and control groups

	No schooling	Primary	Secondary/ Higher secondary	University
Control	142	71	81	5
	(47.49)	*(23.75)*	*(27.09)*	*(1.67)*
Treatment	119	87	108	10
	(36.73)	*(26.85)*	*(33.33)*	*(3.09)*
Total	261	158	189	15
	(41.89)	*(25.36)*	*(30.34)*	*(2.41)*

Note: The shares of farmers from each category of educational background are listed in parentheses

The distribution of households in the treatment and control villages, reported in Table 4.5, presents the sample's demographics, organized by household composition, household socioeconomic status, participation in community activities and characteristics of households participating in the study. The means of the household size in both treatment and control villages are similar. The share of adult males in farming households in treatment villages is much higher compared to the households in control villages while the share of adult females is slightly higher in control villages. As expected, the number of male respondents was larger than the number of female respondents across both treatment and control groups. The household socioeconomic status (SES) was relatively low in the control villages with an average of USD 2,013 compared to USD 3,038 in the treatment villages. The average household in the control group earns three dollars less than an average treatment household at a daily rate, implying that the difference in SES among these households will need to be considered for outcome measurements. Additionally, households in the treatment villages have an additional hired labor compared to those in the control villages.

Similarly, participation in farmer groups are higher in treatment than control villages. Due to the specific requirement by the IAPP schools to recruit women farmers, there is a larger share of women participants from the treatment villages. Still, less than half of the participants are women in treatment villages while less than one third of the respondents are women in the control group. The number of male household heads are the same while the number of female household heads are very low in the treatment and much lower in the control villages. Additionally, there is a one year gap in the formal education levels of household heads in the treatment and control groups.

Table 4. 7: Descriptive statistics by farmer groups and household categories

Categories	Groups	
I. Household composition (2015/16)	**Treatment**	**Control**
Household size (mean)	4.7	4.2
	(1.6)	(1.4)
Adult Males (%)	60.32	39.68
	(0.4)	(0.44)
Adult Females (%)	47.18	52.82
	(0.45)	(0.47)
II. Household socio-economic status (2015/16)		
Total expenditure per year (in BDT)	24,4908	16,2294
(in USD)	3,038	2,013
	(197458)	(182905)
Number of Hired laborers	6.2	4.9
	(3)	(3)
Number of years of education of household head	4.3	3.5
	(4)	(4)
III. Participation in Community Activities (2015/16)		
% in co-operatives	0	100
	(0)	(0.1)
% in farmer groups	94.62	3.38
	(0.41)	(0.17)
IV. Number of households (2015/16)	324	299
Number of female participants	112	59
Number of male participants	212	240
Number of female Household Heads	23	14
Number of male Household Heads	293	293

Note: Standard deviations reported in parentheses

The differences in ratio of SES status, hired labor, formal education of household head, female household heads and household composition by gender between treatment and control villages may be a factor of either 1) the truncated sample of treatment groups used in the study or, 2) biases in the selection of treatment villages or, 3) both. Therefore, in the analyses, these individual variables were diagnosed for any significant influence on program outcomes and were taken into account in the regression models when found influential.

4. B. Survey instruments

The impact of the non-formal education in IAPP schools on productivity, UESAT and KESAT was studied using data obtained from baseline survey administered in 2011 and endline survey administered in 2016[18] (See Table 4.1). The primary unit of analysis in this study are individuals nested in villages or clusters.

4. B. 1. Baseline and endline surveys

The endline survey, adapted from the baseline survey questionnaire, is comprised of a battery of questions on all three variables of interest mentioned above; however, the baseline survey does not contain information about farmers' KESAT[19]. First, the impact of IAPP schooling on all three major outcomes (productivity, UESAT and KESAT) will be evaluated using the data on treatment and control villages from the endline survey. Second, using data from both baseline and endline surveys, the impact of the IAPP program will be evaluated to determine any shifts in UESAT and productivity among the IAPP farmers[20] between the years of 2012 and 2016.

The endline survey was adapted from the baseline survey questionnaire, used to capture data on agricultural productivity and UESAT (See Table 4.8 and 4.9).

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[18] Long term control villages are those villages which were included in the baseline survey and had not received the treatment. Because of a randomized phase in trial design other control villages had received the treatment at different points during the project cycle except the long-term control villages.

[19] The study employs an explanatory sequential design to develop the survey questionnaire for the endline survey (Creswell, 2015). Employing this particular design, in the beginning of the study I collected qualitative data on farmers in the area, which led to a quantitative phase of data collection after adapting the baseline survey instrument to collect data in the immediate post-intervention period. Due to this specific design it was possible to create an endline survey with detailed information about variables, with most impact on the program outcome such as knowledge, literacy and attitude.

[20] Survey data collected in 2012 and 2016 vary by individuals in different villages as the randomization was carried out at the village level and can be explored in descriptive analysis of heterogeneity in group mean and quality. However, I can still causally identify the effects of IAPP education as my data comes from an existing randomized experiment.

Table 4. 8: Description of variables and measurements

Treatment Dummy Variable	Dependent Variables
Farmer education in IAPP iapp=1 iapp=0	-Productivity -Use of environmentally sustainable agricultural technologies (UESAT) - Knowledge of environmentally sustainable agricultural technologies (KESAT)

Additionally, the endline survey was tested for reliability and validity before final administration among a similar group of small farmers in the Dhaka Division. The survey consisted of the following sections: household identification; individual identification; access to extension and other trainings; agricultural input and output; housing, income and expenditure; farmer groups, household gardens; negative shocks[21] and social network; knowledge, perceptions, attitude and beliefs; and literacy and numeracy assessments (See Appendix: Survey Questionnaire for details).

In the endline survey, questions on household identification; individual identification; access to extension and other trainings; agricultural input and output; housing, expenditure; farmer groups and household gardens were retained from the baseline survey. The new items – included in the survey – were grouped under negative shocks and social network; knowledge, perceptions, attitude and beliefs; and basic literacy and numeracy assessments. Drawing from the endline survey data, representing 623 households in 21 villages, the following tables describe the variables utilized in the study, with their means and standard deviations (See Table 4.9).

[21] Negative shocks are defined as the financial setback experienced by a household owing to loss of crops, accident, natural disaster or other similar unanticipated events in the last fiscal year.

Table 4. 9: Categories of variables in order of appearance on the record

Variable categories	Mean	SD
A. Individual Identification		
Household (HH) members	4.5	1.5
Hired labor	5.6	3
B. Access to extension and other trainings		
Total number of sources of information	2.0	0.92
C. Agricultural input and output		
Plot size	78.8	55.7
UESAT score (Total score)	1.5	0.98
D. Housing (Scale 0-1)		
Quality of wall	0.2	0.4
Toilet facilities	0.9	0.3
E. Household Expenditure		
Total expenditure	165,502	175,599
F. Farmer Groups (#)		
Farmer group	266	0.5
Co-operative	3	0.1
G. Household gardens (#)		
Presence of kitchen garden	148	0.4
H. Negative Shocks and Social Network		
Negative shock	0.65	0.72
Total estimated loss	29,370	48,065
Number of close friends	3.5	2.5
Child care	2.8	1.8
Financial assistance (org.)	3.5	0.8
Financial assistance (ppl)	5.6	9.4
Assistance given	2	2.3
I. Knowledge, Attitude, Behavior & Norms		
KESAT score	2	1.7
Attitude	3.3	1.1
Behavior	2.9	0.8
Norms	1.2	0.5
G. Literacy and Numeracy Assessments		
Numeracy score	3.2	1.5
Comprehension score	1.7	1.8

4. B. 2. Measurement

Farmers' performance was measured by operationalizing the three major outcome variables as follows.

1. Productivity was measured as the average output for each active household member (kg/n). Yield, an alternative way to compute productivity used for ensuring robustness of the results, was measured as output from per unit area of land (kg/ha).

2. Second, the UESAT test consisted of questions focusing on the use of seven technologies, based on which farmers' UESAT was evaluated (See Table 4.10). These technologies are: green manure, mulching, alternative wet/dry (AWD) method of irrigation, line planting, double transplanting, vermicompost and installment of *koincha* or a tree branch in paddy fields. Scores were aggregated to represent a total UESAT score.

Table 4. 10: Names of ESATs

Names	**Definitions**
1. Green Manure	This weed in paddy field which is plowed into the soil for fertilization purpose. The local name of this crop is *Dhoincha.*
2. Mulching	The practice of covering earth with decomposed organic matters for enrichment of soil.
3. Alternate wet/dry method (AWD) for rice cultivation	A water saving irrigation method where water is saved by occasionally moistening the paddy field.
4. Line planting	Planting rice seedlings in line and at a specific distance (30-50 cm) from each other to ensure adequate exposure to the sun and the wind for better yield.
5. Double transplanting (*Bolan*)	Transplanting rice seedlings from a seed bed to a relatively high level land and then transplanting them back when the flood is over.
6. Vermicompost	A special type of compost produced in combination of cow dung and a type of earthworm, native to Thailand.
7. Installing *koincha*[22] in the field	This technique is useful to attract birds that prey on harmful insects in the paddy field.

3. Lastly, the test which assessed farmer's knowledge of environmentally sustainable agricultural technologies (KESAT) was called the KESAT test (See Table 4.11). The items on the KESAT test overlaps with those in the UESAT test and the former covers a broader base of farmers' knowledge related to UESAT. Measurement of KESAT is comprised of a battery of 10 questions focusing on use of lime to counter soil acidity, water saving irrigation method, quality of seeds, fertilizer usage and drought resistant

[22] A tree branch

variety of rice[23]. All questions related to UESAT and KESAT were deliberately chosen using a multi-step item-selection procedure with help from the local experts in the field.

Table 4. 11: KESAT items

1	Why is it important to lime your land? State one benefit.
2	What are the characteristics of good quality seeds?
3	Name one water saving irrigation method.
4	What is the appropriate time duration for cultivating Parija rice variety?
5	Choose the names of two beneficial insects.
6	Organic fertilizer helps (pick one of the following answers).
7	What are the two drought-tolerant rice varieties?
8	How can you control insects using integrated pest management (IPM)?
9	How to decrease acidity of soil?
10	Choose the name of a natural way of deterring pests.

Of the 11 sections in the endline survey questionnaire, the following sections received the most attention in this study.

The section on access to extension and other trainings consisted of 14 questions to investigate the sources of KESAT, frequency of access to information, gender of the person receiving information and training, and the subject matter of the information (seeds, fertilizer, pests and diseases, pesticide use, cropping practices, soil types, compost, irrigation, previous year crops or others). The section on agricultural input and output recorded information regarding input and output from the three best lands owned by individual farming households and included UESAT test (See Table 4.10).

The section on housing covered background and physical status of the housing occupancy, physical characteristics of the house, water and sanitation, and electricity. The section on income and expenditure covers food and other regular and infrequent expenses. The section on farmer groups asks questions about farmers' memberships in IAPP and other groups, duration of the membership, positions held in different groups and formal or informal savings account.

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[23] In a similar experimental study by Guo et al. (2015), a detailed knowledge test was administered to farmers in two provinces in rural China about their knowledge of rice production practices. The knowledge test included questions across four modules: nutrient management, pest management, cultivation practices and environmental challenges.

As discussed above, the section on knowledge consists of a multiple component KESAT test – with a Cronbach's coefficient of 0.705 – indicating high reliability. The items on the test are similar to an experimental study carried out in rural China by Guo et al. (2015) where the interviewees were tested for a variety of agricultural practices. Conceptually, these questions focused on land, water, fertilizer and pest management; growing time for high yielding variety and names of drought tolerant rice varieties grown in the area. Similarly, a quick assessment of basic reading comprehension and basic mathematics items was carried out, motivated by Wagner's (2011) "smaller, quicker, cheaper" (SQC) approach to assessment, to discern farmers' functional literacy abilities.

For the purpose of analysis, a composite index for socio-economic status was created to demonstrate the quality of living conditions of a farming household. The index was created by considering the different aspects of the quality of housing, access to water, quality of sanitation facilities and the total household expenditure (including food, clothing, medication etc.) using Principal Component Analysis (PCA). Principal component 1 with the highest eigenvalues was chosen to represent SES of farming households (Vyas & Kumaranayak, 2006). Similarly, indexes for attitude, perceptions and behavioral norms related to use of organic fertilizer were also created.

4. B. 3. Validity and reliability

The adapted survey instrument, used for data collection post-intervention, was vetted by a local panel of experts and successful local farmers. The panel consisted of two agricultural specialists from a local university and RDRS (a local NGO), an agricultural economist from Bangladesh Agricultural Research Institute (BARI), and two successful farmers identified by the program director of the IAPP program in Rangpur to determine the validity of the instrument (Birkenholz et al., 1994). The survey instrument underwent several iterations while under review by the panel of experts. After the preliminary review, it was pilot tested by the survey administration team among a group of rice farmers in Dhaka. Finally, this instrument along with the study obtained the approval of the Internal Review Board.

The baseline survey instrument was tested by the World Bank and they reported a Cronbach's alpha of 0.80 (Baseline report by IAPP, 2012). Later, the reliability of the KESAT test included in the adapted (endline) survey was calculated, which was found to be 0.705, demonstrating the test's reliability.

4. C. Data analysis techniques

This section details the techniques employed for 1) analyzing the data from the endline farmer survey and 2) comparing the endline data with the prior baseline data in order to measure the impact of IAPP schools on farmers' performance. To ensure efficiency, the following data analysis techniques were carefully chosen after a thorough diagnostic and explorative analysis of the data.

4. C. 1. Multivariate regression, random effects modelling and mediation analysis using cross-sectional data from the endline survey

(1) As the experiment was randomized at the village level, the sampling methods required that the individual data be nested in clusters of villages belonging to either the treatment or the control groups. In order to answer the research questions 1, 2 and 3, it was tested whether the outcome variables (productivity, UESAT score and KESAT score) were impacted by farmers' participation in IAPP schools. The analyses included hypothesis tests, bivariate regression and multivariate regressions by controlling for various individual, socio-economic and village level characteristics**.** Additionally, the robust command in Stata14 was used, which produced robust standard errors adjusted for clusters, by accounting for individual farmers nested in villages.

(2) For the final multilevel model, a random effects model was chosen for the following reasons. First, since the sample of this study represents only a portion of the original random sample, a Hausman test[24] (Hausman, 1971) was conducted to determine the consistency of a random effects model versus a fixed effects model. The test indicated that the random effects models were consistent and produced the same estimates as the fixed effect models for all the three

[24] The test was carried out to ensure the consistency of the chosen random effects models as fixed effects models are usually considered more consistent than random effects models and does not assume a random distribution of sample.

outcome measures. Second, individual household data was collected from villages randomized to treatment and control groups and the differences across these villages influence the outcome variables of interest. As the treatment varies by villages, the fixed effects model drops the treatment dummy variable (iapp=0, 1) in Stata unlike the random effects model, which estimates the coefficient for the treatment variable. Additionally, random effects modelling allowed the analysis to retain subject-specific controls (e.g., education level and gender).

The regress and re robust commands in Stata 14 were used to obtain the random effects model with robust standard errors to estimate the impact of the farmer education in IAPP on the three major outcomes while adjusting for cluster standard errors. The benefit of robust standard errors is that they do not rely on the compound symmetry structure (Allison, 2016).

(3) Cohen's d estimates were calculated to measure the effect sizes for the stated outcomes of the program (Cohen 1968, 1969, 1988). Additional variance inflation factors and inter-class correlation were also measured for all random effects models.

(4) Largely, the data analysis process consisted of fitting three ordinary least squares regression models nested within each other, and a random effects model – adjusted for robust, cluster standard errors – in order to estimate the impact of the IAPP farmer field school for each of these outcomes. The final analysis employing random effects modeling takes into account the intra-class correlation i.e. within versus between village variance. Additionally, random effects model remove the risk of omitted variables i.e. unobserved heterogeneity from the analysis that may have influenced the outcome of IAPP schooling.

(5) Employing structural equation modelling in a path diagram, a partial mediation analysis (Brown, 1997) was carried out to explain the relationship among the three outcomes variables. The analysis involved testing KESAT and UESAT as mediators between treatment and farmer productivity.

4. C. 2. Difference in difference estimation using pooled data

(1) To create the two-level hierarchical model and measure the change over time (from t_0 during baseline to t_1 in the endline), difference in difference[25] (DnD) estimation was employed to determine whether any differences in farmer performance outcomes (productivity and UESAT), registered over time, were statistically significant. Additionally, analysis of the pooled data from baseline and endline surveys involved a treatment dummy (iapp), a time dummy (time), and the interaction between time and treatment dummies to measure the impact of the program on productivity and UESAT score of farmers (White, 2013).

(2) White (2013) cautions that "randomisation will not always result in well-matched samples, so we do need check for the quality of the match" (p.42). In this study, checking for the "quality of the match" as well as difference in difference estimates are utilized to account for any imperfections in the match.

4. D. Model specifications

Model specifications were carried out at two levels: individual and cluster or village levels. In two-level cluster randomized trials, individuals are nested within clusters. In this study, the individual farmers are nested within villages that were randomly assigned to the treatment and control conditions. Due to the presence of two levels, this cluster randomized trial needs to consider two-levels of trial in the model specification.

4. D. 1. Testable hypotheses

The data can be represented for a cluster randomized trial in hierarchical form, with individuals nested within clusters. The level 1, or person level model is:

One-level model

$Y_{ij=}\ \beta_{0j} + e_{ij}$ where $e \sim N\ (0, \sigma^2)$

for $i \in \{1, 2, 3 \ldots . n\}$ persons per cluster and $j \in \{1, 2, \ldots .., J)$ clusters

where Y_{ij} =the outcome for person i in cluster j;

i.e. Y_{ij} = mean Productivity

[25] DnD yields the same results as a fixed effects estimation.

Y_{ij} = mean UESAT score

Y_{ij}= mean KESAT score

β_{0j} = mean for cluster j

$e_{ij=}$ error associated with each person in each cluster

σ^2 = within cluster variance

Next, the level 2 or cluster level model is as follows:

γ_{00}= the grand mean;

γ_{01}=the mean difference between the treatment and control groups or the main effect of the treatment;

W_j= the treatment-control indicator, 1 for treatment and 0 for control;

u_0 = the random or fixed effect associated with each cluster; and

τ= the variance between clusters

Replacing (2) in (1) yield the following two level model.

