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The Upper West Region of Ghana faces a food crisis, and food production needs to be increased. The smallholder farmers who overwhelmingly dominate the region's agricultural sector have few opportunities to improve agricultural productivity, mainly because of poor extension services, institutional and cultural constraints, and long adaptation to using traditional practices.

Major limitations to crop production in Ghana include low soil fertility, low and erratic rainfall, low yield potential of indigenous crop varieties, and poor crop management practices. Most smallholder farmers are ignorant of the potential benefits of improved seed and continue to grow own-saved seed. There is a need for closer interaction with farmers through extension services and on-farm demonstrations to create and increase awareness of the importance of improved seed.

Maize demonstration plots were established on farmers' fields in the Upper West Region to introduce improved maize production technology and facilitate the use of high-yielding maize cultivars. I investigated the impact of these demonstrations on maize yields. For production function estimation, farmers' data collected in the region in 2006 and 2008 were used. The estimation models showed that area size, labor input, fertilizer application, and seed cost per area (as a proxy of variety) made significant positive contributions to production; there was some positive impact on yield. Farmer-related constraints included poor availability or affordability of inputs such as hybrid seed and fertilizers. Farmers were still resorting to area expansion to increase yields, thus heavily burdening labor requirements. Differences in production of the new cultivars in the on-farm demonstration and from farmer-estimated functions were identified. Such differences highlighted the inefficiencies associated with farmers' budgetary constraints.

To enable farmers to benefit fully from crop demonstrations, the program needs to be continued and expanded to cover more farmers, and channels for inputs and output markets need to be strengthened.

Key words: Crop demonstration, Package adoption, Crop yield, Technological diffusion, Production function estimation

Introduction

A “perfect storm” of food shortages, water scarcities, and insufficiency of energy resources is threatening to unleash public unrest, cross-border conflicts, and mass migration as people flee from the world’s worst-affected regions. According to a statement made at the 2009 Sustainable Development UK Conference by Professor John Beddington, the United Kingdom's chief government scientist, "The world's food reserves are at a 50 year low, but by 2030 we need to be producing 50% more food. At the same time, we will need 50% more energy and 30% more fresh water" (The Guardian, 2009).

At the 1974 World Food Conference, government leaders proclaimed that “every man, woman, and child has the inalienable right to be free from hunger and malnutrition.” The 1974 Conference...
set an ambitious goal: to eradicate hunger from human society within a decade. At the time of the 1996 World Food Conference, 22 years later, many children still went to bed hungry and many individuals continued to be stunted by hunger and malnutrition.

Although world food production overall and per capita has risen, the goal of the 1974 Conference has not been fulfilled. In fact, today, the world faces a renewed food crisis, one at least as formidable and life-threatening as has occurred in the past (Gebremedhin, 2000).

No one knows exactly how many of the world's people are undernourished today because there is a lack of reliable population counts from many countries (Peter, 2000). However, even in the absence of appropriate data collection and analysis, there is general agreement that the number of people who are severely affected by hunger and malnutrition is extremely large. According to World Food Program estimates, hunger affects one out of seven people on the planet. In 1996, the World Bank estimated that more than one billion of the world's people do not have enough food to lead healthy and productive lives. Furthermore, another one to two billion are at risk of falling into the ranks of the hungry and, if trends continue, the number is expected to grow dramatically (Foster, 1992; The World Bank, 1996).

To reduce the number of undernourished in the world and meet growing demands, global food production needs to double by 2050. Production increases must occur mainly in the developing countries where the poor and hungry live, and where more than 95% of the projected population increase will occur. The farmers in these countries will need access to modern inputs, storage facilities, and rural infrastructure (FAO, 2008).

If we are to double global food production by 2050, there will need to be a major paradigm shift in the formulation of appropriate technologies that are compatible with the activities of smallholder farmers in developing countries, as well as in government agricultural policies at both national and international levels. For instance, in 1983 Ghana, a cocoa-producing country in Africa joined the structural adjustment program. Policies changes formulated and implemented by The World Bank and the International Monetary Fund (IMF) in developing countries. These policy changes are conditions for getting new loans or obtaining lower interest rates on existing loans from the IMF or World Bank. The program enabled Ghana to implement the economic recovery program.

