Courant Research Centre
'Poverty, Equity and Growth in Developing and Transition Countries: Statistical Methods and Empirical Analysis'

Georg-August-Universität Göttingen
(founded in 1737)

Discussion Papers

No. 141

Improved production systems for traditional food crops: The case of finger millet in Western Kenya

Christina Handschuch, Meike Wollni

July 2013

Wilhelm-Weber-Str. 2 · 37073 Goettingen · Germany
Phone: +49-(0)551-3914066 · Fax: +49-(0)551-3914059

Email: crc-peg@uni-goettingen.de Web: http://www.uni-goettingen.de/crc-peg

Improved production systems for traditional food crops: The case of finger millet in Western Kenya.

Christina Handschuch, Meike Wollni

Department of Agricultural Economics and Rural Development

Georg-August University of Göttingen, Germany

chandsc1@gwdg.de; mwollni1@gwdg.de

Abstract

Increasing agricultural productivity through the dissemination of improved cropping practices remains one of the biggest challenges of this century. A considerable amount of literature is dedicated to the adoption of improved cropping practices among smallholder farmers in developing countries. While most studies focus on cash crops or main staple crops, traditional food grains like finger millet have received little attention in the past decades. The present study aims to assess the factors that are influencing adoption decisions among finger millet farmers in Western Kenya. Based on cross-sectional household data from 270 farmers, we estimate a multivariate probit model to compare the adoption decisions in finger millet and maize production. While improved practices such as the use of a modern variety or chemical fertilizer are well known in maize production, they are less common in finger millet production. Results show that social networks as well as access to extension services play a crucial role in the adoption of improved finger millet practices, while the same variables are of minor importance for the adoption of improved maize practices. A Cobb-Douglas production function shows a positive effect of modern varieties and chemical fertilizer on finger millet yields.

Key words: finger millet, Kenya, technology adoption, social networks

1. Introduction

In the second half of the 20th century, the agricultural sector worldwide was characterized by remarkable increases in production and productivity. Nevertheless, about one billion people are undernourished today and due to population growth, degrading natural resources, and climate change, a sustainable and substantial growth in agricultural production remains one of the most urgent challenges in the beginning of the 21st century (Godfray et al. 2010; IFAD 2010). Besides the development of new technologies, e.g. new varieties or management practices, closing the gap between actual productivity and the potential productivity that could be obtained by using and adapting currently available technologies is crucial to facing this challenge (Godfray et al. 2010).

This yield gap is especially high in small-scale production systems in developing countries, where farmers do not have enough information or capacities to adopt innovative technologies. Much effort has been made to tackle this problem and a considerable amount of literature is analyzing the adoption decisions of small-scale farmers in developing countries (Feder et al. 1985; Feder, Umali 1993; Knowler, Bradshaw 2007). However, while a number of studies assess the adoption of improved technologies in maize production systems in Sub-Saharan Africa (Kaliba et al. 2000; Doss, Morris 2000; Groote et al. 2005; Sserunkuuma 2005; Feleke, Zegeye 2006; Langyintuo, Mungoma 2008; Sauer, Tchale 2009; Simtowe et al. 2009; Mignouna et al. 2011), very little attention has been given to the adoption of modern production systems in traditional food crop production. Although many factors influence the adoption of improved cropping practices similarly across different crops, there are likely to be notable differences between a common cash crop (like maize) and a traditional food crop (like finger millet).

Various studies acknowledge that participation in formal social networks like farmer groups can foster learning processes and the adoption of improved cropping systems (Besley, Case 1993; Wollni et al. 2010). Other studies stress the role of informal social networks and neighborhood effects, showing that farmers with experienced and innovative neighbors are more likely to adopt an innovation themselves (Conley, Udry 2010; Foster, Rosenzweig 1995; Langyintuo, Mungoma 2008; Matuschke, Qaim 2009). The role of social networks becomes especially important where other assets and formal sources of information are scarce (Wu, Pretty 2004; Matuschke, Qaim 2009), which is likely the case for traditional subsistence crops. In their study on technology adoption in pineapple production systems, Conley and Udry (2010) point out that social networks are of particular importance for technology diffusion and adoption in the context of a newly introduced crop, for which formal information sources are not yet available. Similarly, improved practices have not been widely used in finger millet production systems and thus experience, information, and extension is scarce in Western Kenya. We therefore expect social capital, and in particular social networks, to play a crucial role in the dissemination of modern finger millet production practices.

Finger millet has been widely neglected by both researchers and policy makers in the past decades. Yet, traditional cereals like finger millet could make an important contribution towards higher farm incomes and improved food security in many regions of the world. Finger millet is known to be more nutritious and more resilient to poor or unpredictable agro-ecological conditions than main cereals like maize. The dissemination of modern technologies in finger millet production is still low, but field trials indicate that yields can be substantially increased by using modern practices and varieties (Oduori 2005). In this article, we analyze the factors that determine the adoption of improved finger millet cropping practices among smallholder farmers in Western Kenya. In addition, we assess the impact of improved finger millet practices on finger millet yields. While a few studies have focused on the adoption of modern sorghum and pearl millet varieties (Nichola 1996; Matuschke, Qaim 2008, 2009; Cavatassi et al. 2011), to the best of our knowledge there is no empirical evidence on the dissemination of modern production systems in finger millet production.

The remainder of the article is structured as follows. In the next section, we discuss the current finger millet production systems in Kenya. Afterwards, we introduce the data collection approach. Section four describes our methodological approach, and sections five to seven present the descriptive and econometric results of our adoption and yield analysis. Finally, section eight draws conclusions and outlines policy recommendations for the promotion of traditional cereals.

2. Finger millet production systems in Kenya

Finger millet (*Eleusine coracana*) originates in East Africa and is an important food crop for millions in Sub-Saharan Africa and India. Despite its importance, it has received very little attention by researchers and policy makers in the past decades. In Western Kenya, finger millet used to be among the most important food crops but was largely replaced by maize over the 20th century. Today the crop is only grown by a minority of farmers and suffers from the poor reputation of being a ‘poor person’s crop’ or a ‘birdseed’ (Vietmeyer 1996; Crowley, Carter 2000). This development ignores the high potential of finger millet in terms of its agronomic properties, its nutritional value, and its marketing opportunities.

Regarding its agronomic properties, finger millet can have advantages over main staple crops, especially in less-favored areas. While maize is growing well under favorable agro-ecological conditions, millets are much better adapted to poor soils, high temperatures, and erratic rainfall and can therefore play an important role in improving food security despite their lower yield potential (Gill, Turton 2001). This holds especially true against the background of climate change and increasingly degraded soils in many African regions (Crowley, Carter 2000). A further advantage of finger millet is its good storability, which is of particular importance for the food security of small-scale farmers, who face persistent risks of drought and crop failure (Oduori 2005).