Two-level model

$Yij= \gamma_{00} + \gamma_{01}W_j + u_0j+ e_{ij}$, $u_{0j}\sim N (0, \tau)$ and $e_{ij} \sim N (0, \sigma2)$ [1.1]

Based on the above simple linear regression model, this study employs two models: one for the cross-sectional data and the second one for the panel data analysis.

Model 1 for cross-sectional data analysis

For random effects, the model, showing unadjusted relationship between the treatment and the outcomes, is modified as follows:

$Y_{ij}= \gamma_{00} + \gamma_{01}Wj + \alpha ij+ u_{0j}$, $u_{0j}\sim N (0, \tau)$

Y_{ij} is the dependent variable observed for individual i in cluster j. W_j is the treatment-control indicator; observed and cannot be estimated directly by the fixed effects model as the treatment was randomized at the village level but can be estimated by the random effects model, α_{ij} is the unobserved individual effect and u_{oj} is the error term, with robust standard errors clustered at the village level.

Any empirical analysis assessing the impact of a farmer field school program must account for the special aspects of the program implementation. Ordinary Least Squares or OLS is a commonly used approach to measure farmer level outcomes (productivity, UESAT and KESAT) by regressing the outcomes on variables associated with farmer's participation in the program and other relevant individual, household and community level variables influencing farm outcomes. What this type of regression is basically a single difference between outcomes of program participants and non-participants.

However, in a rural Bangladeshi context, similar to other places where farmer field schools have been implemented, two problems arise with such single difference comparisons based on cross-sectional data (Feder et al., 2004; Wooldridge, 2002). First, in a non-randomized environment assignment of groups to FFSs might happen due to unobserved variables that are correlated with farm-level outcomes. In such a case, higher farm-level productivity or any other desired outcomes may not be as a result of the program but rather may be due to selection bias. Second, farmers selected to participate in FFS may be different from those outside of the program in ways that cannot be seen by the researcher e.g. if more motivated farmers were likely to be selected, the farm-level outcomes of the program are likely to be overestimated using an OLS regression.

Due to selection of only a sub-sample of 21 treatment and control villages from a larger random sample of 45 treatment and 45 control villages, it is rather difficult to generalize the findings from the study to a larger population beyond the sample.

Model 2 for panel data

The model for fixed effects or difference in difference model using panel data is presented below:

$Y_{ij=}\ \gamma_{00} + \gamma_{01}W_j + \alpha_{ij} + u_{0j,}\ u_{0j\sim}\ N\ (0, \tau\ )$

Y_{ij} is the dependent variable observed for individual i in cluster j. W_j is the time-invariant regressor; observed and can be estimated directly by the fixed effect/difference in difference model where α_{ij} is the unobserved individual effect and u_{oj} is the error term, with robust standard error clustered at the village level. The estimation of the above equation in essence compares the performance of treatment farmers to that of control farmers from t_0 (2012) to t_1 (2016).

In the case of the longitudinal data, difference-in-difference estimator yields similar results as fixed effects modelling, obtained by estimating the effects of time invariant variables i.e. the change between treatment and control groups over time. These effects are unaffected by the intervention and arise mainly due to time-invariant household or village level unobservables (Allison, 2017; Glewwe and Jacoby, 2010). Since fixed effects regression or DnD estimation depends on comparing changes in outcomes between treatment and control groups, it is not affected by selection biases.

4. D. 2. Robustness check

In order to ensure the robustness of the findings, related to the major outcomes of IAPP, this study presents several different specifications of *Model 1* described above using a nested design to explain the impact on the outcomes of interest. Subsequently through this iterative process, the most efficient model explaining the results of this study was identified. While measuring the impact on productivity, a considerably conservative, alternative measurement of the outcome variable (output per active member in an agriculture-based household) was considered and compared with the standard measurement of the outcome (output per unit land area or yield).

4. E. Limitations

1. Possible bias in effect estimation: Randomization assures that individuals are exposed to the treatment and does not necessarily make sure they receive or accept the treatment. However, like any randomized control trials (RCT) in an agricultural setting, this project is likely to have suffered from partial compliance in the treatment group due to attrition of randomly assigned farmers and their replacement with those who are eager to be part of the group (Karlan & Appel, 2016). A possibility of such a phenomenon was reflected in the descriptive statistics of survey data (See Table 3.4) in the form of differing household size, gender distribution and socio-economic conditions. To generate unbiased estimates, the normal expectation from an RCT is

that the only variable which distinguishes the treatment from the control group is the treatment itself (Boruch, Yang, Hyatt, & Turner, 2016). As the core premise of RCTs is "the guarantee of no initial systematic differences in confounding variables," Boruch (2007, p. 60) explains that "beyond this, the randomization permits making statistically legitimate statements about one's confidence in the estimated magnitude of effects relative to chance variation."

2. External validity: The study consisted of a small sample size (*N* = 623). Due to resource constraints, I was not able to collect data from all treatment and control villages making it impossible to generalize the findings to all treatment and control villages.

3. Survey data collection from un-designated members of the household: Enumerators often made the decision to interview both the male household heads and female participants in the program. This was done in order to avoid discomfort and possible confrontation, thereby conforming to the existing cultural norm which specifies men as the "guardians" of women in their family. As a result, even though all KESAT, literacy and numeracy tests were administered to the real participants of the program, the answers about productivity of the household were jointly answered by both household heads and female participants. Excluding the assessments of reading comprehension, numeracy and KESAT, all other information characterizes the operational status of a farming household in this study. As a result, in the interpretation of the survey data, the results of this study reflect outcomes at a household level rather than at an individual level, following the tradition of previous agricultural studies.

4. Evaluation of farmer knowledge: The assessment on knowledge (KESAT test) was administered to IAPP farmers briefly after their training completion at IAPP schools. As knowledge was not measured in the baseline survey, i.e. prior to intervention deployment, the results are likely to capture short-term knowledge retention capacities of farmers in the treatment group rather than long-term gain in knowledge or influence of unobservable variables. Re-surveying the same participants after a few years would be essential to confirm the lasting impact of IAPP on knowledge acquisition.

5. According to Duflo et al. (2006), one of the main caveats of a randomized phase-in trial is that individuals in the control groups may have greater expectations that could affect their behavior. In the present study, due to the geographical distance in the range of 30-50 miles between the treatment and control villages, it was not possible to find any kind of evidence supporting such behavior. Additionally, Feder et al. (2010), in their synthesis of multiple FFS studies, explain that FFSs often face the challenges of finding comparable groups in control villages when locally influential farmers of higher socio-economic status self-select themselves into joining the treatment groups. A few existing incongruities of similar nature between the treatment and control groups regarding gender of the participant, household income, expenditure and other related individual and household characteristics related variations were addressed by controlling for these specific variables in the regression models.

CHAPTER 5: RESULTS

This chapter presents analysis of cross-sectional and panel data on IAPP's impact on farmer performance. The emphasis is mainly on the cross-sectional data from the endline survey due to availability of data to measure the three major outcomes of the program: productivity, use of environmentally sustainable agricultural technologies (UESAT) and related knowledge (KESAT). Panel data is comprised of data from the baseline survey conducted in 2012 by the World Bank and the endline survey administered in 2016 by the researcher and her team. Average output from three best plots, owned by individual households, for each active member of a household-based farm was used to determine farmer productivity; the total score on a battery of ten questions related to the KESAT was used to measure farmers' performance in knowledge; and the total score from the seven-item UESAT test was employed to measure farmers' UESAT performance.

Since the experiment was implemented at a village level, a total of 21 clusters or village-level groups representing 623 individuals were studied in the cross-sectional data analysis. In the panel data analysis, only 5 treatment villages and 6 control villages were compared to discern the impact of the program on productivity and UESAT.

The outline of this chapter is as follows. First, the chapter presents various sources of information and knowledge for farmers, descriptive statistics related to KESAT and UESAT scores by gender, treatment versus control groups and education level. Next, regression analysis using multilevel multivariate and random effects models are presented using the cross-sectional data from the endline survey. Furthermore, a partial mediation analysis is carried out to describe the relationship between the three outcomes variables, which reveals KESAT as a mediator between treatment, and farmers' UESAT and productivity performance. Finally, difference in differences estimation was conducted to assess the impact of IAPP on productivity (measured as yield) and UESAT for the treatment and control groups over time, employing panel data.

5. A. Cross-sectional data analysis

This section presents results on IAPP's impact on the three main outcome measures: productivity, UESAT and KESAT, in light of the proposed conceptual framework and model specifications described in the previous chapter (See Chapter 4). Following the conceptual framework, relevant individual, household and community characteristics were employed to predict the program outcomes.

5. A. 1. Information channels and knowledge levels

Prior to evaluating the impact of IAPP education on farmers' KESAT, the major sources of information from which farmers learn about new knowledge on agricultural practices were examined. This study asked questions about the various sources of information regarding seeds, fertilizer, crop variety, etc. (See Appendix for the Endline Survey Questionnaire). The results show that farmers receive farming related information from agricultural extension agents, IAPP extension agents, relatives, friends, sellers and the *Union Parishad* office[26] (See Table 1.5). The majority of the farmers seek information on seed, fertilizer and pesticides from the agricultural extension agents, IAPP extension agents, friends, relatives and neighbors.

Table 5. 1: Sources of information

	Agricultural extension agent	IAPP	Relatives	Friends	Seller	Union Parishad
Total # of positive responses	245	184	228	358	230	1
Treatment (%)	75.51	100	45.61	51.68	29.57	0
Control (%)	24.49	0	55.38	48.32	70.43	100

The findings align with evidence found in the literature on FFS education where neighbors or friends were identified as major sources of information beside government extension agents (Feder & Slade, 1986; Birkhaeuser et al. 1991). However, it is important to note that a large share of farmers in rural Rangpur also rely heavily on sellers and company salespersons to

[26] Union Parishads are local administrative units, which consist of a collection of villages in the same region and these administrative offices offer support to farmers.

obtain information on fertilizer and pesticides on a regular basis. Eventually, these different sources of information are likely to inform how farmers perform on the KESAT test.

5. A. 2. Knowledge of Environmentally Sustainable Agricultural Technologies (KESAT)

The KESAT score is an index of the total number of points scored by individual farmers on a battery of ten questions on a knowledge test (See Table 4.11). For each correct answer, an individual scores 1 point. For example, if the test-taker provides correct answers to a total of five questions, he or she receives a score of 5 points. The total score on the test is referred to as the KESAT score and the test, which assesses farmers' knowledge, is called the KESAT test. The following discussion is focused on the distribution of KESAT score by the gender of the participant, the participant's assignment to the treatment group or the control group and the household head's education levels (i.e. number of years spent receiving formal education beyond 4^{th} grade).

5. A. 2. 1. Gender

Overall, women scored lower than men on the KESAT test (See Figure 5.1). Of the 623 respondents, only 171 were females and 452 were males from the treatment and control villages (See Table 5.2). About a quarter of the total number of respondents (156 out of 623), could not answer any of the questions correctly. For instance, among all female and male respondents, approximately 35% women compared to 21% men could not answer any of the questions correctly. Similarly, only about 20% of women compared to 37% men scored between 3-4 points, which is slightly above the average KESAT score in the treatment villages. No women and only 3 males (less than 1% of the total number of men) obtained the highest score 8.

Additionally, in Figure. 5.1, one can see that half of the women participants scored in the range of 0-1 while 50% of the men scored in the range of 0-2 points. These findings are reflective of the challenges encountered by women farmers with respect to low levels of agricultural knowledge (Waddington et al. 2014) and limited access to resources (Das et al., 2013) as evidenced in the literature.

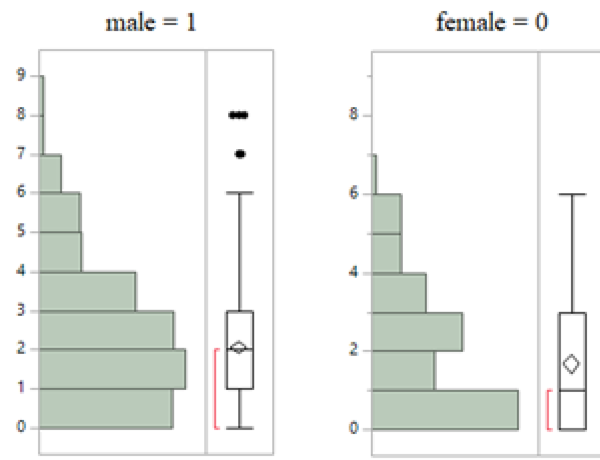

Figure 5. 1: Distribution of KESAT score by gender

Table 5. 2: KESAT score by gender

	Total score on KESAT									
Gender	0	1	2	3	4	5	6	7	8	Total
Females	60 (35.0)	26 (15.2)	37 (21.6)	22 (12.87)	12 (7)	12 (7)	2 (1.2)	0	0	171
Male	96 (21)	106 (23.4)	97 (21.4)	70 (31)	31 (6)	70 (6.6)	16 (3.5)	3 (0.7)	3 (0.7)	452
Total	*156*	*132*	*134*	*92*	*43*	*42*	*18*	*3*	*3*	*N=623*

Note: Percentages reported in parentheses

5. A. 2. 2. Treatment versus control groups

Performance on the KESAT test differed between the treatment group and the control group (See Table 5.3 and Table 5.4). However, the median score was 2 (mean: 2.33) for the farmers in the treatment group and 1 (mean: 1.52) for farmers in control groups, both considerably low. The difference in the scores shows that difference exists between the treatment and control groups related to KESAT as farmers in the treatment villages scored higher than those in the control villages.

Table 5. 3: Summary of KESAT score by treatment versus control groups

	Mean	SD	Min	25 percentile	Median score	75 percentile	Maximum score
treatment	2.33	1.78	0	1	2	3	8
control	1.52	1.57	0	0	1	2	8

More farmers from the control villages scored zero i.e. they were unable to correctly answer any of the questions compared to the treatment group farmers (32% versus 18%) (See Table 5.4). About half of the farmers in the treatment villages scored in the 0 to 2 range but those in the control villages scored in the range of 0 to 1 (See Figure 5.2). Overall, the performance on the KESAT test was not impressive considering the performance of both groups.

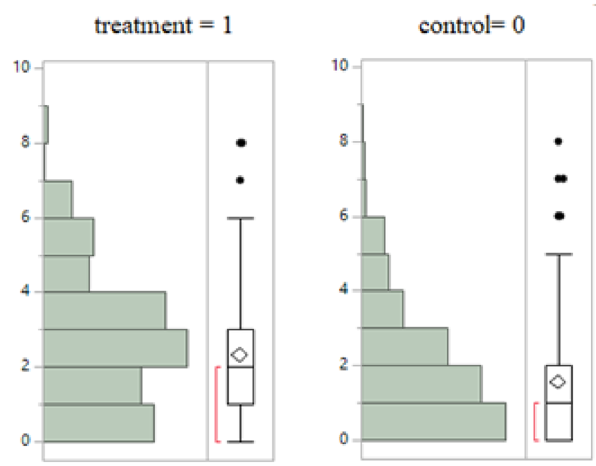

Figure 5. 2: Distribution of KESAT score by treatment versus control groups

Table 5. 4: KESAT score by treatment versus control groups

	KESAT score									
Groups	0	1	2	3	4	5	6	7	8	Total
IAPP participants	58 (18.35)	51 (16.14)	75 (23.73)	64 (20.25)	24 (7)	26 (8.23)	15 (4.75)	1 (0.32)	2 (0.63)	316
Non-participants	98 (31.92)	81 (26.38)	59 (19.22)	28 (9.12)	19 (6)	16 (5.2)	3 (1)	2 (0.7)	1 (0.33)	307
Total	*156*	*132*	*134*	*92*	*43*	*42*	*18*	*3*	*3*	*N=623*

5. A. 2. 3. Education levels

Education levels were broken down into four categories, altogether ranging from 0 to 15 years spent in schooling, based on the highest level of formal education attained. These categories were: (1) No formal schooling or informal schooling; (2) primary schooling; (3) secondary and higher secondary education; and (4) university and above. Performance on KESAT varied by education level. A large section of respondents with no formal/informal schooling and primary education scored less than 3 points on the KESAT test. A greater proportion of those with secondary and higher secondary education and those with university education or above scored in the range of 3-5 points on the test compared to the two former groups. (See Figure 5.3). There exists a visible gap in KESAT score between groups who received no formal education and primary education, and those with higher levels of education beyond grade level 5, as the latter group tend to do better than the former.

Overall, in Figure 5.3, it is observed that the scores are progressively higher for those with higher educational qualifications. The difference between these two sets of groups indicates that individuals from families with household heads with a level of education beyond grade 5 or primary schooling are more likely to be more knowledgeable. The Pearson correlation coefficient estimating the relationship of KESAT score and household head’s education level is 0.11 at the significance level of $p=0.006$, meaning strong connection exists between these two variables. This particular relationship implies that household head’s education may be influential in determining KESAT level of the farmer-in-charge of a household-based farm.

Figure 5. 3: Proportional Distribution of KESAT score by education level

The results are further confirmed in Table 5.5, showing that respondents who failed to provide any correct answer had lower educational qualifications. For instance, only about 17% of the total 189 respondents with secondary or higher secondary education compared to a higher rate of ~30% of the total of 261 respondents with primary education scored zero on the test (See Table 5.5). The distribution of the KESAT test scores in these different education cohorts, more or less, reveal that those with secondary or higher secondary education (n=189) and college education (n=15) tend to be more knowledgeable of ESATs.

Table 5. 5: KESAT score by education level

	Total KESAT score									
Education levels	0	1	2	3	4	5	6	7	8	Total
No formal/informal	76 (29.12)	46 (17.62)	61 (23.37)	30 (11.49)	20 (7.66)	21 (8.05)	5 (1.92)	2 (0.77)	0 (0)	261
Primary	47 (29.75)	39 (24.68)	26 (16.46)	25 (15.82)	8 (5.06)	8 (5.06)	3 (1.9)	1 (0.63)	1 (0.63)	158
Secondary/higher secondary	32 (16.93)	44 (23.28)	44 (23.28)	35 (18.52)	13 (6.88)	11 (5.82)	8 (4.23)	0 (0)	2 (1.06)	189
University and above	1 (6.67)	3 (20)	3 (20)	2 (13.33)	2 (13.33)	2 (13.33)	2 (13.3)	0 (0)	0 (0)	15
Total	*156*	*132*	*134*	*92*	*43*	*42*	*18*	*3*	*3*	*N=623*

5. A. 3. Use of Environmentally Sustainable Agricultural Technologies (UESAT)

Farmers were evaluated for the use of the environmentally sustainable agricultural technologies such as green manure, mulching, alternative wet/dry method of irrigation, line planting, double transplanting, vermicompost and installment of *koincha* or a tree branch in paddy field. Performance on UESAT by gender of the participant, treatment versus control groups and household head’s education levels are explained below.

