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# Testing Integrated Food Energy Systems: Improved Stoves and Pigeon Pea in Southern Malawi

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## Executive Summary

Between 2007-2010 Concern, Universal distributed energy-efficient stoves to 9,000 smallholders in Balaka district, southern Malawi, as part of Msamala Sustainable Energy Project (MSEP) funded by the European Union. Households that purchased a stove each received a gift of 3 kg of pigeonpea seed for the variety *Mthawajuni,* which produces thick and bushy stems. In combination, energy-efficient stoves and pigeonpea formed an Integrated Food Energy System (IFES) that can reduce demand for fuel-wood, increase the supply of fuel-wood from pigeonpea stems, and improve household food security and nutrition by providing pigeonpea grain. This report summarises the results of an evaluation of this IFES.

A household survey was conducted in the 2010/11 cropping season to determine the impacts on demand for fuel-wood, household food security, cash income, and on soil health and fertility. The results are based on a random sample of 230 households from seven villages in Balaka district, comprising 115 households that purchased an energy-efficient stove, and a control group of 115 households using traditional stoves. The survey covered a period of three cropping seasons between 2008/09 and 2010/11.

*Food security:* Between 60-70% of pigeonpea, grain harvested was kept for home consumption. The average quantity consumed was 40 kg/household. Among households growing pigeonpea, nine in ten households fed the grain to children under five compared to only two in ten households that did not grow pigeonpea.

*Cash income:* About 30% of pigeonpea harvested was sold to generate cash income. Fifty-seven per cent of households growing pigeonpea ranked it as their first or second-most important cash crop. The average value of pigeonpea sold ranged from 500 - 1,612 Mk/year ($2 - 11). However, the total value of pigeonpea grain was similar to or less than the value for pigeonpea stems. In 2010/11, the value of pigeonpea grain was only 45% of the value of stems used for fuel.

*Soil health and fertility:* Households that had intercropped pigeonpea with maize over three seasons were significantly more likely to observe bigger maize cobs and higher yields for maize, as well as positive impacts on soil health such as improved water filtration and less compacted soils.

*Adoption of energy efficient stoves:* Households were more likely to buy energy-efficient stoves if they were better-off rather than poor, if they lived far from forests and hills where fuel-wood was available, if they believed that fuel-wood was scarce, and if women had an important role in decision-making. However, the decision to purchase was not significantly related to actual fuel-wood consumption.

*Frequency of fuel-wood consumption:* In combination, energy-efficient stoves and pigeonpea reduced the frequency of fuel-wood collection and purchase by 48%. On average, the use of pigeonpea stems for fuel saved households MK 3,000 ($20) per year. This confirms their effectiveness in reducing pressure on natural resources. However, households that sourced fuel-wood from their own trees or from village woodlots reduced the frequency of fuel-wood collection and purchase by 81%.

*Quantity of fuel-wood consumption from forests and hills:* Households collected an average of 66 kg of firewood per month from nearby forests and hills. The quantity of pigeonpea harvested reduced the quantity of firewood collected, but the difference was not statistically significant. Contrary to expectation, the quantity of fuel-wood collected from this source was *higher* for households that owned energy-efficient stoves. This does *not* mean that improved stoves caused households to increase consumption of fuel-wood. As we have seen, improved stoves reduced fuel-wood consumption.  A more likely explanation for this result is that the incentive to buy an energy-efficient stove was higher for households that consumed more fuel-wood. While the purchase of improved stoves has reduced fuel-wood consumption among buyers, the reduction has not been big enough to reduce the consumption of fuel-wood to the level found among other groups. As a result, buyers of improved stoves remain the biggest consumers of fuel-wood from hills and forests.

*Conclusion:* Pigeonpea has had positive impacts on household food security, cash income and soil health and fertility. Energy efficient stoves and pigeonpea as fuel have also reduced the frequency of buying and collecting fuel-wood. However, the main buyers of energy-efficient stoves are better-off households that are also the biggest consumers of fuel-wood. While the introduction of the IFES has reduced consumption of fuel-wood among this group, consumption remains high. Targeting the IFES at better-off households will have the greatest impact on fuel-wood conservation at the household level. However, since the majority of households are poor, purchase of improved stoves by poorer households may have a greater overall impact on fuel-wood conservation.

***Keywords:*** Fuel-wood, Pigeonpea, Stover, Household energy, Drylands, Technological change

**JEL classification**: O330

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# 1 Introduction

Integrated Food Energy Systems (IFES) may be defined as a combination of interventions that simultaneously address the demand for both energy and food. Smallholder agriculture provides many examples of simple IFES. However, competing demands between food, energy, and maintaining soil fertility limit the potential of traditional IFES in smallholder agriculture. High rates of population growth and pressure on natural resources have increased competition between alternative uses. This highlights the need for innovative IFES that will reduce the demand for energy in rural areas and increase the supply of fuel available from alternative sources.

The need for innovative IFES is particularly acute in southern Malawi, where high population density (185 persons/km$^2$) and small average farm size (0.6 ha$^{-1}$) have increased pressure on the natural resource base. Manure is scarce because ownership of livestock is below the regional average (Ellis *et al*., 2003). Scarcity of alternative fuels means that 95% of rural households rely on fuel-wood for cooking. Biomass (chiefly wood and charcoal) accounts for an estimated 93% of energy consumption (GoM, 2003). Although fuel-wood is no longer believed to be the main cause of de-forestation in Malawi, it remains an important contributory factor (Arnold *et al.,* 2006). Moreover, sourcing fuel-wood is time-consuming. Households in Ntcheu district in Malawi's central region spend 6-8 hours/week collecting fuel-wood for cooking (Brouwer *et al.,* 1997).[1]

Improved or energy-efficient stoves have a long history of research and extension in developing countries. Despite reducing expenditure on fuel, however, adoption of improved stoves remains limited and the majority of rural households continue to use traditional models. Experience suggests that successful programs have targeted areas where fuel-wood prices or collection times are high, where local artisans can manufacture stoves, and where distribution is profitable for the private sector (Barnes *et al*., 1993; Hyman, 1987). In Malawi, improved stoves have been developed and promoted both by government agencies and bilateral projects. The Integrated Food Security Programme (IFSP) in Mulanje district, southern Malawi (1997-2004) developed the *chitetezo mbaula* ('the protecting stove' in Chichewa) based on designs imported from Kenya and Tanzania. The *chitetezo mbaula* is a fired, portable clay stove that can be made by village artisans. Tests demonstrated that this model reduced fuel-wood consumption by an average of 40% over the traditional three-stone stove, while saving of collected or purchased firewood up to 80% was possible when complemented with crop-residues (Roth, 2003). By 2004, over 10,000 households in the project area in Mulanje district had acquired improved stoves.

Pigeonpea (*Cajanus cajan* L. Millsp.) is a grain legume widely grown in the tropics and subtropics. The grain may be eaten either cooked or as raw pods, or sold to earn cash income. An estimated 1.6 million households in Sub-Saharan Africa (SSA) grow pigeonpea (Abate *et al.,* 2012). Malawi was formerly the world's largest exporter of pigeonpea but its share of the world market has fallen because of yield losses from Fusarium wilt. Pigeonpea in Malawi is harvested in July-August, allowing exports to reach Bombay when prices are

[1] The Integrated Household Survey gives a figure of 1.5 hours/week collecting firewood for persons aged 15 and over (GoM, 2005: Table 5.5 p. 59).

highest before the Indian harvest in October. Pigeonpea is exported both in the form of dry grain and as de-hulled and split grain (*dhal*) by Asian processor companies. Net trade is estimated at 31,000 t per year (Abate *et al.,* 2012). However, only one-quarter of production is exported. Growing demand from Indian consumers provide an opportunity to increase exports. India's imports of pigeonpea are projected to reach to 636,000 t by 2020 (Abate *et al.,* 2012). However, inefficiencies in the value-chain for pigeonpea result in low prices and reduce the incentive for Malawian farmers to increase production to meet this growing demand (Makoka, 2004).

