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INTRODUCING NEW AGRICULTURAL TECHNOLOGIES AND MARKETING STRATEGIES: A MEANS FOR INCREASING INCOME AND NUTRITION OF FARM HOUSEHOLDS IN ETHIOPIA

Yigezu AY[1*] and JH Sanders[2]

Yigezu Yigezu

[*]Corresponding author email: y.yigezu@cgiar.org.

[1]Post Doctoral Fellow, Social, Economic and Policy Research Program, International Center for Agricultural Research in the Dry Areas (ICARDA), PO Box 5466, Aleppo, Syria. Fax: (963-21)2213490, 5744622

[2]Professor, Dept. of Agricultural Economics, Purdue University, 403 W. State St., #609, West Lafayette, IN 47907-2056, USA. FAX 001-765-494-9176.

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ABSTRACT

Many developing regions have excellent potential agricultural resources. However, historically, the population has become so concentrated in these regions that acute poverty and malnutrition now predominate. The food scientists' response to the chronic nutrition problem has often been subsidized by bio-fortification with nutrition supplements or more recently cultivars with higher nutrient levels. Where much of the population is in this inadequate nutrition category as in the highland of Ethiopia, the supplements are neither financially feasible nor sustainable. The cultivars can provide a few critical nutrients but are not a comprehensive solution. To improve nutrition, it is necessary to increase income so that an increased quality and quantitative diet can be obtained. Here, a strategy to introduce Striga resistant sorghum varieties, inorganic fertilizers, tied ridges and inventory credit in the Qobo valley of Ethiopia is evaluated. Using the behavioralist criteria defined by the farmers as constraints, a mathematical programming model is built to analyze the effects of different potential combinations of technologies and supporting agricultural policies on the household nutritional gaps and on farmers' incomes. Striga resistance alone has little effect unless combined with fertilization, water harvesting and an improved credit program. The credit program improvement involves the substitution of inventory credit for the existing input credits that are repayable at harvest. Inventory credit enables the farmer to take advantage of the seasonal price variation and repay after the prices have recovered from the usual price collapse at harvest. An integrated approach, involving the combined technologies of water harvesting, fertilization and Striga resistance along with inventory credit increases farm household income by 31% and eliminates under-nutrition except in extreme drought years (10% probability), during which public assistance will be still needed. Both the treatment of the nutritional deficits and the decision making criteria defined by farmers are expected to be useful techniques in other developing country technology analysis as well.

Key words: Income, nutrition, technologies, *Striga*, credit

INTRODUCTION

Background

There continues to be tension among policy-makers on the choice between broad-based economic policies and the use of more targeted interventions such as bio-fortified drinks or crops for eliminating malnutrition [1, 2, 3, 4, 5, 6]. Much of rural poverty is concentrated in better resource-based but over populated regions. In such regions, new agricultural technologies have substantial potential to increase yield and hence provide higher income and more calories to family members. The higher incomes increase family access to other foods so that they can balance their diet with their increased purchasing power. Therefore, the introduction of agricultural technologies that focus on increasing both incomes and caloric intakes of smallholder farm households in impoverished regions needs to be a high priority for many developing countries.

In the face of large seasonal price swings of cereal staples, resource- poor farmers with limited liquidity often sell most of their produce at harvest, during which time prices usually attain their annual lows. Then they re-purchase their food staples later when prices are high and only limited supplies are available. In such situations, inventory credit, which is a system where credit is provided to farmers at harvest with their cereal staple produce as collateral, may enable them to delay sales and take advantage of the price variation.

Objectives of the study

When new technologies are introduced in a given area, farmers would normally test them on a small portion of their farms or start with only one or two items from a technology package and if the outcome is favorable, then they gradually increase the land under the technology. Given their recent introduction and the difficulties to access the input requirements, the levels of adoption of the new technology package (inorganic fertilizers, water harvesting techniques, and *Striga* resistant sorghum cultivars) are low. Hence, this paper focuses on the potential adoption of the technologies. Experimental data and farmers' and experts' estimates are employed to fill in gaps in the data collected from the sample households and community surveys.

