The introduction of orange fleshed sweetpotato on the agricultural farming system of Central Mozambique: the opportunity cost of growing this nutritious crop

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Abstract

Recently, many efforts have been made in Mozambique to disseminate orange fleshed sweetpotato (OFSP) that is 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%. However, little is known about the effect that the massive 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 small farmers. Using an optimization model, this paper performs an ex-ante analysis of the introduction of OFSP within representative multi-enterprise farms of Mozambique. Based on information coming from 84 small farmers in Central Mozambique the model analyzed the adoption and consumption of this nutritious crop under different scenarios and evaluated 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, small farmers holding less than 1 ha of land would not adopt OFSP unless they get the planting material for free, reducing the intake of vitamin A rich crops. On the other hand, 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. These farmers would increase the consumption of vitamin A rich foods and have sweetpotato as an alternative source of energy crops.

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 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)

Recently, there have been many efforts in Mozambique trying to disseminate orange fleshed sweetpotato (OFSP) that is an efficacious and effective source of pro-vitamin A. In this country the levels 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). In addition, the different extension approaches used to disseminate OFSP have also encouraged the commercialization of the OFSP roots and the processing of these roots into many alternatives (OVATA 2007, Low et al 2005).

Currently, the dissemination of OFSP among small farmers in Central Mozambique is scaling up and the expectation of the adoption of OFSP planting material and the consolidation of OFSP as a major source of farm income have raised considerably. However, whether the adoption of this nutritious crop would be sustainable and how this adoption process would affect the whole agricultural system in Mozambique remains unknown.

Previous work have highlighted the importance of considering the various factors underlying technology adoption decisions 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 in marginal lands.

This 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, nutrition status 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 small farmers in Mozambique the model analyzed the different scenarios related to the adoption of OFSP planting material. Results show that under current conditions, small farmers holding around only 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. Then the model formulation and the model parameters are discussed. In the next section model results are presented and discussed while the last section is devoted to draw some conclusions of the analysis.

The production of sweetpotato and the introduction of OFSP in Mozambique

Sweetpotato is considered a secondary crop in Mozambique, but it is however planted by a large number of small households in Mozambique. During the 2001-2002 growing season Sweetpotatoes were in the seventh place of acreage among the 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 1999 there has been many efforts to introduce orange fleshed sweetpotato (OFSP) a promising food with high levels of pro-vitamin A carotenoids in many of its varieties (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 and efficacious alternative to poor Southern Africa countries like Mozambique (Low et al 2007) where the Vitamin A deficiency is estimated in 71% in children of 6-59 months old (Aguayo et al 2005). Since the seminal work conducted by the Southern Africa Roots and Tubers Network (SARRNET) and more recent experiences like the Towards a Sustainable Nutrition Improvement (TSNI) project and the Reaching End Users (REU) project, the dissemination of OFSP have been scaling up in Central Mozambique and most of these activities have been using integrated approaches (seed systems, marketing and nutrition/demand creation components)in order to increase the likelihood of adoption of OFSP and to mainly increase the vitamin A intake among young children and pregnant women, the most vulnerable population regarding vitamin A deficiency.

Currently OFSP is mainly grown during the main agricultural season (November-June), but in certain areas sweetpotatoes can be grown in lowlands after the harvest of the rice production, taking advantage of the moisture that remains on these lowlands for a longer period of time. Although most of the farmers are familiar with this crop, maintaining the OFSP and other sweetpotato vines from one season to another has been the most difficult task that has limited the expansion of this crop. In addition, there have been massive free-vine distributions associated with post-war and emergency programs that have also reduce the incentives among farmers for keeping and multiplying the sweetpotato vines and increase the acreage of this crop (Rohrbach & Kiale 2007)

In the Zambezia province there are mainly two areas where sweetpotato are usually grown. The northern Zambezia where the precipitation level is high (1735 - 1997 ml) sweetpotato is grown in larger areas and can get yields around 10t/ha (CIP 2007). The southern Zambezia is typically considered a drought prone area due to the low levels of precipitation (less than 1000 ml) and the yields have been also remain at low levels and below 6t/ha (Low et al 2005). Under these production conditions, the efforts to disseminate OFSP in the Zambezia province have put a lot of emphasis in disseminated well adapted OFSP varieties and have insisted in the need to improve farmers' knowledge in keeping 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 that by the need of 2008 having reached around 15,000 households in the Zambezia province.

Analytical methods

Data

This study uses data from 84 farm households in the Zambezia province that was recorded in quarterly visits. This data contains detailed information about all plots grown by these households during the 2006-2007 and 2007-2008 growing seasons. 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 calorie production of each cropping system as a mean to meet food security requirements.

In our sample we found mainly two groups of farmers. The small farmers hold no more than one hectare of land where that have to grow different cropping systems. These cropping systems include: 1) Rice, 2) Maize, 3) Cassava, 4) OFSP, 5) Maize/cassava, 6) Maize/cowpea, 7) Cassava/pigeonpeas and 8) Pigeonpeas/Groundnuts. The medium scale farmers are managing between 3 and 5 has of land for establishing the different cropping systems. 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 region, 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 region, medium scale farmers are the predominant sub-group in this area. 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.