Crop improvement for pigeonpea in Malawi has focused on developing improved varieties with higher grain yield, resistance to Fusarium wilt, market traits such as white, bold grains, and medium field duration. Field duration of pigeonpea is controlled by temperature and sensitivity to photoperiod. In southern Malawi, medium-duration varieties flower in May-June. This allows pigeonpea to be harvested after the harvest of maize in March-April and escape late-season drought. Between 2000 and 2010 the Department of Agricultural Research officially released nine improved varieties in Malawi. Two varieties (ICEAP 00557 and ICEAP 1514/15) are medium-duration (150-200 days) and considered suitable for southern and central Malawi. Recently, smallholders have replaced both improved and traditional pigeonpea with a variety known as *Mthawajuni*. The provenance of *Mthawajuni* is not known but it seems likely to be an advanced line that 'escaped' from a research trial in the 1990s. *Mthawajuni* owes its popularity to its early maturity (*Mthawajuni* means 'escapes cold' in Chichewa), high grain yield, and bushy stems that make it a valuable source of fuel-wood. Pigeonpea is 1-2 m tall when harvested annually but when grown as a perennial plant stems may reach a height of 3-4 m. Breeders have not considered the quantity of biomass produced by stems when selecting improved varieties. However, for smallholder households without ready access to fuel-wood this may well be a desirable trait.

The focus of this report is on an innovative IFES tested with smallholders in southern Malawi, which formed part of the Msamala Sustainable Energy Project (MSEP), a five-year project (2007-2012) funded by the European Union and Foundation Ensemble and implemented by Concern Universal (CU), an international Non-Governmental Organisation (NGO). Msamala Traditional Authority (TA) was selected as the project location because of the increasing number of unsustainable businesses based on extraction of energy and natural resources. The project objective was more sustainable access to and use of fuel wood energy. CU promoted an IFES that combined the use of improved, energy-efficient stoves and the use of pigeonpea stems for fuel. Over three years (2008-2010) approximately 9,000 stoves were produced by groups of village artisans and purchased by smallholders at a retail price of MK 300 (USD $2). In addition, households that participated in project activities were rewarded with free seed of *Mthawajuni*. In 2008/09, the project distributed 2 kg of pigeonpea seed each to 3,000 households that participated in its tree nursery programmes. In 2009/10, the project distributed 3 kg of pigeonpea seed each to 6,000 households that had purchased an energy-efficient stove. In total, 24(MT) of seed was distributed to 9,000 smallholder households. In combination, improved stoves and pigeonpea were expected to simultaneously increase the supply of food and reduce the demand for scarce fuel-wood.

The general objective of this report is to evaluate the performance of this IFES over a three-year period (2008-2010). The specific objectives are to:

1. Measure the effects of pigeonpea on household food security, income, and soil health;
2. Identify the determinants of adoption of energy-efficient stoves; and
3. Measure the effects of energy-efficient stoves and pigeonpea on fuel-wood consumption.

# 2. Data and Methods

Research was conducted in Balaka district, central region. Balaka district falls within the Middle Shire Valley Livelihood Zone (FEWS, 2005). Rainfall is unimodal ranging from 200-1000 mm per year and there is a single growing season. The farming system is maize-based with legume intercrops. Traditionally, pigeonpea is not widely grown because the long field duration of local varieties exposes them to the risk of yield loss from free grazing after the harvest of maize. Poverty is high, with 67% of the population living below the $1 per day poverty line compared to an average 58% for rural Malawi (GoM, 2006).

## 2.1 Household survey

### 2.1.1 Questionnaire

A questionnaire was designed by ICRISAT and discussed with by Christa Roth with villagers in Mponda village, Mulanje district, on 29 July 2011. The first version was pre-tested on 21 August with a core team of four CU field facilitators, and the questionnaire was revised. Eleven field facilitators were trained in the revised questionnaire on 21 August 201, which was then pre-tested in Balaka district. A revised version was then developed in collaboration with ICRISAT and FAO. The survey was conducted in November 2011 after the harvest of the 2010/11 pigeonpea crop.

### 2.1.2 Sampling

The villages where households had received pigeonpea seed from CU in 2008/2009 were listed. A sample of nine villages was then selected, based on whether the village was far or near the hills and forest reserve that provides the main source of fuel-wood for the area. Next, the households in these villages were listed. A random sample of households that had received seed from CU in 2008/09 and that had purchased energy-efficient stoves was then selected. A matching random sample of households that had not received seed was selected from the same village. Table 1 shows the distribution of sample households by village and distance from the major source of fuel-wood. A total of 230 households from nine villages were surveyed, of which 75 (33%) were far from hills and forest.

**Table 1: Sample households**

| Village | Traditional Authority (TA) | Distance to firewood from forest: Near (< 1 hr ) | Distance to firewood from forest: Far (> 1 hr) | Total households |
|---|---|---|---|---|
| Lindadi | Chanthunga | 14 | | 14 |
| Mponda | Msamala | 48 | | 48 |
| Njanja | Msamala | 1 | | 1 |
| Sungani | Chanthunga | 44 | | 44 |
| Thapaniwa | Msamala | 48 | | 48 |
| Mchenga | Msamala | | 33 | 33 |
| Mpilisi | Msamala | | 6 | 6 |
| Mponda | Msamala | | 1 | 1 |
| Mpulula | Msamala | | 35 | 35 |
| | | 155 | 75 | 230 |

### 2.1.3 Analytical methods

The data were entered using Excel and analysed using SPSS Version 19. The data was analysed using cross-tabulation. The Chi-Square test and ANOVA were used to test for significant differences between groups. Multivariate regression was used to analyse variables determining the adoption of energy-efficient stoves, the frequency of fuel-wood consumption, and the quantity of fuel-wood sourced from hills and forests. Since adoption is a dichotomous variable (0, 1), we used logit regression, while the frequency and quantity of fuel-wood consumption was estimated by linear regression using Ordinary Least Squares (OLS).

## 2.2 Pigeonpea stem biomass

A separate plot survey was made to measure the quantity of fuel-wood produced by pigeonpea stems. From the 115 households in the sample that had received pigeonpea seed in 2008/09 and that had bought an energy-efficient stove, 120 fields planted to (intercropped) pigeonpea were surveyed. Ten pigeonpea plants from the field were randomly selected by throwing a stone over the shoulder and selecting the plant where the stone landed. Each of the 10 selected plants was marked by red paint. Farmers were asked not to pick green pigeonpea from these 10 marked plants but to harvest only the mature grain. At harvest all the grain (not the pods) from these 10 plants were put into a separate bag, and the stems left in the field. The grain and stems were weighed, and converted to dry weight. A random inspection of plots made at the end of July confirmed that farmers were aware of the need to harvest grain and stems separately for the selected plants. The scales available to measure grain and biomass were accurate to nearest 20 grams. Informal testing in Mulanje showed that improved pigeonpea gave stem biomass of 80 kg/ha. Local gave stem biomass of 800 kg/ha (Christa Roth, pers. comm.)

## 2.3 Weight of firewood

The average weight of one bundle of firewood was measured by weighing 10 bundles of firewood for sale in Balaka market. All the fuel-wood sampled was indigenous wood sourced from hills and forests. The mean weight was 9.396 kg/bundle (standard deviation 3.039) and the mean price per bundle was MK 115. The average price of a bag of charcoal in Balaka market at the time of the survey was Mk 500.

# 3. Results

## 3.1 Treatment and Control Groups

The original sampling design assumed that the analysis could be made using two groups:

1. A “Treatment” Group, comprising households that had bought an energy-efficient stove and that had received seed from CU in 2008/09.
2. A “Control” Group, comprising households that had not bought an energy-efficient stove and that had not received seed from CU in 2008/09.

