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Dryland Cereals and Household Food Security in Tanzania: Potential and Constraints of Improved Sorghum Cultivars

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Abstract

More than one third of the population in Africa is still facing undernourishment and malnutrition. While poor and food-insecure people are most often living in unfavorable agricultural zones, such as semi-arid areas, only few studies have assessed the potential of well adapted dryland cereals to contribute to local food security. Here, we analyze the case of sorghum in Tanzania, and particularly focus on the role of improved sorghum cultivars. Using survey data from smallholder farmers and econometric techniques, we show that sorghum contributes to the food supply of a household. Despite the promise of higher yields and better resistance of improved sorghum cultivars to some biotic and abiotic stresses, adoption rates are, however, still low. Our results indicate that access to information and diversified networks constitute serious adoption constraints. National extension systems are a major bottleneck in overcoming such constraints.

Keywords: Dryland Cereals, Food Security, Sorghum Cultivars

JEL classification: Q160, Q180, Q120

Contents

1 Introduction

Despite the fact that food security is one of the millennium developing goals, more than one third of the population in Africa is still facing undernourishment and malnutrition (Union Africaine, 2005). The food crisis in 2011 at the Horn of Africa stressed once more the urgent need to address the roots of this problem. One essential step towards reducing food insecurity is the improvement of farm level resilience to agricultural production shocks. This holds particularly true for countries that are expected to face an increasing risk of climatic shocks and in which a large share of the population depends on agriculture, like in Tanzania (Cavatassi et al., 2011).

In developing countries, poor and food-insecure people are most often living in marginal or unfavourable agricultural zones such as semi-arid areas. Nevertheless, these regions were often neglected in the past (Lipton, 2005; Pingali and Rosegrant, 1998). Instead, efforts of national governments as well as of the international donor and development cooperation community to improve agricultural production systems often focus on high potential areas and crops only. While this might be a successful strategy for short term successes, it is not a promising strategy to improve the food security situation in marginal areas in the longterm (Edmeades et al., 2008). Moreover, it is widely argued that the neglect of unfavourable areas worsens the situation in these areas (Lipton and Longhurst, 1989).

The agroecological conditions in semi-arid areas limit the production portfolio of a farmer to only a number of crops. Moreover, semi-arid areas face a high risk of droughts, which favours crops with a certain drought tolerance. Traditional crops like sorghum are well adapted to both, the agro ecological conditions of semi-arid areas and droughts (FAO and ICRISAT, 1996). This makes them more resilient to production shocks as for example maize. Moreover, sorghum can contribute to food security through its nutritional quality. Sorghum has high calorie content and offers valuable nutritional ingredients, in particular iron and zinc, which also makes it competitive with maize (Koenders, 2010). In particular in the light of climatic change, that is expected to lead to higher temperatures, more variable rainfall and extreme weather events, and thus negatively effects agricultural production, the potential of sorghum to contribute to food security needs to be further explored (IPCC, 2007).

On the other hand and when compared to other staple crops like maize, traditional crops like sorghum often have the disadvantage of relatively low yields. This puts the farmer in the dilemma to choose between relatively secure, but lower yields (sorghum) and relatively insecure, but higher yields (maize) or a combination of both. In regard to sustaining food security, each decision implies a certain risk (Rohrbach and Kiriwaggulu, 2007).

An important step to improve this situation is the introduction of new sorghum cultivars, which among other aspects offer higher yields. Although traditional crops have been less in the focus of research, compared to cotton and maize, the belief that sorghum can contribute to food security in semi-arid areas spurs a strong interest in the crop, and a respectable number of new sorghum cultivars has been released in Sub Sahara Africa, including Tanzania (Miller et al., 1996). In some situation in Sub-Sahara Africa e.g. early maturing varieties have been shown to reduce the downside production risk, thus enabling a more productive use of land (Mekbib, 2006).

Despite the promise of higher yields and better resistance of improved sorghum cultivars to some biotic and abiotic stresses, there is no guarantee that improved cultivars will be widely adopted. Previous studies on adoption of new agricultural technologies have found that technological, socioeconomic and other context specific constraints, unrelated to specific varietal attributes, limit the dissemination of agricultural innovations (Feder et al., 1985; Noltze et al., 2011; Schipmann and Qaim, 2010). Hence, it is important to understand the motivation and constraints of farmers in adopting improved sorghum varieties that are designed to reduce production risk and improve food security. However, only few studies that assess the contribution of sorghum and in particular, improved sorghum cultivars to the food supply of a household are found and dissemination and adoption patterns are not well understood (Cavatassi et al., 2011). Moreover, previous studies on adoption of new technologies have often neglected the fact that not all farmers in a given environment are exposed to the innovation under consideration. Thus, adoption estimates in these studies can lead to biased results.