This program was often held up as an example of a successful structural adjustment program, and by the late 1980s, The World Bank and IMF were pointing to the growth in exports of cocoa as Ghana's chief agricultural export cash crop under the economic recovery program: cocoa was responsible for more than 70% of Ghana's export earnings. Unfortunately, the world market price of cocoa started to drop steadily in the mid-1980s. As a result, Ghana's food self-sufficiency declined because most of the country's resources were used to produce cocoa instead of staple foods (Hammond and McGowan, 1994).

When the cocoa program did not work out, The World Bank advocated (and the government agreed to) an emphasis on large-scale commercial fishing instead of channeling resources into food crop production. Local fishers, who were unable to obtain credit and compete in the industry, were squeezed out. Cheap fish, the primary source of protein for Ghana's people, began to disappear from local markets because the wealthy fishermen were directly exporting their fish abroad. Because Ghanaians obtain 60% of their protein from fish by-products, the decrease in fish consumption resulting from higher prices increased the rates of malnutrition in the country (Hammond and McGowan, 1994; Smith, 1991).

The domestic economy of Ghana continues to revolve around agriculture, which accounts for about 35% of the gross domestic product (GDP), employs about 55% of the workforce, and is dominated by smallholder farmers in the rural communities. Smallholder farmers experience the population's highest incidence of poverty: the incomes of about 60% of these farmers fall below the poverty line (GSS, 2000).

The smallholder farmers who overwhelmingly dominate the agricultural sector unfortunately have few opportunities to intensify and commercialize their agriculture; for example, they have poor access to inputs, markets, and credit and advisory services. Hence there is little or no adoption of improved technological packages, and the low
yields and rural poverty are further exacerbated.

Despite these problems, agricultural production in Ghana has been increasing over the years, but these increases are achieved basically through the expansion of areas under cultivated and the intensive use of labor, rather than through the use of improved farming technologies. As fertile land becomes scarce because of increased population growth and increasing environmental problems, the economically active rural dwellers—invaluable as farm labor—migrate to urban areas and the use of improved technologies becomes essential. However, the productive gains from improved agricultural technologies have not been fully exploited by farmers in most developing countries, including Ghana (Kalirajan and Shand, 2001; Pingali and Heisey, 1999).

Most smallholder farmers in Ghana—especially in the Upper West Region—still do not use improved production technologies, and farmer-based mechanisms for education about using these new technologies are also not appropriate. Farmers therefore are faced with low productivity and urgently need to improve their total factor productivity, which can raise outputs to meet the country's food consumption needs.

Existing low levels of productivity in food production, reflecting low levels of technical efficiency and the use of primitive technologies, hinder efforts to achieve progress in this direction. The government of Ghana, in collaboration with international organizations, has taken initiatives to raise productivity by helping farmers reduce technical inefficiencies and fostering the adoption of improved production technologies. A prominent example is the introduction of crop demonstrations in rural communities in the Upper West Region by TechnoServe, a non-governmental organization with funding from the United States Department for International Development in collaboration with the Savannah Agricultural Research Institute (SARI) and the Ghanaian Ministry of Food and Agriculture (MoFA).

The crop demonstrations were designed to use farmer field schools and the farmer-to-farmer diffusion concept to spread the use of improved production technologies among farmers in the rural communities of the Upper West Region. The purpose of my study was to investigate the impact of the program on crop yields in the region as compared with those of farmers outside the program.

For this purpose, the production function of maize was first estimated by accounting for differences in production among varieties and in the effects of fertilizer application on varieties. Second, the correlations between years of demonstration experience and the cost to the community of using seed of the new cultivars were tested to confirm the impact of the crop demonstrations on farmers' adoption of the recommended varieties. Third, production from the on-farm demonstrations and the estimated production function were compared under traditional and improved cropping practices and with different maize cultivars. The difference between the two production levels represented the inefficiency in the farmers' cropping; the factors involved in this inefficiency are discussed.

Section 2 of this paper describes recent issues in agricultural technological diffusion and introduces the use of the demonstration approach in the Upper West Region. Section 3 gives the data used in the analysis and estimation model. The results of application of the estimation model and of other tests for identifying the impact of the demonstration approach are given in Section 4. In section 5, the hypothetical test is conducted in order to identify the inefficiency from the constraints on increasing farmers' expense from adoption of high yielding varieties. Section 6 concludes the study and suggests further effective and sustainable technological diffusion approaches in considering these constraints on farmers.

