The Introduction of Orange-fleshed Sweetpotato on the Agricultural Farming System of Central Mozambique:

The Opportunity Cost of Growing This Nutritious Crop

Ricardo A Labarta

International Potato Center (CIP)

P.O.Box 1616 Blantyre, Malawi

email: (r.labarta@cgiar.org)

Abstract

Many efforts have been recently made in Mozambique to disseminate orange-fleshed sweetpotato (OFSP), an efficacious and effective source of pro-vitamin A. It has been demonstrated that the consumption of OFSP during the harvesting period can reduce vitamin A deficiency (VAD) by 15% when it is introduced alongside an effort to create demand and engage in nutrition education at the community level. However, little is known about the effect that widespread adoption of OFSP can produce in the overall agricultural system. This paper analyzes the effect that growing OFSP has on the Mozambican agricultural system, paying attention to potential impacts on farm income and household food security among smallholder farmers. An ex-ante analysis of the introduction of OFSP within representative multi-enterprise farms of Mozambique is presented using an optimization model. Drawing on information obtained from 84 smallholder farmers in Central Mozambique through 4 visits over the course of 1 year, the model analyzes the adoption and consumption of this nutritious crop under different scenarios and evaluates the effect produced on farm revenues, returns to production inputs and the status of household food security, including the intake of nutritious crops. Results show that under current conditions, smallholder farmers holding less than 1 ha of land would not adopt OFSP unless they get the planting material for free. Having to purchase vines in these settings, would result in less than desired consumption of this pro-vitamin A rich food. On the other hand, medium scale farmers holding between 3 and 5 hectares of land could pay for their initial OFSP planting material and would see an increase in farm revenues and the returns to land and labor. These farmers would also increase the consumption of pro-vitamin A rich sweetpotato, which also serves as an alternative source of energy to cassava, maize, and rice – the other carbohydrate sources in the province.

Keywords: Sweetpotato, Optimization, Nutrition, Mozambique, Vitamin A

Introduction

Sweetpotato is considered a secondary crop in Mozambique and is usually introduced into the agricultural system after the major staples, maize, rice, cassava and beans. Few regions in Mozambique manage sweetpotato as a cash crop and the investment to grow this rustic crop on a larger-scale has remained low. However, the importance of sweetpotato as a food security crop and most recently as a source of important micronutrients has been largely recognized (Low et al., 2007).

Since 2001, there have been several efforts in Mozambique to disseminate orange-fleshed sweetpotato (OFSP), an efficacious and effective source of pro-vitamin A. Prevalence of vitamin A deficiency (VAD) among children between 6 and 59 months old reaches 71% (Aguayo et al., 2005) and it has been demonstrated that the consumption of OFSP during the harvesting period can reduce VAD by 15% (Low et al., 2007) when combined with an effective nutrition education intervention. In addition, some of the different extension approaches used to disseminate OFSP have also encouraged greater commercialization of the OFSP roots[1] and the use of OFSP as an ingredient in processed products as an alternative source of income (OVATA 2007, Low et al., 2005).

Currently, the dissemination of OFSP among smallholder farmers in Central Mozambique is scaling up and the expectation of the adoption of OFSP planting material and the consolidation of OFSP as a significant source of farm income in areas with higher agro-ecological potential have risen considerably. However, whether the adoption of this nutritious crop would be sustainable and how this adoption process would affect the whole agricultural system in Central Mozambique remains unknown. This is no doubt due to the intensive nature of data collection required to undertake this type of analysis.

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[1] For example, smallholders in Zambézia Province typically only sell 15% of their harvest on average (Low et al., 2007b)

Previous work has highlighted the importance of considering the various factors underlying the decisions to adopt technology , that range from input availability to more contextual factors issues like access to markets, agro-ecological conditions and infrastructure (Feder & Umali 1993, White et al., 2005). In the case of sweetpotatoes in Mozambique, little is known about the potential effect of increasing the sweetpotato acreage under the current agricultural system, dominated by small-scale agriculture on good to marginal lands.