Our paper aims to address this research gap by analysing such aspects for the case of sorghum cultivating farmers in Kondoa and Singida Rural district in Central Tanzania. Both districts are semi-arid areas with annual rainfall below 600mm. Sorghum is widely cultivated in the districts and, as well as maize, an important food crop for rural households. Building on primary survey data from Kondoa and Singida Rural district, we analyse three main aspects. First, we look at consumption patterns of farmers in regard to major staple crops to assess the contribution of sorghum in general and improved varieties in particular for a households' food supply. This is done by descriptive statistics. Second, based on farmers stated reasons and constraints; we analyse current adoption levels of improved sorghum cultivars and discuss adoption barriers. And third, controlling for a possible exposure and selection bias, we estimate probit models to assess the determinants of exposure to and adoption of new sorghum cultivars. The analysis will allow policy recommendations about the current and potential contribution of sorghum to the food supply in semi-arid areas as well as about dissemination barriers of improved sorghum cultivars.

The paper proceeds as follows. The next section provides background information about sorghum in the study area and the empirical database. Subsequently, the contribution of sorghum to the food supply of a household is discussed. The fourth section provides an overview about the adoption pattern and, based on farmers' statements as well as by estimating econometric models, analyses and discusses determinants of exposure and adoption. The last section concludes.

2 Study Background and data

2.1 Background on sorghum in Tanzania

Tanzania is a least developed and food deficit country, in which more than 40% of the population lives in chronic food deficit regions, where irregular rainfalls cause recurring food shortages. In 2007, 34% of the population were undernourished and the amount of food aid that the country received increased from 12,918 mt in the 1990-92 period to 54,051mt in the 2004–06 period (IFPRI, 2011; WFP, 2011). 80% of the work force of Tanzania depends on agriculture, but the productivity of the sector is low. Increasing the potential of dryland cereals like sorghum presents an opportunity in reversing this trend and reducing the incidence of poverty and food insecurity (Cavatassi, 2011).

Globally, sorghum is the fifth most important cereal and a dietary staple for around 500 million people (Intsormil, 2009). In Tanzania, it is the second most widely grown cereal grain crop, cultivated on an area of approximately 700,000 ha with an annual production of about 500,000 mt. Kondoa and Singida Rural district are two of the areas, where sorghum is primarily cultivated. Sorghum is almost entirely grown by smallholder farmers on a subsistence level. Less than 2% of the harvest enters the formal market. Thus, the main contribution of sorghum is to farm household food security (Rohrbach and Kiriwaggulu, 2007). In recent years, a number of high yielding sorghum varieties, which are also tolerant to other field problems such as pests, diseases and weeds have been developed by the Department of Research and Development, Tanzania in collaboration with international research organizations, e.g. ICRISAT. Despite research efforts, adoption of new sorghum varieties by farmers and spread of improved sorghum production and storage practices (i.e., fertilizers and insecticides for storage) have been low. Thus local varieties are still widely grown (Mafuru et al., 2007).

2.2 Data

For our empirical study we conducted a household survey of 360 farmers in Kondoa and Singida Rural district in Central Tanzania. The survey was carried out between October and November 2010. Survey villages in the two districts were selected through a multistage sampling procedure. In a first stage, a treatment, diffusion and control area were defined in each district, consisting of two to three villages each. This sampling framework was chosen, because the survey was part of a research project of ICRISAT and serves as a baseline as well as a benchmark survey to assess the status quo and monitor and evaluate project activities, respectively.

The treatment groups consist of seven villages in which ICRISAT plans to implement activities to promote improved sorghum cultivars. Activities had not started at the time of the survey. The diffusion groups consist of eight villages, which are neighboring the treatment villages, so that spillover effects from project activities can be expected. The six villages in the control groups have the same agro ecological conditions than villages in the other two groups. However, they are that far away from the control and diffusion villages that spillover effects are unlikely to occur. In each of the three groups, households were randomly selected from a complete household list of all households in the group. 90 households were selected in each treatment group and 45 households in each diffusion and control group, respectively. Subsequently, a random sample of 360 households was selected for the detailed household survey from the six groups.

For the purpose of this paper, the differentiation in three groups is not of interest as project activities have not yet started. As households in the two districts and different groups face similar framework conditions, we analyze the data jointly.

3 Results: Cropping patterns and sorghum's contribution to the household's food supply

3.1 Cropping pattern of major cereals Data

From the 360 households in our sample, 256 cultivate sorghum. Cropping patterns are, however, shown for the whole sample to highlight the relevance of sorghum in the sample. A household owns on average 5 ha of land, of which 2.9 ha are on average cultivated. Around 83% (2.4 ha) of this area is cultivated with cereals. The four most popular cereals are finger millet, sorghum, maize and pearl millet (Table 1). In regard to number of farmers cultivating the respective crop there is no big difference between the first three crops, whereas pearl millet is cultivated by reasonably fewer farmers. However, in regard to the average and total area covered, maize is clearly most important, followed by finger millet and then sorghum. Pearl millet ranks again last. The same pattern can be observed for average and total production quantities.

The results for local and improved sorghum cultivars, which are presented in the lower part of Table 1, show that much fewer farmers cultivate improved compared to local sorghum cultivars. Also the average area allocated to the cultivar is lower for improved varieties. The area share of improved cultivars in the total area planted with sorghum is 66 percentage points lower than the area share of local varieties. In line with this, the average and total production quantities of improved varieties are also lower. The total production quantity of improved varieties is less than one third of the production quantity of local varieties.