Technological Diffusion and its Degree of Adoption by Farmers

1. Recent Issues of Technological Diffusion in Rural Areas

Today, there is a large gap between potential and actual crop yields amongst smallholder farmers in developing countries, mainly because of poor extension services, institutional and cultural constraints, and the farmers' long history of adaptation to traditional practices, which has limited their ability and willingness to fully adjust their input levels (Ghatak and Ingerssent, 1984; Xu and Jeffrey, 1998). Because new technologies require intensive management and information, farmers in developing countries with low literacy rates, poor extension
services, and inadequate infrastructure have difficulties in adapting to new technologies (Ali and Byerlee, 1991; Pingali and Heisey, 1999).

The role of high-yielding technologies in improving the well-being of agricultural households in developing countries has been widely documented in the economic literature. Given the significance of the socioeconomic impacts of these innovations, several papers have examined the theoretical and empirical issues associated with the process of adoption and diffusion of new technologies (Feder, 1980; Foster and Rosenzweig, 1995). Although research institutions are engaged in making scientific discoveries and developing new technologies for farmers in poor countries, the adoption of innovations is frequently gradual and incomplete.

Those studying such adoption have, accordingly, sought to explain differences in adoption behavior. Innovation adoption is subject to a combination of social, economic, and cultural factors, but most of the theoretical models have tended to present discipline-guided explanations. As Clark and Staunton (1989) observed, adoption studies have, to a large extent, been dominated by the division of analysis between economists, sociologists, and geographers. Adoption has been explained in terms of the profitability of the investment (economics), the social rewards associated with adoption and the nature of communication channels (sociology), spatial differences in resource endowment (geography), and the compatibility of the innovation with societal norms (anthropology).

Discipline-guided models represent different aspects of the adoption process. They reveal that innovation adoption is a multi-dimensional process incorporating elements such as perceived relative profitability or attractiveness, ability to bear the cost and risk associated with the innovation, compatibility with value systems, and ability to carry the innovation to other potential adopters.

In recent years, a number of development agencies, including The World Bank, have promoted farmer field schools (FFSs) as a more effective approach as compared with the tendency of many public officers dealing with the transmission of knowledge to conduct their assignment in a "top-down" manner in the conventional extension system. Often, the information conveyed is presented as a technological package comprising recommended practices. This is perceived as a less effective method for improving knowledge compared with more participatory approaches (Braun et al., 2002).

The FFS training program utilizes participatory methods "to help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions" (Kenmore, 1991). Such an approach, in which the trainer is more of a facilitator than instructor, reflects a paradigm shift in extension work (Roling and van de Fliert, 1994).

As an extension approach, the FFS concept does not require all farmers to participate in the training. However, the farmers who attend the training are encouraged to share their knowledge and experiences with other farmers within their communities.

This farmer-to-farmer diffusion has been one of the alternative measures to the conventional extension system taken to achieve a high rate of adoption of new technologies. The basic premise behind such farmer-led technology diffusion is the rich theory of diffusion of innovation, which is described as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995). Farmer-to-farmer technology diffusion builds upon farmers' traditional transfer methods and is based on the observation that farmers prefer their fellow farmers as their primary sources of information even when they have alternative sources (Feder and Slade, 1985; Rogers, 1995).

Thus the traditional dissemination methods used by farmers may have a far greater impact on the spread of selected technologies than the dissemination efforts of either public or private firms. Agricultural researchers and extensionists in developing countries have therefore designed programs to take advantage of, and build upon, indigenous farmer-based technology transfer mechanisms to disseminate new technologies (Grisley, 1994; Kormawa et al., 2004).

The abovementioned experiences directed TechnoServe to introduce on-farm crop demonstrations that used a participatory training approach to convey knowledge to participants so as to make them into "confident improved farm management experts, self-teaching experimenters, and effective trainers to other farmers" (Wiebers, 1993). The
crop demonstrations that employ the FFS concept entail 6 months of hands-on farmer experimentation and informal training during the crop-growing season. Facilitators from the research institution, the extension division of MoFA, and TechnoServe lead this village-level program, basically conveying knowledge of good crop management procedures and practices and also extending information on high-yielding crop varieties and other inputs. Through group interaction, participants sharpen their decision-making abilities and are empowered by learning leadership, communication, and management skills (van de Fliert, 1993).