5. A. 3. 1. Gender

There are more men (452) compared to women (171) who took part in the survey, and as a result the table reports both number and share of women and men regarding UESATs (See Table 5.6). Figure 5.4 shows that most female farmers adopt between 4- 5 ESATs while most male farmers adopt only 2-3 of the ESATs. In alignment with what is evidenced in the literature, women adopt ESATs when they are easy to adopt and do not require access to expensive resources (Waddington et al., 2014).

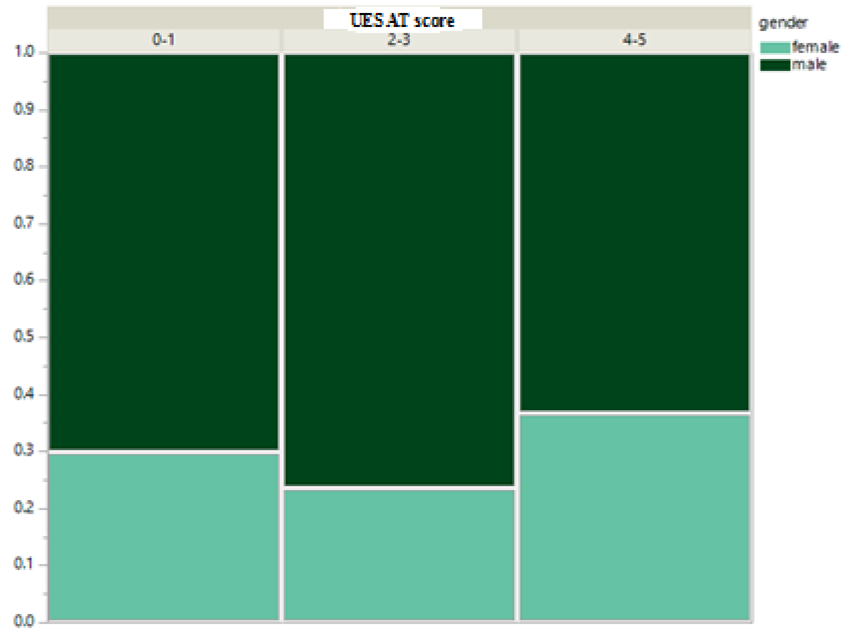

Figure 5. 4: Proportional distribution of UESAT score by gender

A larger share of females (7%) than males (4%) use green manure, alternate wetting and drying (6.4% females versus 5.5% males), and vermicompost (8.8% females versus 6.8% males) (See Table 5.6). These findings practically make sense because these specific ESATs do not require daily supervision or field visits and can be applied with minimal access to resources. Despite lower educational achievements, evidence exist to show that women adopt ESATs at a greater frequency than men, as evidenced earlier (Druschke & Secchi, 2014). One can produce green manure and vermicompost in the backyard of one's house, and the AWD technique is mainly focused on water conservation instead of frequent water usage, making these techniques less costly and more popular among women.

When it comes to more popular techniques, such as line planting and double transplanting, the share (percentage) of women using these ESATs is comparable to men. However, these findings indicate that men adopt these ESATs at a greater rate than women. Interestingly, the heavily publicized vermicompost technology, marked as a unique contribution of IAPP by the local program office, was adopted by more women than men. Higher rate of vermicompost adoption by women implies that they may be more interested than men in experimenting with innovative technologies that require learning and using a new set of skills.

Table 5. 6: UESAT score by gender

Names of ESATs	Test Score (Female)	Test Score (Male)
Green manure	12 (7)	18 (4)
Mulching	9 (5.3)	29 (6.4)
Alternate wetting and drying (AWD) method	11 (6.4)	25 (5.5)
Line planting	89 (52)	244 (54)
Double transplanting	106 (62)	329 (72.7)
Vermicompost	15 (8.8)	31 (6.8)
Installment of sticks in the field	1 (0.5)	4 (0.8)
Other sustainable technologies	1 (0.5)	6 (1.3)
Total	171	452

Note: Total number of males and females in the survey are reported. Multiple responses regarding ESATs were recorded. The proportion of men and women adopting specific ESATs is presented in parentheses.

5. A. 3. 2. Treatment versus control groups

A larger share of IAPP participants compared to non-participants uses ESATs (See Figure 5.5). Additionally, it was seen that a greater proportion of farmers in the treatment group adopted 2-3 of these ESATs compared to the control group farmers. None of the farmers from the control group, and only a very small proportion of them from the treatment group, used 4-5 of these ESATs.

The most frequent UESATs among both groups include line planting and double transplanting (See Table 5.7). With regard to vermicomposting, there is a vast difference between the IAPP graduates and the non-graduates as 14.2% of graduates compared to less than 1% of non-graduates adopted this particular ESAT. Overall, the findings indicate superior UESAT score by the IAPP participants compared to the non-participants.

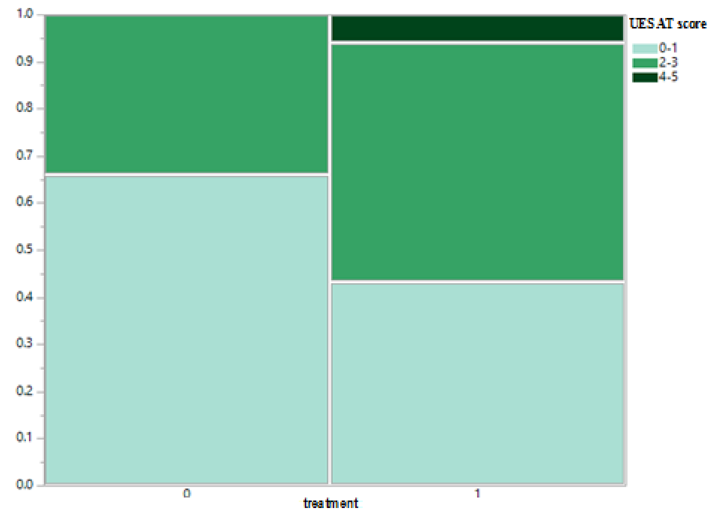

Figure 5. 5: Proportional distribution of UESAT score by treatment versus control groups

Table 5. 7: UESAT score by treatment versus control groups

Names of ESTs	*IAPP participant*	*Non-participant*
Green manure	27 (8.5)	3 (0.9)
Mulching	35 (11.1)	3 (0.9)
Alternate wet-dry method	34 (10.7)	2 (0.6)
Line planting	200 (63.3)	133 (43.3)
Double transplanting	239 (75.6)	196 (63.8)
Vermicompost	45 (14.2)	1 (0.3)
Sticks	5 (1.6)	0 (0)
Other sustainable technologies	7 (2.2)	0 (0)
Total (N=623)	*316*	*307*

Note: Percentages of score reported in parentheses

5. A. 3. 3. Education levels

Bearing in mind the distribution of education levels among farmers from the previous chapter, one can discern that a majority of farmers either have no formal education or only primary education (See Table 4.4 in Chapter 4). Despite the low-levels of educational qualifications among farmers, data shows that a larger fraction of farmers with primary schooling and secondary/higher secondary schooling score higher on the UESAT test involving green manure, mulching and line planting techniques compared to the group with no formal/informal education (See Table 5.8).

Table 5. 8: UESAT score by education level

Names of technologies	No formal schooling	Primary	Secondary/ Higher secondary	University
Green manure	10 (3.8)	11 (7)	9 (4.7)	0 (0)
Mulching	12 (4.6)	10 (6.3)	14 (7.4)	2 (13.3)
Alternate wetting and drying method	10 (3.8)	11 (7)	13 (6.9)	2 (13.3)
Line planting	128 (49)	86 (54.4)	108 (57.1)	11 (73.3)
Double transplanting	192 (73.6)	109 (68.9)	122 (64.5)	12 (80)
Vermicompost	13 (5)	11 (7)	20 (10.6)	2 (13.3)
Installment of sticks in the field	0 (0)	0 (0)	5 (2.6)	0 (0)
Other sustainable technologies	0 (0)	1 (0.6)	0 (0)	1 (6.7)
Total (N=623)	261	158	189	15

Note: The share of farmers with each level of education using specific ESATs are reported in parentheses

A large share of farmers with no formal schooling (49%) and primary education (54.4%) adopt line planting, which requires the involvement of 2-10 household members or hired laborers, depending on the size of the cultivated land. However, farmers with secondary/higher secondary (57.1%) and university education (73.3%) apply line planting at a higher rate than any other education groups.

Concerning double transplanting (See Table 4.10 for definition) – another frequently used ESAT among farmers – those without any formal education (73.6%) adopt this technology to a nearly equal extent as those with university education (73.3%). By contrast, when it comes to vermicomposting, a larger share of farmers with secondary/higher secondary and university education applies this technology.

Those with primary, secondary or higher secondary and university education adopt alternate wet-dry irrigation method – a technique that helps with water conservation during dry season – at a higher rate than those with no formal education background. However, the number of university-educated farmers in this study is very small (n=15). Therefore, it is wise not to decipher any kind of UESAT score pattern associated with this group of farmers based on such a small sample size.

For the most part, a higher proportion of farmers with primary and secondary or higher secondary education report a higher frequency UESAT than those without any formal schooling. The findings align with the results evidenced in established literature (Lockheed & Lau, 1980), confirming that farmers with more than four years of education were expected to be more adaptive concerning newly endorsed technologies. However, an exception is noticed in the case of double transplanting, which requires supplementary labor compared to all other ESATs discussed here. More farmers with no formal education tend to adopt this ESAT than any other education groups. The reason for the popularity of double transplanting among these farmers may be their familiarity with its efficiency in boosting production.

5. A. 4. Models for predicting IAPP's Impact: productivity, UESAT and KESAT

In the following section, a set of multivariate regression models for predicting the major outcomes of the IAPP program, namely productivity, UESAT and KESAT, are discussed.

5. A. 4. 1. Impact on Productivity

This section focuses on estimating the impact of IAPP schooling on productivity using two major regression methods: multivariate and random effects regression modeling. The question of interest here is whether there was a significant improvement in productivity (average agricultural output per active household member involved in agricultural production) among IAPP graduates compared to non-graduate farmers after a year of FFS training independent of their formal education and other socio-economic backgrounds. The effect size based on mean comparison and unequal variances of the impact (Cohen, 1969, 1988) is 0.68, signifying a large impact of IAPP education on household-based farm productivity, greater than the MDES of 0.478.

Goodness of fit measures (R-squared) indicate that the estimated models fit the data reasonably well. The random effects test confirms that IAPP education positively influenced productivity of farmers at p=0.00 significance level (See Table 5.9).

5. A. 4. 1. 1. Estimation based on regression with control variables

The log transformed dependent variable (productivity) is used for the regression analysis due to the non-linear relationship between the dependent and the treatment variables[27]. With the cluster command the analysis was adjusted for clusters or villages consisting of individual farmers. After introducing robust standard errors by adjusting standard errors for 21 clusters the following estimates (See Table 5.9) were obtained, where model B correctly predicted the yield for about 54% of the sample.

In the base model (Table 5.9), which does not control for any associated predictor variables, the impact of IAPP is quite large (92%) and highly significant (p<0.01). However, in this model, individual, household and socio-economic characteristics that are likely to influence productivity were not addressed. In model A, when control for household head's education level (HHedlevel), his/her age (HHage), gender of the participant (gender) and total expenditure on agricultural production (TotAgExpense) were introduced, the impact of the treatment (iapp) on farmers, is still significant at the level of p<0.05. In the same model, participation in IAPP results in a significant increase in farm productivity by 56% [since, $\exp^{0.442}$=1.56]. Likewise, male farmers, compared to female farmers, are expected to be significantly more productive. Additionally, increased expenditure on agricultural production leads to significantly improved productivity but the magnitude of this effect is very small. On the contrary, household head's age had a negative influence on farm productivity. Overall, model A illustrates that along with IAPP schooling, household head's education, gender of the participant (if male) and agricultural expenditure play significant roles in improving farm productivity.

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[27] Spearman correlation coefficient (0.34), when estimated was greater compared to Pearson correlation coefficient (0.27), suggesting non-linearity. Similar observations were made regarding non-linear correlation between the dependent variable and the other predictor variables. Additionally, the transformation was useful in ensuring a normal distribution for the residuals.

Table 5. 9: Measuring impact on productivity+ using multivariate regression

Dependent Variable: Productivity			
VARIABLES	Base Model	Model A	Model B
iapp (treatment)	0.652**	0.442**	0.373**
	(0.169)	(0.125)	(0.107)
HHedlevel		0.209**	0.241**
		(0.0718)	(0.0582)
HHage		-0.007*	-0.006*
		(0.00237)	(0.00238)
gender (male)		0.238*	0.066
		(0.111)	(0.088)
TotAgExpense		9.75e-06**	1.20e-^{05}**
		(1.51e-06)	(1.83e-06)
SESPrin1			0.0482
			(0.0316)
plotsize			0.0129**
			(0.00156)
toted15			-0.009**
			(0.00185)
info_friends			0.202**
			(0.0663)
Plotsize*TotAgExpense			-6.95e^{-08}**
			(1.49e^{-08})
Constant	6.895**	6.657**	6.075**
	(0.0986)	(0.168)	(0.144)
Observations[28]	614	614	614
R-squared	0.104	0.340	0.539
Effect size[29] (Cohen's d)	0.68		

+ log transformed output per active household members in agriculture
Robust standard errors, adjusted for clusters, reported in parentheses
** p<0.01, * p<0.05

Now, it is to be seen how these estimates change when a more elaborate model is introduced by considering a set of multiple variables— representing relevant household characteristics including socio-economic status of the family. Considering model B (See Table 5.9), the magnitude of the coefficient representing the effect of the treatment is decreased but still quite large with a 45% [exp (0.373) = 1.45] increase in (the geometric mean of) productivity at a p<0.01 significance level while controlling for other variables in the model. New variables that are included in the model represent principal component factor of socio economic status of farming

[28] Influential observations that altered the predictive power of the model were removed using multiple diagnostic methods such as Cook's d and DFITS by estimating both studentized residuals and leverage. Additionally, leverage versus residual squared plot was also used to identify the influential observations in the models.

[29] Glass's Delta 1 that uses standard deviation of the control group was also calculated. The estimate shows that average productivity differs by 0.71 and the reported confidence interval is (-0.88 to -0.54).

households (SESPrin1), size of plots used for cultivation (plotsize), total number of years spent in school by household members of age 15 and above (toted15) and the interaction between plot size and the total expenditure on agricultural production (plotsize*TotAgExpense). It was found that the effect of the household head's education beyond 4 years of schooling (HHedlevel) still has a significant positive influence (about 27%) on productivity. However, plot size contributes to only 1.2% while having friends as a major source of information (info_friends) in one's social network leads to 23.4% significant ($p<0.01$) increase in (the geometric mean of) productivity holding other variables constant.

On the other hand, numbers of years spent in school by household members aged 15 and above is negatively associated with higher productivity. This particular observation indicates that despite positive relationship between household head's education (HHedlevel) and productivity, total number of years of schooling of household members tend to negatively influence farm productivity. These analyses confirm observations from the field. Choosing farming as a primary occupation is uncommon among formally educated family members, especially young adults, who prefer other occupations over farming, leaving agricultural decision making in the hands of their elders. Further, in model B (Table 5.9), it is observed that when the area of land used for cultivation and agricultural investment (TotAgExpense) both increase, it has a significant negative influence on productivity, even though the magnitude of such influence is not large (less than 1%). Taken together, these findings point toward the positive influence of the household head's education, economic capacities and social network of a household-based farm in determining improved productivity. Additionally, there were no significant influences of the living standards (SESPrin1) and difference in gender on household-based farm productivity in model B when the variable TotAgExpense was introduced.

5. A. 4. 1. 1. 2. Estimate based on village level random effects

As the sample for this cross-sectional data analysis was drawn from a larger sample in a cluster-randomized control experiment, a conservative approach is taken in estimating the impact of the program. Therefore, a Hausman test was performed to determine the consistency of the random effects model compared to the fixed effects model (Hausman, 1978). The result from the test shows that the random effects model was consistent and produced the same estimates as the fixed effects model. As a result, the random effects model was chosen to measure the impact of IAPP on all three major outcome variables.

In Table 5.10, the random effects model[30] with robust standard errors – adjusted for clusters at the village level – and the same configuration as model B (Table 5.9) is presented. There is additional information available in this model i.e. model C. The estimated R-squared within indicates that the model can account for ~47% variation within clusters i.e. individuals within each village. The estimated R-squared between suggests that the model can account for ~67% variation between the villages[31]. The projected R-squared overall indicates the model can explain about 54% of the total variation in the model. The information in random effects model therefore provides a more efficient estimate of the effects of the program and other individual and household level characteristics on farm productivity.

Overall, the random effects model confirms the effects of treatment (i.e. IAPP) on productivity along with variables related to individual and household level characteristics such as education, age, access to resources (TotAgExpense) and source of information (info_friend), not including gender and living standards (SESPrin1). A farmer in the IAPP program is expected to be significantly about ~40% more productive than the control group farmers considering the geometric mean productivity.

[30] All the random effects models for this study were chosen based on results from the Hausman test to determine the consistency of the model in comparison to fixed effect model. The result of the test confirmed that the random effects models were consistent and produced the same estimates as the fixed effects models. Additionally, the researcher was not able to choose a fixed effects model since the treatment varied at the village level, a fixed effects model on village level resulted in the exclusion of the treatment dummy variable (iapp) from the multivariate regression models.

[31] The value of rho, the inter-class correlation coefficient is ~0.5, explaining only 5% of relationship variation between the individuals in different clusters or villages.