The objective of this paper is to analyze the effect that growing OFSP have on the agricultural system of the Central Mozambique, paying attention to factors like farm income, household food security, available of vitamin A from staple foods, and the use of the limited labor resources. We use an optimization model and conduct an ex-ante analysis of the introduction of OFSP within a multi-enterprise farm. Based on information coming from 84 smallholder farmers in Mozambique the model analyzed the different scenarios related to the adoption of OFSP planting material. Results show that under current conditions smallholder farmers holding less than 1 ha of land would not adopt OFSP unless they get the planting material for free, and that medium scale farmers holding between 3 and 5 hectares of land would adopt OFSP and will increase farm revenues and the returns to land and labor.

The paper follows with a brief description of the production of sweetpotato in Mozambique and a summary of the current efforts to disseminate OFSP in this area. The model formulation and the model parameters are then discussed. Model results are presented and discussed in the following section, while the last section is devoted to drawing some conclusions from the analysis.

The production of sweetpotato and the introduction of OFSP in Mozambique

Sweetpotato is considered a secondary crop in Mozambique, planted by a large number of households on a small-scale in Mozambique. During the 2001-2002 growing season, sweetpotatoes ranked seventh place in terms of acreage sown to different crops grown in Mozambique with 96,515 hectares and in the sixth place regarding the number of households growing it (1,084,447) (TIA 2002).

Since 2000 there have been many efforts to introduce orange-fleshed sweetpotato (OFSP) which, unlike predominant white-fleshed varieties, have high levels of pro-vitamin A carotenoids (100-1600 ug Retinol Activity Equivalents (RAE) per 100 g for varieties in use in Africa) (van Jaarsveld et al.,2005; Hagenimana et al. 1999). OFSP has proved to be an efficacious source of vitamin A for poor Southern African countries like Mozambique (Low et al.,2007) where the prevalence of vitamin A deficiency is 71% in children of 6-59 months old (Aguayo et al.,2005). Building on the seminal work conducted by the Southern Africa Roots and Tubers Network (SARRNET) and the Towards a Sustainable Nutrition Improvement (TSNI) project, the Reaching End Users (REU) project has been seeking to go-to-scale with the dissemination of OFSP in Central Mozambique, utilizing an integrated approach (seed systems, marketing and nutrition/demand creation components) to increase the likelihood of sustained adoption of OFSP and increased vitamin A intake among young children and pregnant women, the most at risk populations in terms of vitamin A deficiency.

Currently OFSP is mainly grown during the main agricultural season (November-June), but in certain areas sweetpotatoes can be grown in valley bottoms or lowland areas after the harvest of the rice production, taking advantage of the moisture that remains on lowland fields for a longer period of time. Although most farmers are familiar with sweetpotato cultivation, maintaining the OFSP and other sweetpotato vines from one season to another has been the most limiting factor to the expansion of this crop. There have been several massive, free-vine distributions associated with post-war and emergency programs that have also reduced the incentives among farmers for conserving their vines at the end of the season, as some expect non-governmental and governmental bodies to supply them annually with vines (Rohrbach & Kiale 2007)

In the Zambézia province there are mainly two areas where sweetpotatoes are usually grown. In northern Zambézia, where the precipitation level is high (1735 - 1997 ml), sweetpotato is grown in larger areas and can get yields around 10t/ha (CIP 2007). Southern Zambézia is typically considered to be more drought prone than the North due to the low levels of precipitation (less than 600 ml) as reflected in the lower yield levels, approximately 6t/ha (Low et al.,2005). Under these production conditions, efforts to disseminate OFSP in the province have emphasized disseminating well adapted OFSP varieties and have insisted in the need to improve farmers' knowledge in conserving the vines from one season to another. The current REU project started the dissemination of OFSP planting material among around 10,000 households (World Vision 2007) and it is expected 15,000 households will have been reached by the end of 2008 in the Zambézia province.

Analytical methods

Data

This study uses data from 84 farm households in the Zambézia province, recorded in a first visit at the end of the 2006-2007 growing season and later during 4 quarterly visits during the 2007-2008 growing season. This information includes plot area, crop yields, crop prices, inputs used and input prices of all cropping systems grown. Likewise, monthly labor calendars were prepared in addition to total caloric production from each cropping system as a mean to meet food security requirements.