However, this simple division proved not to be feasible because:

1. Five households in the Treatment Group did not grow pigeonpea in 2010/11 while 56 households in the Control Group did;
2. Seven households in the Control Group had received pigeonpea from CU in 2010/11 but did not own an energy-efficient stove;
3. The Control Group was found to contain a mix of rich and poor households which made it difficult to obtain meaningful results when compared with the Treatment Group.

The Treatment Group was therefore re-defined as “households that owned an energy-efficient stove and that grew pigeonpea in 2010/11”. The Control Group comprised all households that did not own an energy-efficient stove, and was divided into two sub-groups: those that did and those that did not grow pigeonpea in 2010/11.

Table 2 shows the number of sample households in these Treatment and Control groups. For the Control Group, there was a significant difference between the two sub-groups. Households that grew pigeonpea were more likely to be located far from sources of firewood in the hills or forests.

**Table 2: Treatment and Control groups**

| Variable | Yes (Treatment) | No (Control) | | Total |
|---|---|---|---|---|
| | | No improved stove + pigeonpea | No improved stove + no pigeonpea | |
| Households that own energy-efficient stove and that grew pigeonpea in 2010/11 | 115 (50.0) | 56 (24.3) | 59 (25.7) | 230 (100.0) |
| Of these: | | | | |
| Households that received pigeon pea seed from Concern Universal in 2008/09 | 110 (95.7) | 7 (12.9) | 0 (0.0) | 117 (50.9) |
| Households that live near to firewood from forests (< 1 hour walk) | 82 (71.3) | 22 (37.3) | 51 (91.1) | 155 (67.4) |
| Households that live far from firewood from forests (> 1 hour walk) | 33 (28.7) | 37 (62.7) | 5 (8.9) | 75 (32.6) |

## 3.2 Socio-economic profile

Table 3 provides a socio-economic profile for the sample households. The results showed significant differences between the Treatment and Control Groups. Closer inspection of the Control Group shows that these differences were found in one of the two sub-groups, namely the sub-group with no improved stove and no pigeonpea in 2010/11. Households in this sub-group had smaller households, had a smaller maize harvest, fewer meals per day during the hungry period, and were more likely to earn cash income from casual labour (*ganyu*). These variables are often used as proxy indicators for poverty in Malawi. This sub-group, without an improved stove and without pigeonpea, most likely represents the poorest households in the sample.

**Table 3: Socio-economic profile of treatment and control households**

| Variable | Total (n=230) | Treatment (n=115 ) | Control (n=115) No improved stove + pigeonpea (n=56) | Control (n=115) No improved stove + no pigeonpea (n=59) | Significance-Level (*p* > ) |
|---|---|---|---|---|---|
| Female-headed households (no.) | 168 | 85 | 47 | 36 | 0.171 |
| Household size (no.) | 4.90 | 5.01 | 5.22 | 4.37 | 0.037 |
| Adult males (no.) | 1.46 | 1.43 | 1.64 | 1.41 | 0.232 |
| Adult females (no.) | 1.45 | 1.46 | 1.67 | 1.24 | 0.011 |
| Male children aged 5-14 (no.) | 1.50 | 1.44 | 1.68 | 1.50 | 0.428 |
| Female children aged 5-14 (no.) | 1.55 | 1.73 | 1.27 | 1.38 | 0.029 |
| Male children aged under 5 (no.) | 1.15 | 1.13 | 1.13 | 1.15 | 0.971 |
| Female children aged under 5 (no.) | 1.15 | 1.10 | 1.25 | 1.17 | 0.549 |
| Household heads with primary education (no.) | 147 | 80 | 34 | 33 | 0.201 |
| Household heads with secondary education (no.) | 17 | 4 | 5 | 8 | 0.038 |
| Farm size (acres) | 2.58 | 2.77 | 1.88 | 2.91 | 0.001 |
| Area planted to maize in 2010/11 (acres) | 1.62 | 1.66 | 1.50 | 1.67 | 0.373 |
| Maize harvested in 2010/11(bags) | 11.78 | 14.3 | 10.50 | 7.81 | 0.000 |
| Maize yield in 2010 (kg/ha) | 929 | 1054 | 951 | 657 | 0.000 |
| Households self-sufficient in maize (no.) | 26 | 17 | 6 | 3 | 0.117 |
| Month start buying additional maize | July | June | July | July | 0.480 |
| Meals/day during lean period (no.) | 2.04 | 2.17 | 2.12 | 1.80 | 0.008 |
| Sources of cash income (mean rank) | | | | | |
| Crops | 1.20 | 1.15 | 1.25 | 1.25 | 0.404 |
| Livestock | 0.39 | 0.57 | 0.05 | 0.36 | 0.001 |
| Trading/business | 0.41 | 0.39 | 0.56 | 0.29 | 0.119 |
| Salary | 0.07 | 0.03 | 0.15 | 0.07 | 0.090 |
| Casual labour *(Ganyu)* | 0.89 | 0.83 | 0.56 | 1.34 | 0.001 |
| Remittances | 0.04 | 0.04 | 0.03 | 0.05 | 0.943 |
| Other | 0.04 | 0.05 | 0.07 | 0.00 | 0.379 |

## 3.3 Pigeonpea cultivation

### 3.3.1 Cropping practices

Table 4 shows important cropping practices for pigeonpea over the period of three crop seasons. The quantity of seed ranged from 2.40 to 2.15 kg per household, and the average area planted from 0.69 to 0.70 acres. At the recommended seed rate of 2.43 kg $acre^{-1}$, the 2.5 kg of seed that growers used in 2010/11 was enough to plant 1.03 acres of pigeonpea. The actual area planted was 0.7 acres. Based on these figures, therefore, farmers' planted pigeonpea more densely than recommended.[2] Most pigeonpea was intercropped either just with maize or with maize and other intercrops such as beans, cowpeas, or pumpkins, with very little planted in pure stand.

**Table 4: Cropping practices for pigeonpea, for households growing pigeonpea in that year**

| | 2008/09 (n=129) | 2009/10 (n=133) | 2010/11 (n=160) |
|---|---|---|---|
| Seed quantity (kg) | 2.40 | 2.37 | 2.15 |
| Pure stand (acres) | 0.06 | 0.06 | 0.05 |
| Intercropped with maize (acres) | 0.30 | 0.30 | 0.32 |
| Intercropped with maize and other crops (acres) | 0.33 | 0.34 | 0.32 |
| Total area planted to pigeonpea (acres) | 0.69 | 0.70 | 0.69 |
| Boundary planting (no. of plots) | 0.0 | 0.0 | 0.0 |
| Seed rate for pigeonpea (kg/acre) | 3.47 | 3.39 | 3.12 |

### 3.3.2 Reasons for growing pigeonpea

Households were asked to rank the three main reasons why they grew pigeonpea (Table 5). Of the 150 households that grew pigeonpea in 2010/11, 113 households (75%) ranked "grown for food" as the most important reason. Cash income and fuel received equal ranking (53% of households), while only six households (4%) ranked soil improvement as an important reason for growing pigeonpea.

[2] The recommended seed rate for pigeonpea for either pure stand or intercropped in Malawi is 6 kg $ha^{-1}$. This is equivalent to a seed rate of 2.43 kg $acre^{-1}$. The expected plant population for intercropped pigeonpea is 37,000 plants $ha^{-1}$ at 90 cm ridge spacing (MOALD, 1994: 68).