Table 1: Production patterns of major cereals

Crops grown	No. of cultivating HH	Average Total area (ha)[1]	Total area (ha)	Average production (mt)[1]	Total production (mt)
All	360	2.90	1044	-	-
Finger millet	257	0.66	237	0.41	147
Sorghum	256	0.55	197	0.27	97
Maize	248	0.82	296	0.55	200
Pearl millet	181	0.36	131	0.15	53
Sorghum local	218	0.75	164	0.35	76
Sorghum improved	69	0.48	33	0.30	21

Notes: [1]Average area and production values were estimated by taking into account all farmers in the sample; thus including 0 values. Figures for average area and production therefore present an overview about the average crop portfolio of the whole sample. Exceptions are estimates for local and improved sorghum cultivars. They are based on sorghum cultivators only

3.2 contribution of selected cereals to a households' food supply

The most obvious information about the contribution of a cultivated crop to the food supply of a household is the amount of harvest used for home consumption. We asked farmers in the survey how much of their harvest of a respective crop they had consumed at the time of the survey. As the survey was conducted five month after harvest, consumption figures provided in Table 2 refer to consumption within this time period. It can, however, be expected that farmers do not only consume e.g. maize in these months, but throughout the year, as long as the crop is available. Thus, the annual share of harvest used for home consumption will be higher.

Our analysis shows that finger millet is a cash crop[1], whereas sorghum and maize are clearly food crops. For the latter two, the share of harvest used for home consumption is almost the same. However, as harvested quantities are higher for maize, a household consumes in total values more maize. Thus maize from own production contributes more to the food supply than sorghum. There are no major consumption differences in regard to the different types, local and improved, of sorghum cultivars. Both are almost to the same share used for home consumption. Thus improved varieties are not cultivated for other purposes than local varieties and also contribute to the food supply of a household.

To further investigate the contribution of different cereal crops to the food supply of a household, we have asked farmers in which months in an average year the harvested quantities of a respective crop are available for home consumption. Results are also displayed in Table 2.

Table 2: Contribution to the household's food supply of different cereals

Crop	% harvest for food supply	Food supply (No. of months)	Crop	No supply (No. of months)
Finger millet	6.5	-	Maize & sorghum	1.9
Sorghum	47.5	8.6	Only sorghum	2.3
Maize	49.9	9.2	Only maize	1.7
Sorghum local	46.9	8.5		
Sorghum impr.	50.5	8.7		

We only consider availability of the major food crops maize and sorghum. In total a household can consume sorghum and maize from its own harvest for 8.7 months and 9.2 months, respectively. First of all, this confirms our above statement that the annual share of harvest used for home consumption is higher, than our estimates five month after harvest. Under the assumption that farmers would not buy grain of a cereal that they have still in stock, and having in mind that harvested sorghum quantities are lower than those for maize, but last for almost the same time, the results also confirm that farmers consume more maize than sorghum. This conclusion is confirmed by the expenditure data for the two crops. Table three presents average and total annual expenditure on maize and sorghum for farmers who also cultivate the respective crop.

[1] Further analysis about the utilization of finger millet show that 82% of the harvest is sold

Table 3: Annual Expenditure on Maize and sorghum

Crop	No. of hh	Annual mean quantity bought (mt)	Total annual quantity bought (mt)
Maize	51	0.11	5.7
Sorghum	66	0.12	7.4

The figures in Table 3 are in all three categories higher for sorghum. Compared to maize, more households who cultivate sorghum additionally also purchase it, they purchase on average higher quantities, and thus the total quantity of sorghum purchased in a year is also higher. However, the difference in additionally purchased quantities of sorghum and maize is far less than the difference in harvested quantities. Thus, the conclusion that maize contributes more to the food supply of a household than sorghum is confirmed. The fact that sorghum cultivating households also buy additional sorghum is, however, a hint that households not necessarily prefer maize to sorghum[2]. This is further confirmed when looking at the respective month of consumption of a crop. The data shows that in most months both crops are consumed[3]. Thus, a household does not only consume sorghum as a substitute of maize. This is a positive result, because consumption preferences are an important driver for the adoption of a certain crop.

Another interesting result from Table 2 is that households cultivate neither enough maize, nor enough sorghum to meet their annual consumption demand for the respective crop. Besides different consumption needs discussed above, the results reflect a certain risk coping strategy of a household. Rather than cultivating a higher area share with maize to meet food consumption needs for this cereal, the farmer takes into account months of shortage. This guarantees the farmer that in case of short rainfalls or even droughts, which will affect the performance of maize more than the performance of sorghum, he at least harvests a relatively high quantity of one staple crops.