Furthermore, finger millet also represents a promising opportunity to improve nutrient availability to poor households. As in many parts of Sub-Saharan Africa, dietary diversity in Western Kenya is low, with maize being the dominant staple crop. Consequently, deficiencies in various proteins and micronutrients are very common (Conelly, Chaiken 2000). While the level of food energy is roughly the same for finger millet and maize, finger millet is richer in essential proteins, especially methionine, and important micronutrients such as calcium and iron. Some nutritionists claim that finger millet represents the key crop against micronutrient deficiencies in Sub-Saharan Africa (Vietmeyer 1996).

Finally, there are good marketing opportunities for finger millet, especially in local, easily accessible markets. While finger millet is mainly considered a staple crop that farmers grow for subsistence purposes, demand for finger millet is high and finger millet prices in Kenya are far higher than prices for maize or other cereals. Finger millet can also be processed into value added products like cookies or beer by the farmers themselves, or by processors at the local or national levels (Oduori 2005). The crop therefore has the potential to serve as a profitable cash crop for small-scale farmers in Western Kenya.

Yet, the potential of finger millet production remains largely untapped. In Kenya, millets[1] were grown on 99,000 hectares in 2010 with an average yield of 0.5 tons/hectare. In contrast, maize was grown on 2,000,000 hectares with an average yield of 1.6 tons/hectare in 2010 (FAO 2012b). The average finger millet yield of 0.5 tons/hectare discloses a big yield gap: In finger millet yield trials, yields of up to 3.8 tons/hectare have been observed (Oduori 2005). Little effort has been made to improve the genetic material of finger millet, and while the first modern maize varieties were already available in the early 1960ies, the first improved finger millet varieties were released in the early 1990ies (Byerlee, Eicher 1997; Oduori 2005). The lack of research and development on finger millet is also reflected in most local extension approaches in developing countries. In Kenya, for example, extension programs generally do not provide specific information on finger millet production, but rather focus on maize production systems. Consequently, finger millet production remains very traditional and the crop's reputation is that of an old-people-crop with little agronomic potential. Farmers often cultivate finger millet on their most marginal plots without adding any organic or chemical fertilizer (Crowley, Carter 2000).

Overall, the dissemination of modern technologies in finger millet production is low and we know little about adoption processes. Yet, a range of practices to optimize finger millet production systems are available and promoted in Western Kenya by specialized extension programs. First and foremost, the use of an improved finger millet variety can have several advantages including a higher yield potential, enhanced resilience to pests and erratic weather conditions, and improved nutritional value. Furthermore, even though finger millet is relatively well adapted to poor soils, fertilizer applications are recommended to provide a good nutrient supply in order to obtain high yields. For a more efficient use of fertilizer, a micro-dosing technique can be applied, where the fertilizer is strewed along the rows instead of being broadcasted (information received from KARI[2]). Row-planting is recommended over broadcasting, because it facilitates crop management in terms of weeding, thinning, application of fertilizer, and harvesting. Planting should be done as early as possible, since timely planting protects the crop against insect pests and weeds. Finally, weeding should ideally be done twice; a first time 14 days after germination and a second time 14 days after the first weeding. To assure enough space for the individual plants, a thinning of the rows is recommended during the first weeding (Nyende et al. 2001).

[1] FAO STAT is not differentiating between different types of millet.
[2] Kenyan Agriculture Research Institute

3. Data collection

Our research was carried out in Western Province, located in the southwest of Kenya. Traditionally, finger millet and sorghums were the most common cereals grown in Western Kenya, but the area dedicated to maize production has been increasing rapidly since the beginning of the 20th century (Crowley, Carter 2000). Today, maize is by far the most important staple crop in Western Kenya while finger millet is only grown by a minority of farmers. According to FAO data, about 240,000 hectares were used for maize production in Western Province in 2008, while only 4,000 hectares were dedicated to millet production (FAO 2012a). However, this figure is likely underestimating actual finger millet production, as data for a range of locations is missing or incomplete. Given its untapped potential, finger millet has received growing attention during recent years and the Kenyan Agricultural Research Institute (KARI) implemented extension programs in Western Province to promote the adoption of improved crop management practices in finger millet production.

We conducted a household survey among 270 finger millet farmers in Western Province in 2012. In a first stage we selected three districts, namely, Teso, Busia and Butere-Mumias out of the total of eight districts located in Western Province[3]. These three districts represent the main area in which KARI has carried out extension programs on millet production. The districts vary with respect to agro-ecological conditions and farming systems. During the interviews with different farmer groups and experts from KARI, a general picture of Teso emerged as having the most traditional and less commercialized farming sector. Located at the border to Uganda, finger millet is still of considerable importance in people’s diets and farming systems. Although cash crops such as cotton or tobacco are grown in Teso, farmers mainly cultivate food crops for their subsistence needs. Teso is partly located in mountainous areas with shallow and poor soils. In contrast, farmers in Butere-Mumias have more modern and commercialized farming systems with sugar cane being the most important cash crop and finger millet being of minor importance. Geographically and in terms of its farming systems, Busia is located in between Teso and Butere-Mumias.

In a second step of our sampling procedure, we selected 15 locations situated in Teso, Busia and Butere-Mumias. In 12 of the 15 locations, KARI had provided millet-related extension services to farmers between 2007 and 2010. The 12 locations were randomly chosen from a total of 32 locations were KARI had provided finger millet extension services. To reach the farmers, KARI used a group approach supporting social groups that were interested in finger millet activities. The extension program comprised training on finger millet farming, processing and marketing. In addition, field days with participatory variety selection were organized. To select the farmers for the interviews, we applied a stratified random selection: In each of the 12 KARI locations, we interviewed nine millet farmers who are members of a group that had received finger millet extension from KARI and nine millet farmers who are not members. Additionally to the 12 KARI locations, we randomly chose three external locations, where no KARI intervention had taken place. In each of these control villages we

[3] The administrative areas in Kenya were regularly subject to reforms that split districts into smaller units. The last district reform took place in 2007, were e.g. Teso District was split into Teso North and Teso South. For reasons of simplicity, we are referring to the number of districts and district boundaries that existed before the 2007 reform.

interviewed 18 finger millet farmers. Lists of farmers who cultivated finger millet in 2011 were obtained from KARI group leaders (for extension group members) and from village elders (for all millet farmers in the villages). We then selected farmers randomly from the compiled lists for our survey. Our stratified sampling design is oversampling farmers who received finger millet extension through the KARI program. We take this into account by including sampling weights in the econometric analysis.