**Table 5: Reasons for growing *Mthawajuni* variety, for all households growing this variety in 2010/11 (n=140)**

| No. | Reason for preference | Households reporting | |
|---|---|---|---|
| | | Number | Percent of total households |
| 1 | Mature faster | 140 | 100 |
| 2 | Red variety produces most fuel-wood | 127 | 91 |
| 3 | Higher yield | 69 | 49 |
| 4 | Other | 21 | 15 |
| 5 | Better Taste | 6 | 4 |

### 3.3.3 Reasons for growing Mthawajuni variety

Most households in the sample grew *Mthawajuni,* the variety of pigeonpea first distributed by CU in 2008/09. Households were asked to give their reasons for liking this variety(Table 6). Of the 140 households that grew *Mthawajuni* in 2010/11, the most popular reason was that it was quicker to mature than other varieties (100% of households). However, only half (49%) of those growing *Mthawajuni* reported that it gave higher yields than other varieties, while only six households (4%) reported that it had a better taste. The majority of households (91%) believed that *Mthawajuni* produced more fuel-wood.

**Table 6: Reasons for growing pigeonpea (all households growing pigeonpea in 2010/11) (n=150).**

| Reason for preference | Rank (1 = Highest) | | | Households ranking 1-3 | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | Number | Percent of total households |
| Food | 113 | 31 | 6 | 150 | 100 |
| Cash income | 26 | 69 | 25 | 120 | 80 |
| Fuel | 11 | 48 | 60 | 119 | 79 |
| Soil | 6 | 10 | 10 | 26 | 17 |

## 3.4 Pigeonpea benefits

### 3.4.1 Household food security

All the households that grew pigeonpea at some point in the past three seasons were asked how they had used the grain. Table 7 reports the results for the Treatment Group. The quantity of pigeonpea harvested ranged from 1.57 bags in 2008/09 to 0.98 bags in 2010/11. It is unclear why the quantity of pigeonpea harvested declined over the three-year period. . This may have been due to a decline in the availability of seed for planting (Table 4) or to farmers re-cycling seed resulting in loss of purity and vigor. Households retained about 70% of the pigeonpea harvested for food, while only 30% was sold. This is consistent with the earlier finding that farmers grew pigeonpea primarily for food rather than for cash income (Table 6). Over the three-year period, the price of pigeonpea grain fell by one-quarter, from 52 MK/kg in 2008/09 to 39 Mk/kg in 2010/11. Consequently, the value of pigeonpea grain harvested in 2010/11 was only MK 1346.

**Table 7: Use of pigeonpea grain by treatment households, 2008-2011(n=115)**

| Variable | 2008/09 | 2009/10 | 2010/11 |
|---|---|---|---|
| Households planting pigeonpea (no.) | 115 | 94 | 115 |
| Pigeonpea harvested (50 kg bags) | 1.57 (= 101) | 1.13 (n=85) | 0.98 (n=97) |
| Quantity consumed (50 kg bags) | 0.95 (n=93) | 0.81 (n=76) | 0.69 (n=90) |
| Quantity sold (50 kg bags) | 0.62 | 0.32 | 0.29 |
| Share consumed (%) | 63 | 72 | 70 |
| Average price (MK/kg) | 52 | 54 | 39 |
| Value of cash sales (MK) | 1,612 | 864 | 566 |
| Value of harvest (MK) | 4082 | 2187 | 1346 |

Pigeonpea was eaten in various ways (Table 8). The most common method was to cook pigeonpea together with sweet potato or cassava. Another common dish was *makata*, where pigeonpea was cooked and eaten while the pods were still green. Another common dish was *makata*, where pigeonpea was cooked and eaten while the pods were still green. Consumption of these dishes was significantly higher for households that grew pigeonpea. Among households that did not grow pigeonpea, very few ever bought it. Of the 174 households that grew pigeonpea, 75 had children 5 years of age or under. Of these 75 households, 68 (91%) fed pigeonpea to their under-five children. By contrast, of the 22 households that did not grow pigeonpea, only five (23%) fed pigeonpea to their under-five children. This suggests that pigeonpea has improved nutrition for under-fives.

**Table 8: Use of pigeonpea as food, all households**

| Pigeonpea use | Households growing pigeonpea (n=174) | Households not growing pigeonpea (n=56) | Significance-Level (*p* > ) |
|---|---|---|---|
| Do you yourself like pigeonpea ? | 174 (100.0) | 40 (71.4) | 0.000 |
| How is pigeonpea eaten? | | | |
| With *mbatata* or cassava in one pot | 169 (97.1) | 15 (26.8) | 0.000 |
| As *makata* | 134 (77.0) | 10 (17.9) | 0.000 |
| With green pods | 72 (41.4) | 5 (8.9) | 0.000 |
| Separately as relish | 1 (0.6) | 0 (0.0) | 0.757 |
| Households with children under five | 75 (43.1) | 22 (39.3) | 0.366 |
| Households feeding pigeonpea to children under five* | 68 (90.7) | 5 (22.7) | 0.000 |

* For households with children under five

### 3.4.2 Cash income

Households were asked to rank the importance of the crops that they sold to earn cash income (Table 9). Among the 230 sample households, the three highest ranked cash crops were cotton (122 households), pigeonpea (97 households) and maize (39 households). Among the households in the Treatment Group, however, the most important cash crop was pigeonpea (57% ) followed closely by cotton (51%) and then by maize (22%).

**Table 9: Most important cash crops (no. of households ranking 1 or 2)**

| Crop and number of households growing | Households (n=230) | | Treatment (n=115 ) | Control (n=115) | | Significance-Level (*p* > ) |
|---|---|---|---|---|---|---|
| | Growing | Ranking it 1 or 2 as a cash crop | Improved stove + pigeonpea | No improved stove + pigeonpea (n=56) | No improved stove, no pigeonpea (n=59) | |
| Cotton | 129 | 122 (94.5) | 59 (51.3) | 13 (22.0) | 51 (91.1) | 0.000 |
| Pigeonpea | 170 | 97 (57.1) | 66 (57.4) | 31 (52.5) | 0 (0.0) | 0.000 |
| Maize | 228 | 39 (17.1) | 25 (21.7) | 7 (11.9) | 7 (12.5) | 0.154 |
| Groundnuts | 120 | 37 (30.8) | 11 (9.6) | 15 (25.4) | 11 (19.6) | 0.019 |
| Cowpeas | 85 | 23 (27.1) | 12 (10.4) | 1 (1.7) | 10 (17.9) | 0.015 |
| Sweet potato | 64 | 14 (21.9) | 4 (3.5) | 7 (11.9) | 3 (5.4) | 0.088 |
| Leafy vegetables | 40 | 13 (32.5) | 4 (3.5) | 9 (15.3) | 0 (0.0) | 0.001 |
| Cassava | 29 | 12 (41.4) | 7 (6.1) | 3 (5.1) | 2 (3.6) | 0.785 |
| Other | 19 | 7 (36.8) | 0 (0.0) | 2 (3.4) | 5 (8.9) | 0.006 |
| Tomatoes | 13 | 5 (38.5) | 3 (2.6) | 2 (3.4) | 0 (0.0) | 0.415 |
| Tobacco | 6 | 4 (66.7) | 4 (3.5) | 0 (0.0) | 0 (0.0) | 0.131 |

Pigeonpea was also the most important cash crop for the non-poor Control sub-group, ranked by 53% of households compared to 22% for cotton. This suggests that among households that grew pigeonpea, pigeonpea had replaced cotton.[3] as their most important

[3] Cotton production in Balaka district has expanded through a government seed multiplication programme targeting 500,000 farmers. Farmers are provided with seeds, chemicals, and sprayers. As a result of this programme, the area planted to cotton in Balaka district reached 37,428 ha in 2011/12. *The Daily Times*, February 10, 2012.

cash crop. By contrast, nine in ten of the households in the Control sub-group that we classified as poor reported that cotton was their most important cash crop, followed by groundnuts (20%) and cowpeas (18%). At first sight this is puzzling since cotton requires expensive cash inputs. However, its popularity among poor households may be due to the provision of inputs on credit by cotton ginneries, which then deduct the cost before making the final payment to growers. This may make cotton an attractive option for poorer households