Another interesting aspect to compare is the food shortage situation of households that cultivate either both crops or only one of the two crops. As the household also consumes pearl and finger millet and we are interested in the absolute food shortage, we overlaid the months of consumption of the four major cereal crops and estimated the number of months in which a household does not have any cereal crops from its own harvest available. Results provided in Table 2 show that farmers who are cultivating both, maize and sorghum, face on average 1.9 months of food shortage from their own production. Interestingly, farmers who do not cultivate sorghum, but maize, can reduce their period of food shortage by 0.2 months, whereas farmers who cultivate sorghum, but no maize, increase their food shortage period by 0.4 month. Thus, in years of normal rainfalls, cultivation of sorghum affects the food security of a household negatively. However, figures do not differ

[2] We are aware that factors like availability, prices, etc. determine the demand for a certain crop. However, as maize is bought by a number of households, it can be assumed that all households have in general the option to choose between maize and sorghum and the higher purchased quantities reflect different consumption needs. Moreover, in Tanzania sorghum prices are on average not lower than maize prices (Ratin, 2011)

[3] Data is not reflected in Table 2 and can be made available on request

significantly. We did not differentiate results according to improved and local sorghum cultivar growers, because there is no difference between the two.

In regard to expectations of less rainfall and reoccurring droughts, the figures show an urgent need to introduce improved sorghum cultivars that offer high yields to enable farmers to balance the crop failure of maize. In Tanzania some improved sorghum cultivars have already been released. However, the take up of farmers is still relatively poor. To better understand adoption behaviour and identify strategies how to push improved varieties, the next section explores the adoption improved sorghum varieties by farmers.

4. Results: Explaining farmer's adoption of improved sorghum cultivars

4.1 Overview about adoption patterns

Households in the sample know in total six different improved sorghum cultivars (Table 4). However, not all of the 256 sorghum cultivating households are aware of improved sorghum cultivars and the 143 households who know on average only 1.7 different improved cultivars. Pato and Macia are the two most known varieties, followed by Tegemeo and Serena. Only very few farmers know the varieties Sila and Lulu.

In contrast to the awareness about improved sorghum cultivars, 236 of the 256 sorghum cultivating households know at least one local variety, with Langalanga being the most popular one, followed by Udo and then other local varieties, which could not be named. While almost all households (99%) who know a local variety have at some point in the past also cultivated the respective variety, only 79% of the households who know an improved variety have done so. The same pattern is reflected in the figures for the 2009/10 planting season. 94% of the households who have ever planted a local variety in the past have planted it in the 2009/10 planting season, but for improved varieties, only 61% of the farmers did so (Table 4).

Table 4: Adoption of improved sorghum cultivars (N=256)

Local varieties	Known	Planted	Planted 2009/10	Improved varieties	Known	Planted	Planted 2009/10
	#	%			#	%	
Langala	206	96	86	Pato	80	76	33
Udo	68	94	73	Macia	74	84	61
Other	62	84	71	Tegemeo	46	67	19
At least one	236	99	94	Serena	30	3	75
				Sila	8	100	32
				Lulu	4	100	0
				At least one	143	79	61

In regard to the total sample of 256 sorghum cultivating households this means that only 56% know an improved variety and only 27% (69 farmers) cultivated at least one in the 2009/10 planting season. These results suggest that adoption barriers exist on two levels.

First, access to information about improved varieties and second ability and/or interest to cultivate known varieties.

4.2 Farmer's stated reason for (non-) adoption

To further investigate adoption barriers, we have asked farmers for their reasons to (non-) adopt a certain variety (local and improved). Results are displayed in Table 5.

Table 5: Reasons for (non-) adoption in % (N=256)

Reasons adoption	Local	Improved	Reasons not planting	Local	Improved
Availability	33	5	Availability	16	39
Best adapted	38	31	Diseases and pests	32	36
Yields	19	41	Low yields	11	5
Recommended by	4	7	Poor taste	16	-
Early maturity	2	14	Late maturity	11	-
Best for brewing	4	2	Land shortage	5	11
			Too expensive	-	7
			Other	9	2

The three most important reasons for planting a specific local variety are that the variety is best adapted (38%), that seeds for other varieties are not available (33 %) and yields (19%). In contrast yield ranks first for improved varieties (41%), followed by best adapted (31%) and early maturity (14%). The latter is in particular important in seasons of short rainfalls.

Reasons for not planting a variety also differ between local and improved varieties. While diseases and pests rank first for local varieties (32%), followed by non-availability and poor taste (both 16%), non-availability of seeds ranks first (38%) for improved varieties. Surprisingly, diseases and pests (36%) rank second, indicating that not all improved varieties are well adapted to the conditions in the two districts. A third, but far less important reason is land shortage (11%). This indicates a certain risk aversion of farmers. They are not substituting local by improved varieties, but cultivate them additionally.

The results are supported by farmers' answers to the question, which factors they consider when purchasing seeds. Yield capacity was stated most often (65%), followed by early maturity (18%) and drought resistance (12%). Two suggestions result from these findings. First, farmers are interested in improved varieties; however, they are seed constraint. Second, improved varieties must offer high yields and be well adapted to local conditions to be attractive for farmers.

Concerning seed availability, seed sources are an important issue. In regard to the lack of awareness of improved sorghum cultivars, information constraints need to be addressed. We have asked farmers about their main seed source for specific varieties as well as about their sources for information about new sorghum varieties. The latter was not asked specifically for local and improved varieties. We have, however, in our analysis distinguished answers from households who know only local varieties from those who know at least one improved variety. Results for both questions are displayed in Table 6.