2. The Crop Demonstration Approach in Upper West Region, Ghana

The principal cereals grown in Ghana are maize, sorghum, and rice. The legumes cowpea and soybean are both subsistence and cash crops, and many farmers have recently embraced the cultivation of soybean as a cash crop. However, major limitations to crop production in Ghana include low soil fertility, low and erratic rainfall, low yield potential of indigenous crop varieties, poor crop management practices, and attack by insect pests, diseases, and the parasitic weed *Striga*. Most farmers in remote areas are ignorant of the potential benefits of using improved seed. Such farmers continue to grow their own-saved seed over the years by recycling grain as seed. Accordingly, there is a need to interact more closely with farmers through extension services and on-farm demonstrations to create and increase awareness of the importance of improved seed. Moreover, the introduction of new crop varieties without the appropriate production technologies may be of little value to farmers.

Maize (*Zea mays*) is a major staple crop in Ghana. It is also an important component of poultry and livestock feed and is becoming a major substitute for barley and wheat in the brewing industry. Currently, 90% of the maize planted in Ghana comes from seed saved by farmers and only 10% is from commercial certified seeds. This may contribute to the low mean grain yield of 1.4 Mt/ha (MoFA, 2004), compared with the potential 5.2 Mt/ha of the most popular open-pollinated quality protein maize (QPM) cultivar Obatampa and the 7.3 Mt/ha of the QPM hybrid Mamaba (Twumasi Afriyie *et al.*, 2000). The lower yields may also be attributable to low plant population, inadequate fertilization, and inappropriate weed control.

There is immense potential for improving maize production through the use of hybrid maize cultivars. Research has revealed that hybrid maize is more uniform, higher yielding, and more stable in performance than open-pollinated (OP) maize, and most leading maize-producing nations depend largely on hybrid maize. Consequently, the Crop Research Institute of Ghana (CRI) developed the QPM hybrid maize Mamaba in 1997. Apart from its uniformity, Mamaba is 10% to 15% higher yielding than other OP cultivars with comparable maturity cycles. It is therefore imperative to extend these QPM hybrid cultivars to as many farmers as possible to increase maize productivity and production in Ghana.

The rate of adoption of improved OP cultivars among farmers may be low, but the rate of adoption of the hybrid maize is almost nonexistent. In light of this situation, maize demonstrations plots were established on farmers' fields in the Upper West Region of Ghana to introduce improved maize production technology to farmers and facilitate adoption of the use of high-yielding maize cultivars.

Several on-farm demonstration plots were set up at different locations in the Upper West Region on land volunteered by farmers. TechnoServe selected the communities jointly with MoFA. Then, with the help of SARI, suitable fields were selected and TechnoServe provided the recommended farm inputs for the demonstration. The improved technology blocks were "research managed".

Two sets of three experimental plots ("blocks") were created at each site. Improved maize cultivars (the QPM Mamaba hybrid and OP Obatampa) were planted on either side of the farmers' local variety in the cropping season (May to October); one set of blocks was managed by researchers using improved technology and the other by the local farmers (Fig. 1). Block size for each variety was 20 m × 50 m.

The improved technology blocks were prepared by a plowing followed by a harrowing before the maize was planted. Plant spacing for the improved technology blocks was 80 cm × 40 cm with two plants per hill, to give a target population of 25,000
plants/acre. After planting, a pre-emergence weedicide (alachlor–atrazine) was applied at a rate of 2 L/acre. During planting, a basal compound fertilizer (15–15–15) NPK was spot-placed in a hole 5 to 8 cm away from the planting hole at a rate of 15.2 kg/acre each of N, P₂O₅, and K₂O (100 kg/acre). An additional 25 kg N/acre was side-dressed as urea (50 kg/acre) 4 weeks after planting (Note: 1 hectare = 2.5 acres).

The farmer-managed blocks were prepared once by either bullock or tractor plowing without harrowing and herbicide application. The average spacing on the farmer-managed blocks was 100 cm × 50 cm (16,000 plants/acre), with three plants per hill. Farmers at all the test locations applied only 50 kg of 15–15–15 NPK fertilizer and 30 kg of urea per acre or none at all.

TechnoServe and MoFA organized the farmers to witness and participate in the new methods being applied. Subsequently, field days were organized by the three organizations at different stages of crop growth and at harvest to observe the various advantages of the innovative packages and the comparative yield gains associated with the new techniques and cultivars.

As part of the demonstrations, TechnoServe also introduced a hybrid seed production program to ensure an adequate supply of high-yielding seed to farmers; an input credit scheme that enabled farmers to have access to inputs such as fertilizers and hybrid seed that would otherwise have been impossible to acquire during the farming season; and also input grants to vulnerable farmers in the area to help them get a start in farming. All of these programs were implemented to help remove some of constraints preventing the farmers from adopting the technological package.

