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Ex-ante Assessment of Adoption of Small-scale Post-harvest Mechanization: The Case of Groundnut Producers in Malawi

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Acronyms

ATCC	Agricultural Technology Clearance Committee
CTI	Compatible Technology International
DAES	Department of Agricultural Extension Services
DARS	Department of Agricultural Research Services
FRN	Farmer Research Network
FUM	Farmers Union of Malawi
hh	household
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
MWK	Malawian kwacha
NASFAM	National Smallholder Farmers Association of Malawi
USD	United States dollar
VAT	value added tax
VSL	village savings loan
WTP	willingness to pay

Exchange Rate

USD 1 = MWK 718 as of October 2016

Abstract

The study combines household-level demand function analysis and community-level benefit cost analysis to conduct ex-ante assessment of the adoption of small-scale post-harvest mechanization with a case of groundnut producers in Malawi. Based on the needs assessment conducted in 2010, Compatible Technology International (CTI) designed three pieces of labor-saving equipment for post-harvest operations for smallholder groundnut production, namely, lifter (harvester), stripper (thresher), and sheller (dehuller) in partnership with ICRISAT, Department of Agricultural Research Services (DARS), and C-to-C Engineering. The paper attempts to assess the viability of adoption and dissemination of each of these technologies which are technically categorized as “club goods” or “artificially scarce goods” through examining two steps: (1) smallholders' level of willingness-to-pay (WTP) for use of the equipment after seeing the demonstration, and (2) community leaders' preferences for methods of acquisition. The data collection leverages farmer research network (FRN) established in collaboration with farmer organizations, complemented by gender disaggregated household interviews. The analytical output suggests that the WTP for smallholders to use the equipment for their entire volume of groundnut harvest was approximately 2,000 Malawian kwachas (MWK) per acre, MWK 50 per pail, and MWK 35 per pail for the lifter, stripper, and sheller, respectively and that lead farmers’ investment in acquiring these technologies can be recovered in a single post-harvest season. The critical values for farmer group size to achieve breakeven points were 75, 22, and 129 for the lifter, stripper, and sheller, respectively under the base scenario and 127, 37, and 218 under the conservative scenario. Lead farmers’ return on investment (ROI) for one season was 2.3, 10.5, and 0.9 for the lifter, stripper, and sheller, respectively under the base scenario and 1.0, 5.8, and 0.1 under the conservative scenario, which will further increase as multiple seasons are considered. The sensitivity analysis indicated that the result was largely robust to altering the assumptions on group size and fees for using the equipment. The findings suggest that the business of lead farmers acquiring the equipment and renting it out to member farmers is indeed profitable, meeting the necessary condition for sustainable adoption. Other conditions to ensure successful adoption are also discussed.

Keywords: agricultural equipment, agricultural implement, club goods, artificially scarce goods, labor saving, gender, farmer research network, willingness to pay, benefit cost analysis, sensitivity analysis

JEL classification: O13, Q19, B49

Contents

1. Introduction

The history of agricultural development in many parts of the world has entailed the increasing tendency of mechanization of on-farm operations. Different stages of agricultural mechanization have seen different scales of mechanized operations (Otsuka et al, 2014). Large-scale mechanization occurs typically after adequate growth of non-farm sectors in the region, which comes in tandem with elevating wage levels. Increasingly expensive agricultural labor then induces farm entities to introduce automated machinery. This stage of agrarian transition leads to allocation of labor force from agriculture to non-agriculture (Ghose, 1990), resulting in consolidation of smallholder farms into medium scale farms and large scale estates (Otsuka et al, 2014; Holdena and Otsuka, 2014; Wang et al, 2014; Yamauchi 2014).

By contrast, micro or small-scale mechanization is much more relevant to smallholder farmers in marginalized production environments characterized by such constraints as unreliable rainfall under non-irrigated conditions, limited access to markets and infrastructure, and lack of technology adoption (Feder, 1985; Mottaleb et al., 2016). These farmers predominantly utilize hired and family labor to handle tedious manual operations (Orr, 2003). In sub-Saharan Africa (SSA), the majority of the agricultural production is accounted for by resource-poor smallholder farmers, often faced with labor or credit constraints, among other things, that stand in the way of upscaling of production as an effective means of poverty alleviation (Larson et al., 2012; Kijima & Otsuka, 2011; Nakano et al., 2011).

Groundnut is a growing and/or major income source for smallholder farmers in many countries of SSA such as Malawi, Zambia, Mozambique, Tanzania, Uganda, Sudan, Nigeria, and Senegal. It is also an important food crop being an inexpensive source of balanced protein and essential fatty acids. In particular, in impoverished Malawi, the world’s ninth largest exporter of groundnut, the crop has become the second income earner for smallholder groundnut growers after tobacco (Tsusaka et al., 2016a; Msere et al 2015). Yet, small scale groundnut production is rather labor intensive, especially at the stage of post-harvest operations (Alwang & Siegel, 1999). A survey conducted by ICRISAT and Compatible Technology International (CTI) identified that lifting (i.e., digging or harvesting), stripping, and shelling processes were the main areas of high labor intensity, and that many of the groundnut growers considered labor shortage as one of the critical impediments to boosting production and sales of the crop (Tsusaka et al., 2016b). Likewise, Orr et al. (2011, 2012) pointed out that despite the additional land available in Eastern Zambia, scope for expanding the area planted to groundnut was limited because post-harvest handling was laborious and tedious components of production. Even those farmers who owned, or could hire, ox-drawn ploughs to prepare land (by clearing and creating ridges) had difficulty extending the area to any great extent because their animal-drawn implements were not suitable for application to harvesting and post-harvest operations.

The importance of groundnut production in the region is fuelled by the extent to which women are involved in production, particularly in stripping and shelling (Wanyama et al., 2013). According to Orr et al (2016a), the crop is often referred to as a “women’s crop”, as the aforementioned post-harvest operations are typically handled by women, both family labor and low-paid casual labor. Further, Orr et al (2016b) suggest that women deem such operations rather as drudgery than as income opportunities.