For both exposure groups, not knowing and knowing improved varieties, extension officers are the most important source of information for new sorghum varieties. Other farmers rank second in both groups, even though they are less important for farmers who know improved varieties. Other actors like local leaders or agro dealers play for both groups a minor role. Thus, access to extension officers is as such not the major barrier of being informed about improved varieties. It is rather the quality of information provided by an extension officer that seems to play a role. If extension officers are accessible, but they are themselves not well informed about improved varieties, awareness about improved varieties will remain on a low level.

Table 6: Information and seed sources in % (N=256)

Information sources	Local	Improved	Seed sources	Local	Improved
Extension officer	51	61	Extension officer	6	50
Other farmer	33	19	Other farmer	32	11
Local leader	7	10	Own storage	58	31
Agro dealer	2	2	Agro dealer	3	0
Radio/TV	5	5	Other	1	8
Other	2	3			

Results for seed sources show a similar pattern. For local varieties more than half of the cultivating farmers (58%) stated own storage as the most important seed source, followed by other farmers (30%). Only a minority (6%) relies on extension officers. In contrast, half of the farmers cultivating an improved variety (50%) state an extension officer as their seed source, followed by own storage (31%). Other farmers account for only 11%, which is straightforward to understand as fewer farmers cultivate improved varieties. The results show that only a limited number of seed sources are available to a farmer. External sources are far more important for seeds for improved varieties. However, extension officers are more or less the only external seed source, as agro dealers and local seed producers play as good as no role in the seed sector for sorghum. Thus, extension officers are the bottleneck for both, the dissemination of information as well as of seeds for improved varieties. This implies the risk that if extension officers fail to provide seeds, adoption rates remain low. Having in mind that unfavorable agro ecological areas have been neglected in the past, low adoption rates are straightforward to understand. However, this also shows a potential for change, if national governments refocus agricultural policies.

The answers to the question what farmers, in general, consider as constraints when buying seeds point in the same direction as the results above. Missing information about recommended varieties (36%) and non-availability of preferred seeds (16%) are two of the three most important constraints. The third one is high seed prices (25%).

4.3 Comparing adopters and non adopters

Farmers stated reasons for (non-) adoption provide an overview about adoption barriers and help to understand the low adoption rates. However, adoption of a new crop variety confronts a farmer with various constraints, which cannot all be displayed by this approach. Earlier studies show that adoption constraints differ according to the particular innovation a farmer is confronted with as well as the general framework conditions (e.g., Feder et al., 1985). Based on Cavatassi et al. (2011), we identified the following categories as in particular important when analyzing adoption of improved sorghum cultivars. First, household characteristics like age and education can hinder the adoption of new cultivars. Secondly, farm assets like land constraints and agro ecological conditions may play a role. Another important aspect is the exposure to and accessibility of a new cultivar. Fourth, the social capital of a farmer effects adoption decisions. Through social networks farmers are more likely to learn from experiences from others and repeat those. Regional effects, captured through the location of a farmer, can also act as a constraint. Table 7 shows the variables used for each category of constraint identified above and compare descriptive statistics for adopters and non-adopters.

Results displayed in Table 7 show that adopters and non-adopters significantly differ in most of the variables. Adopters are more often female and Muslims. The reference category for the latter is being Christian. Moreover, adopters have fewer years of sorghum experiences and fewer household members. Even though previous adoption studies have shown significant differences for age and education of the head of household (e.g. Schipmann and Qaim, 2010), this is not the case in our study. Among farm assets, land size and soil fertility are positively correlated with improved variety adoption. As households may have several plots with different soil characteristics, the mean soil quality per household was estimated in the following way: ($\sum$ size $plot_i$ x soil fertility $plot_i$)/total land size. Households that use a lower share of their sorghum harvest for home consumption are also more likely to be adopters. The latter is straightforward to understand. Adoption of a new variety implies risk and a household becomes less risk taking, the more it depends on sorghum for its food supply.

Table 7: Descriptive statistics of adopters and non-adopters

	Total (N=256)	Adopters (N=187)	Non-adopters (N=69)
Household characteristics			
Household head is female (%)	10.6	8.0	17.4**
Age household head (years)	45.6	45.7	45.4
Moslem[1] (%)	53.5	44.4	78.3***
Education (years)	6.4	6.5	6.3
Sorghum experiences (years)	20.1	21.4	16.5***
No. of household members	6.5	6.7	6.0***
Farm characteristics			
Total land (ha)	5.0	3.8	8.3***
Soil fertility (1= poor, 2= medium, 3= good)	2.1	2.0	2.2***
% consumption of sorghum harvest	79.1	83.9	66.0***
Exposure to new varieties			
1st information source: other farmer (%)	35.0	28.3	15.9**
1st information source: extension officer (%)	57.8	57.8	58.0
1st information source: other source (%)	17.2	13.9	26.1**
Farmer has no access to seed sources outside the village (%)	21.9	58.0	8.6***
Ownership mobile phone (%)	44.1	38.5	59.4***
Social capital			
Member in a farmer organization (%)	32.0	26.7	46.4***
No. of farmers knowing an improved variety on village level	8.2	8.3	7.8
No. of improved varieties known by a farmer	1.0	0.6	1.8***
Wards			
Kingale	18.8	15.0	29.0**
Kwamtoro	17.6	10.2	37.7***
Sanzaawa	14.4	15.0	13.0
Mungaa	34.0	39.6	18.8***
Ntuntu	15.2	20.0	1.5***