Besides the new technologies, the potential effects of inventory credit on the adoption of the new technologies, household income and nutrition are analyzed. Comparisons are also made between the benefits of input credit repayable at harvest, the principal policy instrument currently used by the Ethiopian government, and a variation of input credit allowing credit to be repaid after the price recovery. This paper will address the following three questions:

1. Will farmers adopt the new technologies and in which combinations?
2. Do the new technologies improve the caloric intakes and incomes of the farm households?
3. Which of the two policies, inventory or input credit, individually and/or in combination with the new technologies, have the largest impact on farmers' welfares?

STUDY AREA, DATA AND HOUSEHOLD DECISION MAKING

Study Area

The study area is the Qobo valley-one of the high potential agricultural areas in Ethiopia. This valley in the Amhara region has good volcanic soils and adequate rainfall in most years. Cereal production is the main source of livelihood in the Qobo valley and is predominantly rain-fed. *Teff* (*Eragrostis tef*), sorghum, maize and chickpea are also important. Cereal yields are low – averaging a little over one ton per ha. The average family size is 5.6 with average landholding size of only 0.75 ha in the "wereda" (district) and 2.1 ha in the Qobo valley. There is no primogeniture in Ethiopia so land is divided between all the heirs.

The Sirinka Agriculture Research Centre (SARC) tested for the adaptation of three sorghum varieties (P-9401, P-9403, and P-9404 locally called Gobiye, Abshir and Birhan, respectively) developed by Gebisa Ejeta of Purdue University [7]. These varieties are resistant to *Striga* and high yielding. *Striga* is a parasitic weed that attaches itself to the host root and transpires at three times the normal rate of cultivated plants. Hence, water and nutrients are shunted to the parasite rather than to the plant thereby reducing yields. In Qobo valley, 67% of the total cultivated land is infested with striga [8]. In 2001, the country wide Integrated *Striga* Management (ISM) program introduced the *Striga* resistant varieties along with complementary technologies (inorganic fertilizer and tied-ridges) into the Qobo area. As of 2004, only 1.3% of the households in the study area have adopted any of these technologies individually or in combination. Hence, this paper attempts to study the potential for their adoption and the constraints for their introduction.

Data

Farmers with more resources and wealth normally lead the adoption process [9]. Therefore, in this study, more informed and better endowed farmers are deliberately sampled in the valley expecting the rest with fewer resources and less management ability to at least partially imitate these better farmers over time. Consequently, a systematic sample of 101 farm households (38 adopters and 63 non adopters) with better access to land, animal power and off farm incomes was taken. Detailed household and plot level surveys were done on these households complemented with a community survey of extension agents and other experts from Qobo.

Income and Nutritional Status

In spite of the good valley soils and the greater management ability of the sample farmers, erratic rainfall, pest infestation and population pressure make even these farm households food insecure. Sales of *teff* and sorghum are the main sources of cash income for farm households in the Qobo area [10]. Over the period 1994-2003, the expected annual farm household cash income of the sample from farming was Birr 1426 (US$163).To this needs to be added the value of home consumption of Birr 1290 (US$ 147) In normal rainfall years and at their current consumption levels, the average sample farm household meets only 60% of the World Health Organization (WHO) recommended level of cereal calories (2200 Kcal per person per day, see

Table 1). Another study for the same region also reported an energy intake level of only 50% of the WHO recommendation [11]. Having only 50 to 60% of energy requirements undoubtedly makes labor intensive activities difficult even though WHO studies over-state energy requirements for smaller stature individuals.