Since 2010, ICRISAT and CTI have collaborated to work toward developing agricultural equipment designed to alleviate drudgery associated with the groundnut on-farm post-harvest handling. During the 2012 post-harvest season, proto-type lifters, strippers, and shellers were tested. On-farm experiments with improved devices were conducted in the 2014 post-harvest season. Finally, the developed technologies were cleared by the Agricultural Technology Clearance Committee (ATCC) and were officially released in April 2016. Following the awareness creation activities with farmers under National Smallholder Farmers Association of Malawi (NASFAM), Farmers Union of Malawi (FUM), ICRISAT, and Department of Agricultural Extension Services (DAES) during the 2016 post-harvest season, a baseline study was conducted in October 2016 to collect farmer-level data on willingness to pay (WTP) (Gafni, 1998; Weaver et al., 1992) for use of each of the equipment, gendered labor allocation, and agricultural practices, and community-level information on preferred method of acquisition of the equipment by gender as well as group size.

The objective of this paper is to assess the economic potential for adoption of these post-harvest technologies by conducting farmer-level demand function analysis and the community-level benefit-cost analysis. Following this introduction, Section 2 describes the basic methodology used in this study, Section 3 presents the result, and Section 4 concludes the paper.

2. Methodology

2.1. Concept of Club Goods

In economics, goods are categorized into four types depending on whether there is rivalry and whether there is excludability (Table 1) (Benson, 2016; Krugman and Wells, 2015). A private good is defined as an item that is excludable, i.e., its owners can exercise private property rights, preventing those who have not paid for it from using the good or consuming its benefits; and rivalrous, i.e., consumption or use by one necessarily prevents or affects that of another (Pichierri, 2016; Adams and McCormick, 1987). A private good, as an economic resource, is scarce, which can cause competition for it.

Table 1 Types of goods in economic theories

	Excludable (paid)	*Non-excludable (not paid)*
Rivalrous (limited)	**Private goods** seed, food, clothes, cars	**Common goods** (**Common-pool resources**) fish stocks, timber, coal
Non-rivalrous (not limited)	**Club goods** private parks, private schools, cinemas, cable television	**Public goods** free-to-air television, fresh air, scientific knowledge

Sources: Adapted from Krugman and Wells (2015).

A public good is a good that is both non-excludable and non-rivalrous, i.e., individuals cannot be effectively excluded from consumption or use, and use by one individual does not reduce availability to others (Pichierri, 2016; Cornes and Sandler, 1996; Oakland, 1972). Public goods include free-to-air television, fresh air, scientific knowledge, lighthouses, and national security.

A common good, also dubbed a common-pool resource or a common property resource, is a type of good consisting of a natural or human-made resource system, whose size or characteristics makes it costly to exclude potential beneficiaries from obtaining benefits from its consumption or use (Tosun et al., 2016; Mayntz, 2002). Common goods are therefore non-excludable. However, unlike public goods, common goods face problems of congestion by users or overuse of resources, because they are subtractable and somewhat limited (Hughes and Kaffine, 2017). Common goods are therefore rivalrous. Examples of common goods are water in an irrigation system, fish in fishing grounds, grass in grazing pastures, timber in forests, and coal in mines.

A club good is, also dubbed artificially scarce goods, is a type of good that is excludable but non-rivalrous until reaching a point where congestion occurs (Prakash and Potoski, 2007; Potoski and Prakash, 2009). Club goods are sometimes classified as a subtype of public goods (Benson, 2016). These goods are often provided by a natural monopoly (Kennedy, 1990). Club goods have artificial scarcity. A non-congested toll road is an example of a club good. It is possible to exclude someone from using it by simply denying them access but it is not a rival good since one person's use of the road does not reduce its usefulness to others (Engel et al., 2004). Other examples include cinemas, private parks, golf courses, satellite television, and access to copyrighted works.

In this categorization, the post-harvest technologies to be tested for adoption are club goods, as they are excludable, i.e., they can exclude those outside the community who do not pay for use of the equipment, but non-rivalrous, i.e., one farmer's access to the equipment does not affect others' access to it until there are too many farmers wishing to use the same equipment at the same time.

2.2. Framework for Ex-ante Assessment

For sustainable adoption of technologies that are club goods, we need to take into account that the adoption occurs in two steps: community-level acquisition and farmer-level adoption.[1] The first step is for a community leader and/or groups of farmers to decide to acquire each of the three pieces of the equipment. The second step is for farmer members to decide to use the equipment. The farmer-level extent of adoption is characterized as follows:

$$FA = f(x_1, x_2)$$

where the adoption is expressed as a function of x_1, efficiency or performance of the technology, and x_2, access fee. It is assumed that farmers will adopt the technology if the benefits arising from x_1 exceed the cost associated with x_2. In other words, x_1 and x_2 are the determinants of adoption. On the other hand, the community-level acquisition is characterized as follows:

$$CA = f(x_2, x_3, x_4, x_5, x_6, x_7, FA(x_1, x_2))$$

where the adoption is a function of x_2, access fee, x_3, method of acquisition, x_4, farmer-level WTP or demand function, x_5, community size, x_6, purchase cost, and x_7, maintenance cost per season. It is assumed that community leaders will install the technology if the benefits arising from x_2, x_4, x_5, and *FA* exceed the cost associated with x_3, x_6, and x_7.

In this paper, x_1 is assumed to be adequately high as evidenced by the fact that the technologies are officially approved by the ATCC; x_6 is currently set at USD 350 per lifter, USD 50 per stripper, and USSD 216 per sheller; and x_7 is simulated at either 10 % or 30 % of the purchase cost. x_2 and x_4 are suggested from WTP elicitation (see next subsection).

As for x_3, admittedly there are several methods of acquiring the equipment such as individual purchase, group purchase, purchase on credit, renting from the farmer organization, renting from the project, and receiving for free from the project. However, as the purpose of our exercise is to assess sustainable adoption, those methods reliant on project support or credit facilities, which are unavailable for the majority of smallholders in general, are excluded from this assessment. It is assumed that if adoption occurs with individual or group purchase, or any other self-reliant method within the community, then it will also occur in those communities that are blessed with some sort of external support.

As all other variables are determined, the fate of adoption is in the hands of x_6. When x_6 is greater than a certain threshold, which is specific to each technology, then the benefit

[1] The two-step adoption of small-scale post-harvest mechanization is also observed in Eastern Zambia where the agroecology and socioeconomic conditions are similar to those in Central Malawi.

exceeds costs at the community level, and vice versa. The threshold value will be found by determining or simulating all other variables.