A standardized questionnaire was used to collect information on farm and household characteristics, cropping practices, and social networks. All agricultural production data is referring to the year 2011. There are two cropping seasons in Western Kenya: The long-rains (approx. from February to July) and the short-rains (approx. from October to December). Since finger millet is only grown during the long- rains, all figures and analyses presented in this article refer exclusively to the long-rains. To obtain further information on finger millet production and typical group activities in the region, we conducted additional interviews with farmer groups and finger millet experts.

4. Methodology

We model the adoption of improved yield-enhancing technologies including modern varieties and chemical fertilizer using an econometric approach. Our focus lies on the adoption of improved finger millet technologies, but we are also interested in potential differences between adoption decisions in the production of neglected food crops like finger millet and main food crops like maize. The adoption of an improved practice in finger millet production is likely related to the adoption of the same practice for more common food crops. We therefore model the adoption of improved technologies in both finger millet and maize production jointly in a multivariate probit model. To analyze the effect of improved cropping practices on finger millet yields, we estimate a Cobb-Douglas production function

Adoption analysis

Farmers are expected to base their decision to adopt a practice on the expected profitability of that practice. We model the expected profitability of a practice j by farmer i as

$$y_{ij}^{*} = \beta X_{ij} + \varepsilon_{ij}$$

where X is a vector of independent variables, β is a vector of parameters to be estimated, and ε is a normally distributed error term with mean zero and variance one. We are unable to observe the farmer's expected profitability, but we do observe the adoption of a practice as $y_{ij} = 1$ if $y_{ij}^{*} > 0$ and the non-adoption of a practice as $y_{ij} = 0$ if $y_{ij}^{*} < 0$.

However, the adoption decision for one practice is not independent from the adoption decision for other practices. Farmers who obtain information about one new technology are more likely to obtain information about other technologies as well. There is a fixed cost component in information search that makes gathering information about each additional practice relatively less expensive. Also, there might be synergy effects between different practices, e.g. between the use of a modern variety and the use of chemical fertilizer, when the modern variety used is more responsive to fertilizer than traditional varieties. On the other hand, farmers with limited financial resources may have to make a trade-off between the two inputs, deciding to use either one of them. Analogous to synergies and trade-offs that may occur between different practices for the same crop, we may observe synergies or trade-offs between adopting the same practice for different crops. Synergies between maize and finger millet cropping practices are possible in terms of access to inputs, access to information, and experiences made with certain practices. A farmer who buys a bag of chemical fertilizer for his maize production at the input store will have lower transaction costs to buy an additional bag of fertilizer for his millet crop. Similarly, a farmer who knows how to access improved maize seeds will face lower costs of information to access improved finger millet seeds. In addition to the potential synergy effects between maize and finger millet production, the expected profitability of an improved finger millet cropping practice may depend on the expected profitability of the same practice in maize production. Since decades, the use of chemical fertilizer and modern varieties are well-established practices in maize production in Western Kenya. Thus, the farmers' expected profitability of using chemical fertilizer and improved varieties in maize production is based on actual experiences or observations in past production cycles. In contrast, many farmers have never tried or observed the same practices in finger millet production. Those farmers may instead rely on their experiences or observations in maize production when assessing the expected profitability of a finger millet cropping practice. Trade-offs between cropping practices in maize and finger millet production may occur when a farmer is cash constrained and thus cannot afford to buy expensive inputs for both crops.

Considering that the adoption decisions for different cropping practices are likely correlated with each other, estimating the adoption of each practice independently may lead to biased estimates. Following Marenya and Barrett (2007) we therefore model the adoption decisions using a multivariate probit regression framework, which allows the covariance between the error terms to be correlated across different practices and different crops. A positive correlation between two error terms indicates synergies between the respective practices, whereas a negative correlation indicates the existence of trade-offs.

The explanatory variables used in the adoption model are described in table 1. Based on previous adoption studies (Feder, Umali 1993; Govereh, Jayne 2003; Matuschke, Qaim 2009; Wollni et al. 2010), we identify four categories of variables that have a potential influence on the adoption decision of farmers: social networks and connectedness, wealth, human capital, and regional heterogeneity.

Social networks and connectedness can help to improve access to information and markets as well as to overcome input constraints. We include several variables that reflect the households' social networks and connectedness. First of all, group membership is an important factor that has been used in previous studies as an indicator for how well farmers are linked to markets and information (Fischer, Qaim 2012). We therefore include the number of social groups the household participates in as an explanatory variable in our model. There is a large variety of different types of social groups in rural Kenya, including farmer groups, self-help groups, widow groups and religious groups (Place et al. 2004). Since agriculture plays a central role in the livelihoods of Kenya's rural population, even groups who do not consider themselves farmers groups are often involved in agricultural activities. Thus, to better reflect the type of group activities that the household is engaged in, we include a dummy variable that equals one if the household participates in at least one group that is involved in input purchase activities. Lack of access to inputs is a common constraint for the adoption of new agricultural technologies (Moser, Barrett 2003), which, however, can be overcome through joint purchases of farm inputs. Besides group membership, farmer-to-farmer relationships are an important aspect of social connectedness (Wu, Pretty 2004). In particular, previous studies have shown that such informal information channels can play an important role when formal sources of information are limited (Conley, Udry 2010). We measure contact intensity for millet farmers as the frequency with which they discuss their finger millet cropping practices with other farmers. This was based on a maximum of three finger millet farmers that the interviewees could name to have regular contact with. Possible responses ranged from “never discuss practices” (1) to “very often discuss practices” (5) and were summed up over the household’s contacts. Since formal sources of information on finger millet cropping practices are not easily available in Western Kenya, we expect that access to informal information on finger millet practices plays an important role in their adoption.

Furthermore, we include a variable on the distance to the next main market and a dummy variable that equals one if the farmer uses a cell phone. Being located in close proximity to a market center and disposing of a cell phone both are expected to increase the farmer’s access to markets and market information and thus increase the likelihood of adoption of improved technologies. Similarly, access to extension is expected to improve the farmer’s knowledge about improved practices and thus to positively affect adoption. We therefore include a dummy variable that captures whether farmers have received finger millet related extension. Furthermore, finger millet farmers who did not receive finger millet extension directly, but live in a village where KARI implemented its program are more likely to learn about new practices through observations or discussions with other farmers than farmers who live in villages without a finger millet extension program. To account for these possible spillover effects, we include a dummy variable that equals one if the household is located outside the KARI program villages.