Table 5. 10: Random effects regression estimates for productivity

VARIABLES	Model C
iapp	0.336**
	(0.0975)
HHedlevel	0.236**
	(0.0602)
HHage	-0.00690**
	(0.00243)
gender (male)	0.032
	(0.0816)
TotAgExpense	$1.13e^{-05}$**
	($1.62e^{-06}$)
SESPrin1	0.047
	(0.0294)
plotsize	0.013**
	(0.00160)
toted15	-0.009**
	(0.00195)
info_friends	0.203**
	(0.0675)
plotsize*TotAgExpense	$-7.22e^{-08}$**
	($1.53e^{-08}$)
Constant	6.103**
	(0.141)
Observations	614
Number of clusters	21
R-squared within	0.471
R-squared between	0.673
R-squared overall	0.537

Robust standard errors, adjusted for clusters, reported in parentheses
*** p<0.01, * p<0.05*

5. A. 4. 1. 1. 3 Robustness check

Allowing that this study employed a small sample of treatment and control group farmers for comparison, it is reasonable to check for the robustness of the models employed earlier for predicting the outcomes of the program (See Table 5.11). An alternative way to determine whether IAPP improved productivity is to predict the impact of an intervention using a different but relevant measurement for the outcome (Feder et al., 2004). The alternative dependent variable chosen is “yield,” which was created by dividing the total output (in kg.) by the total area of the three best lands (in hectares) used for agricultural production by the household-based farms.

The question of interest here is that whether the significant impact of the program on farm productivity will still hold for this alternative outcome variable. Considering the random effects regression estimates, it is observed that the effect of the treatment variable is still positive and strongly significant, although the magnitude of the coefficient is greatly reduced and so are the effects of most variables (except HHage and TotAgExpense) in the model. Still, the geometric difference in mean productivity between IAPP graduates and non-graduates is approximately 22% at a highly significant level (p<0.01) (See Table 5.11). This provides further evidence to believe that IAPP indeed had a strong positive effect on farm productivity.

Table 5. 11: Random effects regression estimates for yield (kg/ha)

Dependent variable: Yield (log transformed kg/ha)	
VARIABLES	Model D
1.iapp	0.196**
	(0.0750)
HHedlevel	0.076
	(0.0543)
HHage	-0.003*
	(0.00141)
1.sex	0.024
	(0.0385)
TotAgExpense	3.26e-06**
	(9.83e-07)
SESPrin1	-0.009
	(0.0193)
plotsize	0.0002
	(0.000858)
toted15	0.002
	(0.00164)
info_friends	0.067
	(0.0401)
c.plotsize*c.TotAgExpense	-1.01e-08
	(1.03e-08)
Constant	8.364**
	(0.102)
Observations	615
Number of clusters	21
R-squared within	0.061
R-squared between	0.328
R-squared overall	0.164

Robust standard errors adjusted for clusters reported in parentheses
** p<0.01, * p<0.05

5. A. 4. 2. Impact on UESAT

5.A.4.2.1. Estimation based on regression with control variables

In the base model (Table 5.12), one sees that the UESAT score is significantly (p<0.01) better by ~0.50 units (total score possible is between 0 and 7) for farmers in the IAPP schools compared to those in the control group. This bivariate analysis examined an unadjusted relationship between the treatment variable and the UESAT score.

The newly introduced variables in model A (See Table 5.12) represent a variety of household and individual level characteristics based on the conceptual framework (See Chapter 2, Figure 2.2). In model A, an IAPP graduate is expected to score 0.51 units higher on UESAT test at a similar level of significance compared to the base model. Among the household characteristics, the family's socio-economic status (SESPrin1), number of household members involved in agriculture (HHmemagri) and total number of years spent in school by household members of age 15 or above (toted15) appear in this model. Individual characteristics of the participant included in this model consist of attitude toward organic fertilizer usage (attorgPrin1) and numeracy test score (numeracy). All these variables have significant influence on UESAT score except attitude (attorgPrin1), contrary to earlier expectation following the conceptual framework (See Chapter 2).

Similar to what is observed in the established literature, higher socio-economic status is often positively correlated with farm outcomes related to UESAT score (Guo et al., 2015). With improved SES status one is likely to report a significant 0.12 units increase in UESAT score in model A (See Table 5.12). Findings indicate that participation of a larger number of household members in agriculture makes a household-based farm more likely to improve their performance on UESAT. For every additional member involved in agricultural production, a participant's UESAT score improves by ~0.18 units. This particular finding indicates that just having more members in a household does not guarantee an improved UESAT score unless these family members are actively involved in agriculture. In the same vein, UESAT score is negatively impacted by the total numbers of years spent in school by household members, which is statistically significant but practically insignificant due to the very small size of the coefficient (~0.01). By contrast, the numeracy score of the participant significantly improves household's UESAT score by 0.08 units.

Table 5. 12: Impact of IAPP schooling on UESAT score

	Dependent variable: UESAT Score		
VARIABLES	Base model	Model A	Model B
1.iapp	0.498**	0.513**	0.391*
	(0.166)	(0.167)	(0.181)
SESPrin1		0.113**	0.0657
		(0.0317)	(0.0364)
HHmemagri		0.182**	0.168**
		(0.0363)	(0.0421)
toted15		-0.00873*	-0.0107**
		(0.00375)	(0.00368)
attorgPrin1		0.0355	0.0295
		(0.0348)	(0.0346)
numeracy		0.0833*	0.0708*
		(0.0307)	(0.0305)
info_tv			1.518**
			(0.376)
demonstration			0.129
			(0.178)
lplotsize			0.259**
			(0.0587)
c.demonstration#c.toted15			0.0113
			(0.00915)
Constant	1.239**	0.748**	-0.196
	(0.0514)	(0.149)	(0.301)
Observations	617	617	617
R-squared	0.065	0.134	0.201
Effect size[32] (Cohen's d)	0.51		

Robust standard errors, adjusted for clusters, reported in parentheses
** p<0.01, *p<0.05

Similar to base model and model A, in model B, the effect of being an IAPP graduate leads to significantly large increase in UESAT score of ~0.4 units (when total score possible is between 0 and 7). Three new independent variables were introduced: demonstration plots (demonstration) and size of agricultural land (lplotsize) used by household-based farms for production along with an interaction term (demonstration*toted15). If size of agricultural land (lplotsize) increases by 1%, UESAT score improves by 0.0025, which is practically insignificant but statistically significant. However, increasing the number of demonstration plots does not positively influence UESAT. It is observed that in all these three models the effect of being an

[32] Glass's Delta 1 that uses standard deviation of the control group for effect size estimation was also calculated. The estimate shows that average UESAT score differs by 0.77 and the reported confidence interval is (-0.94 to -0.69).

IAPP graduate on UESAT score is consistently large and significant even after household and individual characteristics related variables were introduced in the model. The estimates are reliable as the standard errors are robust and adjusted for clusters. The overall goodness of fit of the final model (model B) is ~20% demonstrating that the model estimates UESAT score for only about 20% of the sample.

5. A. 4. 2. 2. Estimate based on village level random effects

When the select individual and household characteristics are held constant, farmers in IAPP schools are likely to score 0.42 units more than those in the control group (See Table 5.13). Model C exemplifies a significant effect of the treatment on UESAT. In this random effects model, the estimate for R-squared reveals that similar to model B, the model can explain only about 20% of the variation overall. (Table 5.12). However, this model accounts for ~34% variation between villages related to how farmers' UESAT score are impacted.

The coefficient for the treatment dummy variable (iapp) improved slightly and now has a p-value of 0.011 in the random effects model (model C) compared to model B, where it was marginally significant (p=0.042). Additionally, the interaction term (demonstration*toted15) now appears as a significant predictor of UESAT score. As a result, the more number of years in spent school by household members of age 15 or above, the stronger the effects of demonstration on UESAT test score, despite no significant influence of demonstration plots on the score alone. Similarly, a family's socio-economic status (SESPrin1) also seems to have significant impact on improved UESAT score by almost 1 unit, which is quite large considering all possible scores vary between 0 and 7. For all other variables the significance levels of the coefficients remain more or less the same. Variables like attitude toward organic fertilizer usage (attorgPrin1) and number of demonstration plots (demonstration) owned by the household farm, however, still do not have any significant impact on UESAT.

Table 5. 13: Random effects regression estimates for UESAT score

Dependent Variable UESAT score	
VARIABLES	Model C
1.iapp	0.421*
	(0.166)
SESPrin1	0.0706*
	(0.0295)
HHmemagri	0.138**
	(0.0444)
toted15	-0.00813*
	(0.0031)
attorgPrin1	0.0164
	(0.0299)
numeracy	0.0737**
	(0.0251)
info_tv	1.393**
	(0.348)
demonstration	0.0163
	(0.159)
lplotsize	0.229**
	(0.0506)
demonstration*toted15	0.0169*
	(0.00950)
Constant	-0.0644
	(0.239)
Observations	617
Number of clusters	21
R- squared (within)	0.139
R-squared (between)	0.347
R-squared (overall)	0.1973

Robust standard errors, adjusted for clusters, reported in parentheses
** p<0.01, * p<0.05

The value of rho, i.e. inter-class correlation coefficient (~0.17) suggests that only 17% of the relationship between the individuals in different clusters (i.e. villages) can be explained through the model. Rho represents the proportion of the variance that is accounted for by the individuals. This is expected as the treatment was randomized at a village level and the variance between villages is truly indicative of the differences between the treatment and control groups.

5. A. 4. 3. Impact of IAPP on KESAT

5. A. 4. 3. 1. Estimation based on regression with control variables

To estimate the impact of IAPP training on KESAT score, multivariate regressions involving indicators of participation in IAPP program and a set of individual and household characteristics-related variables were utilized (See conceptual framework in Chapter 2).

The question of interest is whether there exists any significant difference in KESAT between treatment group and control group farmers, i.e. between IAPP participant and non-participants after a year of IAPP training independent of their individual and socio-economic backgrounds. The hypothesis test, which examines differences between treatment and control farmers, finds significant differences between the two groups, with a moderate effect size of 0.45, which is slightly below the MDES calculated earlier. Goodness of fit measures indicate that the estimated model B fits the data reasonably well (See Table 5.14). Random effect tests show that the parameter estimates were statistically significantly different from zero at p=0.00 significance level. This model correctly predicted KESAT test score for about 28% of the sample (See Table 5.15).

Overall, the results show that the coefficients of most of the variables hypothesized to influence KESAT have the expected signs. For instance, in the base model (See Table 5.14), being a graduate of IAPP increases one's chance of scoring higher in KESAT test by ~0.8 units (8%) at the level of significance at p<0.05 without considering any other indicator variables. In model A, however, KESAT score is expected to increase by 0.82 units with IAPP participation at the same significance level, controlling for numeracy and comprehension test scores of the participant, average years of education of household members and the socio-economic status of the household. Being proficient in basic mathematics such as addition, subtraction, division and multiplication positively and significantly improves KESAT score by 0.33 units. Similarly, reading comprehension skills significantly increases a farmers' KESAT score by a small margin i.e. ~0.14 units. Socio-economic status of a household also have significant positive influence on one's KESAT score with a smaller coefficient (~0.03). The findings make sense on a practical ground as farmers who are able to decode information using reading comprehension skills are practically more likely to have greater access to knowledge (KESAT).

Table 5. 14: Impact of IAPP schooling on KESAT score

	Dependent variable: KESAT		
VARIABLES	Base model	Model A	Model B
iapp	0.76*	0.82**	0.67**
	(0.297)	(0.266)	(0.231)
numeracy		0.33**	0.28**
		(0.0471)	(0.04)
comprehension		0.14**	-0.037
		(0.0356)	(0.08)
edbyhhmem15		-0.09**	-0.144**
		(0.0257)	(0.04)
SESPrin1		0.11*	0.09
		(0.0529)	(0.05)
garden			0.58**
			(0.115)
hiredlabor			0.08**
			(0.0218)
info_relatives			0.46*
			(0.190)
info_tv			-0.45
			(0.296)
info_tv*info_relatives			4.77**
			(0.338)
comprehension*edbyhhmem15			0.04*
			(0.0182)
Constant	1.56**	0.63**	0.24
	(0.193)	(0.180)	(0.253)
Observations	619	619	619
R-squared	0.05	0.18	0.28
Effect size[33] (Cohen's d)	0.45		

Robust standard errors, adjusted for clusters, reported in parentheses
*** p<0.01, * p<0.05*

In model B (See Table 5.14), similar to the base model and model A, the effect of being an IAPP graduate leads to significant increase in one's KESAT score, precisely by 0.82 units (8.2%). Those with higher numeracy skills are still significantly more likely to perform better on the KESAT test; however, better reading comprehension score does not significantly improve one's performance in KESAT, unlike what was observed in model A. Numeracy as a significant

[33] Glass's Delta 1, which employs the standard deviation of the control group for effect size estimation, was also calculated. The estimate shows that average KESAT score differs by 0.474 and the reported confidence interval is (-0.64-0.31).

predictor of KESAT score highlights the importance of measurement and mathematical reasoning in better understanding sustainable farming, which requires employing these cognitive skills for measurement precision. Also, average schooling years of household members still tend to decrease the score by 0.14 units as opposed to 0.09 units in model A. Unlike education of household members, socio-economic status of the household, does not anymore have any significant influence. It is important to note that, the negative relationship between farmer performance and average years of education of household members contradicts existing evidence (Phillips, 1994). This observation illustrates that average educational qualification of household members is not a critical factor in determining farmers' knowledge. There may be multiple reasons to explain this negative relationship. One of the reasons could be that higher education qualification allows household members to choose non-farming occupation, thereby making them less knowledgeable of new technologies. Another reason could be that formal schooling does not lead to the acquisition of basic reading skills required for learning new information (Wagner, 2018).

However, if the average number of years of educational qualifications of household members and reading comprehension score of the participant both increase, KESAT score is significantly improved by a very small amount i.e. ~0.04 units. The weak predictive power of participants' reading comprehension skills combined with the overall educational status of the household possibly tells an interesting story about farmers' learning practices. In a densely populated and highly connected rural society with pervasive use of mobile phones, learning about new information from friends and relatives seems more plausible than learning by reading agricultural texts or brochures. Therefore, participants' reading comprehension skills and mean educational status of the household do not seem to be the best predictors of KESAT success.

Among other household characteristics, while socio-economic status does no longer have any significant impact on KESAT score in model B, farmers in household-based farms in possession of kitchen/vegetable garden(s) score 0.6 units more than those without garden(s). This means that with access to kitchen garden, farmers are more likely to have acquired better

KESAT by practicing related skills, as projected in the conceptual framework in Chapter 2 (See Figure 2.2). When it comes to employing social networks to gather information, relatives seem to make a significant difference in KESAT score of the participants by ~0.5 units. However, watching television does not influence one's KESAT. Even though television as the only source of information cannot predict KESAT score, a participant who watched television as well as received agricultural information from his/her relatives improved their test score significantly by 4.8 units (48%). This finding is reflective of the reality given most households possess a TV set in rural Bangladesh and national channels are traditionally known for broadcasting daily/weekly farmer education programs.

The impact of IAPP on KESAT score is consistently large and significant even though the magnitude of the coefficient varies in the three different models. The estimates are reliable as the standard errors are robust and were adjusted for 21 clusters. Although it is a sound method, the coefficients are still not fully efficient as the models do not account for variation between and within villages (the treatment was randomized to farmers at a village level) and any possible omitted variable bias. These issues are addressed in the following random effects model (See Table 5.15) based on model B.

5. A. 4. 3. 2. Estimate based on village level random effects

There is additional information available in the current random effects model (See Table 5.15). R-squared within estimate indicates that the model can account for 20.4% variation within groups or villages. The R-squared between estimate shows that the model can account for ~47% variation between villages while the value of R-squared overall demonstrates that the model can explain ~27% of the total variation in the model. In comparison, in model B the variance explained by the model was ~26.5%. The information in the random effects model provides a more efficient picture of the effects of the program and other individual, household and community level characteristics on KESAT.

Table 5. 15: Random effects regression estimates for KESAT

Dependent variable: KESAT VARIABLES	Model C
iapp	0.617**
	(0.219)
numeracy	0.284**
	(0.0343)
comprehension	-0.0589
	(.0904)
edbyhhmem15	-0.117**
	(.0471)
SESPrin1	0.0678
	(.0420)
garden	0.593**
	(0.100)
hiredlabor	0.0715**
	(0. 0183)
info_relatives	0.370**
	(0.192)
info_tv	-0.0259
	(0.261)
info_tv*.info_relatives	3.871**
	(0.297)
comprehension*edbyhhmem15	0.0400*
	(0.019)
Constant	0.252
	(0.331)
Observations	619
Number of clusters	21
R- squared (within)	0.204
R-squared (between)	0.467
R-squared (overall)	0.270

Robust standard errors, adjusted for clusters, in parentheses
** p<0.01, * p<0.05

The effect of the treatment, i.e. IAPP, on KESAT score is still positive and strongly significant and the standard error is about one third the size of the coefficient (See Table 5.15). Participants in the treatment group are likely to score ~0.62 units (6.2%) more than those in the control group, provided all the other variables are held constant at p<0.01, compared to ~0.7 (7%) units in model B. Coefficients do not change for numeracy score and only slightly change for all other variables. Similarly, p- values remain more or less the same for all variables. The value of rho, the inter-class correlation coefficient (~0.14), suggests that only 14% of the relationship between the individuals in different clusters or villages can be explained through the model.

5. A. 4. 3. 3. Structural Equation Modeling showing Partial Mediation Analysis

In the previous section, it was observed how various socio-economic, household-level and individual characteristics along with IAPP schooling are responsible for farmers' productivity, UESAT and KESAT, in alignment with the conceptual framework discussed earlier (See Chapter 2, Figure 2.2). Next, following the conceptual framework, it is explained how the major outcomes are interconnected. In order to demonstrate these relationships, mediation analysis using path diagram was carried out to provide practical insights into the program-level workings of an FFS education system, especially when a program is expected to influence several constructs as in the case of IAPP.

The path diagram (See Fig. 5.6) shows that the treatment variable (IAPP) has both direct and indirect effects on the two other outcome variables: productivity and UESAT. In other words, KESAT was tested for mediating the effect of IAPP schooling on the two other major outcomes (productivity and UESAT) (Baron & Kenny, 1986; Shrout & Bolger, 2002). In the following model, while IAPP education significantly improves productivity, part of its impact on productivity is mediated by KESAT (See Table 5.16). The same is also true for the impact of IAPP on UESAT, which is partially mediated by KESAT.