2.3. Farmer-level WTP Elicitation

Elicitation of WTP for use of the equipment allows us to map the demand function of smallholder groundnut farmers. In elicitation practice, we presented several levels of fee within a realistic range, and asked the respondent what percent of their groundnut production or area they would be willing to handle by the equipment instead of hands, at each of the presented fees. This way we obtain the quantity of groundnut for which they are willing to use the equipment at different fee levels. Plotting the population average of these values will reveal a demand curve, from which we can estimate the maximum fee that can be paid by farmers to utilize the equipment for the full volume.

In analysis, farmers are divided by tertiles with respect to household income as they are expected to exhibit different purchasing powers. Hence, the demand function is separately obtained for three segments of farmers: lowest income segment, middle income segment, and highest income segment, for which the average annual household income was 105,726 kwachas (USD 146), 337,048 kwachas (USD 467), and 1,233,015 kwachas (USD 1,708), respectively, estimated as of October 2016.[2]

2.4. Community-level Benefit Cost Analysis

The necessary condition for community level adoption of the equipment is that the net benefit is to be positive, which is expressed as follows:

Net Benefit = Gross Benefit – Cost

$$= x_2 * FA(x_1,\ x_2) * x_5 - (x_6 + x_7) > 0$$

This inequality implies that with the given model of equipment, which is economically characterized by x_2, $FA(x_1,\ x_2)$, x_6 , and x_7, there is a certain threshold value for x_5. We will find this value for each of the three types of equipment under two different scenarios: base scenario and conservative scenario, which are defined as follows:

[1] Base Scenario

- Groundnut production level is as in the 2015-2016 season.
- The maintenance and repair cost per season is 10 % of the purchase cost.

[2] Conservative scenario

- Groundnut production level is 30 % below that in the 2015-2016 season due to crop failure from biotic and/or a biotic stresses.
- The maintenance and repair cost per season is 30 % of the purchase cost.

Lastly, sensitivity analysis is performed with respect to changes in farmer group size and service fees in order to examine the robustness of the result and the applicability to wider rural communities.

[2] The exchange rate was 718 Malawian kwachas for one United States dollar as of October 2016.

2.5. Labor Intensity

Labor intensity in specific processes in crop production is the basis for introducing small-scale mechanization. Although Tsusaka et al. (2016b) identified the labor-intensive operations in groundnut farming using simple response questions, quantity of labor inputs was not elicited. This study collects information on labor inputs in terms of person hours by gender. The same information is also collected from two other main crops, namely, maize and soybean in order to compare the labor concentration across crops.[3]

[3] Tobacco is another main crop among the studied farmers. Nationally, however, area planted to tobacco has been decreasing as it is replaced by legume crops. The government has been increasing support for legume crops at the cost of tobacco, in view of food and nutrition security as well as soil fertility conservation.

3. Results

3.1. Groundnut Production

The average area planted to groundnut was 1.32 acres.[4] For the 2015-2016 crop season, the average volume of harvest was 405 kg, 355 kg, and 383 kg for the highest income, middle income, and lowest income segments, respectively. An interesting observation is that farmers in the lowest income segment produced more groundnut than did those in the middle income segment, on average. This implies that the income elasticity of supplying (producing) groundnut is not monotonic, which may suggest the importance of groundnut production in the welfare of the poorest farmers.[5] The subsequent subsections discuss farmers' demand function for use of the equipment, by technology and by income segment.

3.2. Labor Intensity of Manual Operations

Table 2 presents the quantity of labor applied per acre into the different post-harvest processes of groundnut production from lifting to marketing. This confirms that lifting (25 % of the total workload), stripping (33 %), and shelling (17 %) are indeed the three most labor intensive post-harvest operations. It also confirms that a majority of the labor is contributed by women except for drying and marketing. In particular, men are almost absent in the winnowing process.

Table 2 Labor inputs for groundnut post-harvest operations: 2016 Season

	Average Labor Input (person-hours/acre)		Share of Workload by Gender (%)		Labor Breakdown by Process (%)
	Women	Men	Women	Men	
Lifting	46	32	59	41	25
Drying	0.2	22	0.7	99	7
Stripping	69	34	67	33	33
Transport to Home	15	11	57	43	8
Shelling	30	23	56	44	17
Winnowing	10	0.8	93	7.4	4
Sorting/grading	10	5.3	65	35	5
Transport to Markets	1.1	5.1	18	82	2
Total	182	134	58	42	100

Source: Authors' calculation with the survey data

Tables 3 and 4 show the same information for maize and soybean grown by the studied farmers, suggesting that the post-harvest operations for groundnut are the most labor intensive per unit area among the three main food crops.

[4] The average area planted to maize and soybean was 1.86 and 0.67 acres, respectively.

[5] For income elasticity of supply, see the discussions by Balié et al. (2016) and Reder (1962).

Table 3 Labor inputs for maize post-harvest operations: 2016 Season

	Average Labor Input (person-hours/acre)		Share of Workload by Gender (%)		Labor Breakdown by Process (%)
	Women	Men	Women	Men	
Harvesting	24	18	57	43	14
Drying	0.3	3.1	8	92	1
Threshing	25	12	68	32	12
Transport to Home	2.7	6.9	28	72	3
Dehulling	107	72	60	40	61
Winnowing	11	0.7	94	6	4
Sorting/grading	7.1	2.3	76	24	2
Transport to Markets	0.2	1.6	12	88	1
Total	177	116	60	40	100

Source: Authors' calculation with the survey data

Table 4 Labor inputs for soybean post-harvest operations: 2016 Season

	Average Labor Input (person-hours/acre)		Share of Workload by Gender (%)		Labor Breakdown by Process (%)
	Women	Men	Women	Men	
Harvesting	36	35	51	49	32
Drying	0.0	16	0	100	7
Threshing	5.8	11	34	66	8
Transport to Home	12	15	43	57	12
Dehulling	21	15	58	42	16
Winnowing	25	3.4	88	12	13
Sorting/grading	11.2	7.6	59	41	8
Transport to Markets	3.5	4.3	45	55	4
Total	115	108	52	48	100

Source: Authors' calculation with the survey data

It must be noted however that it is not only the person hours that determine the level of drudgery, but physical stress also matters. Hand shelling is reported to hurt the ball of the thumbs and even cause bleed.