In order to measure household wealth, we include three variables in our model, namely, total farm size, the number of cattle owned by the household, and the off-farm income earned by the household in 2011. Since wealthier households have better access to liquidity and often to credit (Croppenstedt et al. 2003) and are thus less likely to be cash constrained, we expect them to be more likely to adopt improved crop management practices. In addition, we control for various human capital related variables including the age of the household head, the gender of the person responsible for finger millet production, education, and the households’ dependency ratio. These variables are used as proxies for the quality and quantity of labor endowment of the household. Finally, we include two regional dummies for Teso and Butere-Mumias to account for differences in agro-ecological conditions and farming systems in the three different districts.

Table 1: Explanatory Variables for the Adoption of Improved Finger Millet Practices

Variable name	Variable description	Mean	Std. Dev.
Social networks and connectedness			
Group number	Number of groups the household is participating in	1.848	1.239
Group input Purchases	1 = The household is participating in at least 1 group that is purchasing farm inputs	.315	.465
Contact intensity	Frequency of discussions with other finger millet farmers (ranging from 1 to 15)	8.244	4.374
Market distance	Distance to main market (in walking minutes)	75.896	71.703
Cell phone	1 = At least one household member uses a cell phone	.848	.360
Extension_fm	1 = The household received finger millet extension in the past 5 years	.422	.495
Extension_mz	1 = the household received maize extension in the past 5 years	.252	.435
External	1 = The household is situated in an external location without KARI intervention	.200	.401
Human capital			
Age	Age of household head (in years)	54.468	13.449
Female_fm	1 = Responsible person for finger millet production is female	.493	.501
Female_mz	1 = Responsible person for maize production is female	.444	.498
Education	1 = At least one household member has a secondary school education	.496	.501
Dependency Ratio	Number of household members aged 0 -14 and over 65 Divided by number of household members aged 15 – 64	1.121	.999
Wealth			
Farm size	Total farm size (in acres)	3.973	3.978
Cattle	Number of cattle owned by household	2.944	3.133
Off-farm income	Off-farm households income in 2011 (in 1000 KES)	129.436	507.493
Regional dummies			
Teso	1 = Farm is located in Teso district	.333	.472
Mumias	1 = Farm is located in Butere-Mumias district	.400	.491

Regarding the adoption of improved cropping practices in maize, we largely include the same variables as potential explanatory variables[4]. However, improved maize cropping practices have been propagated by extension programs for decades and formal sources of information are widely available for maize production. We therefore expect access to markets and information to be less of a constraint for the adoption of improved maize cropping practices. In particular, since nearly every farmer in Western Kenya grows maize, contact intensity among maize farmers is generally high and does not vary much between households. We therefore do not include a similar variable on contact intensity in the maize equations. In contrast, we do include the dummy variable that assumes one if households are located in external control villages in the maize equation, even though the KARI program focuses exclusively on finger millet. However, including it in the maize regressions allows us to

[4] Regarding extension, we include a dummy that equals one if the household received maize (not millet) related extension. Furthermore, we include a variable on the gender of the person responsible for maize (not millet) production.

control whether differences in the use of improved finger millet technologies reflect a systematic difference between the locations or can be interpreted as spillover effects from the KARI extension program.

Yield analysis

In order to analyze the effect of improved cropping practices on finger millet yields, we estimate a Cobb-Douglas[5] production function:

$$\ln Y_i = \alpha_0 + \sum_{j=1}^{j} \alpha_j \ln X_{ji} + \sum_{k=1}^{k} \alpha_k D_{ki} + u_i$$

where Y_i is the finger millet yield (in kg per acre) for observation i, X_j is a vector of input factors, D_k is a vector of dummy variables and u_i is a random error term. We include a dummy variable that equals one if the farmer has adopted an improved variety. The use of chemical fertilizer is quantified in kg per acre. Following Battese (1997), we additionally include a dummy variable that takes the value one if the input of chemical fertilizer is zero in order to avoid biased estimates caused by zero values in the quantity of chemical fertilizer used. Other continuous input variables are the quantity of seeds and the labor input for soil preparation, sowing, and weeding. Since farmers are often not able to give very accurate specifications of the amount of organic fertilizer applied, we do not include the use of organic fertilizer as a continuous variable, but instead, use a dummy variable that takes the value one if the farmer applies any organic fertilizer. In order to reflect the extent of mechanization in millet production, we include a dummy that equals one if the farmer uses an ox plough or tractor for soil preparation. Another dummy variable is included to control for the application of row-planting. Furthermore, the timing of planting can have an important influence on yields. The optimal planting time depends on the start of the rainy season and varies slightly between the districts, but early planting is usually advantageous in cereal production. To differentiate between early planters and late planters, we include a dummy variable for early planting that equals one if farmers planted between December and February and zero if they planted between March and May. Finally, we include altitude and a plot specific dummy for high soil fertility to account for agro-ecological differences. Summary statistics for the variables used in the Cobb-Douglas production function are provided in table 2.

[5] Alternatively, a translog production function would increase the flexibility of the model. However, in our data set the translog functional form leads to problems of multicollinearity. We therefore choose the more restrictive Cobb-Douglas functional form.

Table 2: Variables Used in the Cobb-Douglas Production Function

Variable	Variable description	Mean	Std. Dev.
Ln harvest per acre	Logarithm of harvest per acre (kg)	5.321	1.141
Ln seed quantity	Logarithm of seed quantity (kg)	1.505	.740
Ln chemfert	Logarithm of chemical fertilizer quantity (kg)	1.830	1.885
Ln soilprepsow lab	Logarithm of soil preparation and sowing input (working days)	3.434	.885
Ln weed lab	Logarithm of weeding input (working days)	3.519	.851
Ox-tractor	1 = Use of an ox-tractor	.504	.501
Early planting	1 = Planted between December and March	.578	.495
Row-planting	1 = Practice of row-planting	.678	.468
Modern variety	1 = Use of a modern variety	.491	.501
Zero chemfert	1 = No use of chemical fertilizer	.389	.488
Orgfert	1 = Use of organic fertilizer	.337	.474
Altitude	1 = Altitude of dwelling (meters)	4131.137	291.236
High soil fert	1 = High soil fertility (plot specific)	.296	.457

As a result of unobserved factors that potentially influence both the probability of adopting an improved variety and finger millet yields (e.g. the farmer's motivation), estimates of the Cobb-Douglas function might be biased. To control for potential selection bias, we estimate a treatment effects model in which an auxiliary probit model estimates the probability of adopting a modern variety. The inverse Mill's ratio of the probit model is then included as a selectivity correction in the Cobb-Douglas regression. The variable 'external' serves as an exclusion restriction in our treatment effects model. Being located in an external location is likely to have a negative impact on the probability of adopting a modern variety, since farmers in external locations do not easily access the information given by KARI extension services. At the same time, the variable is unlikely to be directly related to finger millet yields, except for its effect through the improved practices. A selectivity bias is present when the error terms between the two regressions of the treatment effects model are correlated ($\rho \neq 0$).