**Data and Analytical Framework**

1. **Study Area**

   The Upper West Region was selected for this study. This region is the youngest in Ghana: it was carved out of the then Upper Region in 1981. The region had to build government institutions and infrastructure virtually from scratch. It is divided into eight administrative districts, with Wa as the capital, and occupies a land area of 18,476 km², representing 8% of the country’s total land area of 238,537 km².

   The region is situated in the northwest corner of Ghana, with an estimated population of 576,583, of which about 90% is rural. The average population density is 29.8 persons/km². The region is one of the poorest in Ghana, with an annual per capita
GDP of USD 170, and on most social indicators, it is the most neglected region of the country. Infant mortality, seasonal hunger, cash income, school attendance, and transport networks are weaker in the region than in other regions of the country (GSS, 2000; IFAD, 2005).

Agriculture is the mainstay of the economy of the rural society of the region, employing over 72% of the rural population. Farming is generally small scale and subsistence, producing just enough for home consumption and very little for the markets. The districts are all in the same ecological zone and hence have the same climatic characteristics. Rainfall is mono-modal, lasting from May to October. Average annual rainfall ranges from 900 to 1200 mm. Crops grown include corn, millet, groundnuts, yams, rice, and vegetables. The people also rear animals such as sheep, goats, poultry, and pigs. Soybeans and cotton are grown as cash crops, and women pick shea nuts either for sale as a cash crop or for processing into butter for home consumption.

Farmers in the region are confronted with extremely challenging conditions, with high temperatures, erratic rainfall, and eroded soils making for ever-lower crop yields. Average per-hectare yields of crops cultivated in the region are far below the recommended yields from the application of improved agricultural practices. For example, average yields of the major cereals are: maize, 1.4 Mt/ha; sorghum, 0.6 Mt/ha; and rice, 0.4 Mt/ha (SRID, 2006). Crop yields continue to decline because of the continual decline in soil fertility, the use of indigenous, outmoded farming practices and low-yielding crop varieties, and over-dependence on rainfall. Irrigation is still underdeveloped and dry-season cultivation is done at a very low scale at small dam sites.

2. Data

All the raw data were obtained from farmer field surveys conducted by TechnoServe in 2006 and 2008 in the Upper West Region. The purposive sampling technique was applied. Sampling was done at three different levels (community, group, and farmer). This translated into a sample size of 200 farm households. A questionnaire was designed for data collection.

The questionnaire consisted of eight modules covering background information on household members; participation in farmer and food-processing groups; production and yields; value of produce; agricultural expenses; use and sources of agricultural inputs, credit, and loans; and household food insecurity and coping mechanisms. In addition to the conventional survey method, a checklist was designed for community profiling.

A farmer estimation data collection approach was used. This involved surveying farmers to obtain their estimates of the crop harvest and dividing by how much land they had planted (ideally obtained by direct land-area measurements) to estimate production. Trained enumerators collected the data through interviews between March and July by visits to the sample households. These data included information such as size of land cultivated, agricultural expenses, level of output, price of yield, and food availability. Details of the prices of all purchased inputs were also collected during this time. A separate survey was conducted to collect input and output price information from nearby markets during planting and harvesting times of the major crops.

Focus group discussions and key informant interviews were held by employing participatory rural appraisal (PRA) techniques. The community profile analysis covered topics such as demographics, infrastructure, and economic activities, as well as agricultural and non-agricultural constraints. In addition, data on inputs and yield were collected from all the crop demonstration sites in the Upper West Region.

The purpose of my study was to investigate the impact of the program on crop yields in the region as compared with those of farmers outside the program. To achieve the objective of the study, a regression model was used to analyze the data collected from farmers through the 2006 and 2008 field surveys. Some inconsistent data were dropped, and the sample size for the analysis was therefore 153 farmers. Table 1 summarizes the statistics for the variables used in the analysis.