3.3. Community Leaders' Preferences for Acquisition

The community leaders, both male and female, from 20 communities in five districts were interviewed during the awareness creation exercises conducted from April to August 2016. The three districts (Lilongwe, Mchinji, and Kasungu) in the Central region are the largest groundnut producers in Malawi and are therefore included. In addition, to cover different agro-ecologies, Mzimba district and Balaka district were added from the Northern and Southern regions, respectively.

Table 5 shows the community leaders' preferences as to whether and how they wish to purchase the equipment of which they observed the performance, along with the availability of credit within the community. In all of the communities being studied, the leaders showed keen interest to purchase the stripper and sheller either individually, by sharing the cost with some other community members, or using credit available within the community.

Table 5 Community leaders' post-demonstration preferences as to methods of purchase of the post-harvest equipment

		Male Leader				*Female Leader*			
District	***Community ID***	***Lifter***	***Stripper***	***Sheller***	***Credit Availability***	***Lifter***	***Stripper***	***Sheller***	***Credit Availability***
Mchinji	1	1, 2, or 3	1, 2, or 3	1, 2, or 3	Yes	1, 2, or 3	1, 2, or 3	1, 2, or 3	Yes
Mchinji	2	na	na	2 or 3	Yes	2 or 3	na	2 or 3	Yes
Mchinji	3	2 or 3	2 or 3	2 or 3	Yes	na	na	2 or 3	Yes
Mchinji	4	1 or 2	1 or 2	1, 2, or 3	Yes	1, 2, or 3	1, 2, or 3	1, 2, or 3	Yes
Mchinji	5	1 or 2	1 or 2	1 or 2	No	na	na	1 or 2	Yes
Kasungu	6	1, 2, or 3	1, 2, or 3	1, 2, or 3	Yes	2	1, 2, or 3	1, 2, or 3	Yes
Kasungu	7	2	2	2	No	1 or 2	1 or 2	1 or 2	Yes
Kasungu	8	2	1 or 2	1 or 2	No	2	2	2	No
Kasungu	9	2 or 3	1, 2, or 3	2 or 3	Yes	2	2	2	No
Mzimba	10	2	1 or 2	2 or 3	Yes	2 or 3	1 or 2	2 or 3	Yes
Mzimba	11	2	2	2	No	2 or 3	2	2 or 3	Yes
Mzimba	12	2	1 or 2	1 or 2	No	2	1 or 2	2	No
Lilongwe	13	na	na	2 or 3	Yes	na	na	1, 2, or 3	Yes
Lilongwe	14	2	1	2	No	1	1	1	No
Lilongwe	15	2	1	1	No	1	1	1	No
Lilongwe	16	2	1	2	No	2	1	2	No
Lilongwe	17	3	1	2	No	2 or 3	1	2 or 3	Yes
Lilongwe	18	2	2	2	No	3	2	2	No
Lilongwe	19	2 or 3	1	2 or 3	No	1	1	2	No
Balaka	20	2	1	1	No	2	1	1	No

1 = Individual Purchase
2 = Group Purchase
3 = Purchase on community-level credit schemes

Source: Authors' interviews with lead farmer collaborators in 2016 April-August

As for the lifter, the male leader in Community 17 and the female leader in Community 18 stated that credit is not available in their community and yet would be needed. Apart from these two, the 18 other leaders showed interest to purchase the lifter. There was no significant gender difference in stated preferences as to methods of acquisition. Nonetheless, this indicates that the lifter seems relatively difficult to be adopted in comparison with the other two technologies introduced, due to the relatively high price and the requirement of oxen.

3.4. Farmers' Demand Functions

3.4.1. Lifter

Figures 1, 2, and 3 show the estimated demand functions for the lifter averaged among the highest, middle, and lowest income segments, respectively. The WTP for use of the lifter is expressed in terms of price per acre of land from which to use the equipment for lifting their groundnut. The dotted lines indicate the revealed maximum fee that farmers in each income segment can theoretically afford to pay for the service to lift their entire area planted to groundnut, which was approximately, MWK 3,300, 4,200, and 2,000, respectively. Again, a monotonicity breakdown was registered.

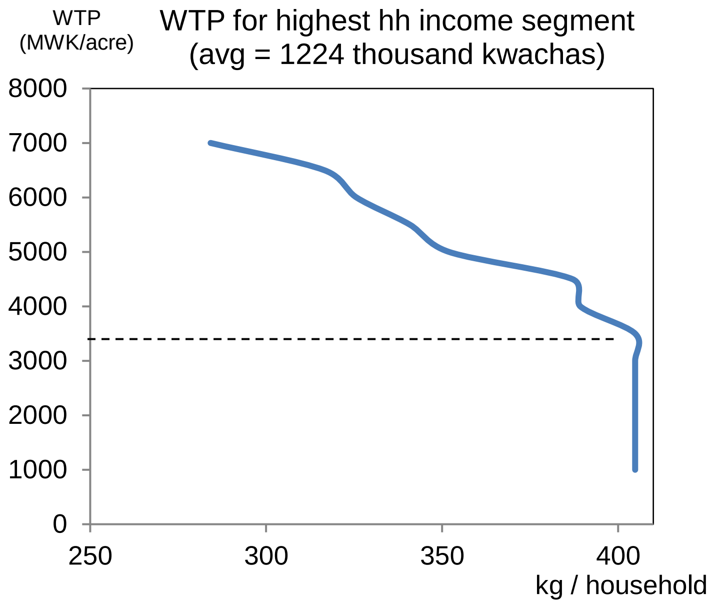

Figure 1 Demand curve for the lifter: highest income segment
Source: Authors' calculation with survey data