5. Descriptive results

With an average farm size of four acres (1.6 hectares), most households in our sample are small-scale farmers. During the long-rains in 2011, farmers dedicated 0.84 acres to the production of finger millet and 1.32 acres to the production of maize, on the average. Although we did not explicitly sample maize producers, only 14 farmers in our sample did not grow any maize during the long-rains and only three farmers did not grow any maize in 2013.

Adoption of improved cropping practices

Improved finger millet cropping practices applied by farmers in our sample include the use of modern varieties and chemical fertilizer as well as enhanced planting and weeding practices. Modern finger millet varieties have only been commercially available for a few years and are not yet widely used in Western Kenya. Accordingly, a relatively large share of the farmers in our sample (34.1%) is not aware of any modern finger millet varieties. Similarly, fertilizer application is not a common practice in finger millet production and many farmers rely on the crop's resilience to poor soils. In fact, 21.5% of the interviewed farmers indicated that they have never observed fertilizer application in finger millet production. Other practices such as row-planting, weeding and thinning are well known to over 90% of the farmers. The relatively high share of farmers that are not aware of modern varieties and chemical fertilizer applications in finger millet production suggests that lack of information may be an important reason for non-adoption in our sample.

Among the interviewed farmers, 49.1% used a modern finger millet variety in 2011 and 54.1% applied chemical fertilizer to their finger millet production area. Micro-dosing was practiced by 38.3% of the farmers who applied chemical fertilizer. With respect to planting techniques, we find that 67.8% of the farmers practice row-planting and 42.2% of the farmers are early planters with planting dates between December and February. Our survey data shows little variation of the weeding and thinning practices: While only one farmer did not weed at all and over 90% of the farmers thinned their finger millet during the first weeding, less than 5% of all farmers conducted a second weeding[6].

As shown in table 3 important synergies seem to be associated with the use of the same practices in maize and millet production. Adoption rates of improved technologies are generally higher in maize production, with 71.1% of the interviewed farmers using an improved maize variety and 61.5% applying chemical fertilizer in maize production. Among the adopters of a modern maize variety, 54% also use a modern finger millet variety. Among the non-adopters of a modern maize variety, only 35% cultivated a modern finger millet variety in 2011. Likewise, 72% of the farmers who use chemical fertilizer in maize production also use it in finger millet production, while only 25% of the farmers who to not apply fertilizer in maize production use fertilizer in finger millet production.

Table 3: Relationship between Maize and Finger Millet Cropping Practices

	Modern variety (maize)		Fertilizer (maize)	
	Non-adopters	Adopters	Non-adopters	Adopters
Modern variety (finger millet)	.35 (.48)	.54 (.50)***		
Fertilizer (finger millet)			.25 (.43)	.72 (.45)***

Values in brackets are standard deviations

*** indicates a correlation between the adoption of a practice in maize and finger millet production on a 1% significance level (based on chi^2 test)

Participation in farmer groups

As described in the previous section, variables related to social networks and connectedness can alleviate adoption constraints by improving access to information, labor, cash, and product markets. In our research area, social networks and groups play an important role. The great majority of households in our sample (85.9%) participate in at least one active social group. Most households (77.4%) are member in one to three groups, while 8.5% participate in more than three groups. The social groups are very diverse regarding their members and activities, including for example self-help groups for widows, youth groups or church groups.

[6] It is important to keep in mind that farmers who have received finger millet related extension are oversampled in our data and that the simple descriptive adoption rates presented here are therefore not representative for the whole region in the case of finger millet.

Among the households who participate in at least one group, 36.6% purchase farm inputs together with other group members.

When asked about their contact to other finger millet farmers, 11% of the interviewed farmers claimed not to be in contact with any other finger millet farmer. A total of 21% stated to be in contact with one or two other finger millet farmers, while a majority of 68% indicated to be in contact with three or more other finger millet farmers. As described in Chapter 4, we asked finger millet farmers how often they discuss their cropping practices with other finger millet farmers on a scale from one (“never) to five (“very often”). Most farmers (53%) responded that they discuss cropping practices often or very often. Practices are never or rarely discussed in 17% of the cases and sometimes discussed in 31% of the cases.

Finger millet yields

Regarding finger millet yields, we find significantly higher yields among adopters than among non-adopters of improved finger millet cropping practices (see table 4). For example, farmers who use a modern variety obtain an average yield of 420 kg per acre as compared to an average yield of 235 kg per acre among farmers who do not use a modern variety.

Similarly, we find significantly higher maize yields among farmers who use a modern variety and chemical fertilizer in maize production. We furthermore find a major discrepancy between finger millet and maize yields; while the average finger millet yield ranges at 330 kg per acre, we observe an average maize yield of 603 kg per acre.

Table 4: Average Yields per Acre

	Modern variety		Fertilizer		Row-planting		
	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	All
Finger millet yields (in kg per acre)	234.93 (211.56)	420.31 (333.77)***	217.92 (196.23)	423.69 (329.27)***	201.78 (182.59)	387.51 (316.76)***	327.67
Maize yields (in kg per acre)	398.92 (331.85)	689.12 (589.77)***	290.37 (252.73)	776.72 (582.82)***			603.84

Values in brackets are standard deviations
*** indicates that the mean difference is significant on a 1% significance level

When asking farmers about their main yield constraints in finger millet production, the availability and costs of inputs were mentioned as the most important constraint by 36% and as the second most important constraint by 33% of the households (see table 5). Another important constraint mentioned by farmers is poor crop management, which was mentioned as the most important constraint by 27% of the farmers. These answers can reflect both poor access to financial capital and input markets as well as lack of skills and information. Other important constraints mentioned include erratic rainfall, pests, diseases, and poor soils.