### 3.4.3 Soil health and fertility

Households growing pigeonpea were asked if they had observed any benefits to soil health and fertility. Table 10 cross-tabulates the answers with the number of years that households had grown pigeonpea since 2008/09. The results show that, over time, households observed significant changes to the maize crop and to soils. These included:

**Table 10: Effects of pigeonpea on soil health and fertility (for all households growing pigeonpea in 2008/09-2010/11 (n= 174)**

| What changes have you observed since you started growing pigeonpea? | Farmers observing change | | Number of years growing pigeonpea between 2008/09 – 2010/11 | | | Significance-Level (*p* > ) |
|---|---|---|---|---|---|---|
| | Number | Percent | 1 | 2 | 3 | |
| On maize crop: | | | | | | |
| Broader leaves | 76 | 43.7 | 4 | 18 | 54 | 0.004 |
| Darker leaf colour | 77 | 44.3 | 4 | 14 | 59 | 0.014 |
| Thicker stems | 30 | 17.2 | 4 | 5 | 21 | 0.997 |
| Better root development | 22 | 12.6 | 0 | 2 | 20 | 0.050 |
| More cobs/plant | 50 | 28.7 | 10 | 9 | 31 | 0.271 |
| Bigger cobs | 39 | 22.4 | 3 | 16 | 20 | 0.000 |
| Higher grain yield | 19 | 10.9 | 7 | 1 | 11 | 0.006 |
| On soil: | | | | | | |
| Loose soil, easier to work | 127 | 73.0 | 13 | 24 | 90 | 0.054 |
| Better water infiltration | 48 | 27.6 | 2 | 13 | 33 | 0.012 |
| Less water logging | 14 | 8.0 | 3 | 2 | 9 | 0.685 |
| Less surface run-off and erosion | 13 | 7.5 | 0 | 1 | 12 | 0.160 |
| Better water retention capacity | 30 | 17.2 | 5 | 5 | 20 | 0.878 |
| Better resilience to drought | 11 | 6.3 | 2 | 2 | 7 | 0.887 |
| Other aspects: | | | | | | |
| Firewood yield/savings | 145 | 83.3 | 20 | 21 | 104 | 0.214 |
| Leaves/fodder for livestock | 4 | 2.3 | 0 | 2 | 2 | 0.172 |
| Local soda from ash | 22 | 12.6 | 1 | 3 | 18 | 0.325 |
| Grain for sale | 90 | 51.7 | 10 | 13 | 67 | 0.338 |
| Grain for own consumption | 87 | 50.0 | 13 | 12 | 62 | 0.576 |
| Ashes for pest and insect/disease control | 4 | 2.3 | 0 | 1 | 3 | 0.686 |

- Maize: broader leaves, darker color, better root development, bigger cobs and higher yields.
- Soils: Looser and easier to work, and better water infiltration.

By contrast, benefits like fuel-wood and grain for sale or consumption were immediately obvious in the first season and therefore were not significantly associated with the number of years that households had grown pigeonpea. These results suggest that farmers do perceive significant benefits from pigeonpea to maize yields and soil quality, but these changes are gradual and a minimum period of three years is needed for farmers to notice them. This suggests the need to sensitise farmers to the longer-term benefits of growing pigeonpea that are not visible immediately.

#### 3.4.4 Sources of fuel

Households were asked to identify their most important sources of cooking fuel. Table 11 shows the number of households that ranked a particular source as their most important or second-most important source of fuel. The results show significant differences between the Treatment and Control Groups. Table 11 shows that:

**Table 11: Effects of pigeonpea on soil health and fertility (for all households growing pigeonpea in 2008/09-2010/11 (n= 174)**

| Ways of obtaining cooking fuel | Treatment (n=115 ) | Control (n=115) | | Significance-Level (*p* > ) |
|---|---|---|---|---|
| | Improved stove + pigeonpea | No improved stove + pigeonpea (n=56) | No improved stove, no pigeonpea (n=59) | |
| Collect firewood from own trees | 51 (44.3)* | 25 (42.4) | 36 (64.3) | 0.026 |
| Collect firewood from other trees near village | 49 (42.6) | 20 (33.9) | 19 (33.9) | 0.398 |
| Collect firewood from hills and forests | 48 (41.7) | 17 (28.8) | 39 (69.6) | 0.000 |
| Collect pigeonpea stems | 38 (33.0) | 30 (50.8) | 5 (8.9) | 0.000 |
| Buy firewood | 17 (14.8) | 15 (25.4) | 3 (5.4) | 0.011 |
| Buy charcoal | 8 (7.0) | 2 (3.4) | 1 (1.8) | 0.280 |
| Collect firewood from village woodlot | 7 (6.1) | 0 (0.0) | 6 (10.7) | 0.044 |
| Collect maize stalks/other crop residues | 0 | 0 | 0 | - |

* Figures in brackets are the percentage of households within the group.

- Among the Treatment Group, 42% of households ranked collecting firewood from hills and forests, and 15% ranked buying firewood as their most important sources of cooking fuel. Thus, even for households that owned improved stoves and that grew pigeonpea, these remain an essential source of fuel.

- Pigeonpea stems were ranked as an important fuel source by one-third of households in the Treatment Group, and by half the households in the Control Group that grew pigeonpea.
- Households in the Control Group that neither owned an improved stove nor grew pigeonpea had a significantly different pattern of fuel consumption. They were less likely to buy firewood, more likely to collect firewood from hills and forests, and more likely to collect firewood from their own trees. This is consistent with their status as poorer households.

### 3.4.5 Pigeonpea as fuel

Table 12 shows the benefits of pigeonpea stems as fuel for those households growing the crop in 2010/11. Households that owned an energy-efficient stove planted significantly more pigeonpea seed, and used pigeonpea stems as fuel for a significantly longer period than those without a stove. The value of pigeonpea stems as fuel was calculated by asking households to estimate how many bundles of firewood they saved, and the market price per bundle. No significant difference was found in the number of bundles of firewood saved or in the cost of firewood saved. On average, the use of pigeonpea stems for fuel saved households MK 3,000 per year. Thus, the value of pigeonpea stems (Mk 3000) was similar to the value that farmers reported for pigeonpea grain (Table 8). Indeed, in 2010/11 the value of pigeonpea grain was Mk 1346 per household, or only 45% of the value of pigeonpea stems for fuel.

**Table 12: Use of pigeonpea as fuel (for households reporting use of pigeonpea as fuel)**

| Variable | Own improved stove | | Significance level($p$ > ) |
|---|---|---|---|
| | Yes (n =115) | No (n = 58) | |
| Pigeonpea seed planted, 2010/11 (kg) | 2.87 | 1.75 | 0.000 |
| Months use pigeonpea stems for fuel (no.) | 2.44 | 1.40 | 0.000 |
| Number of bundles of firewood saved/month | 6.7 | 8.3 | 0.154 |
| Number of bundles of firewood saved/year | 18.5 | 10.9 | 0.010 |
| Quantity of fuel-wood saved (kg/year) | 174 | 103 | 0.010 |
| Quantity of fuel-wood consumed from forests/hills (kg/household/month) | 69 | 78 | 0.480 |
| Value of pigeonpea firewood (MK/bundle) | 126 | 159 | 0.082 |
| Price of firewood (Mk/bundle) | 128 | 157 | 0.317 |
| Total cost of firewood saved (MK) | 3560 | 3189 | 0.797 |
| Travel time required to walk to hills and forests (hours, one-way) | 0.90 | 1.04 | 0.441 |
| Travel time saved by using pigeonpea for fuel (bundles saved X time required X 2) | 13.43 | 12.77 | 0.854 |

Table 13 shows the frequency with which households used fuel-wood. There were no significant differences between the Treatment and Control Groups in how often households bought firewood or collected firewood from the forest. However, households in the Control sub-group that were classified as poor acquired firewood less often than others. Again, this is consistent with their classification as poorer households.