The coefficients presented in the path analysis diagram (See Figure 5.6) are significant excluding the one linking UESAT to productivity (See Table 5.16). The analysis shows that relevant knowledge on sustainable agriculture (KESAT) mediates the impact of farmer education in IAPP schools on both UESAT and productivity of household-based farms. However, contrary to what was hypothesized in the conceptual framework, Figure 5.6 demonstrates non-significant impact of UESAT on productivity, meaning UESAT does mediate the impact of the program to improve farmer productivity in this study. Taken together, these observations imply that enhanced knowledge of sustainable technologies can improve productivity as well as increase farmers' UESAT score. With better knowledge, farmers have better productivity and UESAT skills.

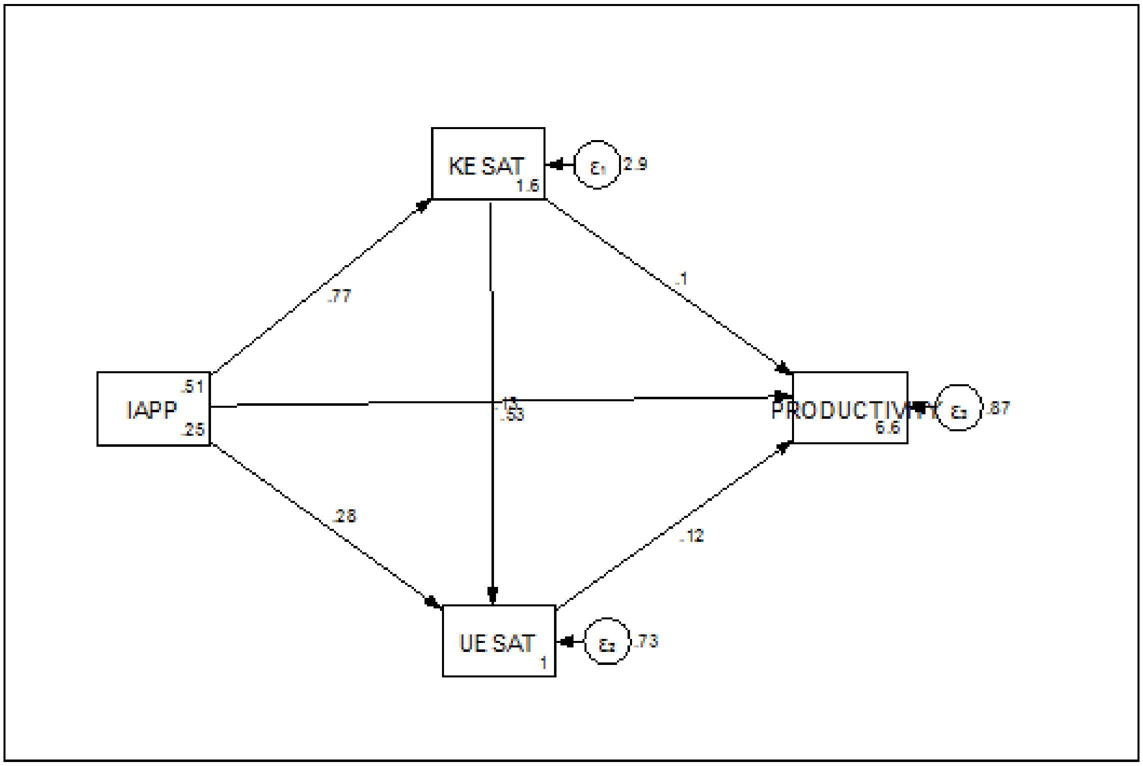


Figure 5. 6: Path diagram showing partial mediation, regression coefficients and error terms

These findings have serious implications for adult education in FFSs, focused on creating learning systems for farmers from marginalized backgrounds such as small farmers and women farmers with limited access to resources and basic literacy skills. As it was observed earlier in the random effects regression models (Tables 5.11, 5.13 and 5.15), having access to agricultural resources and land, social network and numeracy skills improves the chances of farmers' KESAT, UESAT and productivity successes. Making knowledge accessible to marginalized groups will mean that education programs have to be designed in a way that combine both basic literacy (especially numeracy) and agricultural education for these individuals so they are able to effectively learn and apply new methods of sustainable production. Therefore, while KESAT is seen as an effective mediator of success in UESAT and productivity, other relevant characteristics, which promote learning, are instrumental for achieving these major outcomes. Drawing from these findings, an effective farmer education program—designed to improve farmers' skills and productivity— will need to have a special emphasis on learning. It would also create opportunities for higher productivity and technology adoption.

Table 5. 16: Structural Equation Modelling showing partial mediation using maximum likelihood estimation

VARIABLE NAMES	(1) KESAT	(2) UESAT	(3) PRODUC-TIVITY	(4) Var (e.KESAT)	(5) Var (e.UESAT)	(6) Var (e.PRODUC-TIVITY)
KESAT		0.132**	0.102**			
		(0.0355)	(0.0261)			
UESAT			0.124			
			(0.0665)			
IAPP	0.767**	0.283*	0.528**			
	(0.296)	(0.139)	(0.152)			
Constant	1.559**	1.030**	6.590**	2.850**	0.727**	0.874**
	(0.194)	(0.0705)	(0.112)	(0.207)	(0.111)	(0.0894)
Clusters	21	21	21	21	21	21
Observations	619	619	619	619	619	619
SRMR	0.00					
CD	0.137					

Robust standard errors, adjusted for clusters, reported in parentheses
** p<0.01, *p<0.05

5. B. Panel data analysis

Using panel data from the baseline and the endline surveys, the impact of IAPP on yield (kg/ha) and UESAT[34] score is measured. The figure below (Figure 5.7) shows the distribution of yield in all treatment and control villages. The second figure (Figure 5.8) shows the change of average yield with varying scores on UESAT. Beyond a score of 1, UESAT has a positive relationship with yield as yield improved over time (See Table 5.8).

[34] The UESAT test for the panel data analysis consisted of only five ESAT items, instead of all seven ESATs examined in the previous cross-sectional study, due to limited data availability.

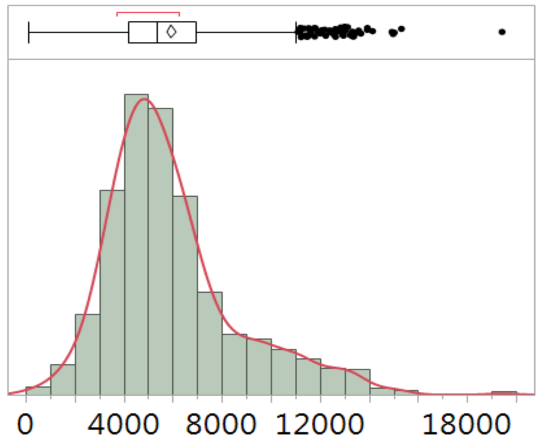


Figure 5. 7: Distribution of yield (kg/ha)

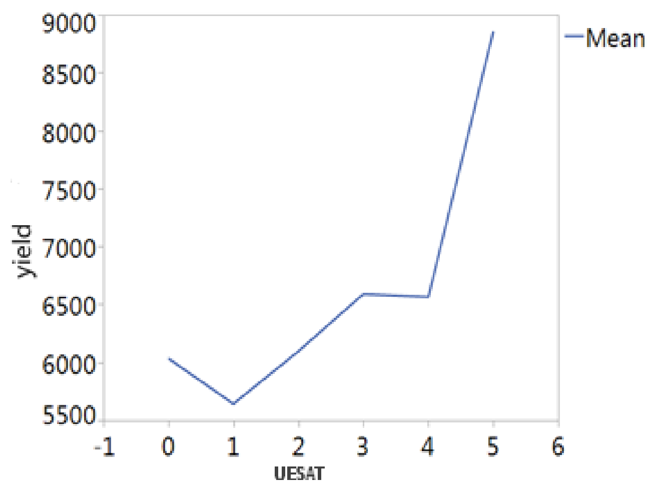


Figure 5. 8: Trend line for mean yield and UESAT

5. B. 1. Impact on yield and UESAT

IAPP education did not improve yield and UESAT score remained unaffected over time. From the difference in difference estimation (See Table 5.17) it becomes apparent that the treatment had no significant impact on yield. It was recorded that yield was significantly lower during the year of the endline survey i.e. 2016 compared to 2012, the year of the baseline study. This result is acceptable considering the flood of July-August, 2016, which affected over 50 percent of the villages in the treatment group in 2016 for over two months, resulting in a sharp decline in yield in that area. The flood ensued as the Teesta River overflew due to heavy rainfall during the summer, inundating most land areas in one of the project districts included in this study.

Table 5. 17: Difference in difference estimation to measure impact on yield and UESAT

VARIABLES	(1) Productivity (yield)	(2) UESAT Score
1.iapp	638,790*	0.167
	(284,092)	(0.171)
1.post	-255,877**	-0.121*
	(1,305)	(0.0518)
iapp*post	-3,866	0.177
	(233,831)	(0.160)
Constant	1.264e+06**	1.333**
	(33,272)	(0.146)
Observations	529	532
Clusters	21	21
R-squared	0.163	0.022

Robust standard errors, adjusted for clusters, reported in parentheses
** p<0.01, *p<0.05

5. B. 2. Explanation of results

The analysis (Table 5.17) shows that productivity decreased by 3,866 kg/ha between the years of 2012 to 2016 in the IAPP villages compared to the control villages. Similarly, the second model showing the impact of IAPP schooling on the UESAT score reports positive change in UESAT over time. Based on the panel data, farmers' performance on the UESAT score improved by 0.18 units from 2012 to 2016. However, both of these results are insignificant. These analyses contradict the results evidenced in the OLS and random effects models presented earlier.

In the box plots below we see that yield decreased while there was almost no change in UESAT between the years of 2012 and 2016 (See Figure 5.9, Figure 5. 10 and Table 5.17). The limited results on UESAT may be a result of the small sample size (Tripp, Wijeratne, Piyadasa, 2005). Another way to think about the lack of impact on UESAT is selection bias, which may have led to stronger farmers already equipped with UESAT skills being chosen to join the IAPP program, showing no difference over time.

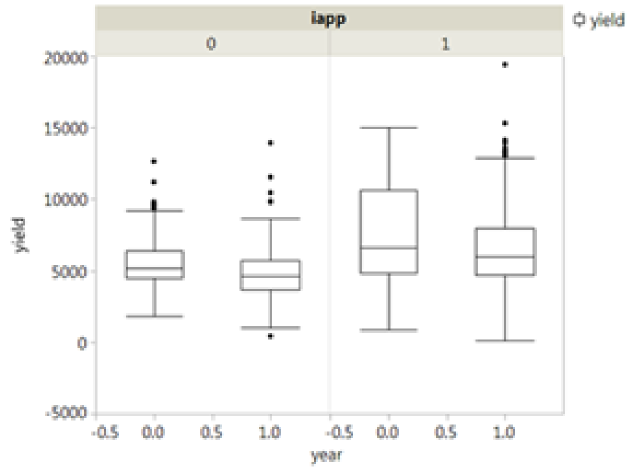


Figure 5. 9: Change in Yield over time

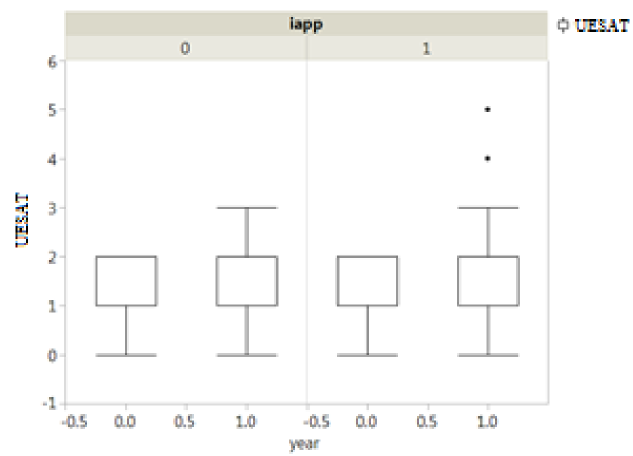


Figure 5.10 Change in UESAT Score over time

Although the program was allegedly randomized, it is a predominant challenge to maintain full implementation fidelity in the deployment of a randomized control trial in development settings (Karlan & Appel, 2016). Considering the path analysis model in the previous section (5.A.4.3.3.) and the panel data analysis, it is likely that improved UESAT skills may not lead to improved productivity, which brings into question the relationship between sustainable practices (mainly, the list of ESATs included in this study) and improved productivity. This specific topic will be further explored in a future study by the researcher.

5. C. Summary

Cross-sectional data analysis indicates that the IAPP program had strong and significant effects on all three major outcomes: productivity, UESAT and KESAT. By contrast, panel data analysis showed inconclusive results regarding the impact of non-formal training in IAPP schools on UESAT and productivity. As hypothesized in the conceptual framework guiding the methodology of this study, various household characteristics (socio-economic status, number of hired labor, agricultural expense etc.), individual characteristics (gender, attitude, education, age etc.) and community characteristics (e.g. sources of information, participation in IAPP) aided in explaining factors responsible for farmers' performance. While some individual characteristics (e.g. household head's education, reading and numeracy skills of the participant) had positive influence on these outcomes, some other (e.g. average number of years spent in school by household members) wielded a negative influence.

Nested models provided some possible explanations for these results, at the same time ensuring the consistency of estimation procedures. Additionally, due to the various constraints faced by the local extension office in implementing a perfectly orchestrated cluster-randomized control trial, the unobserved heterogeneity in OLS models was accounted for by random effects models. This was done to ensure that the results of the outcomes would be unbiased.

Selection bias may have affected the treatment groups due to the unpredictable nature of rural societies and/or associated cultural norms. However, one can still be confident about the positive effect of the program on productivity and KESAT due to the multivariate nature of the OLS and random effects models. Characteristics related to the farmers' socio-economic status and individual characteristics – that may have led to self-selection of some farmers into the treatment group – were controlled for in the full model.

CHAPTER 6: DISCUSSION

This chapter is focused on highlighting some of the major findings presented in the previous chapter to gain an in-depth understanding of the impact of farmer field school education in IAPP schools on farmers' performance in productivity, UESAT and KESAT. First, the discussion will focus on the nature and magnitude of IAPP's impact on these three major outcomes and the mediating influence of KESAT on productivity and UESAT, as demonstrated in the previous chapter. Second, this chapter will present a set of predictor variables responsible for generating significant differences pertaining to the program outcomes. Following the conceptual framework for this study, the second half of the chapter will be framed around explaining the effects of important individual, household and community characteristics on farmer productivity, UESAT and KESAT performance. Finally, building on the major findings, this chapter will state three major implications for relevant public policy and evaluation studies.

6. A. Impact on the three major outcomes

6. A. 1. Impact on productivity

The effect of IAPP on productivity, according to the reported OLS and random effects estimates, is significant with a large effect size (See Tables 5.9, 5.10 and 5.11) based on cross-sectional data from the endline survey. The coefficient related to treatment, i.e. IAPP, indicates a 45% increase in mean productivity. This means that farmers in the IAPP schools obtained a large increase in their productivity compared to the farmers in the control group. Since productivity is measured as average productivity of each household member involved in agriculture, improvement in productivity is a critical indicator of household level food security. Although the effects of FFS training programs on farmer performance vary quite a bit in other experiments, the effect of IAPP schooling in this study is large enough to suggest that it had a notable impact on farm productivity. Findings from the multiple nested models along with the robustness test suggest that the program positively influenced farm productivity.

A difference in difference estimation using panel data from both the baseline and endline surveys does not corroborate the evidence from the cross-sectional analysis based on the endline survey data. Results from the panel data analysis show that the IAPP graduates experienced decreases in productivity but improvement in UESAT; however, the results were insignificant. Considering the small sample size of farmers utilized in the panel data analysis, it is possible to conclude that the lack of significance of the impact of IAPP education on farmers' performance is due to the small sample size. Therefore, these results may not be applicable to other treatment villages excluded from the analysis.

In addition to participation in IAPP schools, several predictor variables exerted significant influence on farm productivity. Among these variables, household head's education, agricultural production expenditure, cultivable land size and access to relevant information through friends were associated with improved productivity. Overall, the final random effects model (Table 5.10), indicated the importance of both formal and non-formal educational qualifications of the person in charge of decision-making for improved farm productivity. The significance of household head's education in determining a farm's performance aligns with the agricultural practices in rural Bangladesh, where major economic decisions are primarily made by the household head (Asadullah & Rahman, 2009). Additionally, access to monetary resources and information in rural societies allow household-based farms to invest in hired labor and machineries which dramatically decrease the time invested in land preparation and cultivation, thereby increasing efficiency.

By contrast, as the household head's age and the total number of years of schooling of family members (age 15 or above) increased, chances of improved productivity were significantly reduced. The negative relationship between household head's age and productivity offer insights into the current rural economy. With age, household heads are likely to limit their active participation in agricultural production due to health issues and/or lack of incentives to invest in agriculture as younger members of the family secure employment in non-agricultural sectors. Also, greater number of years spent in school by household members indicates increased chances of finding non-agricultural employment, reducing their involvement in agriculture; they may not be farmers any longer.

6. A. 2. Impact on UESAT

Farmers were required to respond to a set of seven questions on the UESAT test in order to record their adoption behavior concerning environment-friendly technologies. The impact of treatment on UESAT score is positive and significant, according to both the OLS and the random-effects estimates. The treatment had a moderate effect on UESAT score with an effect size of ~0.51. Farmers in IAPP schools were expected to improve their UESAT score by 0.42 units (6%), where the scores varied from 0 to 7, depending on how many ESATs they had reportedly employed (See Table 5.7).

Along with IAPP education, some factors pertaining to household characteristics such as socio-economic status, total number of active household members in production and size of cultivated land significantly predicted farmers' performance in UESAT. It is understandable that better socio-economic conditions increase the resources available to farmers, thus making it easier to adopt ESATs. For instance, some ESATs such as transplanting and line planting are labor intensive. Therefore, it seems reasonable that more prosperous families and/or those with a larger number people involved in agriculture scored higher on the UESAT test. Similarly, the quantity of land available for cultivation – one of the significant predictors of improved UESAT skills among all farmers – shows that access to a larger area of land makes it more convenient for farmers to experiment with diverse ESATs.