Decision Making

Farmers in developing countries consistently explain their decision making in terms of a series of goals to be met sequentially as a method of maximizing their incomes and reducing risk. Their first priority is to meet their income requirements immediately after harvest. Secondly, they attempt to store sufficient cereals for subsistence during the year. Farmers must pay for such urgent expenses as repayment of official and unofficial credit, payment of a land tax and payment of harvest labor. When it is difficult to satisfy both objectives, farmers choose to meet their pressing financial needs at harvest first and then purchase their food later in the year at higher prices. These purchases require some combination of off-farm work, sale of assets, or dependence on remittances from family members. Farmers in many other parts of Africa also make consumption and marketing decisions in the same way [12, 13, 14].

AGRICULTURAL TECHNOLOGIES AND A MARKETING STRATEGY

In the literature, sorghum yield losses due to *Striga* range from 40-100% [15]. For instance, the crop loss due to *Striga* in semi-arid regions of low soil fertility is between 65-100% [16]. Striga can be controlled by increasing soil fertility and/or with host plant resistance [17]. The hungry season in Qobo is the period 6-10 months after harvest - usually between June and September. During the hungry season, farm households can run out of food and the markets are often in short supply resulting in very high prices even in normal years [7]. For instance, the average price of sorghum in August 2002 was 85% higher than the previous harvest season (December 2001).

Usually, the seasonal price differentials go to marketing middlemen. The lack of liquidity and the urgent need to sell at low prices during harvest cause resource-poor farmers to lose income. By enabling farmers to capture these price differentials, the incentives to adopt new technologies can be increased. An important focus of this study is to evaluate the efficacy of inventory credit in enabling farmers to delay sales and tap into the high prices during the hungry season.

THE MODEL

Significant progress has been made in using choice models to examine the effects of farm and household characteristics in past adoption decisions and in *ex ante* modelling [18, 19, 20, 21, 22, 23, 24]. However, their contribution towards understanding how to target potential adopters and enhance future adoption is limited because they fail to capture the changes in farmer preferences in response to changes in technology mixes [25]. These models also have limited ability to adapt to behavioral changes among farmers in response to external factors such as weather and markets. Generalization of findings to other populations and contexts are also not credible. Farm household simulation models based on mathematical programming, however, provide the flexibility to simulate the response of the typical households to both internal and external shocks. These models then provide good insight into the potential for the adoption of new technologies under different scenarios and among different populations.

The standard method of programming farmer decision making is to maximize a utility function with a trade-off between expected income and risk. Risk is proxied by some measure of the variation of income [26, 27]. Here, the risk avoidance mechanisms are specified by the farmer and then incorporated into a utility maximization problem.

The sample farmers expressed a strong desire to meet their cash needs at harvest before everything else. So these income objectives at harvest were put in as the first constraint. Secondly, small farmers reduce their risk of being dependent on the market by storing their basic staples. This is also evident as they produce their basic staples even when the opportunity cost of its production is higher than the expected market price. Therefore, the technique developed by existing literature is used to systematically introduce the harvest income and subsistence requirements as constraints, which need to be met sequentially before profit is maximized [13].

Moreover, farmers express a strong desire to be self reliant in their basic cereal consumption requirements. To capture this behavior of farmers, a parameter called the self reliance factor (denoted by λ) is introduced in this paper. This parameter serves as a measure of the burden on farmers of relying on the market for own consumption. In the mathematical model built here, λ appears as a multiplier to the value of consumption crops purchased by the farm household later during the hungry season. When λ takes a value of 1, it means the marginal cost of own production is equal to the expected price for purchasing food later in the year. In such a situation, the farmer is market oriented and hence is indifferent between producing his own food and purchasing from the market. However, when λ takes a higher values than 1, it shows that farmers are producing their own staples at higher opportunity costs in order to avoid dependence on the market. To calibrate the model, an initial λ value of one has been used which was gradually increased until the simulated crop areas and quantities of the staples purchased in the different states of nature match with the observed values.