In our sample we found two distinct groups of farmers. The smallholder farming households hold up to one hectare of land, with a variety of growing systems depending on the environment. The principal cropping systems are: 1) Rice, 2) Maize, 3) Cassava, 4) OFSP, 5) Maize/cassava, 6) Maize/cowpea, 7) Cassava/pigeonpeas and 8) Pigeonpeas/Groundnuts. The medium-scale farming households[2] are cultivating between 3 and 5 has of land. The main cropping systems among this group of farmers are: 1) Rice, 2) Maize, 3) Cassava, 4) Sweetpotatoes (including OFSP) 5) Sweetpotato/Cassava, 6) Maize/Pigeon/Millet, 7) Maize/Pigeonpeas/Cowpea, and 8) Pigeonpeas/groundnuts.

In the Southern part of Zambézia, small and medium-scale farmers are equally important. In our sample of 36 households, we found 18 households with 1 hectare or less total land. In the northern part of Zambézia, medium-scale farmers are the predominant sub-group in this study. Out of the 48 households included in our sample, 36 are medium-scale producers while only 12 are growing one hectare or less as total farm acreage.

Using the recorded quarterly farm data, we constructed detailed cropping system budgets consisting of all inputs and outputs related to household farms for the small and medium scale farmers. The first step was to estimate gross revenues per hectare for each cropping system, including all crop yields and market prices (the price at which farmers interviewed sold different crops). The second step was to calculate the production cost associated with each crop and for the entire cropping system. A critical component of this production cost is the total labor used for each farm activity. This labor has been valued at the lowest labor market price found among the 84 selected farmers. This price is set at 5 Mt per a period of 4 hours of work (half of a typical working day). Table 1 summarizes the production costs of the different cropping systems as well as the net revenues.

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[2] Throughout the remainder of the document, when we refer to medium-scale farmers or smallholder farmers, we are referring to their entire households.

Table 1. Average crop yields, crop price, gross revenues and production cost of different cropping systems in the Zambézia province, Mozambique

Cropping system	Crop yield (Kg/ha)	Price (Mtn/Kg)	Gross revenue (Mtn/ha)	Production cost (Mtn)
Monocrops				
Rice	2150	4	8600	2845
Maize	1980	3	5960	3970
Cassava	4000	1	4000	2775
OFSP	5000	1	5000	2970
Intercropping				
1) Maize	1730	3	8190	4325
Cassava	3000	1		
2) Maize	1730	3	7230	4690
Cowpea	680	3	7950	4000
3) Maize	1730	3		
Pigeonpea	720	3	3520	2480
Millet	600	1		
4) Pigeonpea	720	3		
Groundnuts	680	2		

As expected, monocrops have higher yields per crop when compared to their production under intercropping. This is because nutrient competition under intercropping reduces the potential yield of each crop. On the positive side, intercropping often enables farmers to reduce some production costs, like ridge construction or weeding, that are done at once for all crops. All cropping systems produce positive net revenues (subtracting production cost from gross revenues), but clearly the production of rice produces the highest per hectare net revenues. Maize/cassava and maize/pigeonpea/millet intercropping also provide high net revenues.

In addition to crop revenues and production costs, we estimated the labor requirements and potential calories obtained from the total production of each cropping system. As indicated in Table 2, each system has different labor requirements and peak requirements occur at different times for different crops. Likewise, the potential quantity of calories derived from the production of staple crops varies according to the crop and the cropping systems. Our data show that although maize is a crop that produces low revenues, it is the crop that provides the highest amount of calories required by the family. Rice is the more profitable crop in Zambézia, however its contribution to food security through energy calories is relatively low. Cassava and sweetpotatoes are also key crops in household food security since they produce large quantities of calories per unit area.