As evidenced earlier (Cai et al., 2016), with greater involvement of household members in agricultural production, opportunities for agricultural innovation improves as employing innovative ESATs requires human capital alongside wealth. In conjunction with knowledge and resources, a farming household also needs a sizeable number of people involved in agriculture. As the number of years spent in schools by the family members increases, productivity and UESAT are negatively affected. This observation further confirms that the involvement of family members in agriculture is likely to decrease as opportunities to enter into other occupations emerge. This phenomenon is more common among the young adults in the family. Moreover, due to the training-intensive nature of farmer field schools, knowledge diffusion is often limited only to those who are in the program (Feder et al., 2004). Consequently, diffusion of ESATs is likely to impact those households with a higher number of family members involved in agriculture.[35]

6. A. 3. Impact on KESAT

Various studies on integrated pest management programs chronicled evidence on FFS education enhancing farmers' ecological knowledge (Siddiqui, Siddiqui & Knox, 2012; Reddy and Suryamani, 2005; Rola, Jamias & Quizon, 2002). Results concerning the influence of IAPP schooling in improving farmer KESAT align with existing evidence. The related OLS and random effects estimates validate that IAPP education had a significant impact on KESAT. Farmers in the treatment group were expected to score 0.62 units (6.2%) more on the KESAT test compared to those not trained at IAPP schools (See Table 5.4).

Under individual characteristics, the positive effect of numeracy score on farmers' KESAT performance indicates that those with basic numeracy skills are likely to have better knowledge of environmentally-friendly technologies. Regarding the use of social networks, having relatives as sources of agricultural information also improves one's chance at being knowledgeable. This particular finding implies that farmers who mainly rely on relatives to update their knowledge tend to receive relevant information on KESAT. Moreover, household characteristics such as possession or non-possession of a vegetable garden and the quantity of hired labor are expected to improve one's KESAT. A household with a vegetable garden improves a farmer's chance to have better knowledge through active participation in garden management. The case is somewhat similar when family-run farms hire external laborers, thereby, allowing household members to learn to give clear instructions about land, water and soil management to hired individuals. These hands-on practices, therefore, positively influence a farmer's knowledge, resulting in a better KESAT score. Finally, results show a trivial but positive influence of reading literacy of the participant and average formal educational qualification of household members on farmers' KESAT performance.

[35] Contrary to what is observed in the cross-sectional data analysis, IAPP had positive but non-significant impact on farmers' UESAT score in the treatment villages in the difference in difference estimates using panel data. It is possible that the lack of any significant effect is likely due to the small sample size.

The path diagram (See Fig. 5.6 and Table 5.16) presented in Chapter 5 makes it apparent that KESAT helps farmers to produce more and improve UESAT skills. Practically, it makes sense that a higher KESAT score allows a farmer to increase production and to be more adaptive to environment-friendly practices, such as use of organic fertilizer, avoidance of harmful chemicals, responsible water usage, efficient management of seeds and better land management. As is evident in existing research (Genius et al, 2013; Van der berg 2007), farmer education in IAPP schools influenced not only productivity, but also immediate outcomes, such as knowledge and technology adoption. Earlier studies, however, did not explore the relationships among these different outcomes. As a result, this study makes an attempt to extend the existing evidence base to present a viable case of inter-dependent relationships among major farmer outcomes. With the evidence that knowledge can positively impact both use of environmentally sustainable technologies and productivity, governments, international organizations and local institutes, responsible for investment in farmer education, can be motivated to further investigate the nature of knowledge that propels program success. Finally, based on the results of this study, creating improved systems of learning for small farmers, where education translates to relevant knowledge and skills, will increase the likelihood of an overall positive impact of non-formal FFS education.

6. B. Relationship between outcome variables and major predictor variables

The major predictors – responsible for influencing the major outcomes – fall under three main categories: household characteristics, individual characteristics and social networks.

6. B. 1. Household characteristics

Household characteristics include socio-economic status, number of household members involved in agricultural production, quantity of laborers hired in the past year, agricultural expenditure and ownership of a vegetable garden, among others, according to the conceptual framework (See Chapter 2, Figure 2.2). A few specific household characteristics having significant influence on the main outcomes of interest are discussed below:

6. B. 1. 1. Socio-economic status

Socio-economic status[36] of a farming household, signifying the quality of living conditions, has significant and positive impact on farmers' UESAT. Although this variable was considered for predicting the impact of IAPP on all three major outcomes, SES only had significant positive impact on farmers' adoption skills. It was seen that farmers from households with higher SES were likely to perform slightly better (~0.1 units) than those from lower SES backgrounds. Better performance on UESAT by farmers from higher SES background can be explained by their tendency to "take advantage of new opportunities" (Hall, Scoones & Tsikata, 2017, p. 552). On the brighter side, the significance of household's SES' influence on UESAT indicates an opportunity for prioritizing low SES families in FFSs by offering monetary incentives to focus on both learning and applying new methods. Otherwise, poorer households subsisting on a daily basis would not be able to prioritize innovation, unlike those with adequate resources, time and labor.

6. B. 1. 2. Agricultural expenditure

Limited access to monetary and other kinds of resources hampers farm productivity. In this study, households that spend more on agricultural input (such as fertilizer, compost, irrigation) tend to be significantly more productive than those that do not invest or invest less. Established evidence also points to the fact that the system of agricultural production anywhere in the world requires increased input for higher productivity (FAO, 2014).

However, it was seen that farms that spend more on agricultural input improved mean productivity by less than 0.1 % in the treatment group, which does not indicate a practical difference. This finding is insightful in understanding why farmers need steady financial assistance to kick start farm productivity by investing in relevant tools and technologies. Over time, the positive difference is likely to accrue and create larger impact on small household-based farms.

[36] An index for SES was created using principal component analysis (for details see Chapter 4).

6. B. 1. 3. Size of agricultural land

In line with the above result, access to larger areas of land leads to higher productivity by a small magnitude (~0.1%) and slightly improves UESAT (~0.002 units or ~0.03%), when the land area is increased by 1%. It is reasonable that with the availability of larger lands, a farm has a better chance at experimenting with new agricultural methods and produce more. However, it is clear that the size of land is not the only condition for improved farmer performance. In fact, increased expenditure on agricultural input and larger area of agricultural land jointly has a negative effect on farms by diminishing the rate of production per household members. This finding demonstrates that improved productivity requires efficient, not indiscriminating, use of input, be it land, fertilizers, pesticides, or other inputs.

6. B. 1. 4. Hired labor

Households that hire more laborers are likely to have a higher score on KESAT. The impact of hired labor on knowledge shows that financial resources available to a family to hire agricultural help for production does positively influence a farmer's KESAT. It is probable that those households with access to more manpower – indicative of a better financial status – have better access to information on efficient ways of land, water and crop management compared to less prosperous households. Additionally, it is important to note that a greater rate of participation by family members in agriculture positively influenced UESAT. Jointly, these results confirm the established idea that successful farming requires availability of human resources, whether a farmer wants to improve his/her knowledge (KESAT) or skills (UESAT).

6. B. 1. 5. Education of household members

The total number of years spent in formal schools by all family members of age 15 and above, and the average number of years spent in school by them, were employed to predict farmer success in all three major areas of outcomes. The first indicator had a significant but somewhat tenuous, negative relationship with farmer performance concerning farm productivity (less than 0.1%) and UESAT (less than 0.15%). These influences, however small they might be, shows that higher educational qualifications of adult household members (age 15 and above) and engagement in agricultural production are not complementary. Correspondingly, average number of years spent in school by adult family members also reduced the participant's KESAT score (0.12 units or 1.2%). This finding provides further evidence that reduced engagement in agriculture by family members may be a result of their higher formal education training. With more formal schooling, rural youth seeks employment outside of the agricultural sector, eventually giving up farming for good.

6. B. 1. 6. Number of household members involved in agriculture

The greater the number of family members, who involve themselves in agricultural production, the better a participant's chance in performing well in UESAT by ~0.2 units or ~3%. This means that increased involvement in agriculture of a family, and access to additional labor and human capital make improved UESAT performance more likely.

6. B. 2. Individual characteristics related variables

Among individual characteristics, formal schooling of the household head, the household head's age, attitude regarding organic fertilizer, gender of the participant and basic literacy (numeracy and reading) skills had varying levels of influence on farmer outcomes.

6. B. 2. 1. Household head's education

Education in its different forms – such as FFS education and formal schooling – has consistently been a critical indicator of farmer performance. In comprehending the effects of FFS education on farmers' productivity, FFS education was compared to traditional schooling – measured as the years spent (above 4 years) in formal schools – of the household head or the person in charge of decision-making. The estimates reveal that for every additional year spent in school by the household head beyond 4 years of schooling, farm productivity increases by almost 26%, showing schooling's strong impact. Previous research in Bangladesh showed similar results when household head's education was considered, combined with neighborhood level educational qualifications (Asadullah & Rahman, 2009).

This estimate, when compared with the effect of IAPP education on productivity, reveals that household head's education improves productivity by almost 40%. Taken together, these findings mean non-formal education of a household member, when compared to formal education of household head, plays a more significant role in improving productivity. Although non-formal education in IAPP is a better predictor of farm productivity compared to household head's education, both formal and non-formal learning significantly predict farm productivity and are necessary for farmers' success.

Similarly, the insignificant relationship between household head's educational qualification and participant's (who may or may not be the household head) KESAT and UESAT performance is indicative of the reality of rural farms. In rural households, despite the fact that household heads usually make major agricultural decisions, there exists a system of collective knowledge sharing and adoption among family members. As a result, agricultural knowledge (KESAT) and skills (UESAT) are not dependent on one individual's formal education background but rather are shared among all family members. Additionally, it is quite possible that formal education is not a necessary condition to improve one's KESAT or UESAT.

6. B. 2. 2. Literacy skills: Basic numeracy and reading comprehension

Formal educational background of the household head is not a critical indicator of farmer's knowledge (KESAT). Advanced basic reading comprehension skills and higher average years of formal education of household members jointly makes only a slight difference in KESAT performance (less than 0.5% on the 10-point scale KESAT test). However, a better grasp of basic numeracy or mathematical skills allows farmers to perform significantly better in both KESAT and UESAT. The latter findings indicate better performance by numerically literate farmers in adopting new environment-friendly technologies by 10% and knowing more about these ESATs by 3%.

By and large, a formally educated and literate – i.e. have reading comprehension – household member or a literate household member in a farming household with formally educated family members is expected to perform slightly better on KESAT than those without these characteristics. Importantly, basic numeracy skills help farmers significantly improve their knowledge of sustainable technology application. These estimates support the conclusion that basic literacy, especially, numeracy competence of the person in charge of decision-making in a household-based farm plays a significant role in determining knowledge and adoption of sustainable technologies.

6. B. 2. 3. Gender

Gender was hypothesized to be a critical indicator of farmers' performance in the conceptual framework (See Figure 2.2). Gender had a significant impact on farm productivity when some variables indicating household's access to monetary and land resources were not considered (See Table 5.9, model A). However, in the final model to predict productivity, male farmers did not perform significantly better than women farmers in farm productivity when access to resources was taken into account. In alignment with the existing evidence in current literature (Waddington et al. 2015), this study found that male farmers were more likely to have higher productivity compared to female farmers when access to resources by these groups varied. As earlier discussed in Chapter 3, women who are involved in agricultural production in rural societies are often not allowed to make economic decisions independently without consulting their male counterparts. The final analysis (See Table 5.10) reveals that despite the gender-related constraints, women are able to lead a productive household-based farm when they have equal access to resources.

This assertion is supported by the results from models predicting farmers' KESAT and UESAT performance where gender of the farmer had no bearing on knowledge (KESAT score) and skills (UESAT). Additionally, results from the decomposition of UESAT score by gender revealed that a greater share of women adopted more environment-friendly practices compared to men – even when their KESAT levels were lower than men (See Figure 5.1, Figure 5.4 and Table 5.6). Based on these findings, it is possible women farmers can be equally productive as male farmers in leading household-based farms, given equal access to resources.

6. B. 2. 4. Attitude

Contrary to what was theorized in the conceptual framework, farmers with positive attitude toward organic fertilizer experienced no difference in UESAT. This finding shows that attitude toward organic versus chemical fertilizer usage is not a critical predictor of performance regarding all environment-friendly practices examined in this study. The evidence concerning the lack of impact of attitude on UESAT and KESAT in this study contradicts established literature from other counties in the South Asian region (Siddiqui, Siddiqui & Knox, 2012; Moumeni-Helali & Ahmadpur, 2013). However, the results are relevant, bearing in mind that the number and diversity of ESATs studied here go beyond the sole use of organic fertilizer. Of the seven ESATs, only three were linked to organic fertilizer usage. Therefore, it is possible that farmers who reported positive attitude toward use of organic fertilizer did not have adequate knowledge of other ESATs. Alternatively, it is also probable that positive attitude toward organic fertilizer does not translate into use of organic fertilizer and avoidance of harmful pesticides.

6. B. 3. Social network

Information from extension agents, friends, relatives and TV

Regular contact with IAPP facilitators and extension agents in IAPP schools had positive and significant influence on improved farmer performance in all three major outcomes. Since IAPP services were targeted at educating farmers on KESAT and UESAT for better productivity, farmers in control villages located far from IAPP villages – who follow traditional methods of cultivation requiring extensive use of chemical fertilizers – were not practically aware of the technologies addressed in IAPP training sessions. The results, therefore, demonstrate that IAPP extension services did not influence farmers' behavior in the control villages, also reflected in the ethnographic data collected during the study[37].

It was observed that receiving information from friends about new practices in agricultural production improved a farmer's chance to be productive by 22.5%. Additionally, using TV as a source of agricultural information contributed toward a 20% increase in farmers' UESAT

[37] The findings from the short-term ethnography will be shared in a future publication.

performance (See Table 5.13). Drawing from these findings, it can be said that employing friends and relatives as sources of information generally improves farm productivity and UESAT as farmers are able to see new practices and directly learn from their acquaintances.

Correspondingly, receiving information from relatives improves a farmer's KESAT performance by 4%. However, when farmers combine their sources of information to include both relatives and television, it significantly improves their KESAT performance related to the selected environmentally sustainable agricultural technologies by 34%. It was seen that more knowledgeable farmers usually combine an electronic source of information, such as TV with information from their close acquaintances, to significantly improve their performance in KESAT. The multimodal nature of information sources utilized by farmers illustrates that accessing information on multiple platforms is critical for better performance in all three major areas of outcomes.

6. C. Implications

Based on the discussion above, the findings in this study have three major implications:

1. *Resources for the marginalized farmers:* Educational investments on smallholder farmers in developing countries often do not impact the most marginalized groups, such as women and poor farmers, which is due to restricted access to resources, and existing socio-economic and cultural norm-associated challenges. Findings in this study have consistently pointed toward the significance of monetary, land and human resources in farmer outcomes. Particularly, access to agricultural resources – in the form of larger agricultural land and hired labor – was seen to play a positive role in improving farmer performance. Therefore, when new programs are conceived, there needs to be a direct focus on improving access to agricultural resources for the resource poor groups to ensure they are able to improve their overall performance. Programs should consider putting a practical system in place so that resource-constrained farmers can share labor and resources with others on a regular basis.

Similarly, findings imply that women farmers' productivity seems to suffer from unequal distribution of resources as they do not perform as well as male farmers when access to agricultural resources is not equal. Evidence from this study also suggests that equal access to agricultural resources for women and men at farmer field schools like IAPP or similar non-formal educational settings can neutralize the differences between male and female farmers' productivity. Therefore, giving women better access to resources in FFSs has the potential to eradicate any gender inequality in agricultural productivity. Additionally, these findings have implications for enhancing impact of farmer education on female farmers by informing state policies, which can eventually rework the traditional gender norms that hinder women farmers' participation and access to resources in FFSs. Moreover, standing at the crossroads of rapid rural-urban migration and climate change, a culture of change in FFSs – inclusive of women and poor farmers – is crucial to address the changing nature of environment and economy in order to sustain food security in Bangladesh and other countries in the Global South.

2. *Emphasis on numeracy:* It is critical to note here that functional numeracy skills often are more predictive of farmers' performance in knowledge and use of sustainable technologies compared to formal education and reading comprehension. Being numerically literate practically allows farmers in Rangpur to process information and adopt innovative sustainable technologies by using basic reasoning skills and adhering to different measurement requirements. As a result, local FFSs can help farmers with no prior access to literacy learning or access to poor quality education by supporting literacy education, especially, mathematical reasoning along with the practical training offered at FFSs. Based on the findings from this study, numeracy skills training for low-literacy level and resource-poor farmers will play positive roles in aiding effective access to quality education when new environmentally-sustainable technologies are introduced and changes need to be expedited.

3. *Learning in the FFS system for better farmer productivity*: For an educational program to be effective, the implementers need to a) understand the relationship among various farmer outcomes in an FFS and b) carefully consider household, community and individual level variables to achieve the multiple farmer outcomes. For example, in this study, better knowledge of environmentally sustainable technologies (KESAT) made farmers more productive and

sustainable technology-efficient at a program level. Therefore, one can inquire about the ways knowledge acquired by marginalized farmers can be improved to match the knowledge outcome of successful farmers at a school level. Information from multiple sources, including relatives, friends and TV, boost knowledge and adoption of sustainable technologies, particularly with FFS training and a few other variables. Building on these empirical findings, it is clear that farmers need enhanced learning opportunities utilizing multimodal sources of information and education to improve their knowledge of sustainable agriculture. It is critical to leverage information on predictors associated with knowledge to improve farmer productivity. To improve farmer program outcomes, enhance the conditions that facilitate learning.

CHAPTER 7: CONCLUSION

The present research found a significant impact of non-formal education at IAPP schools on all three major outcomes of interest: knowledge (KESAT), use of sustainable agricultural practices (UESAT) and productivity. The study asked questions about the impact of FFS education on the major outcomes and investigated how FFS education impacts farmers at a system level. For instance, at a program level, the study investigated whether improved knowledge translates into better technology adoption and/or improved productivity, and found positive evidence. Additionally, at a school level, different sets of variables that predict farmer success on these major outcomes were identified by examining various individual, household and village-level indicators, with implications for program designs concerning adult education and capacity development.