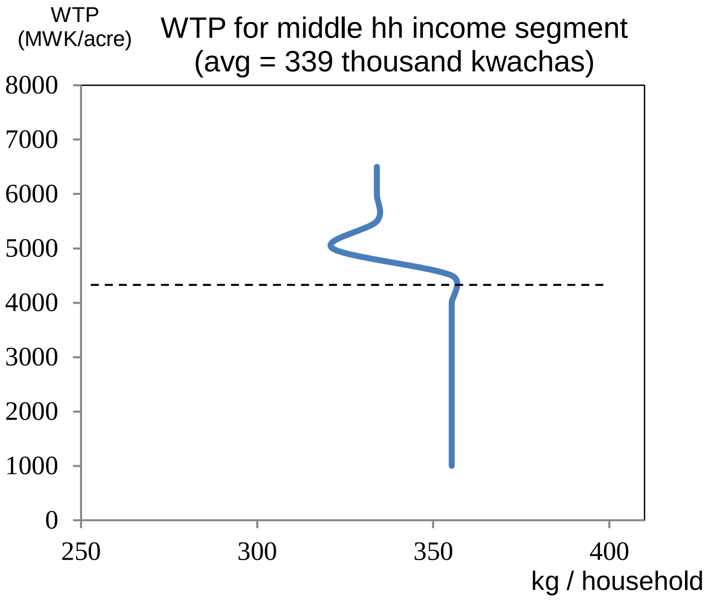

Figure 2 Demand curve for the lifter: middle income segment
Source: Authors' calculation with survey data

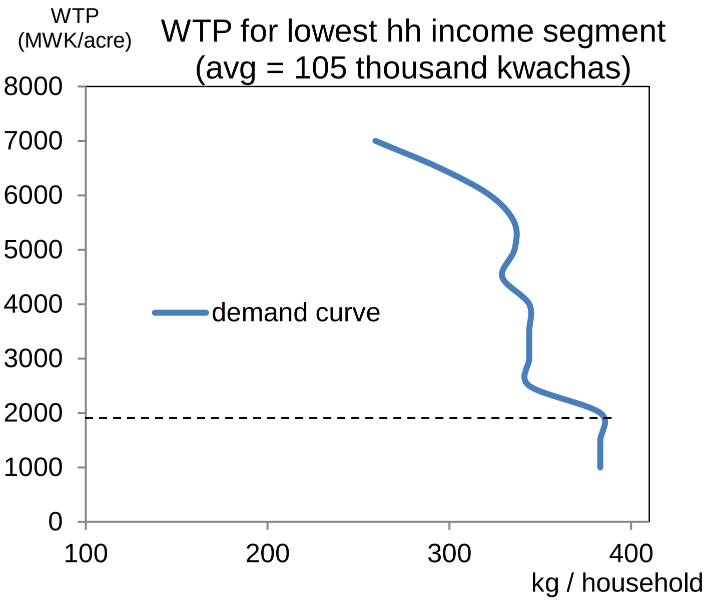

Figure 3 Demand curve for the lifter: lowest income segment
Source: Authors' calculation with survey data

The demand curves are generally downward sloping above the critical fee level in accordance with the theory of demand curves faced by monopolists as discussed by Falck-Zepeda et al. (2000) and Brown et al. (1999). However, the demand curve for the middle income segment was somewhat inelastic and kinked, suggesting that the decision to use the lifter may not be so price sensitive up to a certain price level. [6]

3.4.2. Stripper

Figures 3, 4, and 5 show the estimated demand functions for the stripper averaged among the highest, middle, and lowest income segments, respectively. The WTP for use of the stripper is expressed in terms of price per pail of groundnut harvest for which to use the equipment for stripping. The demand curves were generally of standard downward sloping shapes. The dotted lines indicate the revealed maximum fee that farmers can theoretically afford to pay for the service to strip their entire volume of groundnut harvest, which was approximately MWK 50, 80, and 50 for the highest, middle, and lowest income segments, respectively. This observation suggests that the income elasticity of demand was not necessarily positive, leaving a possibility of the service being an inferior good.[7]

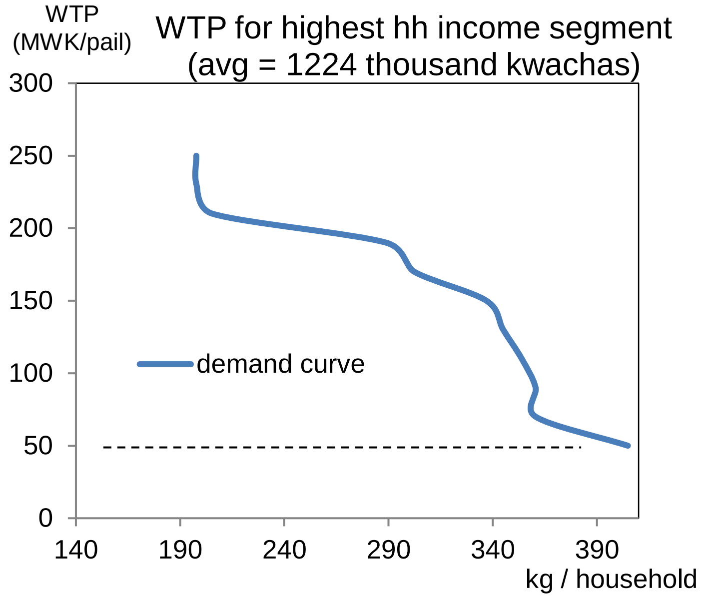

Figure 4 Demand curve for the stripper: highest income segment

Source: Authors' calculation with survey data

[6] Fraiture and Perry (2002) provide useful insights into how the demand for a certain agricultural technology can be inelastic.

[7] For characteristics and examples of inferior goods, see the discussions in Basker (2008) and Baruch and Kannai (2001).

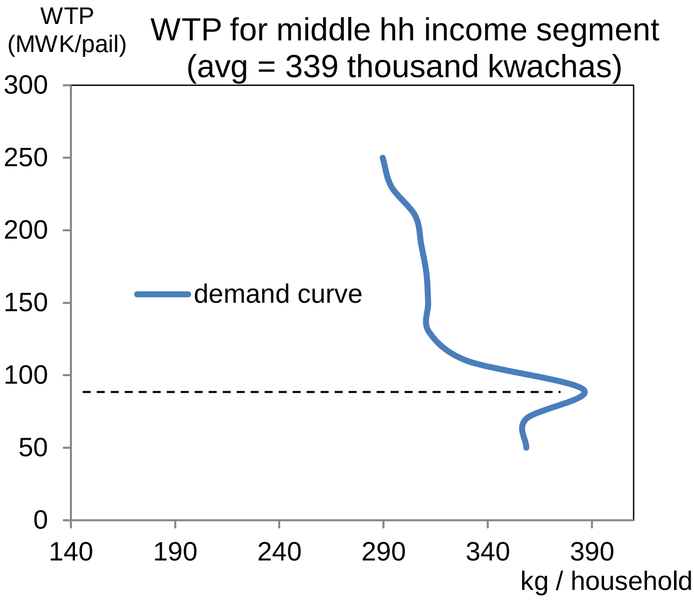

Figure 5 Demand curve for the stripper: middle income segment
Source: Authors' calculation with survey data