**Table 13: Consumption of fuel-wood, all households**

| Fuel-wood consumption | Treatment (n=115 ) | Control (n=115) | | Significance-Level (*p* > ) |
|---|---|---|---|---|
| | Improved stove + pigeonpea (n=115) | No improved stove + pigeonpea (n=56) | No improved stove, no pigeonpea (n=59) | |
| Frequency of collecting firewood from forests (times/month) | 4.9 | 4.4 | 3.6 | 0.227 |
| Frequency buying firewood (times/month) | 3.8 | 5.1 | 5.7 | 0.547 |
| Frequency acquiring firewood (times/month) | 5.5 | 6.4 | 4.1 | 0.073 |
| Travel time required to walk to hills and forests (hours, one-way) | 0.90 | 1.06 | 0.71 | 0.252 |
| Persons collecting fuel-wood from hills and forests (no/household) | 1.74 | 1.68 | 1.41 | 0.154 |
| Fuel-wood collected from hills and forests (kg/person/month) | 46.78 | 42.23 | 33.89 | 0.198 |
| Fuel-wood collected from hills and forests (kg/household/month) | 70.28 | 77.32 | 47.46 | 0.055 |

### 3.5 The decision to buy an energy-efficient stove

Although energy-efficient stoves were provided at a subsidized price, households still had to make a decision to buy them. The decision to buy a stove (OWNSTOVE) was hypothesized to depend on several factors (Table 14).

**Table 14: Definition of regression variables for decision to buy improved stove (Dependent variable OWNSTOVE)**

| Variable | Definition | Mean | Standard deviation |
|---|---|---|---|
| **Dependent variable**: | | | |
| OWNSTOVE | Dummy variable if household owns improved stove (1 = Yes, 0 Otherwise) | 1=124 | |
| **Independent variables** | | | |
| FUELWFREQ | Frequency of fuel-wood consumption (number of times household collects fuel-wood from forest/hilla plus number of times buys fuel-wood (times/month) | 5.4 | 5.54 |
| TOTMEALS | Number of adults multiplied by average number of meals eaten in hungry period (total number/day) | 6.92 | 3.16 |
| MZHARV | Quantity of maize harvested in 2010/11 (50 kg bags) | 11.78 | 9.60 |
| DISTANCE | Dummy variable for distance from hills/forests (1=Near, 0 otherwise) | 1=155 | |
| FSCARCE | Dummy variable if household considers fuel-wood is scarce (1 = Yes, 0 otherwise) | 1=45 | |
| BUYFWOOD | Dummy variable if household ranks buying firewood as a major source of fuel (1=Yes, 0 otherwise) | 1=35 | |
| HHAGE | Dummy variable if household head is classed as 'elderly (1=Yes, 0 otherwise) | 21=1 | |
| HHSEX | Dummy variable if household head is female-headed (1 = Yes, 0 otherwise) | 1=168 | |
| SECONDARY | Dummy variable if household head has secondary education (1=Yes, 0 otherwise) | 1=17 | |
| DMAKER | Dummy variable if woman is decision-maker for land (1=Yes, 0 otherwise) | 1=88 | |

First, we hypothesized that households were more likely to purchase a stove if they saw opportunities to save time and money. Thus, households would be more likely to adopt if they spent more time collecting fuel-wood from forests and hills (FUELWCONS), relied on purchased firewood (BUYWOOD), were distant from forests and hills (DISTANCE), and perceived fuel-wood as 'scarce' (FSCARCE). Second, we hypothesized that adoption was a function of socio-economic variables. Thus, households were more likely to adopt where the household head was elderly (HHAGE), where the household was headed by a woman (HHSEX), and where women had a role in decision-making (DMAKER). Finally, we hypothesized that purchase depended on income, with adoption more likely among better-off households. Since we did not have a direct measure of household income, we used the quantity of maize harvested (MZHARV), the average number of meals/adult per day during the hungry period (TOTMEALS), and education of the household head (SECONDARY) as proxy variables.

Table 15 shows that the specification explained 71% of the variation in adoption. Five of the 10 independent variables were statistically significant at the 10% level or better. The results show that the decision to buy a stove was positively related to the distance of the household to forests and hills and the perception that fuel-wood was scarce, but not to fuel-wood consumption from forests and hills or to the purchase of firewood. Adoption was also significantly related to the proxy variables for income, namely quantity of maize harvested and the average number of meals eaten during the hungry period. Finally, adoption was positively related to the woman's role as a household decision-maker.

These results suggest that energy-efficient stoves were bought by relatively better-off households, where women had some say in decision-making and where households were concerned about the availability of fuel-wood. However, the decision to buy was not a function of how much fuel-wood from forests and hills was being consumed or how much firewood was purchased. Thus, the primary determinants of adoption seem to be financial (the ability to afford a stove) and social (whether women, who would benefit most, had a say in household decision-making).

**Table 15: Determinants of ownership of improved stove (dependent variable = OWNSTOVE=1). (n=115).**

| Variables | Unstandardised coefficients | S.E | Wald statistic | Significance-level (*p* > ) |
|---|---|---|---|---|
| CONSTANT | -1.299 | 0.616 | 4.441 | 0.035 |
| MZHARV | 0.118 | 0.026 | 19.733 | 0.000 |
| FSCARCE | 1.016 | 0.434 | 5.479 | 0.019 |
| DISTANCE | 0.983 | 0.363 | 7.310 | 0.007 |
| BUYFWOOD | -0.148 | 0.489 | 0.092 | 0.762 |
| FUELWCONS | 0.000 | 0.032 | 0.000 | 0.988 |
| TOTMEALS | -0.099 | 0.053 | 3.449 | 0.063 |
| HHAGE | -0.390 | 0.504 | 0.601 | 0.438 |
| SECONDARY | -0.669 | 0.598 | 1.251 | 0.263 |
| HHSEX | -0.118 | 0.358 | 0.110 | 0.740 |
| DMAKER | 0.604 | 0.340 | 3.153 | 0.076 |
| Model Chi-square | 39.283 | Sig. 0.000 | | |
| -2 Log likelihood | 263.498 | | | |
| Percent predicted correctly | 71.4 | | | |

## 3.6 Frequency of fuel-wood consumption

Energy-efficient stoves and pigeonpea stems were expected to reduce the frequency of consumption of fuel-wood. The household survey did not collect information on the quantity of fuel-wood consumed by the household, but on the frequency of collecting fuel-wood from forests and hills and of buying firewood. These measures were added to give an index of the frequency of fuel-wood consumption (FUELWFREQ) which was used as the dependent variable in the regression analysis.

We hypothesized that the frequency of fuel-wood consumption was determined by several variables (Table 16). First, we expected consumption to be *negatively* related to ownership of an energy-efficient stove (OWNSTOVE), and to the availability of pigeonpea stems for fuel (PPHARV and PPLAST). Second, we expected consumption to be *negatively* related to the availability of alternative sources of fuel-wood such as the household's own trees (OWNTREES), or a village woodlot (WOODLOT). We also expected consumption to be *negatively* related to the distance the household had to walk to forest and hills (DISTANCE) but *positively* related to the labour available for collecting fuel-wood (WOMENGIRLS). Finally, we hypothesised that consumption was *positively* related to the size of household (HHTOT) and how quickly it consumed fuel-wood (DAYSBUNDLE). We also included two proxy variables for household income (POOR, MEALS).