7. A. Summary of findings

Using cross-sectional data from endline survey, this study found strong impact of participation in IAPP schools on all three outcomes, namely productivity, UESAT and KESAT at a school level. To measure productivity, a context-specific approach was adopted by emphasizing food security at a household level. Similar approach was adopted to measure KESAT and UESAT by addressing relevant local knowledge and practices. The robustness of the positive results associated with FFS participation is demonstrated by both OLS and random effects estimation methods. In contrast, panel data from baseline and surveys, employed to analyze the impact of the FFS program showed insignificant improvement in farmers' UESAT and productivity. The reason for the inconclusive result was perceived to be a result of small sample size and absence of adequate matched data from treatment and control villages.

Allowing for both school and program level perspectives, this study found that one of the major outcomes i.e. knowledge influenced farmers' performance in both productivity and technology adoption at a program level. Using structural equation modeling, a partial mediation analysis was conducted, revealing that not only the program enhanced KESAT, but also KESAT plays the role of an influential mediator in determining the full impact of the program on both productivity and UESAT. At a program level, the influence of knowledge on productivity and UESAT means that farmer education needs an exclusive focus on quality learning to ensure the maximum impact of an FFS education on farmer outcomes. Taken together, the above results will aid better comprehension of an FFS education system at both school and program levels.

7. B. Recommendations

Several recommendations would be useful for future research and evaluation projects.

1. *Prioritize marginalized and women farmers:* Poor farmers need to get much greater priority. Just training a handful of resource-poor farmers through occasional FFS schooling will not create lasting economic impact. In a place like Rangpur, with the highest poverty incidence in the country, majority of the farmers do not have adequate resources for improved productivity. Evidence from this study clearly shows that limited access to monetary, land and human resources function as bottlenecks to achieving higher productivity among both poor and women farmers. As a result, it is imperative to create opportunities where resource poor farmers can adopt technologies without facing too many financial barriers as well as share human and material resources with others. As women farmers perform significantly poorly compared to men with unequal access to agricultural resources, it is practical to ensure improved educational and monetary resources for this group. Large scale FFS initiatives, exclusively designed to focus on providing financial support to women and poor farmers, can improve overall agricultural performance in the region. These programs can also incentivize financially well-off farmers to share human and agricultural resources with the marginalized ones. Specially, considering the small number of women (171) who took part in this study, and more generally in the IAPP intervention, it is imperative to extend FFS training and resources to more women farmers, delivering on the promise of gender balance in agriculture in reality and not just on paper (DIME & GAFSP, 2012). Additionally, emphasis needs to be given on designing inclusive agricultural education policies as policies often has a greater influence than individual programs on shifting existing social biases against women and poor farmers.

2. *Teach farmers mathematical reasoning:* At this moment, more than just FFS education is required for farmers in climate vulnerable places as they face diverse sets of financial and environmental challenges on a regular basis. Basic numeracy skills demonstrated strong influence on farmers' performance in knowledge and skills building. Therefore, new FFS programs will benefit from investing in basic education, especially numeracy skills development among adult farmers by providing learning opportunities to those with low-literacy levels. It is possible to create and sustain such a program if FFSs form partnerships with existing adult education projects such as community learning centers and adult education programs. Combining literacy and FFS training is a way forward to make sure farmers are well-equipped to readily adopt new technologies to address climate change through sustainable use of ever-diminishing natural resources.

3. *Assess and augment learning outcomes:* Like any education system, FFS system also thrives on learning outcomes of its participants as better knowledge leads to higher productivity. Policy makers and program designers will be wise to invest in assessing adult learners in farmer field schools to ensure program effectiveness. An FFS can easily design its own assessment tool by collaborating with local farmers, extension agents and agricultural officers. Additionally, multiplying the sources of information for better farmer knowledge is likely to enhance learning outcomes as evidenced earlier. FFSs can incentivize learners to employ multimodal sources of information to enhance learning outcomes. This goal can be achieved by partnering with television and radio programs interested in supporting farmer education.

4. *Sustain FFSs by recruiting local teachers:* From a program sustainability angle, educating farmers for a year will lead to little change. Considering the critical influence of learning on farmer productivity, FFSs will need to have a built-in system to create its own educators among existing learners. This kind of initiative will also enhance sustainability of the program by weaving a network of local educators into the social fabric of the agrarian economy. Notably, majority of IAPP-recruited CFs (community facilitators) from local communities possess college and graduate degrees. The higher educational qualifications of these professional CFs made it difficult

to retain them over a long period of time as they prefer to transition to better paying jobs. Training fresh FFS graduates – already committed to farming – as future CFs will help FFSs to leverage participants' knowledge and enthusiasm, and save money, given the cost-intensive nature of these schools.

5. *Create a market for sustainable farmers:* Clearly, non-formal education in FFSs can lead to higher productivity, greater knowledge and adoption of environmentally sustainable technologies; however, this does not guarantee that farmers' earnings will be positively influenced. Often in IAPP schools farmers were heard complaining about not securing the right price for their produces as big companies are not interested in conducting business with small farmers. The marginalized farmers, therefore, end up selling their produces in the local markets or to middle men for a much lower price. Along with education for improved productivity, opportunities need to be created for a better market for local produces by partnering with the private sector.

In sum, the importance of this work lies in informing policy makers and program planners about the critical role of learning and resource distribution in productivity. This research is also expected to illuminate understanding of specific predictive indicators – that need the utmost attention to ensure better farmer performance – and performance indicators designed with contextual considerations for a climate sensitive location. First, this research brings forward evidence confirming that there is no alternative to non-formal education to achieve better knowledge, skills and productivity in rural Bangladesh for creating an environmentally sustainable agricultural system. Farmers from marginalized groups such as poor, illiterate or women farmers present an untapped opportunity for further investment in non-formal education to push the agricultural sector to the next phase of sustainable production, not just in Bangladesh but also in other places in the world. Future interventions will need to take into account the changing roles of women farmers given that men are increasingly migrating to the cities for office and factory jobs. Investing in specific household and community level development, which emphasizes access to tangible resources such as land, money and hired labor, along with literacy education, will be critical for enhancing the impact of farmer field schools on farmers' overall performance.

Second, keeping the “Zero hunger” goal[38] in mind, farm productivity in this research was measured as a performance indicator that directly captures the state of food security in individual farming households. By accounting for productivity of each active member of the household, this research extends the concept of farm productivity to consider and assess a family’s food security status.

Finally, building on previous scholarship and current evidence from the field, this study offers a deeper understanding of ways to improve knowledge, skills and productivity with non-formal education. Understanding that non-formal FFS education is a system of learning – with particular mechanisms in place at both school and program levels – will allow local stakeholders and development agencies to make better investments to enhance learning for the next-generation farmers.

[38] Sustainable Development Goal 2

APPENDIX

Farmer Education and Productivity Survey

Section A: Household Identification
- Part 1: Identification
- Part 2: Verification
- Part 3: Date and time of interview
- Part 4: Target respondent

Section B: Individual Identification
- Part 1: Household (HH) members
- Part 2: HH labor

Section C: Access to extension and other trainings

Section D: Agricultural input and output
- Part 1: Plot
- Part 2: Agricultural technologies

Section E: Housing
- Part 1: Background and status of the housing occupancy

Section F: Income and Expenditure
- Part 1: Household expenditure

Section G: Farmer Groups

Section H: Household gardens

Section I: Negative Shocks and Social Network
- Part 1: Negative Shocks
- Part 2: Social Network

Section J: Knowledge, Perceptions, Attitude and Beliefs
- Part 1: Knowledge
- Part 2: Perceived behavioral norms, attitudes and beliefs

Section K: Literacy and Numeracy Assessments
- Part 1: Numeracy
- Part 2: Literacy

Farmers' Education and Productivity Survey

SECTION A: HOUSEHOLD IDENTIFICATION

Part 1: Location (To be filled in by Enumerator before HH Visit)

A.1.1	Zilla Name	
A.1.2	Upazilla Name	
A.1.3	Union Name	
A.1.4	Village Name	
A.1.5	Para Name	
A.1.6	Bari Name	
A.1.7	List the closest landmarks to the house	

Part 2: Verification

A.2.1	Name of Enumerator		Code	|__|__|__|	Date |__|__|/|__|__|/2016
A.2.2	Initials of Supervisor		Code	|__|__|__|	Date |__|__|/|__|__|/2016
A.2.3	Initials of Editor		Code	|__|__|__|	Date |__|__|/|__|__|/2016
A.2.4	Initials of Back Checker		Code	|__|__|__|	Date |__|__|/|__|__|/2016
A.2.5	Initials Data Entry Operator 1		Code	|__|__|__|	Date |__|__|/|__|__|/2016
A.2.6	Initials Data Entry Operator 2		Code	|__|__|__|	Date |__|__|/|__|__|/2016

SECTION A: HOUSEHOLD IDENTIFICATION				
Part 3: Date and Time of Interview				
READ TO RESPONDENT IN THE BEGINNING OF THE INTERVIEW: Sala'm/Adaab, I am [NAME]. I am representing a researcher from University of Pennsylvania who is conducting a research study on *Farmer Education and Productivity in Rangpur*, Bangladesh. I will be asking you some important questions regarding your agricultural production, personal well-being, and household information. We ensure strict confidentiality for the information you will share with us. No personally identifiable information will be published or shared with anyone outside of the project team. There are no risks to you or your family in answering these questions. Your participation is completely voluntary and you may stop the interview at any time. If you have any questions about the study or the survey at a later date, you may contact Fatima Zahra, Primary Investigator for the project at 01199054650				
A.3.1	Do you agree to participate?	1 = Yes 2 = No		If "2" --> STOP SURVEY
A.3.2	Name of Respondent			
A.3.3	Is s/he an IAPP farmer?	1= Yes, 2=No		
A.3.4	Date of First Visit	Day/Month/Year		
A.3.5	Start Time of Interview 1	Use 24 Hour Clock		
A.3.6	Respondent Member ID	Use from HH Roster		
A.3.7	End Time of Interview 1	Use 24 Hour Clock		
A.3.8	Date of Second Visit	Day/Month/Year		
A.3.9	Start Time of Interview 2	Use 24 Hour Clock		
A.3.10	Respondent Member ID	Use from HH Roster		
A.3.11	End Time of Interview 2	Use 24 Hour Clock		

Part 4: Target Respondent				
ENUMERATOR INSTRUCTIONS: Identify target respondent. You need to interview the household member who is primarily responsible for making decisions about the HH farm or who is a member of IAPP. This is most likely the head of the household, but if the head of the household works off the farm, it will be another household member who is responsible for the household farm.				
A.4.1	**Name of HH Head** Write Name used on official documents, with nickname in parentheses			
A.4.2	HH Head's Father/Husband's Name			
A.4.3	HH Head's Religion	1 = Muslim 2 = Hindu 3 = Buddhist	4 = Christian 5 = other	
A.4.4	Is Respondent the HH Head?	1 = Yes 2 = No		If 1 --> **A.4.8**
A.4.5	**Respondent Name** Write name used on official documents, with nickname in parentheses			
A.4.6	Respondent's Father/Husband's Name			
A.4.7	Relationship of Respondent to HH Head	2 = Spouse 3 = Son/Daughter 4 = Son/Daughter-in-law	5 = Parent 6 = Brother/Sister 11 = Other relative (Please specify)	

A.4.8	Mobile Numbers of HH Members (for follow-up) Include a REQUEST number if applicable. Please write "REQ" in the margin next to the number.	Mobile Owners	Numbers
		a.	
		b.	
		c.	

Part 5: Personal Wellbeing

A. 5.1. Below are five statements that you may agree or disagree with. Using the 1 - 7 scale below, indicate your agreement with each item by placing the appropriate number on the line preceding that item. Please be open and honest in your responding. {Enumerator: Please add up all the numbers assigned to each statement].

- 7 - Strongly agree
- 6 - Agree
- 5 - Slightly agree
- 4 - Neither agree nor disagree
- 3 - Slightly disagree
- 2 - Disagree
- 1 - Strongly disagree

____ In most ways my life is close to my ideal.
____ The conditions of my life are excellent.
____ I am satisfied with my life.
____ So far I have gotten the important things I want in life.
____ If I could live my life over, I would change almost nothing.

SECTION B: INDIVIDUAL IDENTIFICATION

Part 1: HH Member

HH Member ID	B.1.1	B.1.2	B.1.3	B.1.4	B.1.5	
	NAME FIRST, List HEAD OF HH FOLLWED BY SPOUSE AND CHILDREN. SECOND: List other HH members related to the head of household or his spouse(s). THIRD: List other HH members NOT related to the head of household or his spouse. The HH Roster should include all people that "eat out of the same pot". Be sure to include the following people: someone temporarily gone for less than six months, students studying away from home, and someone that lives away from home but is seriously involved in HH economic decision-making.	Age	Sex	Relationship to HH Head	Marital Status	Education: What is the highest level of education that he/she has achieved?
		Only completed years. No fractions.	*1 = Male* *2 = Female*	*1 = HH Head* *2 = Spouse* *3 = Son/Daughter* *4 = Son/Daughter-in-law* *5 = Parent* *6 = Brother/Sister* *7 = Grandparent*	*1 = Married* *2 = Single* *3 = Divorced* *4 = Separated* *5 = Widower*	*1 = None* *2 = Some Primary* *3 = Completed Primary* *4 = Some Secondary* *5 = SSC Passed* *6 = Some Higher Secondary* *7 = HSC Passed*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

SECTION B: INDIVIDUAL IDENTIFICATION

Part 2: HH Labor

HH Member ID	B.2.1	B.2.2	B.2.3	B.2.4	B.2.5	B.2.6		B.2.8	B.2.9	
	ENUMERATOR CHECKPOINT: IS THIS HH MEMBER 6 or more years old? (WILL RESPOND TO THIS SECTION) 1 = Yes 2 = No	During the last completed month did [NAME] work in agriculture or land husbandry?	During the last completed month did [NAME] **work for a salary** or any other form of payment?	During the last completed month, did [NAME] work or provide help in a business **without receiving a salary**?	ENUMERATOR CHECKPOINT: IS THERE A "YES" RESPONSE IN B.2.2, B.2.3 or B.2.4?	What was [NAME]'s main occupation in the last completed month?	During the last 12 months how many months did [NAME] work in this occupation?	During these months, on average, how many days did [NAME] work in this occupation?	Has [NAME] received wages, salary or other payments either in cash or in other forms from this occupation?	How much was [NAME]'s last cash payment?
		[EITHER IN HH FARM OR SOMEONE ELSE'S FARM]] *1 month = 1 month from the date of the interview*	*1 month = 1 month from the date of the interview* 1 = Yes 2 = No	*[EITHER IN HH BUSINESS OR SOMEONE ELSE'S BUSINESS]* *1=Yes 2=No*	1 = Yes 2 = No	*1=Own Farm/Sharecropper* *2=Agricultural Day Labor* *3 = Own business* *4 = Salaried Job* *5=Domestic Work (Non-HH)* *6=Petty/Retail Trade* *7= Construction labor* *8=Transportation Sector* *9 = Carpentry* *10=Other Non-Ag Day Labor* *11 = Other (Specify)*	*Last 12 months = from date of interview* *[Months*	*Days*	1 = Yes 2 = No	*If in-kind payment, ask respondent to estimate value* *Taka/Day*
	If 2 --> Next HH				If 1 ► B.2.6					
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

SECTION C: ACCESS TO EXTENSION AND OTHER TRAININGS

C.1.1	Did a government extension worker visit your HH farm between June 1, 2015 and June 31, 2016, to provide advice about farming?	1 = Yes 2 = No			If 2 ► C.1.5
C.1.2	How many times did the government extension worker visit to provide advice about farming?	Number			
C.1.3	Who met with this extension worker? Multiple responses possible	A = a female HH member B = a male HH member C= a non-HH member			
C.1.4	What topics were discussed during these visits? Multiple Responses Possible	A = seeds B = fertilizer C = pests and diseases D = pesticide use E = cropping practices F=soil type	G=compost H=irrigation I = previous year crop on your land J=other____		
C.1.5	Have you or anyone else in your household attended a Department of Agriculture Extension training in the last six months (six months from the day of the interview)?	1 = Yes 2 = No			If 2 ► C.1.8
C.1.6	In what month was the most recent training you attended?	Use Month code on Code Sheet			
C.1.7	What topics were discussed in this most recent training? Multiple Responses Possible	A = seeds B = fertilizer C = pests and diseases D = pesticide use E = cropping practices	F=soil-type G=compost H=irrigation I=previous year crop on your land J=other (specify)		
C.1.8	Did anyone from an NGO visit your HH farm between July 1 2015 to July 31, 2016, to provide advice about farming?	1 = Yes 2 = No			If 2 ► C.1.12
C.1.9	How many times did the person from the NGO visit to provide advice about farming?	Number of Visits			

C.1.10	Who met with this person?	A = a female member B = a male member C= a non-HH			
C.1.11	What topics were discussed during these visits? Multiple Responses Possible	A = seeds B = fertilizer C = pests and diseases D = pesticide use E = cropping practices	F=soil type G=compost H=irrigation I=previous year crop on your land J=other(specify)		
C.1.12	Have you ever accessed information about agricultural prices using your mobile phone?	1 = Yes 2 = No			
C.1.13	If yes, how often did you use mobiles for this kind of information?	A=Daily, B=More than once a week, C=Once a week D=Less than once a week, E= Once in a month F= Rarely			
C. 1. 14	Who did you call for information? Check all that apply.	A. Extension officer B. Community Facilitator C. Area Manager D. Sub assistant Agricultural Officer E. E. Other (Specify)			

SECTION D: AGRICULTURE

Part 1: Plot ID

D.1.1: How much land does your household	|__|__| (in decimals)	If "0" --> Section E

Plot ID	D.1.2	D.1.3		D.1.4	D.1.5	D.1.6	D.1.7	D.1.8	D.1.9	D.1.11
	PLOT DESCRIPTION: 3	Plot Size		Current Operational Status	Was this plot used as a demonstration plot in this time period?	Who was primarily responsible for making decisions and field management about this [PLOT] in this	Who spent the most time working on this plot in this time period?	List all Crops planted on this plot in this time period	Crop Type	What was the source of this seed?
	Write description that will not change in the next five years. For example, landmarks, depth, plot name.	*Number*	*Unit* *In decimals*	*1 = Own 2 = Rent 3 = Mortgage 4 = Joint Ownership 5 = sharecropping 6 = other (specify)*	*1 = Yes 2 = No*	*Use HH Member ID If non-HH member, write "0"*	*Use HH Member ID If non-HH member, write "0"*	*Use CODE 1 and a separate line for each crop.*	*1 = Local Variety 2 = HYV 3 = Hybrid 88 = Unknown*	*1 = Community seed bed 2 =NGO 3 = Seed multiplier 4 = Own production 5 = purchased from private company*
1										
2										
3										