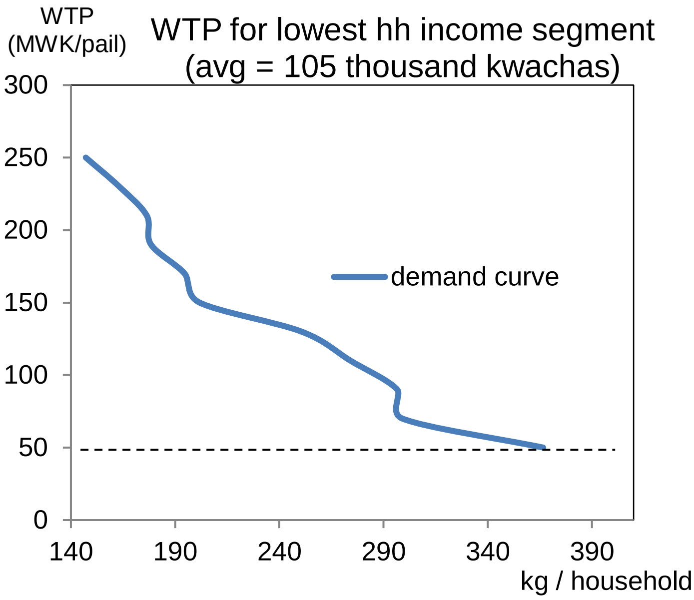

Figure 6 Demand curve for the stripper: lowest income segment
Source: Authors' calculation with survey data

3.4.3. Sheller

Figures 6, 7, and 8 presents the estimated demand functions for the sheller averaged among the highest, middle, and lowest income segments, respectively. The WTP for use of the sheller is expressed in terms of price per pail of stripped nuts for which to use the mechanized shelling. The demand curves were generally downward sloping, though there were some small upward sloping segments. The dotted lines indicate the revealed maximum fee that farmers in each income segment can theoretically afford to pay for the service to shell their entire groundnut volume, which was approximately, MWK 50, 73, and 35, respectively. Again, the income elasticity of demand was not necessarily positive.

Our on-field elicitation of lead farmers suggests that the fee for using the stripper will be set in the rage of MWK 50-100 per pail, indicating that the estimate from the revealed WTP was coherent.

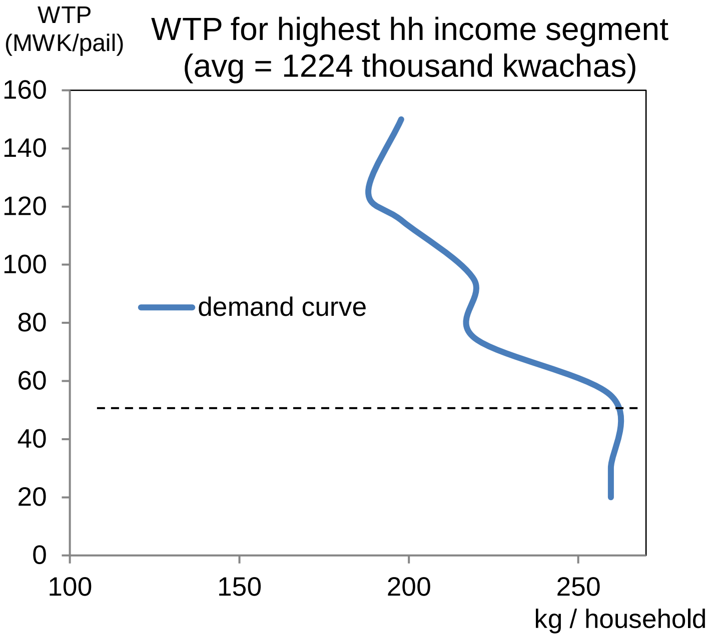

Figure 7 Demand curve for the sheller: highest income segment
Source: Authors' calculation with survey data

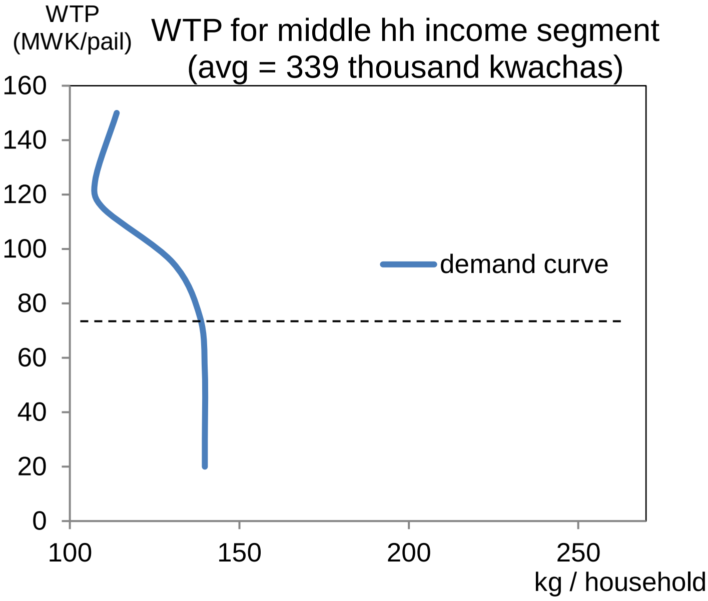

Figure 8 Demand curve for the sheller: middle income segment
Source: Authors' calculation with survey data