3. The Model

It is assumed that the production technology of the surveyed farmers is represented by a Cobb-Douglas production function:
Table 1. Summary statistics of variables used in the analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>2006</th>
<th></th>
<th>2008</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Mean</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>Area (Acres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sissala</td>
<td>2.99</td>
<td>2.31</td>
<td>3.23</td>
<td>2.69</td>
</tr>
<tr>
<td>Lawra</td>
<td>1.73</td>
<td>0.80</td>
<td>1.05</td>
<td>0.21</td>
</tr>
<tr>
<td>Fertilizer (Ghana cedis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sissala</td>
<td>6.82</td>
<td>6.33</td>
<td>15.27</td>
<td>15.73</td>
</tr>
<tr>
<td>Lawra</td>
<td>1.93</td>
<td>1.27</td>
<td>6.14</td>
<td>1.08</td>
</tr>
<tr>
<td>Labor (Ghana cedis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sissala</td>
<td>153.26</td>
<td>137.38</td>
<td>357.58</td>
<td>519.33</td>
</tr>
<tr>
<td>Lawra</td>
<td>91.13</td>
<td>45.08</td>
<td>92.07</td>
<td>20.54</td>
</tr>
<tr>
<td>Seed cost per area (Ghana cedis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sissala</td>
<td>3.34</td>
<td>2.41</td>
<td>7.43</td>
<td>4.37</td>
</tr>
<tr>
<td>Lawra</td>
<td>3.16</td>
<td>2.30</td>
<td>6.78</td>
<td>1.45</td>
</tr>
<tr>
<td>Production (maxi bag-100 kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lawra</td>
<td>5.33</td>
<td>3.57</td>
<td>6.81</td>
<td>2.34</td>
</tr>
</tbody>
</table>

Source: Farmer surveys.

\[ Y=f(A, L, F) = c \cdot A^\beta_a \cdot L^\beta_l \cdot F^\beta_f \]

where \( Y \) is production of maize; \( A \) is cropped land size, \( L \) is labor input, \( F \) is fertilizer input, \( c \) describes constant term. The production parameter of the \( i \)-th input \( \beta_i \) denotes not only the production elasticity, but also known as the characteristics of this functional form, that also relates to the share of the factor for the case of Cobb-Douglas production function, that is, the cost share of the \( i \)-th input can be described as \( \frac{\beta_i}{\sum\beta_i} \) under the profit maximization condition.

However, this is modified from the typical Cobb-Douglas function in incorporating the effects of adoption of cultivars adopted in the present paper in order to identify the constraints on farmers from adoption of new varieties that induce higher expenditure.

\[ Y=f(A, L, V, F) = c(V) \cdot A^\beta_a \cdot L^\beta_l \cdot F^{(\beta_f+\beta_v \cdot V)} \]

\( V \) represents seed cost per area as a proxy variable for the cultivar used. Two modifications are included. The First, describes the effect of cultivar on total factor productivity as constant term \( c \). The second is the specification, which facilitates understanding of the effect of high-yielding cultivars on the change in production elasticity of fertilizer by including the term \( \beta_v \cdot V \) in the Cobb-Douglas production function. The specification of the production function as shown above enables the evaluation of how high-yielding cultivars that induce changes in the cost structure of farmers. This is because high-yielding cultivars require more labor input for application of fertilizer and for weeding and other activities, and they require higher rates of fertilizer application at the expense of the farmer's budget.

To determine the above Cobb-Douglas Function, the following log regression model was estimated:

\[ \log Y = \beta_0 + \beta_v \cdot V + \beta_l \cdot \log L + \beta_f \cdot \log F + \beta_V \cdot \log F + \beta_D \cdot D_D + \beta_{2008} \cdot D_{2008} \]

where \( A \) is the total area planted to maize (acres); \( L \) denotes the total monetary value of family, exchange, and hired labor; \( F \) is the total monetary value of fertilizer applied; \( V \) represents seed cost per area as a proxy variable for the cultivar used; \( D_D \) is the district dummy variable (for farmers in the Sissala district the variable is 1; for others the variable is 0) in considering the
difference in geographical condition between districts; $D_{2008}$ is a dummy variable for the year 2008; and $\beta_i$ is the estimated parameter.

Estimation Results and Impact of Demonstration

1. Production Function Estimation

The ordinary least squares estimates of the parameters of the Cobb-Douglas production function are given in Table 2. The coefficients for area, labor, fertilizer application, seed cost per area, and district revealed a significant positive impact on yield increase. However, the marginal productivity of fertilizer was decreased by the introduction of new cultivars, as shown by the significant negative value of the parameter estimated from fertilizer $\times$ seed cost per area (Table 2). The decline in the production elasticity of fertilizer was consistent with a reduction in the share of fertilizer or an increase in the share of other factors. Farmers were unable to meet the requirements of the improved technologies because the high input requirements may have led to budgetary problems.