With the farm observations recorded we constructed detailed cropping system budgets consisting of all inputs and outputs related to household farms for the small and the 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 interviewed farmers sold different crops) The second step is to calculate the production cost associated to each crop and to each cropping system. An important part of this production cost is the total labor used for each farm activity. This labor has been value 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 and the net revenues as well.

Monocrops have the highest yield per crop comparing to the production of the same crops but under intercropping. As expected, nutrient competition in an intercropping reduces the potential yield of each crop, but on the other side, intercropping allow farmer to reduce some production costs like weeding that are done at once for all crops in the system. 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

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

In addition to crop revenues and production costs, we estimated the labor requirements and potential calories deducted from the total production of each cropping system. As indicated in Table 2, each system has different labor requeriments and this requirement happens at different periods of time. Likewise, the potential quantity of calories derived from the production of staple crops varies according to the crop and the cropping systems. Our data shows that although maize is a crop that produces low revenues, it is the crop that can provide the higher quantities of calories required by the family. Rice is the more profitable crop in Zambezia, however its contribution to the food security through energy calories is relatively low. Cassava and sweetpotatoes are also key crops in the household food security as they make available large quantities of calories.

Table 2. Average labor requirement and potential production of calories in different cropping systems. Zambezia 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) Pigeonpeag	200	1124.09
Groundnuts		1410.00

A multi-enterprise optimization model

The use of farm household models has a long history in the agricultural economics literature (Barnum & Squire 1979, McGregor et al 2001). Usually these models have been developed to assess farm interventions, including technology diffusion, and to estimate the impact that these intervention have had on the whole household under various farm production environments. 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 but guaranteeing household food security. This household food security can easily be represented by the availability of the household to produce enough food to meet their required daily calorie intake. The Second type of households represents a medium scale producers that holds between 3 and 5 has of total land but that also face limited labor resources and has also to satisfy first the household food requirements and then sell the surplus in local markets.

The production function of the model is as follows:

$$\text{Max} \ \sum (R_i - C_i)$$

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: $\sum \text{Kcal}_i$ >= 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 crops produced 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 the Southern Zambezia 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 Zambezia we included one alternative scenario: the OFSP price increases by 27%. In all the scenarios we estimated the optimal area used for different cropping systems, the maximum potential profits, the proportion of calories produced by each system and farms returns per unit of labor and per unit of land (1ha)

Model results

The basic scenarios show how it would be the land allocation 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 showed 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$), would produce most of the calories needed from the cassava/pigeonpea system (62%) and would have as returns to half of a working day a total of 13.7 Mtn (0.53 US$). An optimizing farmer would not plant OFSP under current production and market conditions. 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 1067 Mtn.

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

	Rice	Maize/ Cassava	Cassava/ Pigeonpea	Total farm
Area	0.46	0.20	0.54	1.20
Net revenues	2095	457	2303	4856
Kcal produced	8%	30%	62%	4822560
Returns 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 Zambezia province. This farmers making 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$). This farmer would need to use a total of 1090 half days of their available labor and would produce a total of 2637 Mtn (105.5 US$) 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 land to produce it. It is also important to notice and 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 3b 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

In order to evaluate the sensitivity of our base scenarios results we evaluated two alternatives scenarios for the small scale representative farmer and one scenario for the medium scale representative farmer. For the small scale representative farmer we first analyze the case when the growing farmer receive 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 after many model runs it turned out to be an inflexion point in the small scale representative farmer.

It turns out that the free vines possibility reduces considerably the production cost of the intercropping Rice/OFSP and increases significantly the net revenue of this cropping system. 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 the OFSP production which is usually established after the rice harvesting and taking advantage of the residual moisture of the lowlands where rice is usually grown. By doing this representative farmer significantly increases farm revenues and the returns to land and labor.

The other scenario where the price of OFSP price is increased by 32% has a similar effect on farm outcomes as it also increases the rice/OFSP intercropping net revenues and therefore makes this option more attractive for the optimizing representative small farmer. Of course the changes in the farm profits and returns to land and labor are slightly lower as the cropping system revenues are increased at a lower level

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 it production by adding the cassava/sweetpotato intercropping. As a consequence the farm revenues and the returns to land and labor would increase even more.

Concluding remarks

Farmers' decisions among small scale growers in poor countries are made considering many factors. Maximization of farm revenues is always an objective of these farmers, but household food security is another component of this decision. We used an optimization model were combined farmers desire to maximize farm revenues with the minimum quantity of calories that should be produced in order to meet household requirement of 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 Zambezia province, Mozambique, provides interesting insights of the impact of introducing orange fleshed sweetpotato (OFSP) in the Mozambican farming system. Small scale farmer would not adopt OFSP under current conditions. Giving land limitation, farmers would devote their resources to produce other crops (rice, maize, cassava, pigeonpeas). Labor availability is not really a constraint as farmer has no enough land to employ all its labor resources. On the other hand farmers has 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, OFSP becomes an attractive crop (reducing its production cost) and making it another source of calories for the household.

Medium scale producers face different conditions. This type of farmers faces no restriction on the land available and the binding constraint is the availability of labor. Then famers would allocate these resources to the enterprise that provides the greatest return to labor. OFSP under current production and market productions is one of the crops that meet this requirement suggesting that medium scale producers in Zambezia, Mozambique would adopt this crop. For the medium scale producers the food security constraint it is not binding reflecting the different sources that a household of this type has for producing the required calories.

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