Notes: Mean values are shown.
*, **, *** differences are significant at the 10%, 5%, and 1% level, respectively. T-test and chi-square are used for continuous and categorical variables, respectively. Differences are always tested between adopters and non-adopters.
[1]The reference variable is households who are Christians

In terms of variables capturing exposure, the information source for new sorghum cultivars plays an important role. Adopters rely significantly less on other farmers and significantly more on other information sources, which comprises local leaders, agro dealers and radio/tv. In line with our earlier findings, adopter groups cannot be distinguished in regard to having extension officers as the most important information source. This confirms our conclusion that quality of extension rather than access to it is a constraint for farmers. The other two variables in this category also differ significantly. Fewer adopters are seed constraint, which is reflected in the variable 'no access to seed sources outside the village' and more adopters own a mobile phone. In regard to social networks, adopters know more improved sorghum cultivars and more adopters are a member of an organization. The latter is a common finding in the adoption literature (e.g. Matuschke and Qaim, 2009) Four out of five regional variables also differs significantly. A higher share of adopters lives in Kingale and Kwamtoro ward, whereas Mungaa and Ntuntu ward host a lower share.

4.4 Specification of the adoption model

Differences in mean values should not be over-interpreted, since possible confounding factors are not controlled for. This requires estimation of appropriate regression models.

In our study, as in many other cases, exposure to the new technology is a pre-condition for a positive adoption outcome. While there is a broad literature on adoption behaviour of smallholder farmers, few studies explicitly addressed this aspect (Diagne, 2006; Simtowe, 2010). Earlier studies often analysed adoption of an innovation by applying classical adoption models such as probit or tobit. However, the fact that not all farmers are exposed to the new technology makes it difficult to obtain consistent estimates of the determinants of adoption from these models (Diagne and Demont, 2007; Dimara and Skuras, 2003).

The analysis in this paper is therefore based on the theoretical framework proposed by Diagne and Demont (2007), which suggests the following argument. In an early stage of an innovation, the target population is not necessarily fully exposed to it. Thus, classical adoption models that do not account for the (non-) exposure lead to biased and inconsistent estimates, even when based on a randomly selected sample. The reason is a twofold selection bias. First, farmers who are not aware of an innovation cannot adopt it, even though they might have done so in the case of knowing the innovation. Diagne and Demont (2007) call this the non-exposure bias. Second, farmers who have a higher propensity to be adopters might either self-select to exposure or be particularly targeted by an organization that introduces the innovation. This leads to a classical selection bias, also known in other situations.

Diagne and Demont (2007) developed an approach to overcome this problem. Based on different scenarios, they apply different assumptions and estimation procedures to account for the non-exposure and self-selection of part of the population. For a detailed description see Diagne and Demont (2007).

In our case the conditional independence (CI) assumption holds true. It states that the treatment status w is independent of the potential treatment outcomes y0 and y1 and conditional on an observed set of covariates x. In other words, there is no targeted exposure of part of the population. Thus, determinants of adoption can be derived through parametric estimation procedures, e.g. probit models, from the subsample of only exposed farmers. We apply the CI assumption, because there are currently no initiatives that promote new sorghum cultivars to only part of the population in the two districts and conditional on observed factors all farmers are assumed to have the same likelihood of exposure. We have also estimated a two stage heckman model to test for the self-selection of farmers to exposure. The estimated coefficient of the inverse mills ratio was not significant, indicating that there is no selection bias. We therefore estimate a simple probit model based on the subsample of exposed farmers.

The dependent variable in our model is ‘adoption’. The variable is 1 if the household cultivated at least one improved variety in the 2009/10 planting season and 0 otherwise. The independent variables are those explained in Table 7. The general reduced form for adoption of improved sorghum varieties can thus be written as follows:

AISV = f (HH, FA, Exp, Soc, Reg),

Where adoption of an improved sorghum cultivar (AISV) is explained by household characteristics (HH), farm assets (FA), exposure status (Exp), social capital (Soc) and regional variables (Reg). In the adoption model, we apply the same underlying assumption as Matuschke et al. (2007) that farmers base decisions on utility, rather than profit maximization. This assumption is reasonable, because sorghum is grown on a semi-subsistence basis, with an average of more than 80% of the produce kept for consumption by the household (Table 2). In addition, farmers are assumed to be risk averse, as the majority of them are smallholders who operate in a poverty- stricken environment.

Our main interest lays in the explanation of adoption decisions. However, low adoption rates might be caused by low information levels, or low actual adoption or a combination of both. Each case demands for different policy interventions. If e.g. information levels are low, more efforts are needed to make the variety known. However, if actual adoption is low, dissemination constraints need to be overcome (Diagne, 2006). In this study, only half of the sample population knows at least one improved sorghum variety. It is therefore important to also understand the determinants of awareness about new sorghum cultivars. For this purpose, we estimate a probit model with the dependent variable ‘awareness’. The dummy variable equals 1 if a household knows at least one improved sorghum variety and 0 otherwise. Unless stated in the discussion of the results, the independent variables are the same as for the adoption model. Results for models, information and adoption, are displayed in Table 8. Coefficients always reflect marginal effects.