**Table 16: Definition of regression variables for frequency of fuel-wood consumption**

| Variable | Definition | Mean | Standard deviation |
|---|---|---|---|
| **Dependent variable:** | | | |
| FUELWFREQ | Fuel-wood consumption (number of times household collects fuel-wood from forest/hilla plus number of times buys fuel-wood (times/month) | 5.42 | 5.34 |
| **Independent variables** | | | |
| POOR | Dummy variable for poverty status (1 = Yes, 0 otherwise). (1 = Sub-group 3 in Table 2, with no stove and no pigeonpea) | 1=56 | |
| OWNSTOVE | Dummy variable if household owns improved stove (1 = Yes, 0 otherwise) | 1=124 | |
| HHTOT | Average size of household (no.) | 4.90 | 1.82 |
| WOMENGIRLS | Dummy variable if both women and girls in household collect fuel-wood from the forest/hills (1 = Yes, 0 otherwise) | 1 =44 | |
| DAYSBUNDLE | Duration of one bundle of firewood (days) | 8.98 | 5.74 |
| MEALS | Meals eaten in normal period (number/day) | 2.59 | 0.50 |
| PPLAST | Period that household uses pigeonpea stems for fuel (months) | 1.65 | 1.61 |
| PPHARV | Average pigeonpea harvest over 2008-2010 (no. of 50 kg bags) | 0.68 | 1.20 |
| DISTANCE | Time required to walk from household to forest/hills (hours, one-way) | 0.88 | 1.08 |
| OWNTREES | Dummy variable if household ranks own trees as main source of fuel-wood (1 = Yes, )0 otherwise). | 1=112 | |
| WOODLOT | Dummy variable if household ranks woodlot as a main source of fuel-wood (1 = Yes, 0 otherwise) | 1=13 | |

Table 17 shows that the specification explained 17% of the variation in fuel-wood consumption. While low, this is acceptable for household survey data. More important is the fact that, of the 11 independent variables, eight were statistically significant at the 10% level or above.

The variables for ownership of an energy-efficient stove (OWNSTOVE) and the quantity of pigeonpea harvested (PPHARV) displayed the expected negative sign and were both statistically significant. This confirms that energy efficient stoves and pigeonpea stems reduce the demand for fuel-wood. The coefficients suggest that an energy-efficient stove reduces the frequency with which households collect or buy firewood by up to 2 times per month. The average frequency is 5.3 times/month (Table 16). Thus, energy-efficient stoves reduce the frequency by 38%. The coefficient for PPHARV is lower and suggests that the use of pigeonpea stems for fuel reduces the frequency by 0.6 times/month or 11%. Holding other variables constant, in combination energy-efficient stoves and pigeonpea reduce fuel-wood consumption by half (48%).

Availability of alternative fuel sources (OWNTREES and WOODLOT) also displayed the expected sign and was statistically significant. Holding other variables constant, they reduce fuel-wood consumption by 4.6 times per month or by 81%. Thus, they are more effective in reducing consumption of fuel-wood from forests and hills than pigeonpea and energy-efficient stoves. This is not surprising since they address the problem of conservation directly by providing an alternative supply of fuel-wood. The results confirm the need for a combination of complementary approaches to reducing pressure on fuel-wood supply.

**Table 17: Determinants of frequency of fuel-wood consumption (dependent variable FUELWFREQ) (n=168)**

| Variables | Unstandardised coefficients | T-value | Significance-level (*p* > ) |
|---|---|---|---|
| CONSTANT | 7.155 | 3.462 | 0.001 |
| POOR | -2.775 | -2.515 | 0.013 |
| OWNSTOVE | -2.035 | -2.410 | 0.034 |
| HTOT | -0.342 | -1.677 | 0.096 |
| WOMENGIRLS | -1.370 | -1.596 | 0.113 |
| DAYSBUNDLE | -0.166 | -2.522 | 0.013 |
| MEALS | 1.829 | 2.726 | 0.007 |
| PPHARV | -0.643 | -1.759 | 0.080 |
| PPLAST | 0.346 | 1.302 | 0.195 |
| DISTANCE | -0.468 | -1.258 | 0.210 |
| OWNTREES | -1.859 | -2.543 | 0.012 |
| WOODLOT | -2.702 | -1.841 | 0.067 |
| Adjusted $R^2$ | 0.169 | | |
| F | 4.102 | Sig 0.000 | |

Fuel-wood consumption was significantly related to household income. The proxy variable POOR displayed a negative sign, indicating that poorer households consume less fuel-wood, while the proxy variable MEALS displayed a positive sign, indicating that better-off households consumed more fuel-wood. Poorer households may have less labour available to collect fuel-wood over long distances and be less able to afford to purchase firewood in the market and cook fewer meals.

Household size (HTOT) displayed an unexpected negative sign, indicating that smaller households collect and purchase fuel-wood more frequently. We had expected that larger households would require more fuel-wood. Smaller households have to collect more frequently because they have less labour available to carry fuel over long distances. Finally, the speed with which households used fuel (DAYSBUNDLE) showed a negative sign as expected, therefore the energy efficient stove reduces the frequency of fuel-wood collection and purchase.

### 3.7 Quantity of fuel-wood consumed

Energy-efficient stoves and pigeonpea were expected to reduce the total quantity of fuel-wood consumed. The total quantity of fuel-wood consumed (FUELWCONS) was measured as the frequency of collection from hills and forests, multiplied by the average weight per bundle (9.4 kg) and the total number of collectors/household. The number of collectors was measured as the total adult females in the household plus the number of girls aged 5-15 in households that reported the use of girls for collecting firewood from forests and hills.

We hypothesized that fuel-wood consumption was determined by several variables. First, hypothesized that the quantity of fuel collected was *negatively* related to ownership of an energy-efficient stove (OWNSTOVE), and by the average number of days that one bundle of fuel-wood lasted (DAYSBUNDLE). We also hypothesized that consumption was *negatively* related to the quantity of pigeonpea harvested (PPHARV) and the number of months that households used pigeonpea stems for fuel (PPLAST), and the use of alternative sources of fuel-wood (BUYFWOOD, OWNTREES, WOODLOT). Consumption was hypothesized to be *positively* related to the total number of meals per day eaten by adults in the household during normal periods (TOTMEALS). Finally, we hypothesized that consumption of fuel-wood was negatively related to the distance to fuel-wood in forests and hills (DISTANCE).

**Table 18: Definition of regression variables for quantity of fuel-wood consumed from forest/hills**

| Variable | Definition | Mean | Standard deviation |
|---|---|---|---|
| **Dependent variable**: | | | |
| FUELCONS | Fuel-wood consumption from forests/hills(frequency of collection X number of household members collecting X mean weight/bundle) (kg) | 66.29 | 68.71 |
| **Independent variables** | | | |
| OWNSTOVE | Dummy variable if household owns improved stove (1 = Yes, 0 otherwise) | 1=124 | |
| DAYSBUNDLE | Duration of one bundle of firewood (days) | 8.98 | 5.74 |
| TOTMEALS | Average number of meals eaten in normal period X number of adults in household (number/day) | 2.59 | 0.50 |
| PPLAST | Period that household uses pigeonpea stems for fuel (months) | 1.65 | 1.61 |
| PPHARV | Average pigeonpea harvest over 2008-2010 (no. of 50 kg bags) | 0.68 | 1.20 |
| DISTANCE | Time required to walk from household to forest/hills (hours, one-way) | 0.88 | 1.08 |
| BUYFWOOD | Dummy variable if household ranks buying firewood as a major source of fuel (1=Yes, 0 otherwise) | 1=35 | |
| OWNTREES | Dummy variable if household ranks own trees as main source of fuel-wood (1 = Yes, )0 otherwise). | 1=112 | |
| WOODLOT | Dummy variable if household ranks woodlot as a main source of fuel-wood (1 = Yes, 0 otherwise) | 1=13 | |

Table 19 shows that the specification explained 19% of the variation in quantity of fuel-wood consumed. Of the 10 independent variables, five were statistically significant at the 10% level or above.

The DISTANCE variable displayed the expected negative sign, indicating that quantity of fuel-wood sourced from forests and hills depended on the time required for collection. DAYSBUNDLE also displayed the expected negative sign, indicating that when fuel-wood lasted longer the quantity consumed was reduced. TOTMEALS showed the expected positive sign as households that required a greater number of cooked meals consumed more fuel-wood.