Another component of risk is defining the stochastic nature of production faced by farmers, especially rainfall variation. Information collected from the group interviews and twenty years of rainfall data collected from the meteorology station at Qobo agricultural research sub-station (QARSS) were used to define 8 states of nature and to estimate their respective probabilities of occurrence. Using these probabilities and the amount and temporal distribution of rain, the eight states of nature were consolidated into 4 (bad, average, good and very good) where, bad includes both the adverse and most adverse states of nature each with 0.1 probability of occurrence. Household and community level data corresponding to the 4 states of nature were then collected and used for this analysis.

In this modeling framework, farm households are assumed to be risk averse. Profit maximization is, however, undertaken after the household has handled its risky

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environment by insuring its harvest time cash and subsistence needs [13]. This combination of objectives and constraints result in the typical risk aversion behavior of decision making in an expected utility context (Figure 1).

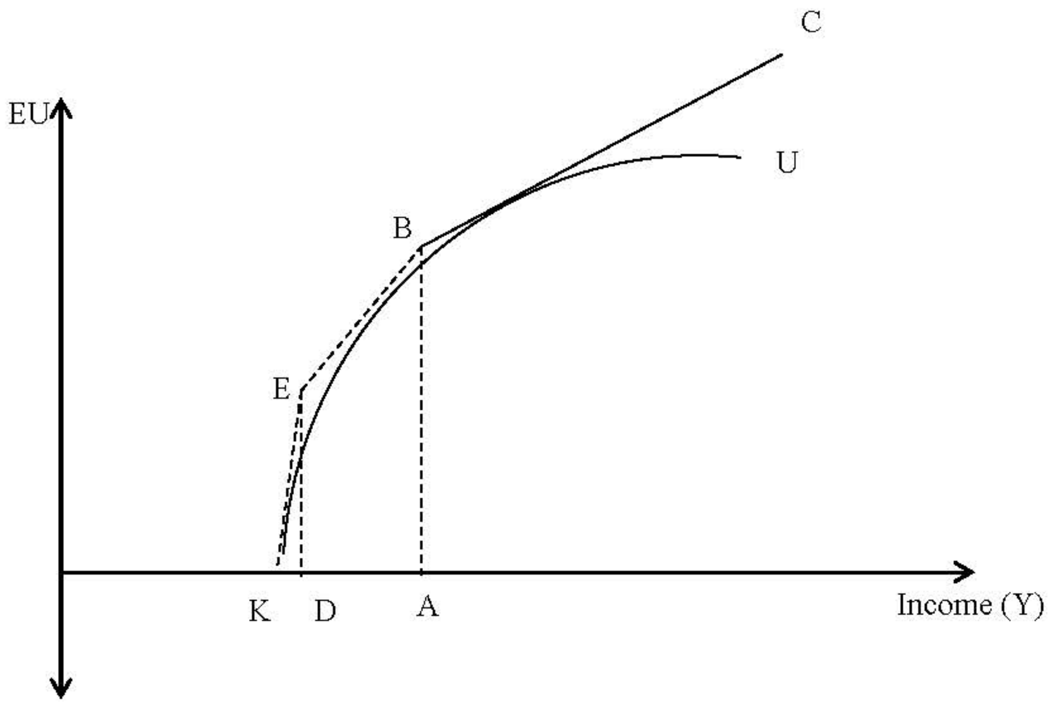

Figure 1: Graphical exposition of the Qobo farm households' optimization problem

This treatment enables to handle a critical farmer decision on when to sell grain as well as to evaluate policies that enable the farmer to perform some of the functions normally undertaken by middlemen. Farmers with strategic marketing can take advantage of the seasonal price changes thereby increasing their incomes and family nutrition.

In Figure 1, D represents the family's cash requirement at harvest. Once the household attains its harvest income goal (point E), the next objective becomes attaining the highest possible point on EB. Point A represents the monetary value of meeting both the cash and subsistence requirements.