We did not include the variables soil fertility and share of harvest used for home consumption in the information model, as there is no relation between those two variables and a potential awareness about improved sorghum cultivars. We obviously also did not include the variable ‘number of improved varieties known by a farmer’ in the model. Instead we included a variable that captures the number of farmers who know at least one improved variety on a village level. Diagne and Demont (2007) used the number of improved NERICA rice varieties known in a village in their study on rice in Cote d’Ivoire. We also tested this variable and it leads to the same results.

Results for the information model show several significant variables. As in the descriptive statistics, being a Muslim (compared to being a Christian) increases the likelihood of knowing an improved variety. Muslims might be better organized in internal or external networks, or might generally be more open to new information. Interestingly, neither other household characteristics nor one of the farm asset variables show a significant effect. Based on our findings above and also the findings from other studies (e.g. Diagne, 2006), we expect exposure and network variables to have a significant effect on knowing improved sorghum varieties. Indeed, two exposures and one network variable show a significant effect. If other farmers are the main information source for new varieties, the probability of knowing an improved variety is reduced. The reference variable is farmers, who have extension officers as their main source of information. This result is plausible and in line with the descriptive statistics. As few farmers know improved varieties, knowledge is less likely disseminated through other farmers. The same holds true for seed sources. If a farmer does not have access to seed sources outside the village and thus relies on own storage or other farmers, the farmer is less likely to be informed about new sorghum varieties. In contrast and as expected, membership in an organization increases the likelihood that a farmer knows an improved sorghum variety. The same was found by Simtowe et al. (2010) for improved groundnut varieties in Malawi. Thus targeted information exchange as occurring in organizations can promote the dissemination of information. In regard to regional effects, only the dummy variable for Sanzaawa ward increases the likelihood of knowing an improved variety. The reference variable is Ntuntu ward. Thus, regional effects are small.

We can conclude from these results that social networks, which comprise persons and institutions, with which farmers regularly interact as well as those, to whom a farmer has access for specific needs, e.g. seeds, have the greatest influence on information dissemination. The more diversified these networks are, the higher the likelihood that a farmers accesses information about new sorghum varieties.

Turning to the adoption model, we also find various significant variables. The household characteristics years of education and years of sorghum experience both effect adoptions negatively. While the latter could have been expected to increase the likelihood of adoption, the opposite is also plausible. Farmers who are less experienced are often more likely to experiment with innovations. The same was e.g. found by Odendo et al. (2010) for the adoption of soil fertility enhancing technologies in Western Kenya.

Table 8: Modeling information and adoption of improved sorghum cultivars

	Information model		Adoption model	
Variable	dy/dx	Stand. dev.	dy/dx	Stand. dev.
Household head is female (d)	-0.06	0.12	0.07	0.23
Age (years)	0.01	0.01	0.01	0.01
Education (years)	0.07	0.05	-0.19*	0.12
Muslim (d)	0.15 **	0.08	-0.01	0.15
Sorghum experiences (years)	-0.01	0.01	-0.02**	0.01
No. of household members	-0.02	0.02	-0.02	0.03
Total land (ha)	0.01	0.01	0.01	0.01
Soil fertility (1= poor, 2= medium, 3= good)			-0.23*	0.14
% consumption of sorghum harvest			-0.01*	0.00
Major information source: other farmer (d)	-0.14**	0.08	0.03	0.17
Major information source: other (d)	-0.03	0.10	0.34*	0.13
Farmer has no access to seed sources outside the village (d)	-0.17**	0.08	-0.73***	0.07
Ownership mobile phone (d)	-0.01	0.07	0.34**	0.13
Member in a farmer organization (d)	0.14**	0.07	0.17	0.13
No. of farmers knowing an improved variety on village level	0.01	0.01		
No. of improved varieties known by a farmer			0.04	0.09
Kingale (d)	0.19	0.11	0.33	0.23
Kwamtoro (d)	0.15	0.12	0.47*	0.19
Sanzaawa (d)	0.22*	0.10	-0.12	0.31
Mungaa (d)	0.06	0.10	0.34	0.21
Constant	-0.47	0.50	4.2**	1.90
N	256		143	
LR chi2	42***		109***	
Pseudo R^2	0.12		0.55	

Notes: *, **, *** significant at the 10%, 5%, and 1%level, respectively.
(d) = dummy variable.