Table 5: Main Yield Constraints in Finger Millet Production (Farmers' Perception)

Main constraints	Access to inputs	Poor crop management	Erratic rainfall, pests, diseases	Poor soils
I	96 (36%)	72 (27%)	68 (25%)	26 (10%)
II	90 (33%)	46 (17%)	66 (24%)	14 (5%)
III	47 (17%)	22 (8%)	42 (16%)	9 (3%)

6. Results on the adoption of improved practices

Table 6 presents the results on the adoption of improved cropping practices in finger millet production from the multivariate probit model. As expected, variables related to social networks and connectedness play an important role in the adoption of improved finger millet cropping practices. The contact intensity with other finger millet farmers has a positive influence on the adoption of both cropping practices. Furthermore, the ownership of a cell phone increases the likelihood of using a modern variety and chemical fertilizer by 31% and 33%[7], respectively, pointing to the importance of cell phones for accessing input markets. In terms of group membership, participating in a group where members jointly purchase certain farm inputs increases the probability of adopting a modern variety by 25%, but is insignificant in the case of chemical fertilizer. As opposed to modern finger millet varieties, chemical fertilizer is an input that has widely been used by small-scale farmers in the region for many years. Access to chemical fertilizer is therefore rather limited by cash constraints than by market information constraints and farmers who can afford to purchase chemical fertilizer do not need to buy this input through a group. For a new and less accessible input like improved finger millet varieties, collective purchasing is effectively increasing the farmers' access to this input. As expected, the reception of extension services fosters the adoption of both practices. We furthermore observe a negative effect of the external location dummy on the adoption of both practices. This indicates that spillover-effects exist within program villages, where farmers are more likely to adopt modern practices in millet cultivation, even if they did not actively participate in trainings.

The variables reflecting household wealth have a positive effect on the use of chemical fertilizer, confirming our hypothesis that the non-adoption of chemical fertilizer can rather be attributed to a cash constraint than to information constraints. Finally, the district dummies reveal regional differences in the dissemination of modern finger millet production practices: compared to the excluded district Busia, farmers in Teso are less likely to practice improved finger millet cropping practices.

[7] We calculated the marginal effects by introducing an observation where all variables equal the mean value of that variable. The marginal effect of a dummy variable is measured as the change in the predicted probability of that observation due to a change of the dummy value from zero to one. The marginal effect of a continuous variable is measured as the change in the predicted probability due to an increase of the mean value by 1. In the case of off-farm income, the mean value was increased by 1% to measure the marginal effect.

Table 6: Regression Results on the Adoption of Improved Finger Millet Practices

	Modern variety			Chemical fertilizer		
	Coefficient		Standard Error	Coefficient		Standard Error
Female_fm	.125 (.050)		.220	.128 (.049)		.215
Age	.010 (.004)		.009	.014 (.005)		.010
Education	-.203 (-.081)		.236	-.166 (-.063)		.233
Dependency ratio	-.034 (-.013)		.104	.034 (.031)		.087
Farm size	.046 (.018)		.042	-.001 (-.001)		.040
Off-farm income	.000 (.000)		.000	.000 (.002)	***	.000
Cattle	-.039 (-.016)		.036	.083 (.031)	**	.037
Group number	.000 (.000)		.110	-.010 (-.004)		.105
Group purchase	.646 (.253)	**	.270	.343 (.126)		.315
Contact intensity	.090 (.036)	***	.032	.087 (.033)	***	.028
Cell phone	.840 (.308)	**	.349	.843 (.326)	***	.387
Market distance	-.002 (-.001)		.002	-.002 (-.001)		.002
Extension_fm	1.306 (.486)	***	.239	1.112 (.391)	***	.271
External	-.811 (-.303)	***	.316	-.971 (-.373)	***	.270
Mumias	-.213 (-.084)		.293	.285 (-.106)		.296
Teso	-.615 (-.240)	**	.298	-1.180 (-.437)	***	.313
Constant	-2.236	***	.785	-2.375	***	.852

Marginal effects are given in parentheses.

*** and ** indicate a significance level of 1% and 5%, respectively

Results from the maize equations of the multivariate probit model can be found in table 7. Clearly, social and market connectedness pose less of a constraint to the adoption of improved crop management practices in maize production. The only variable that is significant is the number of groups a household participates in, which has a positive influence on the adoption of modern maize varieties. This confirms our hypothesis that social and market connectedness is much more critical in the case of a neglected crop, like finger millet, for which formal sources of information are scarce. Furthermore, some of the human capital and wealth related indicators have a significant effect on the adoption of modern varieties and chemical fertilizer in maize production. In particular, age has a negative sign, indicating that younger farmers are more innovative, and the number of cattle has a positive sign, providing some evidence that wealthier households may be less cash constrained. Finally, farmers in external locations are less likely to use chemical fertilizer not only in millet but also in maize production, indicating that general access to agrochemical input stores might be more limited in those villages.

Table 7: Regression Results on the Adoption of Improved Maize Cropping Practices

	Modern variety			Chemical fertilizer		
	Coefficient		Standard Error	Coefficient		Standard Error
Female_mz	-.143 (-.046)		.212	-.146 (-.051)		.216
Age	-.014 (-.004)	*	.008	-.013 (-.005)		.009
Education	.129 (.041)		.211	.238 (.083)		.214
Dependency ratio	-.116 (-.039)		.085	.110 (.037)		.130
Farm size	-.059 (-.019)	**	.030	-.034 (-.012)		.031
Off-farm income	.000 (.000)		.000	.000 (.000)		.000
Cattle	.135 (.041)	***	.041	.114 (.039)	***	.043
Group number	.248 (.072)	**	.103	.141 (.047)		.102
Group purchase	.111 (.035)		.267	.028 (.010)		.276
Cell phone	.153 (.050)		.306	.221 (.080)		.346
Market distance	-.000 (-.000)		.001	-.000 (-.000)		.001
Extension_mz	-.027 (-.009)		.252	.027 (.009)		.248
External	.183 (.056)		.249	-.800 (-.300)	***	.227
Mumias	.230 (.071)		.267	1.129 (.343)	***	.291
Teso	.364 (.113)		.266	-.276 (-.097)		.252
Constant	.512		.636	.169		.761

Marginal effects are given in parentheses.

***, **, and * indicate a significance level of 1%, 5%, and 10%, respectively

The rho values reported in table 8 reflect the correlation between the error terms of the equations. The error terms of the two finger millet equations are positively and significantly correlated, indicating synergies rather than trade-offs in the adoption of improved crop management practices in finger millet production systems. Likewise, the error terms of the maize equations are positively correlated. Regarding the adoption of the same practice for different crops, we find synergies in the adoption of chemical fertilizer in finger millet and maize production. Similarly, the error terms of the equations for modern maize variety adoption and modern finger millet variety adoption are also positively correlated. These results indicate that synergies exist in the adoption of improved crop management practices within and across cropping systems that result from reduced transaction costs as well as knowledge spillovers from maize to finger millet production.