If the household meets both the income and subsistence goals (B), then its objective becomes maximizing the linear utility function BC. The smoothed curve approximation of the overall utility function is given by U, which is concave and hence indicates conceptually (without a formal proof), that the farm household is risk averse. Mathematically, this can be formulated as:

Max *EU*:

$$EU = \begin{cases} \alpha Y, & if\ Y \leq D \\ \alpha D + \beta(Y - D), & if\ D < Y \leq A \\ \alpha D + \beta(A - D) + \mu(Y - A), & if\ Y > A \end{cases}$$

Where *EU* is expected utility, $0 < \mu < \beta < \alpha$ and α, β and μ respectively are the slopes of the curves KE, EB and BC on Figure 1 above.

Solution Method and Model Validation

Malnutrition is a continuing problem in the Ethiopian agricultural sector. In the bad (adverse and most adverse) states of nature - 20% of the time, attaining the WHO defined minimum calorie requirement was not always feasible. Hence, in these cases, the caloric goals are reduced to the maximum caloric levels that yield a feasible solution since in the adverse years farmers attempt to close as much of the calorie gap as possible. To implement this program, the General Algebraic Modeling Systems (GAMS) software is used [28].

Starting from a value of 1, the model is calibrated by altering the value of λ to the value best matching observed farmers' behavior. When $\lambda>1$, then farmers are willing to pay more in the implicit opportunity costs of their own production than they would have to pay to buy their cereals. This expected price for their cereals, though, would be below the price in adverse years. So a higher λ value helps cover farmers from the price risk of these adverse years.

At a self reliance factor (λ) value of one, farmers put most of their land into teff, which always fetches the highest price. However, farmers in the study area are observed producing most of their basic staple cereals (sorghum and maize) instead. By so doing, they demonstrate that they do not want to depend on the market for these crops. As the value of λ is gradually increased above 1, the model progressively allocates more land to sorghum and maize where, a λ value of 1.45 results in land allocation with the smallest percentage deviations from the observed land use both from the sample (Table 2) and from another source [29]. A value of 1.45 for λ shows that farmers produce their own food until their costs of production are 45% higher than the expected food purchase prices. This value is used in the model as another risk adjustment factor for these farmers.

RESULTS

Introducing fertilizers and the water harvesting technique of tied-ridges individually leads, respectively to the adoption of the individual technologies on 0.94 ha (44%) and 2ha (95% of total land) and 7% and 13% higher expected gross margins (Table 4). Note that the revenue component of gross margin includes the value of own crop consumption. Nutritionally, with the introduction of fertilizers alone, 91% of the WHO recommendation would be met in the adverse state of nature (0.1 probability) and there would be no nutritional effect in the most adverse year (0.1 probability). On the other hand, if farmers were to adopt tied-ridges alone, then they would be able to fully meet the WHO calorie recommendation in the adverse state of nature and meet 66% of the WHO recommendation in the most adverse year (Table 5).

The typical farmers will adopt the new *Striga* resistant cultivars by themselves on 0.14 ha replacing the local short season sorghum varieties (Table 5). The current practice is that farmers plant short season cultivars only when the rains are late, approximately 60% of the time. Moreover, there are two improved short season sorghum varieties (locally called *Wediaker* and *Meko*), which have already been adapted to the Qobo area and through time, farmers have gotten used to their consumption features. Consequently, the expected income effect of the new *Striga* resistant cultivars alone is low with an increase of only 1% in net household income. From field observations, there was a price discount for the Striga cultivars, which would be expected to be reduced over time as farmers got used to them.

The simultaneous introduction of fertilizers and tied-ridges increased the expected gross margin by 18% (Table 4). Nutritionally, the farm households can fully meet the WHO recommended level of cereal calorie for the adverse state of nature and reach 82% of the WHO recommendation for the most adverse state of nature, an increase of cereal calories by 57% relative to the base case (Model H in Table 5).

The introduction of the complete ISM technology package (SR varieties, tied-ridges and fertilizers) results in 19% increase in gross margin (Table 5). Here again, the adverse state attains adequate calories while in the most adverse state, 18% of the WHO requirements will not still be met. Note that in many studies [12, 13, and 14], the most adverse state in semi-arid regions is not included as it is expected that the public sector will intervene then.