Table 2. Average labor requirement and potential production of calories in different cropping systems. Zambézia province, Mozambique

Cropping system	Labor requirement (Man-days)	Potential quantity of calories (Kcal per kg)
Monocrops		
Rice	478	439.40
Maize	194	3450.00
Cassava	271	1548.88
OFSP	294	706.80
Intercropping		
1) Maize	265	439.40
Cassava		1548.88
2) Maize	258	3450.00
Cowpea		371.20
3) Maize	288	3450.00
Pigeonpea		1124.09
Millet		1124.09
4) Pigeonpea	200	1124.09
Groundnuts		1410.00

A multi-enterprise optimization model

The use of farm household models has a long history in agricultural economics literature (Barnum & Squire 1979, McGregor et al., 2001). These models have usually been developed to assess farm interventions, including technology diffusion, and to estimate the impact that these interventions have had on the whole household under various farm production regimes. To evaluate the effect of the introduction of OFSP in the agricultural system of small-scale farmers in Central Mozambique, two representative farms are employed. The first representative farm is a very small household with less than 1.2 ha of total land available and with limited labor resources that has as a major objective to maximize farm revenues while guaranteeing household food security. The concept of household food security can legitimately be represented by the availability of the household to produce enough food to meet their required daily calorie intake. The second type of households represent medium scale producers that hold between 3 and 5 has of total land, but that also face limited labor resources and have to also first satisfy their household food requirements and then sell the surplus in local markets.

The production function of the model is as follows:

Max $\sum (R_i - C_i)$

Where R_i is the Revenues provided by the cropping system I and Ci is the total production cost of the cropping system i

Subject to

Farm size constraint: A <=1.2 ha (Small farm only)

Labor constraint: L< 75 days or 150 half days (equivalent to the full time of 3 household members)

Food Security constraints: $\sum Kcal_i$ >= 4,822,560 Kcal (The sum of the quantities of Kcal produced by all cropping systems should exceed the minimum calorie intake required by the household of 7 members during one year)

Non-negative constraints: all cropping system area >= 0

As explained before, cropping systems revenues are estimated average crop yields found on the 84 selected households and crop market prices reported by farmers either for selling their home produced crops or for buying the crop for home consumption. Labor is also valued as it lowest market price (5 Mt per half of a working day or 10 Mt for a full working day).

We estimated two base models of two representative farms that produce a combination of cropping systems suitable for the agro-ecological conditions of each specific area. Then we estimate some alternative scenarios and compare the farm outcomes across the scenarios. For Southern Zambézia we analyze two alternative cases: 1) The sweetpotato vines are given for free (no seed cost) and 2) The price of OFSP increases by 32%. In the Northern Zambézia we included one alternative scenario: the OFSP price increases by 27%. In all scenarios, we estimated the optimal area used for different cropping systems, the maximum potential profits, the proportion of calories produced by each system, and returns to farms per unit of labor and per unit of land (1ha).

Model Results

The basic scenarios show how land would be allocated across different available cropping systems if farmers seek to maximize profits, subject to the production conditions and calorie intake requirements that the representative households face. As shown in Table 3a, the representative small scale farmer would choose to grow rice as a monoculture and to grow the intercropping of maize and cassava and cassava and pigeonpea. She/he would plant a total of 1.2 hectares, would make a total of 4,856 Mtn (186.8 US$), would produce most of the calories needed from the cassava/pigeonpea system (62%) and would have a total of 13.7 Mtn (0.53 US$) as returns to half of a working day. An optimizing farmer would not plant OFSP under current production and market conditions if all planting material had to be purchased. The model has also estimated that the opportunity cost of producing one hectare of OFSP is 1067 Mtn (42.7 US$). It means that if the representative small scale farmer decides to grow OFSP, the farm profits would be reduced by this 1,067 Mtn.

Table 3a. Results of basic scenario on the representative small scale farmer

	Rice	Maize/ Cassava	Cassava/ Pigeonpea	Total farm
Area (ha)	0.46	0.20	0.54	1.20
Net revenues (Mtn)	2095	457	2303	4856
Kcal produced	385805	1446768	62%2989987	4822560
Returns (Mtn) to:				
Land (1 ha)	4554	2285	4265	4018
Labor (1/2)	14.9	15.0	13.2	13.7

Table 3b shows the results for a representative medium scale-farmer in the Zambézia province. A farmer making an optimal decision would allocate her/his land to the production of rice, and the intercropping of cassava and OFSP, maize, cowpea and millet, and groundnuts and pigeonpea. This farmer would plant a total of 3.06 hectares and would make a total of 11,616 Mtn (446.8 US$) in one season. This farmer would need to use a total of 1090 half-days of their available labor and would produce a total of 2,637 Mtn (105.5 US$) per hectare of land cultivated and 13.2 Mtn (0.53 US$) per half day of working of her/his available labor. In this case, a representative farmer would find it profitable to plant OFSP jointly with cassava and will devote an important proportion of her/his land to their production. It is also important to notice that in this case the food security constraint is not binding as the optimal solution would easily exceed the production of calories needed by the household.