Table 8: Model Statistics of the Adoption Analysis

Rho value	Coefficient		Standard Error
Interaction millet practices			
Rho21 (finger millet fertilizer / finger millet modern variety)	.626	***	.144
Interactions maize practices			
Rho43 (maize fertilizer / maize modern variety)	.600	***	.279
Interactions millet and maize practices			
Rho31 (maize modern variety / finger millet modern variety)	.278	**	.137
Rho32 (maize modern variety / finger millet fertilizer)	.278	**	.022
Rho41 (maize fertilizer / finger millet modern variety)	.067		.131
Rho42 (maize fertilizer / finger millet fertilizer)	.397	***	.133

N	250	Prob>Chi^2	0.000
Wald Chi^2 (78)	449.030	Log pseudolikelyhood	-1757.972

7. Yield effects of improved cropping practices

Table 9 reports the results of the Cobb-Douglas production function estimating yield effects of improved finger millet practices. The hypothesis that rho = 0 is rejected in the treatment effects model (Prob > Chi^2 = 0.05), indicating the presence of a selection bias[8]. Coefficients in the Cobb-Douglas production function represent the partial production elasticities of the different input variables and can thus be interpreted as percentage changes. Results show that the adoption of a modern finger millet variety has a positive and significant impact, increasing yields by 107%[9]. Furthermore, chemical fertilizer applications have positive yield effects. According to our results, increasing the quantity of chemical fertilizer by 1% leads to a yield increase of 0.16%. Finally, the quantity of seeds applied has a positive effect on finger millet yields.

[8] First stage results of the treatment effects model are presented in table 10 in the annex

[9] since the dependent variable is a log-dependent variable, coefficients of dummy variables are interpreted as [exp(coefficient)-1]*100

Table 9: Cobb-Douglas Production Function

Variable	Coefficient		Standard Error
Ln seed quantity	.268	***	.096
Ln chemfert	.159	***	.047
Ln soilprepsow lab	.001		.114
Ln weed lab	.156		.096
Ox-tractor	.350		.176
Early planting	.203		.168
Row-planting	.024		.241
Modern variety	.729	***	.266
Zero chemfert	-.188		.202
Orgfert	.104		.180
High soil fert	-.047		.164
Altitude	-.000		.000
Constant	4.333	***	.904
N	267	Log pseudolikelihood	-1805.372
Wald Chi^2 (12)	104.490	Wald test of indep. Eqns. (rho=0): $chi^2(1)$	3.860
Prob > Chi^2	.000	Prob > Chi^2	0.050

***indicates a significance level of 1%

8. Conclusions

To increase agricultural productivity in rural areas of developing countries, the dissemination of improved agricultural technologies needs to be stimulated. While previous and current research dedicated to this topic usually focuses on cash crops or main food crops such as maize, rice and wheat, traditional cereals like finger millet have been widely neglected despite their importance for many small-scale farmers worldwide. Based on cross-sectional household data from 270 finger millet farmers, the present study analyzes the adoption of modern varieties and chemical fertilizer among finger millet farmers in Western Kenya. We furthermore assess the use of the same practices in maize production in order to compare adoption processes for a traditional cereal with adoption processes for a main staple crop.

Results of a multivariate probit analysis show that variables related to social networks and connectedness have a substantial influence on the adoption of improved finger millet technologies. Specifically, we find contact intensity among finger millet farmers, the use of a cell phone and extension to have a positive effect on the adoption of improved finger millet practices. At the same time, these variables are found to be of minor importance for the adoption of the same practices in maize production. The error terms of the different equations are positively correlated, indicating complementarities rather than trade-offs between modern variety adoption and fertilizer applications for the same crop, but also across crops. Furthermore, results of a Cobb-Douglas production function demonstrate a strong positive effect of the adoption of modern varieties and chemical fertilizer on finger millet yields.

Our findings indicate that improved cropping practices for traditional food crops are widely applied once the prevailing constraints such as lack of information and access to inputs can be overcome. While in the case of maize the effect of extension on adoption is negligible in our research area, extension plays a critical role for the adoption of improved finger millet practices. These differences can be attributed to the fact that knowledge about maize cropping practices is widely available, while knowledge regarding improved finger millet practices is scarce. Furthermore, while traditional crops have a lower yield potential than main staple crops under ideal growing conditions, the strong yield effect of improved practices in our analysis shows that there is a substantial untapped yield potential in finger millet production.

Therefore, policy-makers aiming to promote the use of modern inputs in neglected traditional crops should support targeted extension programs. Extension programs dedicated to traditional crops can disseminate knowledge on best practices and at the same time improve the crops' reputation, thus encouraging farmers to unleash the full potential of traditional food crops. This is especially important against the background that finger millet and other traditional food crops can play a crucial role for the resilience of agricultural systems and the micronutrient supply of the rural population.

Besides formal extension, farmer-to-farmer networks are found to be an effective trigger for the dissemination of finger millet practices. In rural Kenya, many social groups exist and the majority of farmers participate in at least one group. However, group activities vary widely and can be a decisive factor for the diffusion of new technologies. In particular, joint input purchases may help farmers to overcome high transaction costs associated with accessing improved technologies. To facilitate these activities, training social groups on group organization and management might be as important as the training on agricultural practices itself to ensure a broad adoption of improved practices.

References

Battese, G. E. (1997): A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values. In *Journal of Agricultural Economics* 48 (1-3), pp. 250–252.

Besley, T.; Case, A. (1993): Modeling technology adoption in developing countries. In *The American Economic Review* 83 (2), pp. 396–402.

Byerlee, D.; Eicher, C. K. (1997): Africa's emerging maize revolution: Lynne Rienner Pub.

Cavatassi, R.; Lipper, L.; Narloch., U. (2011): Modern variety adoption and risk management in drought prone areas: insights from the sorghum farmers of eastern Ethiopia. In *Agricultural Economics* 42 (3), pp. 279–292.

Conelly, W. T.; Chaiken, M. S. (2000): Intensive farming, agro-diversity, and food security under conditions of extreme population pressure in western Kenya. In *Human Ecology* 28 (1), pp. 19–51.

Conley, T. G.; Udry, C. R. (2010): Learning about a new technology: Pineapple in Ghana. In *The American Economic Review*, pp. 35–69.

Croppenstedt, A.; Demeke, M.; Meschi, M. M. (2003): Technology adoption in the presence of constraints: The case of fertilizer demand in Ethiopia. In *Review of Development Economics* 7 (1), pp. 58–70.