The negative result for education is surprising. Usually, better educated farmers are more open to innovations. In our case, however, these farmers might be more critical and thus reluctant to cultivate new varieties. Although not significant, education had e.g. also in the study of Diagne (2006) on the adoption of NERICA rice varieties in Cote d'Ivoire a negative coefficient. Adoption is also negatively influenced by two farm asset variables. First, the more fertile the soil, the less likely a farmer adopts new sorghum varieties. There are two explanations for this. Local varieties, when cultivated on fertile soils, might offer high yields, so that new varieties are less attractive. Moreover, when relatively high potential soils are available, farmers might prefer to cultivate more maize. Second, the share of sorghum harvest that is used for home consumption negatively effects adoption decisions. As discussed earlier, farmers who depend more on sorghum for their food supply are less likely to take any risk and experiment with new varieties. In regard to exposure and social asset variables, the model reveals the following results. In contrast to the negative effect depicted in the information model, having other farmers as the main information source for new sorghum cultivars does not compromise adoption decisions. On the other hand, having other information sources like local leaders or agro dealers positively influences adoption behavior. The reference category for both variables is having an extension officer as the main information source. While 'other sources' do not seem to be more active than extension officers in the dissemination of information, once knowledge is obtained, they are more likely to support adoption decisions. In other words, information exchange with extension officers helps to introduce knowledge about improved sorghum cultivars, but does not positively influence actual adoption. This is plausible as not all farmers who are having extension officers as a source of information, also obtain seeds from them. The latter is captured in the variable for seed constraints, which indeed shows that farmers, who do not have an external seed source are less likely to adopt a new sorghum variety. This raises the question, why farmers who access extension officers for information exchange, do not access them for seed supply. As farmers have mentioned non-availability of seeds as a major adoption constraint, it might be that the extension service is not equipped with enough seed for all interested farmers. Matuschke and Qaim (2008) have e.g. shown for the case of hybrid pearl millet adoption in India that adoption rates increased when the formerly state controlled seed market was liberalized and private companies started to supply seeds. Ownership of a mobile phone, which did not show an effect in the information model, does positively influence adoption. Farmers who own a mobile phone, which is also a new technology, might be more progressive farmers, which are also more likely to adopt other innovations. Moreover, mobile phones are an important communication tool, which can broaden the networks of farmers. Regional effects are again limited. Interestingly, even though farmers in Sanzaawa ward are more likely to know improved varieties, they are not more likely to adopt them. The situation is the opposite way round in Kwamtoro ward. To better understand these effects, results need to be discussed with stakeholders in the respective ward.

In general, the adoption model confirms our earlier findings. Once information barriers are overcome, other adoption barriers exist. These are found on two levels. First, the interest of farmers, reflected e.g. in the fact that better educated and more experienced farmers less likely adopt new varieties. Second the adoption ability of farmers reflected in various access constraints.

5. Conclusion

We have analyzed the contribution of sorghum to the food supply of a household and determinants of adoption of improved sorghum cultivars among smallholder farmers in Central Tanzania. Sorghum is an important staple crop in the semi-arid areas of Tanzania and cultivated by many farmers. However, in regard to total area cultivated and total production quantities, maize is even more important. Accordingly, maize currently also contributes more to the food supply of a household. While sorghum is better adapted to production risks like droughts that occur regularly in semi-arid areas, it is not a high yielding crop. To improve food security in drought prone areas, the introduction of improved sorghum varieties that offer competitive yields is therefore necessary. While a number of improved varieties has been released in Tanzania, only around 50% of the sample population know at least one improved sorghum variety. Adoption rates are even lower.

We displayed farmers' stated reasons and applied econometric techniques to understand the determinants of both, awareness and adoption of improved sorghum cultivars. Our analysis has shown that farmers can only access a limited number of sources to obtain information about new sorghum cultivars. Strikingly, at an early stage of an innovation diffusion process, access to relevant information sources is a major success factor for the dissemination of an innovation. Schipmann and Qaim (2010) found the same result for sweet pepper adoption in Thailand. However, most farmers rely on other farmers as an information source, which are most often also not aware about new sorghum cultivars.

Moreover, our analysis has shown that access to extension officers and membership in an organization increases the likelihood of knowing improved sorghum varieties.

Despite the lack of awareness, adoption is restricted by seed constraints and other social network variables. Moreover, some household characteristics hinder adoption. The fact that better educated and more experienced farmers are less likely to adopt new varieties might be a hint that the currently available varieties cannot offer obvious advantages over local varieties. Results from farmers' stated reasons about non-adoption point in the same direction. We have not explicitly assessed yield superiority and other advantages of improved sorghum cultivars in this study. However, this question needs to be addressed in the future.

Two policy recommendations are proposed to realize the potential of sorghum to contribute to the food supply of a household and thus to local food security. First, new sorghum varieties need to be well adapted to local agro-ecological conditions and need to show a clear yield advantage over local varieties. This advantage must also be widely demonstrated to farmers. Second, efforts to address information and adoption constraints need to be increased. As the national extension system plays herein a major role, more public sector involvement in promoting improved sorghum cultivars is necessary. Extension officers must themselves be well informed about new sorghum cultivars and must be accessible for all farmers. Moreover, seed supply systems need to be improved. This includes the involvement of other stakeholders, like local agro dealers. As our analysis showed that some farmers are more likely to adopt innovations than others, in particular progressive farmers should be exposed to information. Additionally the effective provision of appropriate information through various information channels needs to be established and networks of information exchange strengthened. Although it is difficult to directly influence the network of farmers, the provision of different platforms, like e.g. agricultural fairs, can be a step in the right direction.

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