2. Impact of Demonstration for Technological Diffusion

From the estimation of production function, the demonstration approach has impacted on production. However, how has this approach impacted on the adoption of these improved varieties in the Upper West Region? In order to indentify this, a simple test is conducted. Table 3 shows the seed cost per area by the number of years after first experience of demonstration.

The numbers shown in Table 3 for farmers with demonstration experience and no demonstration experience did not differ significantly, but the results showed that farmers were at least using improved seed cultivars. For instance, farmers in communities with one and three years experience spent 8.26 and 8.87 Ghana cedis, respectively, on seed per hectare in 2008, whereas farmers in communities with no demonstration experience spent 3.09 in 2006 and 6.78 in 2008. This shows that there is a spillover effect, from the farmers who attend the demonstrations and start using the new cultivars to other farmers, through diffusion of information. The lack of a significant difference in varietal adoption between farmers in communities with no demonstration experience and those with demonstration experience could also be attributed to other programs that TechnoServe is running in these communities, such as the vulnerable input support program to promote productivity.

Notwithstanding these significant improvements in the use of improved seed and in fertilizer application, farmers still resorted to area expansion as a means of increasing yield; area therefore had a very strong significant impact on yields as shown in Table 2. This, however, put a lot of pressure on labor, making it a very scarce production factor during peak seasons and a very significant input to

<p>| Table 2. Ordinary least squares estimates of Cobb-Douglas production function for maize farmers in the Upper West Region of Ghana |
| --- | --- |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>$-0.794$ ($-1.767$)</td>
</tr>
<tr>
<td>Log (Area)</td>
<td>$0.383***$ ($3.042$)</td>
</tr>
<tr>
<td>Log (Fertilizer)</td>
<td>$0.438***$ ($5.019$)</td>
</tr>
<tr>
<td>Log (Labor)</td>
<td>$0.426***$ ($3.776$)</td>
</tr>
<tr>
<td>Dummy for 2008 ($2008 = 1, 2006 = 0$)</td>
<td>$-0.212$ ($-1.677$)</td>
</tr>
<tr>
<td>Seed cost per area</td>
<td>$0.060**$ ($2.253$)</td>
</tr>
<tr>
<td>District dummy (Sissala = 1)</td>
<td>$0.310***$ ($3.406$)</td>
</tr>
<tr>
<td>Log (Fertilizer) $\times$ Seed cost per area</td>
<td>$-0.024**$ ($-2.548$)</td>
</tr>
<tr>
<td>$R^2$: 0.8014; adjusted $R^2$: 0.7918; n: 153</td>
<td></td>
</tr>
</tbody>
</table>

Estimations from the farmer survey data. Figures in parentheses are t-ratios; $***$, significant at 1%; $**$, significant at 5%. 
Table 3. Seed cost per acre by demonstration experience

<table>
<thead>
<tr>
<th>Demonstration experience (years)</th>
<th>Year</th>
<th>Average seed cost/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2006</td>
<td>3.09</td>
</tr>
<tr>
<td>1</td>
<td>2006</td>
<td>3.67</td>
</tr>
<tr>
<td>0</td>
<td>2008</td>
<td>6.78</td>
</tr>
<tr>
<td>1</td>
<td>2008</td>
<td>8.26</td>
</tr>
<tr>
<td>2</td>
<td>2008</td>
<td>5.33</td>
</tr>
<tr>
<td>3</td>
<td>2008</td>
<td>8.87</td>
</tr>
</tbody>
</table>

Calculations from farmer survey data. Farmers in communities with demonstration experience score 1, 2, or 3 depending on the number of years of experience; those with no experience score 0 (2.5 acres is equal to 1 ha).

productivity owing to the continued use of traditional implements. Also, area expansion is not sustainable in the near future because of the diminishing availability of arable land due to population increase and the associated problems of deforestation.

The above results, however, indicated that farmers were adopting the packages from the crop demonstration. However the adoption rate seems to be slow looking at the decreasing trend of marginal productivity. This situation can be attributed to the following constraints faced by farmers: continuous upward adjustment to input prices, in ability to source credit, non-availability of inputs, poor seed availability, poor input and output market channels, and poor farmer-extension-research contact.

The results, however, indicated much higher productivity among communities with demonstration experience than among those without it; therefore, farmers would be likely to fully adopt the packages if their constraints were minimize or eliminated.