The introduction of inventory credit alone increases the expected gross margin by 13% (Model J in Table 4). However, it has no effect on the available cereal calories in the two most adverse states of nature (Table 5). However, if inventory credit were introduced along with the whole technology package, expected gross margin would increase by 31% (Table 4). Nutritionally, the sample farm household will be able to meet 100% and 82% of the WHO calorie recommendation in the adverse and most adverse states of nature, respectively.

The model results show that there are neither caloric nor income benefits to the provision of input credits if farmers have to repay them at harvest. Currently, input credits are provided to Ethiopian farmers. However, these credits have to be repaid at harvest, during which time prices are low, leading to financial loss to farmers. If all the technologies were introduced with a flexible input credit where input credit is turned into a type of inventory credit program by a later repayment requirement, farmers can realize a 22% higher expected gross margin simply by delaying the sale of their grain.

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DISCUSSION

The potential impacts of introducing the whole IPM package including Striga resistant cultivars are not substantially higher than those of introducing only fertilizers and tied-ridges. Presently, consumers have preferences for the local long and intermediate season sorghums as reflected in the different market prices. The price discounts were 42% for the SRVs and 31% for Wediaker, a local short season variety. The Wediaker price differential has decreased over time and it is expected that consumers will adjust their tastes to the SRVs and this price differential will decline. But for a more rapid introduction of the SR cultivars, their price needs to increase and become at least 8% higher than that of Wediaker.

There are favorable results from the model for the introduction of the complete IPM package along with inventory credit. Moreover, these results indicate some directions for future research. For instance, the new *Striga* resistant sorghum varieties have a similar growing period (3.5-4 months) to that of other improved, short season sorghum varieties in the region, *Wediaker* and *Meko*. All the short season materials mature 4-5 months earlier than the long season varieties. So a major direction for breeding would be to focus on the medium and long season cultivars rather than attempt to get both drought escape through earliness and Striga resistance from the new cultivars. The water harvesting techniques reduce the threat of drought and the farmers prefer the higher yields of their longer season cultivars when this threat is reduced. Fertilization also reduces the Striga problem as it is a low soil fertility phenomenon.

Even with the introduction of the whole technology package and inventory credit, the farmers of Qobo will not be able to fully close their nutritional gap in the most adverse state of nature (0.1 probability). This should not come as a surprise as farmers in most of the world receive some food or cash transfers from government or NGO action in such adverse states of nature. This intervention was not included in this analysis as food aid coverage is considered to be inadequate and often not available for farmers in the region.

Qobo farmers produce and consume a substantial amount of the least nutritious and most expensive crop (teff), especially in the very good and good states of nature (Table 1). By reducing the production and consumption of teff and increasing the production and consumption of sorghum, farm households in Qobo could attain the WHO minimum calorie goals 80% of the time even without the new technologies and/or inventory credit (Table 5). The question then is: why are actual nutrition levels so much lower than 80%? The principal hypothesis of this paper is that farmers lack awareness about the nutritional values of the different crops they consume. Moreover, there usually are socially unacceptable expenses such as purchase of liquors and other entertainment expenses (often by male household heads) that are not reported but compete for the limited family income. This is evident from the comparison of the current nutritional deficit reported in Table 1 and the maximum attainable nutrition levels reported in the base case column of Table 5. This issue will be a good direction for future research.

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Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

CONCLUSION

The farm households in the Qobo area would benefit the most from the full ISM technology package (SRV, fertilizer and tied-ridges) combined with inventory credit. Hence, development policies which aim at improving the nutritional and income status of the farm households in Amhara and similar regions need to not only facilitate the adoption and diffusion of the three technologies, but also introduce inventory credit to help farmers benefit from the seasonal price changes. Elsewhere in Africa, this strategy has proved useful [3, 13].