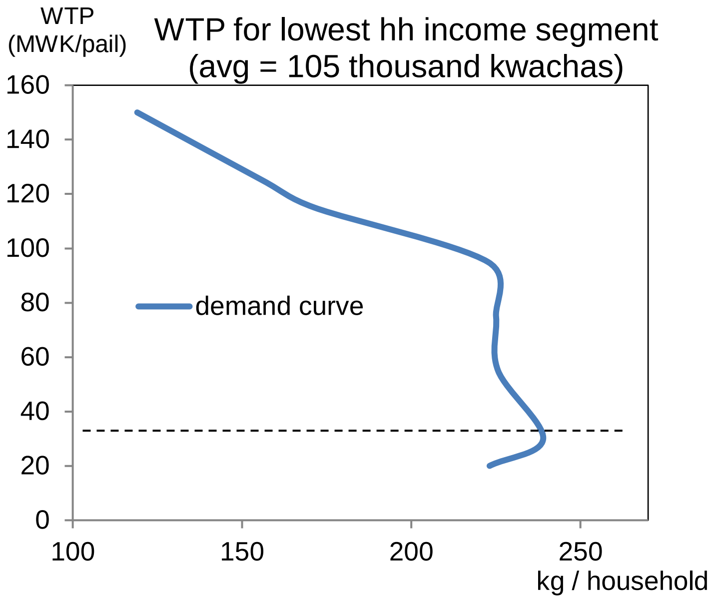

Figure 9 Demand curve for the sheller: lowest income segment
Source: Authors' calculation with survey data

3.5. Benefit-cost Simulation

This section conducts benefit-cost analysis of the business of lead farmers purchasing and renting out the equipment under the two different scenarios defined in Section 2.4. Based on the revealed WTP found in Sections 3.1-3.3, the fee for farmers to use each of the equipment is estimated to be MWK 2000 per acre, MWK 50 per pail, and MWK 35 per pail for the lifter, stripper, and sheller, respectively. The average number of members per farmer group under NASFAM and FUM was approximately 250 as of September 2016. The average groundnut harvest was 384 kg per household in the 2016 post-harvest season. Feeding these parameters in, Table 6 calculates the breakeven number of households per group and the return on investment (ROI). The breakeven number under the conservative scenario was 127, 37, and 218 for the lifter, stripper, and sheller, respectively, while under the base scenario it was 75, 22, and 129. The ROI was computed to be 14.6, 50.8, and 8.5 respectively under the conservative scenario, whereas it was 24.7, 85.7, and 14.4 under the base scenario. The breakeven numbers that are below the average farmer group size under NASFAM and the ROIs that are greater than one imply that investing in these technologies pays off even in a single post-harvest season if lead farmer(s) purchases the equipment and rents it out for their member farmers to use and pay the fee.[8] The ROI would certainly increase if we considered more than one seasons in the calculation. However, this still requires that the lead farmer(s) plan well and prepare cash for the purchase or have access to credit either from outside or within the community.

[8] While in reality the equipment can be used over multiple seasons, it is better to consider the short-term (i.e., one season) return in light of high subjective rates of time preferences among smallholders found for instance by Holden et al. (1998) and Lawrence (1991).

Table 6 Benefit cost analysis of the business of lead farmers purchasing and renting out the equipment in a single season.

	Parameters	Lifter	Stripper	Sheller
Common Parameters	Benefit Factors			
	Fee (MWK; per acre for lifter; per pail for stripper and sheller)	2,000	50	35
	Fee (MWK per kg) (a)	10.0	5.6	3.9
	Typical membership of a NASFAM farmer group (b)	250	250	250
	Cost Factor			
	Purchase cost (MWK) including VAT (c)	262,125	41,940	174,750
Conservative Scenario	Benefit Factors			
	Groundnut Production (kg): 2016 level with 30% loss (d)	268	268	268
	Average fee payment per household (a)x(d)	2,685	1,491	1,044
	Total max revenue per season (a)x(d)x(b)	671,136	372,853	260,997
	Cost Factors			
	30% maintenance per season (e)	78,638	12,582	52,425
	Total costs (c)+(e)	340,763	54,522	227,175
	Breakeven number of households [(c)+(e)]/[(a)x(d)]	127	37	218
	Return on Investment (ROI) [(a)x(d)x(b)-{(c)+(e)}]/[(c)+(e)]	1.0	5.8	0.1
Base Scenario	Benefit Factors			
	Groundnut Production (kg): 2016 level (f)	384	384	384
	Average fee payment per households (a)x(f)	3,835	2,131	1,491
	Total max revenue per season (a)x(f)x(b)	958,766	532,648	372,853
	Cost Factors			
	10% maintenance per season (g)	26,213	4,194	17,475
	Total costs (c)+(g)	288,338	46,134	192,225
	Breakeven number of households [(c)+(g)]/[(a)x(f)]	75	22	129
	Return on Investment (ROI) [(a)x(f)x(b)- {(c)+(g)}]/[(c)+(g)]	2.3	10.5	0.9

Sources: Authors' calculation with survey data.

3.6. Sensitivity Analysis

Although Table 6 sets the farmer group size to be 1,856, there are in fact many farmer groups that are smaller than that in terms of number of members. Figure 10 shows how ROI would change with farmer group size under the base scenario, holding other parameters constant. As the vertical axis represents the natural logarithm of ROI + 1, the value of zero indicates the breakeven point. The critical values of the horizontal axis at the three intersections are consistent with the values in Table 6. Overall, it is suggested that the farmer group size being greater than 130 will make the business profitable and meet the breakeven point within a single season.