SECTION D: AGRICULTURE

Part 1: Plot ID

D.1.12	D.1.13	D.1.14	D.1.15	D.1.16		D.1.17	D.1.18	D.1.19	D.1.20	D.1.21	D.1.22		D.1.23
On how much of this plot did you cultivate this [CROP]? Rice/Potato/Maize/ Sugarcane	Did you irrigate this [CROP ID]?	How much did you <u>spend</u> on irrigation for this [CROP ID]?	Did you apply any inputs to this [CROP ID]?	Which inputs did you apply to this [CROP ID]? Multiple Responses Possible Please ask about each input		How much in total did you <u>spend</u> on seed for this [CROP ID]?	How primarily did you till the land for this [CROP ID]?	Did you hire labor to work on this [CROP ID]?	How much in total did you spend on hired labor for this [CROP ID]?	Month Harvesting Began *Write "0" if not harvested*	How much of this [CROP ID] have you harvested up to now?		How much in total did you earn from sales of this [CROP ID]?
Write in Decimals	*1 = Yes* *2 = No*	*Record Taka. Estimate value of crop given.*	*1 = Yes* *2 = No*	*A = Compost* *B = Animal Manure* *C = Farm Yard Manure* *D = Urea* *E = Calcium/Lime* *F = NPKS/mixed fertilizer* *G = Pesticides/Insecticides* *H = Pheremone/Traps*	*I = DAP* *J = Potash/MOP* *K = TSP/SPP* *L = Zinc* *M = Ammonia* *N = Gypsum* *O = Potassium* *P = Vitamins* *Q = Other (specify)*	*Taka*	*1 = by hand* *2 = with animal power* *3 = with machine* *4 = did not till*	*1 = Yes* *2 = No*	*Taka*	*66 = continuously harvested* If "0"-> Next row	*Number*	*Unit (kg)*	*Taka*
	If "2" --> D.1.16		If "2" --> D.1.19					If "2" --> D.1.22					

SECTION D: AGRICULTURE

Report for ALL PLOTS, from July 1 2015 to July 31, 2016

Part 2: Technologies

D. 1.2.5 Do you use any of the following technologies? Yes=1, No= 2. If yes, was it part of a government or NGO implementation project?

a) Green Manure: This is a crop grown to be plowed into the soil for fertilizing. The local name of this crop is "Dhoincha". ___Yes, ___No If Yes, name_____
b) Mulching (Use the Bangla term) ___Yes, ___No If Yes, name_____
c) Alternate wet/dry method for rice: Saving water by occasionally drying the paddy field ___Yes, ___No If Yes, name_____
d) Line planting: Transplanting rice with the correct distance between the lines of seedlings ___Yes, ___No If Yes, name_____
e) Double transplanting (bolan) of paddy ___Yes, ___No If Yes, name_____
f) Vermicomposting ___Yes, ___No If Yes, name_____
g) Others (specify)____

SECTION E: HOUSING

PART 1: BACKGROUND AND STATUS OF THE HOUSING OCCUPANCY				
E.1.1	How long has your household inhabited this dwelling?	1 = Less than six months 2 = 6 months - 1 year	3 = 1 - 5 years 4 = 5 - 10 years 5 = 10+ years	
E.1.2	What is your current occupancy status?	1 = Own 2 = Renting 3 = Dwelling provided for free	4 = Temporary Shelter 5 = Other (Specify)	
PART 2: PHYSICAL CHARACTERISTICS OF THE HOUSE				
E.2.1	What is the main construction material of the walls of your main dwelling?	1 = Concrete/Brick 2 = Tin/CI Sheet 3 = Wood 4 = Mud	5 = Bamboo 6 = Jute Straw 7 = Plastic/Polythene 8 = Other (specify)	
E.2.2	What is the main material used for roofing your main dwelling?	1 = Concrete/Brick 2 = Tin/CI Sheet 3 = Wood	4 = Mud 5 = Bamboo 7 = Plastic/Polythene 8= Other (specify)	
PART 3: WATER & SANITATION				
E.3.1	What is the primary source of drinking water?	1 = Supply Water (piped) inside house 2 = Supply Water (piped), outside 3 = Own tube well 4 = Neighbor's tube well	5 = Community tube well 6 = Rainwater 7 = Ring Well/Indara 8 = Tube well for irrigation 9 = Other (specify)	
E.3.2	How many minutes does it take you to walk there?	Number of minutes		
E.3.3	What type of toilet facility does your household use?	1 = None (open field) 2 = Kutcha 3 = Pucca 4 = Sanitary without flush (water sealed)	5 = Sanitary with flush (water sealed) 6 = Community latrine 7 = Other (specify)	
PART 4: ELECTRICITY				
E.4.1	What is the main source of lighting?	1 =PDB Electricity (government provided) 2 = palli biddut samity provided electricity	3 = Private Generator 4 = Solar Electricity 5 = Others (specify)	
E.4.2	What is your primary source of energy for cooking?	1 = Electricity 2 = Supply Gas 3 = LPG	4 = Kerosene 5 = Firewood 6 = Dried cow dung 7 = Other (specify)	

SECTION F: EXPENDITURES

PART 1: HOUSEHOLD EXPENDITURE ON DIFFERENT SOURCES					
2.1a FOOD EXPENDITURE: How much do you weekly spend on food for the entire household on average? ____ (in Taka) **2.1b [Enumerator:** multiply the number with 52 and insert here] ________ (in Taka)					
INFREQUENT PURCHASES: Record Expenditures from June 1, 2015 to July 31, 2016. Write 0 if NO expense in category.					
		TAKA			*TAKA*
F.2.2	School Fees (for example: tuition fees, books and uniforms, etc.)		**G.2.8**	Renting land	
F.2.3	Vocational Training		**G.2.9**	Purchase of land	
F.2.4	Housing (Construction/Repairs)		**G.2.10**	Purchase of livestock	
F.2.5	Household Furnishing and Appliances		**G.2.11**	Livestock expenses (e.g. Animal feed)	
F.2.6	Insurance		**G.2.12**	Agricultural equipment (rented or purchased)	
F.2.7	House Rental		**G.2.13**	Electricity	
			G.2.14	Others (specify)	

SECTION G: FARMER GROUPS

G.1.1	Is any member of your household a member of a Farmer Group or Cooperative?	*1 = Farmer Group* *2 = Cooperative* *3 = None*		if "3" --> Section I
G.1.2	Is the Farmer Group or Cooperative Part of the Integrated Agriculture Productivity Project (IAPP)?	*1 = Yes* *2 = No*		
G.1.3	How many years have you been a member of this group or Cooperative?	*Record Number of years*		
G.1.4	What is the name of your Farmer Group or Cooperative?	*Record Name*		
G.1.5	What is your position in the Farmer group or Cooperative?	*1 = Chairman* *2 = Secretary* *3 = Treasurer* *4 = Member* *5 = Other (specify)*		
G.1.6	What is the purpose/theme of your Farmer Group? Multiple Responses Possible	*A= Cereal Crops* *B = ICM (Integrated Crop Management) C = IPM (Integrated Pest Management)* *D = SFFP (Soil Fertility Farmers' Production) E = Fisheries* *F = Livestock* *G = Irrigation*		
G.1.7	Does your farmer group have a savings account?	*1 = Yes* *2 = No*		if "2" --> Section I
G.1.8	Is this a formal account (in a microfinance institution or bank) or informal (savings kept by the group)?	*1 = formal* *2 = informal*		

SECTION H: HOUSEHOLD GARDENS					
Enumerator: Please fill in information from July 1, 2015 to July 31, 2016					
H.1.1	Does your HH have a kitchen garden?	1 = Yes 2 = No			If 2 ► Section J
H.1.2	Which crops did you grow in the kitchen garden during this time period? Multiple Responses	Use Crop Code list Write ALL crops			
H.1.3	Which HH members were involved in planting and managing the crops in the kitchen garden during this time period?	WRITE HH MEMBER ID			
H.1.4	Did you apply any inputs to the crops grown in the kitchen garden during this time	1 = Yes 2 = No			If 2 ► Section J
H.1.5	Which inputs did you apply? Multiple Responses Possible	*A = Compost* *B = Animal Manure* *C = Farm Yard Manure* *D = Urea* *E = Calcium/Lime* *F = NPKS/ mixed fertilizer* *G Pesticides/Insecticides* *H = Pheromone Traps* *I = DAP*	*J=Potash* *K=TSP/SP* *L = Zinc* *M = Ammonia* *N = Gypsum* *O = Potassium* *P = Vitamins* *Q = Other (specify)*		

SECTION I: NEGATIVE SHOCKS AND SOCIAL NETWORKS

Part 1: Negative shocks

I. 1. 1. Has your household experience any of these negative shocks? Yes= 1, No=2

If yes→ N. 1.2. Choose from the given options (multiple responses possible):

I.1.2. Give a total estimate of the loss ____ (in Tk.)

A	Closure of a large firm affecting livelihood in your village
B	Crop loss due to storms or other weather event
C	Drought
D	Sudden health problems / accidents (and associated costs)
E	Loss of income due to death or illness of family members
F	Robbery/Theft of Property or Loss/damage of valuable assets
G	Sudden job loss
H	Crop failure
I	Low prices for agriculture production
J	Others (specify)

Part 2: Social Network

I. 2.1 About how many <u>close</u> friends do you have these days? These are people you feel at ease with, can talk to about private matters, or call on for help.________

I. 2.2. If you suddenly had to go away for a day or two, could you count on your neighbors to take care of your children? ________

1 Definitely
2 Probably
3 Probably not
4 Definitely not

I.2.3. If you suddenly faced a long-term emergency such as the death of a breadwinner or [harvest failure], how many people beyond your immediate household could you turn to who would be <u>willing</u> to assist you? _________

1 No one
2 One or two people
3 Three or four people
4 Five or more people

I.2.4 [IF NOT ZERO] Of those people, how many do you think are currently <u>able</u> to assist you? ___________

I. 2.5. In the past 12 months, how many people with a personal problem have turned to you for assistance? _________

I. 2.6 [IF NOT ZERO] Are most of these people of similar/higher/lower economic status? __________

1 Similar
2 Higher
3 Lower

I. 2.7. Who do you reach out for information?
a. Agricultural extension agent
b. IAPP extension agent
c. Relatives
d. friends
e. Seller
f. radio
g. news paper
h. TV
i. Internet
j. Others (specify)

I. 2.8. How do you reach out to any of the above sources?
a. Face to face
b. phone call
c. SMS
d. Others (specify) ___

SECTION J: KNOWLEDGE, ATTITUDES AND BELIEFS

Part 1: Knowledge

There are ten questions (each carrying 1 point for the correct answer). Put 0 where they do not know answers. If the respondent doesn't know the answer to any question move to the next question.

J.1.1. Why is it important to lime your land? State one benefit. (general).

a. To fertilize the soil
b. To reduce acidity of the soil (correct)
c. To kill insects
d. None of the above

J.1.2. What are the characteristics of good quality seeds? (general)

a. Moisture content is low and the size of the seed is uniform
b. Insect and disease free
c. Free from inert materials and bright in color
d. All of the above (correct)

J.1. 3. Name one water saving irrigation method (special) [This question needs to be in appropriate form, ask the farmers how they describe AWD).

a. Alternate drying (AD) pipe)
b. Alternate wetting and drying (AWD) pipe (correct)
c. Alternate wetting (AW) pipe
d. None of the above

J.1.4. What is the appropriate time duration for cultivating Parija rice variety? Correct answer 1, wrong answer 0

a. Between May and June (Bhadro Ashwin)
b. Between May and July (correct) (Bhadro Karthik)
c. Between May and August (Bhadro- Ograyohon)
d. Between May and September (Bhadro- Poush)

J.1.5. Choose the names of two beneficial insects? (general)

a. Lady bird beetle and epilacna beetle
b. Spider and grasshopper
c. Stemborer and rice hispa
d. Cutworm and brinjal shoot and fruit borer
e. All of the above

J.1.6. Organic fertilizer helps.
a. to make lands fertile
b. reduce pesticide pollution
c. increase water-holding capacity
d. All of the above (correct)

J.1.7. What are the two drought-tolerant rice varieties? (Special). Correct answer 1, wrong answer 0
a. BRRI dhan 56 and 57 (correct)
b. BR 11 and BR 14
c. BRRI dhan 51 and 52
d. BRRI dhan 28 and

J.1.8. How can you control insects using integrated pest management (IPM)?
a. early cultivation
b. resistant variety
c. light trap
d. All of the above (correct)

J. 1.9 How to decrease acidity of soil?
a. By applying water
b. By applying nothing
c. By applying calcium carbonate (chun)
d. By applying pesticides

J. 2.0 Choose name of a natural way of deterring pests?
a. Pheromone trap
b. Light trap
c. Parsing
d. All of the above

Part 2: Perceived Behavioral Norms, Attitudes (A) and Beliefs (B)

	5= Strongly agree	4= Agree	3=Neutral/Not sure	2=Disagree	1= Strongly disagree
J.2.1. It is not important for me to use organic fertilizer (A)					
J.2.2. My neighbors whom I ask for advice use organic fertilizer (A)					
J.2.3 My community thinks producing organic fertilizer is easy (B)					
J. 2.4 My friends think chemical pesticides is harmful for soil (B)					
J. 2.5 I want to avoid using Chemical pesticides (A)					
J. 2.6 People I go for advice will approve of me avoiding chemical pesticides (BN)					
J. 2.7 My friends do not produce and use green manure (B)					
K. 2.8 My neighbors believe that organic fertilizer (cow dung) is good for the soil (B)					
J. 2.9 I do not have plans for using organic fertilizer instead of chemical fertilizer (A)					
J. 2.10 am sure that if I wanted to use cow dung in the field I will do so (A)					
J. 2.11 Wise people I know will approve of me using organic fertilizer (BN)					

SECTION K: Literacy and Numeracy Assessment

Part 1: Numeracy
1=Correct answer, 0=Wrong answer (Count the total points based on correct answers)

1. In total, how many bottles are in the two full cases? (Correct answer= 48) ____
2. If each one bottle is Tk. 15, how much will 7 bottles cost? (Correct answer= 105) ______
3. Say there is a discount of 20%, how much money will you save for a bottle of coke? (Correct answer= 3) _____
4. What will be the price of each bottle of coke after a 20% discount? (Correct answer=12)______
5. A mobile phone costs Tk. 2000. You earn 200 taka per day, how many days will it take you to buy that mobile phone?

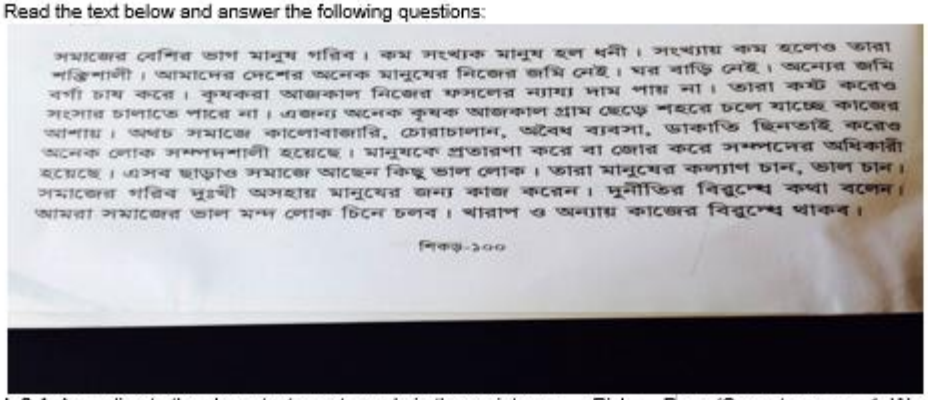
Part 2: Literacy (Word recognition, reading simple sentences and reading comprehension)

K.2.1___Eggplant ____ Cauliflower ____Cabbage

K.2.2 ___ Spade ____Scissors ____ Rose

Read the following sentences (1= Correct, 0= Incorrect, Partially correct=P)
K.2.2. Guests have come to our house this morning
K.2.3. I will clear out the field off weeds in the afternoon

Read the text below and answer the following questions:



সমাজের বেশির ভাগ মানুষ গরিব। কম সংখ্যক মানুষ হল ধনী। সংখ্যায় কম হলেও তারা শক্তিশালী। আমাদের দেশের অনেক মানুষের নিজের জমি নেই। ঘর বাড়ি নেই। অন্যের জমি বর্গা চাষ করে। কৃষকরা আজকাল নিজের ফসলের ন্যায্য দাম পায় না। তারা কষ্ট করেও সংসার চালাতে পারে না। এজন্য অনেক কৃষক আজকাল গ্রাম ছেড়ে শহরে চলে যাচ্ছে কাজের আশায়। অথচ সমাজে কালোবাজারি, চোরাচালান, অবৈধ ব্যবসা, ডাকাতি ছিনতাই করেও অনেক লোক সম্পদশালী হয়েছে। মানুষকে প্রতারণা করে বা জোর করে সম্পদের অধিকারী হয়েছে। এসব ছাড়াও সমাজে আছেন কিছু ভাল লোক। তারা মানুষের কল্যাণ চান, ভাল চান। সমাজের গরিব দুঃখী অসহায় মানুষের জন্য কাজ করেন। দুর্নীতির বিরুদ্ধে কথা বলেন। আমরা সমাজের ভাল মন্দ লোক চিনে চলব। খারাপ ও অন্যায় কাজের বিরুদ্ধে থাকব।

শিকড়-১০০

L.2.4. According to the above text, most people in the society are __ Rich __ Poor (Correct answer =1, Wrong answer= 0)
L.2.5. According to the above text, there are some good people who want good for others (True/False)
L.2.6. According to the above text, the farmers are leaving for the city because they want to become richer (True/False)
L.2.7. According to the above text, we need to speak against the actions of the rich people. (True/False)

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