Table 7b Results of basic scenario on the representative medium scale farmers

	Rice	OFSP/ Cassava	Maize/ Cowpea / pigeonpea	Groundnut/ pigeonpea	Total farm
Area	0.36	0.65	1.71	0.34	3.09
Net revenues	2255	667	7981	721	11616
Kcal produced	7%	43%	132%	14%	4822560
Returns to					
Land (1 ha)	6264	1026	4667	2121	3759
Labor (1/2)	17.0	10.0	10.2	15.1	13.2

To evaluate the sensitivity of the results of our base scenarios, we executed two alternative scenarios for the small-scale representative farmer and one scenario for the medium-scale representative farmer. For the small scale representative farmer, we first analyzed the case when the growing farmer receives the OFSP planting material for free, which has been a common practice in Mozambique during various extension programs. Secondly, we evaluate the effect of increasing the price of OFSP by 32% of its current level of 1 Mtn per kilogram. We select this level of increase because it turned out to be an inflexion point in the small scale representative farmer after many model runs.

The use of free vines, it turns out, substantially reduces the production cost for the intercropping Rice/OFSP system and significantly increases its net revenue. As this happens, the first reaction of the representative small scale farmer is to reduce the production of rice as monoculture and combine the rice production with OFSP production. The latter is usually established immediately after rice harvesting, taking advantage of the residual moisture of the lowlands, where rice is usually grown. By doing this, the representative farmer significantly increases farm revenues and the returns to land and labor.

Another scenario where the selling price of OFSP price increases by 32% has a similar effect on farm outcomes. Net revenues from the rice/OFSP intercropping increase and therefore make this option more attractive for optimizing returns for the representative small farmer. As expected, the changes in farm profits and returns to land and labor are slightly lower than 0.3 Mtn, as the cropping system revenues are increased at a lower rate.

As the representative medium scale producer would have already decided to grow OFSP, the effect of this change would only make OFSP more profitable and the representative farmer would increase his/her production by adding cassava/sweetpotato intercropping. As a consequence, the farm revenues and the returns to land and labor would increase even more.

Concluding remarks

Decision making by small scale growers in poor countries is determined by many factors. Maximization of farm revenues is always an objective of these farmers, but household food security is an equally important component of their decision. We used an optimization model which combined farmers' desire to maximize farm revenues with the minimum quantity of calories that should be produced to ensure adequate household food energy intake. We also include household production constraints related to labor demand and availability of land for agricultural production.

Analyzing a representative small farmer and a representative medium scale farmer in the Zambézia province, Mozambique, provides interesting insights into the impact of introducing orange-fleshed sweetpotato (OFSP) in the Mozambican farming system. Small scale farmers would not adopt OFSP under current conditions, if all planting material had to be purchased. Given land limitations, farmers would devote their resources to produce other crops (rice, maize, cassava, pigeonpeas). Labor availability is not a binding constraint in this setting as farmers lack sufficient land to employ all their labor resources. On the other hand, farmers have to carefully produce crops in the small piece of land available in order to provide the required quantities of calories needed by the household. Only when the vines of sweetpotato are subsidized and, hence, production costs are lowered, does OFSP become an attractive crop for commercialization, while concurrently making it another source of calories for the household.

Medium scale producers face different conditions. These types of farmers have labor availability as the binding constraint, not land. Consequently farmers allocate resources to the enterprise that provides the greatest return to labor. OFSP under current production and market conditions is one of the crops that meet this requirement, suggesting that medium scale producers in Zambézia, Mozambique would adopt this crop on a broader scale. For the medium scale producers, the food security constraint is not binding, reflecting the different sources that a household of this type has for producing requisite calories to ensure adequate energy intake at the household level.

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