The agronomic success of the SRVs on *Striga* infested fields is evident. The benefits of this agronomic success can be increased if the preferred consumption features of the local long and intermediate sorghum varieties (reflected in their higher market prices) could be incorporated into the SR varieties and hence the prices received for the *Striga* resistant cultivars increased. Moreover, farmers will want to exploit the higher yield potential of local long season and intermediate sorghum varieties in the good states of nature (30% probability). Incorporating the *Striga* resistance element into these medium and long season varieties or developing a new intermediate or long season *Striga* resistant sorghum variety would give farmers a fuller range of choices with desirable qualities.

The benefits to farm households of input credits, as administered currently, are low because farmers have to repay their credits immediately after harvest at which time prices regularly collapse to their annual lows. If farm households are to benefit from the provision of input credits, the credit administration needs to be flexible enough to allow farmers to delay their repayments until later during the hungry season, generally the time of substantial price increase. This modification of credit programs turns input credit programs into inventory credit.

In the long run, the increase in income due to the introduction of inventory credit will decrease once many farmers delay sales. As inventory credit becomes widespread, the price difference between months will approach the costs of storage plus the opportunity costs of capital. Even though farmers will still benefit from the reduced role of middlemen, it will be necessary to search for other marketing strategies that make the income and nutrition benefits sustainable. One possible method is to begin facilitating the development of the food and feed processing sectors. This development would moderate the price collapse of the food staples in good rainfall years, when the lack of alternative markets can result in staple price collapse.

Model results show that current food preferences for teff - an expensive but less nutritious grain- make it more difficult for the farm households to meet nutritional goals. Consumer education may help to modify these habits. There also are undoubtedly data problems due to farmers' inabilities to remember all expenditures and the lack of social acceptability of some expenditures leading to failure to report. Hence, there is a return from delivering improved nutritional information to farmers and from obtaining more accurate consumption data.

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Table 1: Crop Consumption (in Kg) by the Average Sample Farm Household in Different States of Nature

		States of Nature				
		Very good	Good	Average	Bad	Expected
Crop type	Probability	0.1	0.2	0.3	0.4	
Teff		487	401	366	164	304
Sorghum		521	559	552	500	529
Maize		100	100	100	50	80
Chickpea		60	60	60	36	50
Total calories (in millions)		1.84	1.78	1.71	1.21	1.54
Observed calorie intakes as percentage of the WHO recommendation		72	70	67	47	60.1

Source: [8]

Notes: The initial eight states of nature were reduced to four to make the interview easier. To focus more on the nutritional inadequacies, the bad state of nature was broken into three categories (slightly adverse, adverse, and most adverse). In the first case, with approximately 20% probability, the rainfall is late but generally adequate. In such years, farmers resort to short season crops. Yields are reduced but without serious nutritional problems. The second and third cases are the focus of the nutritional analysis. In the second (adverse) state (0.1 probability), there are good but short rains which stop before the long season crops mature. In the third (most adverse) states (0.1 probability), rains start and stop early. This state of nature is the most serious for yield decline and malnutrition.

Table 2: Observed and Simulated Land Allocation by Crop Type and Variety in the Qobo Area (percentage of Total Area)

	Observed Area Size by Crop		Base Model Estimates			
	Average from another study (for 2006)	Average of our sample farms (Average of 2002 and 2003)	Model A λ=1	Model B λ=1.40	Model C λ=1.45	Model D λ=1.50
Crop		%	%	%	%	%
Teff	47.63	60.28	60.33	49.81	48.83	48.83
Short season sorghum		9.51	5.89	17.10	17.10	17.10
Intermediate sorghum		15.84	16.73	16.73	16.73	16.73
Long season sorghum	46.32	11.89	17.06	13.55	13.55	12.62
Striga resistant varieties (SRVs)		NA	NA	NA	NA	NA
Chickpea		1.08	0.00	0.61	1.59	2.06
Maize	6.05	1.41	0.00	2.20	2.20	2.66
Total	100.00	100.00	100.00	100.00	100.00	100.00

Sources: Survey Results and Model Estimates [8, 29].