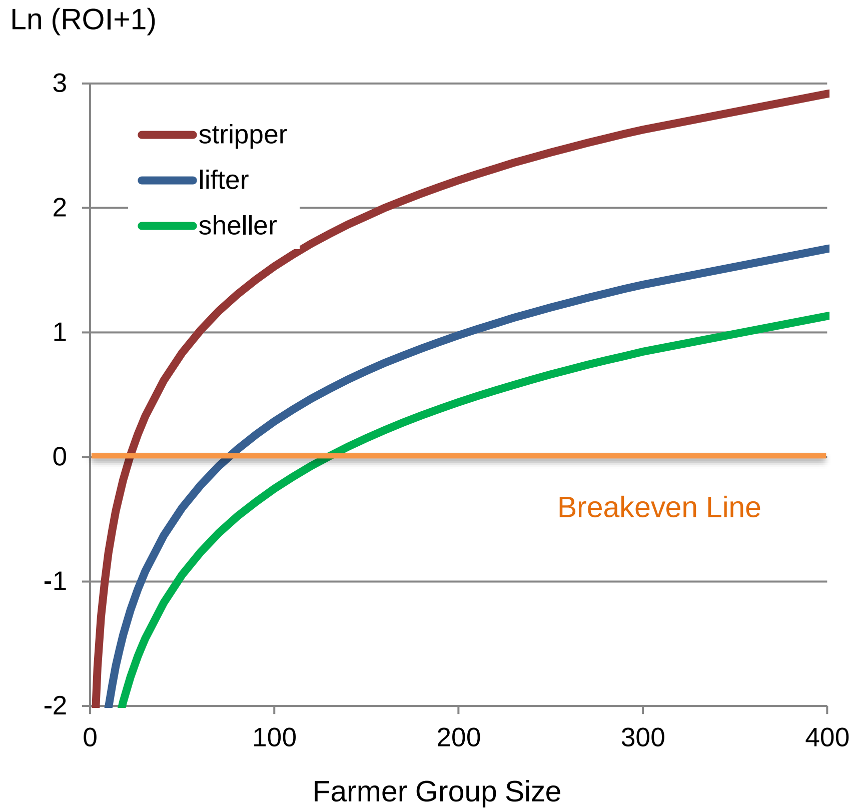

Figure 10 Farmer group size and return on investment (ROI)
Source: Authors' calculation with survey data

Although the service fee was determined based on the WTP elicitation and it was somewhat consistent with information obtained from selected lead farmers, it had some range, admittedly. In this regard, the next sensitivity analysis is to see how changes in service fee would affect the ROI. Figure 11 illustrates how the ROI for lead farmers would change according to altering levels of fees by setting the farmer group size to be 250 as in Table 6. Since the levels and unit of fees differ among the three technologies, percentage changes are adopted on the horizontal axis. It is shown that the ROI (or Ln (ROI+1)) would remain above zero even with fees of 10 % of the WTP-based fee in the case of the stripper, while it needs to be about 50 % of the WTP-based fee in the case of the sheller.

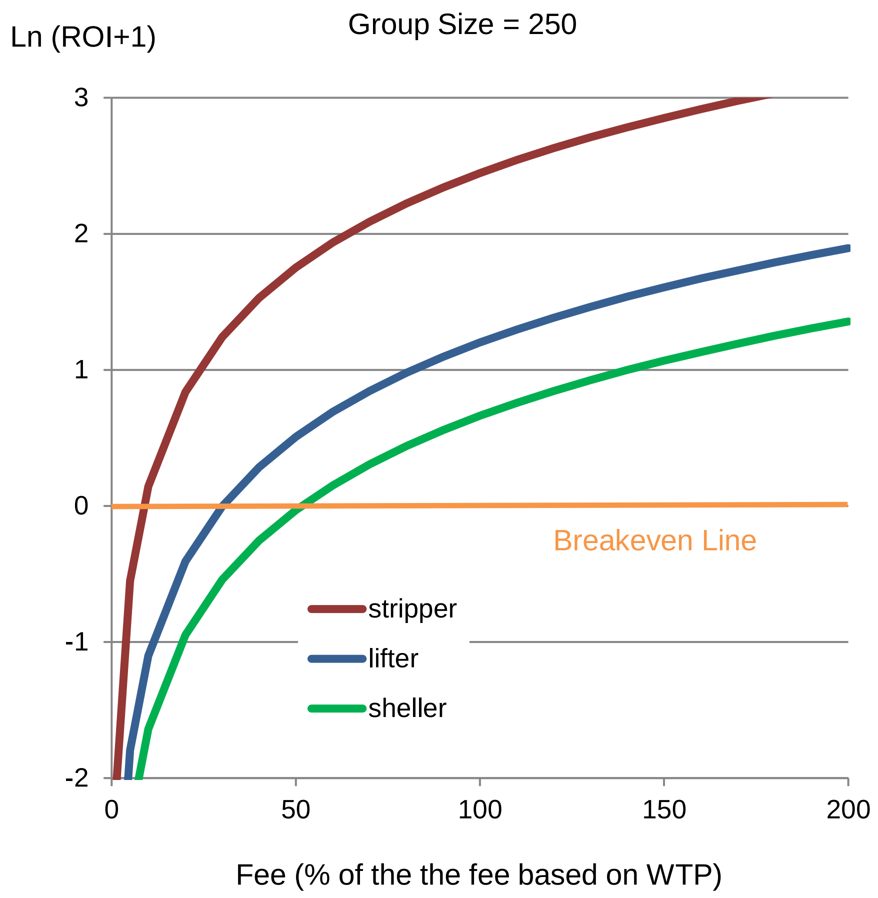

Figure 11 Fee (pay per use) and return on investment (ROI): Group size = 250
Source: Authors' calculation with survey data

4. Discussion

The study conducted ex-ante assessment of adoption of the post-harvest technologies, namely, CTI groundnut lifter, stripper, and sheller in smallholders' communities through two-stage analysis: acquisition by lead farmers and use by smallholders. Smallholders' WTP for using the technologies was elicited using a survey method and fed into the benefit-cost analysis for the lead farmers. The result showed that lead farmers' investment in purchasing these technologies can be recovered in a single post-harvest season in general. The sensitivity analysis indicated that the profitability remained positive when altering the assumptions on group size and fees for using the equipment to a large extent.

Our quantitative findings and qualitative insights however imply that three conditions need to be met for these technologies to be successfully and sustainably adopted. First, farmers need to be organized into a group. Since each one of the smallholders cannot afford buying the equipment, there need to be lead farmers who acquire the equipment and rent it out for their member farmers to use the equipment. While farmers under NASFAM and FUM are relatively organized, the farmers outside these farmer organizations are not necessarily organized or are formed into much smaller groups. Second, lead farmers need to receive training on business skills and mindset, since we observed that lead farmers tended to think of repaying using the crop produce, not the fees collected from smallholders. It needs to be emphasized that these technologies are not just to reduce drudgery at the cost of money, but to bring profit to those lead farmers by collecting minimal fees from member farmers. Third, since farmers usually do not have access to external loan facilities, and suppliers of the equipment are not equipped with loan providing functions or capacities, lead farmers need to have access to credit within the communities if cash purchase is a challenge. It was found that most farmer groups operated a system of village savings loan (VSL) or some other community level credit scheme. Nonetheless, they need to plan ahead and arrange to gain approval from community steering committees in order to avail of such community level credit schemes. For that, proactive and hands-on involvement of the lead farmers will be essential.

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