**Efficiency Estimates of Cultivars Under Traditional and Improved Practices**

From the production function estimation, the reduction of cost share of fertilizer by introducing the improve varieties suggests that, this can be understood as the budget constraint of farmers because of higher labor input requirement with the adoption of improved varieties.

However, because improve varieties require more fertilizer application; this constraint would limit efficient crop production of the varieties. Actually, as the improved practice in the demonstration approach is derived from the experiences from research, it means this practice may be efficient but doesn’t consider the actual constraints on farmers. In other words, the actual farmers’ harvest for improve varieties would be lower than the potential yields of these varieties. This should be tested in order to understand the possibility of farmers’ under evaluation of the effect of the demonstration. It is also understood that the farmers’ practice in demonstration can reflect the farmers’ actual constraints.

For the above interests, it is tested that the derived production from estimated production function is significantly lower than the production in demonstration for improved practice, but there is insignificant difference between both for the farmers practice. If both are true, farmers constraints on the payments for labor input, fertilizer application and expense on seeds are crucial for actual benefit on farmers from the adoption of new varieties.

In order to test these hypotheses, one community demonstration data in the Sissala district is used. For controlling the input levels, the fitted production from the estimated function for the levels of inputs in improved and farmers’ practices in demonstration are compared with the demonstration productions for both varieties of Obatampa (HYV) and traditional one.

In the farmer survey data for the estimation of production function, a comparison was made between two varieties—Obatampa and the farmers’ variety—because these are popular and available to farmers in the Upper West Region. Although Mamaba is also being promoted, its seed is not readily available so farmers are unable to use it. The results of the comparison analyses are given in Table 4.

Before conducting the statistical hypothetical test, the gap between productions from demonstration and estimated function are overviewed. For the traditional farmers’ practice, the estimated gap index (the ratio of production from the estimated function to that from the demonstration data for Obatampa) was 0.90, and for the farmer varieties,
The figures for the traditional farmers’ practice showed that our estimation of the production function fitted the demonstration data well. In fact, the hypothetical test of the null hypothesis—that the fitted production from the estimated function was the same as the demonstration production—could not be rejected in the two cases of traditional cropping of Obatampa and local varieties. The null hypothesis is \( \log(Y_{\text{demo}}) = \log(Y_{\text{fitted}}) \), where \( Y_{\text{demo}} \) and \( Y_{\text{fitted}} \) are, respectively, the production from the demonstration and the fitted production from the estimated function for the different practices and varieties. For farmers’ practices, the F-values for Obatampa and the farmers’ variety were 0.33 and 1.44, respectively; these were not statistically significant. The F-values for Obatampa and the farmers’ variety with the improved practice were 5.16 and 6.21, respectively; both were significant at less than 5%.

On the other hand, there was a substantial gap between demonstration production and fitted production in the case of the estimated function for the cases of improved technology.

The estimates suggested that the potential for use of improved cultivars and technology was underutilized. This could be attributed to constraints that prevented the farmers from applying sufficient fertilizer or using sufficient labor, as estimated by the farmers’ reduction in the share of fertilizer for high-yielding cultivars, which require more fertilizer, and in their reduced share of the labor input. Efficient use of the new technologies is possible only if farmers have adequate technical and financial support through the extension and credit systems, as well as adequate and timely provision of inputs and information.

The results are also in agreement with the findings of other studies that have shown the existence of substantial technical inefficiencies in developing agricultural economies and the consequent implications for agricultural growth with existing resources and technology (Arega and Rashid, 2005). Technical efficiency is one of the possible avenues for increasing production by using available resources and (traditional) technology.

**Conclusion**

A Cobb-Douglas production function was used to analyze the impact on maize yields of technological diffusion among smallholder farmers in the Upper West Region through on-farm crop demonstrations and also to analyze the levels of technical efficiency among farmers using either traditional practices or improved technology. The results showed that the crop demonstration program had a positive impact by increasing production.
Apart from area and labor, which also had a positive impact, all the other variables were indicative of the impact of the demonstration on production. However, the fertilizer X seed cost per area variable had a decreasing positive impact on marginal productivity. This could be attributed to inefficiencies of resource allocation by farmers due to budgetary constraints.

The production estimates indicated that farmers could increase their production efficiencies if they were to fully adopt the technological package. However, because of constraints, they were unable to achieve the required production efficiency, leaving a capacity gap. This gap could be filled if farmers were exposed to more training and information on improved technologies and on the implementation of sustainable programs that would ease the farmers' burden of resource allocation and reduce the constraints to adoption of technology.

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