Notes: a) As the farm households could not meet the WHO level of cereal calories in the adverse and most adverse states, models A-D are solved based on simulation of the maximum attainable levels. b) Based on the amount and distribution of rainfall, the years 2002 and 2006 are categorized as good while 2003 is categorized as an average rainfall year in Qobo. c) The figures under the column “observed area” are for the year 2006, a good year [29].

Table 3: Quantity (Kg) of the Main Food Staples Purchased at λ Values of 1 and 1.45

Crop Type	States of Nature							
	Very good		Good		Average		Bad	
	λ=1	λ=1.45	λ=1	λ=1.45	λ=1	λ=1.45	λ=1	λ=1.45
Teff	0	0	0	0	0	0	164	164
Sorghum	0	0	315	0	552	0	275	0
Maize	100	0	100	0	100	0	50	50
Chickpea	60	60	60	60	60	0	36	36

Source: Model Predictions

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Table 4: Income and Land Allocation Effects of the Individual and Combined Use of the Three Technologies and Inventory Credit

	Model Estimates							
	Base Case	SRV alone	Fertilizer alone	Tied-ridges alone	Tied-ridges and Fertilizers	All three technologies	Inventory credit alone	Inventory Credit and the whole technology package
Item	Model C	Model E	Model F	Model G	Model H	Model I	Model J	Model K
Expected gross margin in Birr	4381	4387	4669	4930	5225	5231	4956	5722
Expected gross margin in US$	501	501	533	563	597	598	566	654
Land allocation by Crop	%	%	%	%	%	%	%	%
Teff	48.83	47.48	56.64	50.14	54.57	53.59	55.00	54.72
Short season sorghum	17.10	10.23	12.86	12.66	7.43	3.83	11.63	3.69
Intermediate sorghum	16.73	16.73	16.74	11.36	11.35	11.35	16.72	11.35
Long season sorghum	13.55	15.37	12.35	21.50	24.39	22.57	13.27	22.43
Striga resistant varieties (SRVs)	NA	6.40	NA	NA	NA	5.79	NA	4.72
Chickpea	1.59	0.98	0.61	1.87	0.841	0.84	1.07	0.84
Maize	2.20	2.80	0.80	2.48	1.402	2.00	2.29	2.24
Total = 2.14 ha	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Model Results.

Notes: With the introduction of the whole technology package, total land allocation to the short season sorghums (SRVs and local short season sorghum) is reduced because the returns to fertilizers are the highest with *teff* and the returns to tied-ridges are the highest with the long season sorghums.

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Table 5: Caloric Effects of the Individual and Combined Introduction of the Three Technologies and Inventory Credit

State of nature	Model Estimates of the Maximum Attainable Level of Cereal Calories for the Farm Households in the Qobo area (as percentage of the WHO recommended level of cereal calories)							
	Base Case	SRV alone	Fertilizer alone	Tied-ridges alone	Tied-ridges and Fertilizers	All three technologies	Inventory Credit alone	Inventory Credit and the whole technology package
	Model C	Model E	Model F	Model G	Model H	Model I	Model J	Model K
Most Adverse	52	52	52	66	82	82	52	82
Second Most Adverse	82	82	91	100	100	100	82	100
Expected Attainment*	93	93	94	97	98	98	93	98

Source: Model results.

Notes: In the model built in this paper, no allowance is made for socially unacceptable expenses such as purchase of liquors and other entertainment expenses by male household heads. Hence, all the figures reported in the above table refer to the maximum amount of calories the farm household can afford to consume without any change to their food consumption habits, but by devoting all resources to meeting the family's calorie goals after meeting their post harvest income needs. Unlike the observed figures in Table 1, model results for the base case scenario show that the sample average farm household in the Qobo area can meet the WHO recommendation in all but the most adverse and adverse states of nature (0.2 probability) where it meets respectively 52% and 82% (still better than the observed level which is below 47%). In such years, disaster insurance and relief of various kinds are used even in the developed world [30].

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