Crowley, E.; Carter, S. (2000): Agrarian Change and the Changing Relationships Between Toil and Soil in Maragoli, Western Kenya (1900–1994). In *Human Ecology* 28 (3), pp. 383–414.

Doss, C. R.; Morris, M. L. (2000): How does gender affect the adoption of agricultural innovations? In *Agricultural Economics* 25 (1), pp. 27–39.

FAO (2012a): CountrySTAT Kenya - Indicators. Available online at http://countrystat.org/ken/cont/pages/page/indicators/en, checked on 30/11/2012.

FAO (2012b): FAOSTAT. Available online at http://faostat.fao.org/site/567/default.aspx#ancor, checked on 30/11/2012.

Feder, G.; Just, R. E.; Zilberman, D. (1985): Adoption of agricultural innovations in developing countries: A survey. In *Economic development and cultural change* 33 (2), pp. 255–298.

Feder, G.; Umali, D. L. (1993): The adoption of agricultural innovations: a review. In *Technological forecasting and social change* 43 (3), pp. 215–239.

Feleke, S.; Zegeye, T. (2006): Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. In *Food Policy* 31 (5), pp. 442–457.

Fischer, E.; Qaim, M. (2012): Linking Smallholders to Markets. Determinants and Impacts of Farmer Collective Action in Kenya. In *World Development* 40 (6), pp. 1255–1268.

Foster, A. D.; Rosenzweig, M. R. (1995): Learning by doing and learning from others: Human capital and technical change in agriculture. In *Journal of political Economy*, pp. 1176–1209.

Gill, G.; Turton, C.(2001): Pearl millet in developing countries. *Sorghum Improvement Conference of North America, Lubbock, USA; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)*

Godfray, C.; Beddington, J.; Crute, I.; Haddad, L.; Lawrence, D.; Muir, J. et al. (2010): Food security: the challenge of feeding 9 billion people. In *science* 327 (5967), pp. 812–818.

Govereh, J.; Jayne, T. S. (2003): Cash cropping and food crop productivity: synergies or trade-offs? In *Agricultural Economics* 28 (1), pp. 39–50.

Groote, H. de; Owuor, G.; Doss, C.; Ouma, J.; Muhammad, L.; Danda, K. (2005): The maize green revolution in Kenya revisited. In *Journal of Agricultural and Development Economics* 2 (1), pp. 32–49.

IFAD (2010): Rural Poverty Report 2011: IFAD (International Fund for Agricultural Development) Rome, Italy.

Kaliba, A. R. M.; Verkuijl, H.; Mwangi, W. (2000): Factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones of Tanzania. In *Journal of Agricultural and Applied Economics* 32 (1), pp. 35–48.

Knowler, D.; Bradshaw, B. (2007): Farmers’ adoption of conservation agriculture: A review and synthesis of recent research. In *Food Policy* 32 (1), pp. 25–48.

Langyintuo, A. S.; Mungoma, C. (2008): The effect of household wealth on the adoption of improved maize varieties in Zambia. In *Food Policy* 33 (6), pp. 550–559.

Marenya, P. P.; Barrett, C. B. (2007): Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. In *Food Policy* 32 (4), pp. 515–536.

Matuschke, I.; Qaim, M. (2008): Seed market privatisation and farmers' access to crop technologies: The case of hybrid pearl millet adoption in India. In *Journal of Agricultural Economics* 59 (3), pp. 498–515.

Matuschke, I.; Qaim, M. (2009): The impact of social networks on hybrid seed adoption in India. In *Agricultural Economics* 40 (5), pp. 493–505.

Mignouna, D. B.; Manyong, V. M.; Rusike, J.; Mutabazi, K. D.S.; Senkondo, E. M. (2011): Determinants of adopting Imazapyr-resistant maize technologies and its impact on household income in Western Kenya.

Moser, C. M.; Barrett, C. B. (2003): The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. In *Agricultural Systems* 76 (3), pp. 1085–1100.

Nichola, T. (1996): The Decision to Adopt and the Intensity of Adoption of Technology: A Double Hurdle Model Application in the Adoption of a Sorghum Hybrid. In *Journal for Studies in Economics and Econometrics* 20, pp. 49–57.

Nyende, P.; Tenywa, J. S.; Oryokot, J.; Kidoido, M. M. (2001): Weed profiles and management assessment for increased finger millet production in Uganda.

Oduori, C. (2005): The importance and research status of finger millet in Africa. In *Nairobi: The McKnight Foundation Collaborative Crop Research*.

Place, F.; Kariuki, G.; Wangila, J.; Kristjanson, P.; Makauki, A.; Ndubi, J. (2004): Assessing the factors underlying differences in achievements of farmer groups. methodological issues and empirical findings from the highlands of Central Kenya. In *Agricultural Systems* 82 (3), pp. 257–272.

Sauer, J.; Tchale, H. (2009): The Economics of Soil Fertility Management in Malawi. In *Applied Economic Perspectives and Policy* 31 (3), pp. 535–560.

Simtowe, F.; Zeller, M.; Diagne, A. (2009): The impact of credit constraints on the adoption of hybrid maize in Malawi. In *Review of Agricultural and environmental studies* 90 (1), pp. 5–22.

Sserunkuuma, D. (2005): The adoption and impact of improved maize and land management technologies in Uganda. In *Electronic Journal of Agricultural and Development Economics* 2 (1), pp. 67–84.

Vietmeyer, N. (1996): Lost Crops of Africa. v. 1 Grains: Washington: National Academcy Press.

Wollni, M.; Lee, D. R.; Thies, J. E. (2010): Conservation agriculture, organic marketing, and collective action in the Honduran hillsides. In *Agricultural Economics* 41 (3-4), pp. 373–384.

Wu, B.; Pretty, J. (2004): Social connectedness in marginal rural China: The case of farmer innovation circles in Zhidan, north Shaanxi. In *Agriculture and Human values* 21 (1), pp. 81–92.

Annex

Table 10: First Stage Results of Treatment Effects Model on Finger Millet Yields

Variable	Coefficient		Standard Error
Female_fm	.008		.232
Age	.009		.009
Education	-.331		.227
Dependency ratio	-.036		.100
Farm size	.020		.037
Non-farm income	.000		.000
Cattle	-.028		.035
Group number	-.012		.108
Group input purchase	.740	***	.264
Contact intensity	.086	***	.029
Market distance	-.001		.001
Cell phone	.873	**	.368
Extension_fm	1.284	***	.245
External	-.749	***	.286
Mumias	-.017		.277
Teso	-.349		.285
Constant	-2.242	***	.762