However, other significant variables displayed unexpected signs. OWNSTOVE and BUYFWOOD displayed positive signs, indicating higher fuel-wood consumption among households that owned energy-efficient stoves and that purchased firewood consumed higher levels of fuel-wood from forests and hills. On average, households with improved stoves collected 20 kg more fuel-wood per month. The explanation may be that households with higher demand for fuel-wood have more incentive to buy energy-efficient stoves and a greater need to buy firewood. [4]

**Table 19: Determinants of quantity of fuel-wood consumed from forests/hills (dependent variable FUELWCONS) (n=175)**

| Variables | Unstandardised coefficients | T-value | Significance-level (*p* > ) |
|---|---|---|---|
| CONSTANT | 20.181 | 2.654 | 0.009 |
| DISTANCE | -7.636 | -2.005 | 0.047 |
| OWNSTOVE | 20.780 | 2.431 | 0.016 |
| TOTMEALS | 5.144 | 4.466 | 0.000 |
| DAYSBUNDLE | -1.495 | -2.208 | 0.029 |
| PPHARV | -5.833 | -1.562 | 0.120 |
| PPLAST | 1.018 | 0.378 | 0.706 |
| OWNTREES | 3.789 | 0.462 | 0.645 |
| WOODLOT | -10.813 | -0.710 | 0.479 |
| BUYFWOOD | 28.862 | 2.391 | 0.018 |
| OWNTREES | 3.789 | 0.462 | 0.645 |
| Adjusted $R^2$ | 0.194 | | |
| F | 5.667 | Sig 0.000 | |

The variables for pigeonpea (PPHARV and PPLAST) were not statistically significant, although PPHARV had the expected negative sign, and the coefficient (-5.8) suggests that pigeonpea reduces consumption of fuel-wood by 6 kg/month.

Finally, neither the WOODLOT nor OWNTREES variables were statistically significant, although WOODLOT had the expected negative sign.

## 4. Conclusions

The general objective of this study was to evaluate the effectiveness of energy-efficient stoves and pigeonpea as an IFES. Specifically, the objectives were to:

- Measure the effects of pigeonpea on household food security, income, and soil health;

[4] Another possible explanation could be (as observed in another study CU conducted) that as the improved stoves are considered to be safer than the three stone method users don't tend to extinguish the fire as they do with the three stone stoves but tend to keep topping it up. There is evidence that users in Balaka keep the improved stoves burning (100 degrees +) for up to 12-14 hours per day. Villagers explained that they preferred to keep the fire going as it was easier and cheaper than starting a new fire every time they wished to cook or heat water.

- Identify the determinants of adoption of energy-efficient stoves; and
- Measure the effects of energy-efficient stoves and pigeonpea on fuel-wood consumption.

## 4.1 Household impacts

Pigeonpea was primarily grown for food and 60-70% of pigeonpea harvested was kept for home consumption. The share of pigeonpea sold fell over the three-year period, probably in response to falling prices. Pigeonpea was eaten by all household members including children under five. Pigeonpea growers were more likely to use it as food for under-fives than non-growers. Cash income from pigeonpea was relatively small, average MK 566 per household in 2010/11. Despite this, households growing pigeonpea ranked it as either their first or second-most important cash crop, before cotton. Growers clearly recognize the potential of pigeonpea as a cash crop but may be discouraged by low prices offered by local buyers. Households growing pigeonpea for three consecutive years were more likely to notice benefits to soil health and fertility. These included bigger maize cobs, higher maize yields, looser soils that were easier to work, and better water infiltration, which increased soil moisture. Leaf litter from pigeonpea is rich in nitrogen and grown in the same field over a three-year period is likely to raise maize yields.

### 4.1.1 Adoption of energy-efficient stoves

The decision to buy an energy-efficient stove was determined primarily by three factors: income, the travel time to collect fuel-wood from forests and hills, and the degree to which women controlled household decision-making.

Although the purchase price was low (MK 300), energy-efficient stoves were bought by better-off households with bigger maize harvests and that were more likely to eat three meals per day. Within this group, however, the decision to buy was also determined by whether women were involved in important decisions like which crops to plant. Since women are responsible for collecting fuel-wood, they are likely to favour innovations that reduce their workload. Households were also more likely to buy an improved stove if they had longer travel-times to collect fuel-wood, and if they perceived fuel-wood as scarce. Again, these variables are likely to reflect the views of women.

By contrast, poorer households are not only less able to afford energy-efficient stoves, but may also have less demand for them. Poorer households have fewer family members, and eat fewer meals. They may also use strategies that economise on the use of fuel-wood and reduce the need to travel long distances for collection.

### 4.1.2 Fuel-wood consumption

Adoption of pigeonpea and energy-efficient stoves reduced the *frequency* with which households bought and collected fuel-wood. On average, they reduced frequency by half (48%). This represents a significant saving of labour time. Using pigeonpea for fuel was estimated to save households 13 hours per month in travel time. Better-off households collected and bought fuel-wood more frequently than poorer households. This reflects higher demand for fuel-wood among better-off households, as well as the ability to afford to buy firewood, and the greater availability of female labour to travel long distances in search of fuel, reducing potential risks for lone women. The frequency of fuel-wood consumption was reduced where households could obtain fuel from their own trees or from village woodlots. The share of households reporting village woodlots as an important source of fuel-wood was very small (6%). However, woodlots and own trees reduced the frequency of collecting or buying fuel-wood by 80%.

Adoption of energy-efficient stoves did not, by itself, significantly reduce the *quantity* of fuel-wood collected from hills and forests. On average, for households that grew pigeonpea, households with improved stoves collected 70 kg/month compared to 77 kg/month collected by households without improved stoves.[5] This difference was not statistically significant. Regression analysis controlling for other variables showed that households with improved stoves consumed significantly higher amounts of fuel-wood from the hills and forests than others. This was an unexpected result.

One explanation is that households with the biggest consumption of fuel-wood have most incentive to buy energy-efficient stoves. As we have seen, households that adopted energy-efficient stoves were bigger and better-off, and were thus more likely to have the greatest demand for fuel-wood. Such households may find it difficult or be unwilling to copy the strategies used by poorer households to economise on fuel-wood (gleaning crop residues, using twigs, using inferior fuel-wood). However, they can afford to buy an energy-efficient stove. This will certainly allow them to consume less fuel-wood than before, but not to the point where they use less than other households. A more relevant approach would be to pose the counterfactual question: how much additional fuel-wood these households consumed *before* they bought energy-efficient stoves?

Similarly, pigeonpea fuel did not significantly reduce the quantity of fuel-wood consumed. Among households with improved stoves, the quantity of fuel-wood saved was estimated at 18.5 bundles per year, or 174 kg/year. Regression analysis indicated that, holding other variables constant, pigeonpea reduced the quantity of fuel-wood sourced from hills and forests by 6 kg/month (about 9% of the average quantity collected).This represents less than one bundle of fuel-wood per month.

In sum, the improved stove-pigeonpea IFES is just one of many factors that determine the quantity of fuel-wood consumed. Consequently, the effect of these other factors must be taken into account when analysing its effectiveness.

## 4.2 Conclusion

The IFES has had beneficial impacts on household food security, cash income, soil health and fertility, and reduced the frequency with which households buy and collect indigenous fuel-wood. The main buyers of energy-efficient stoves have been better-off households that consume the most fuel-wood. While this has reduced fuel-wood consumption among these households, they remain the biggest consumers of fuel-wood. By contrast, poorer households consume much less fuel-wood and have less incentive to buy energy-efficient

[5] Obtaining accurate estimates of fuel-wood consumption from mostly illiterate poorer households was also a major challenge, and they may have under-estimated their fuel-wood consumption.

stoves. Poverty reduction and the environment require different approaches. An environmental programme that targets better-off households will have the biggest impact at the household level. However, since the majority of households are poor, targeting improved stoves at poorer households may have the greatest overall impact.

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