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Do agroforestry technologies improve the livelihoods of the resource poor farmers? Evidence from Kasungu and Machinga districts of Malawi

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Abstract Fertilizer tree technologies such as intercropping, relay cropping, improved fallows and biomass transfer have been promoted as sustainable, low-input alternative or complimentary inputs to inorganic fertilizers in Malawi. However, research into the long term effects of their adoption on household food security and poverty reduction is limited. This study examined whether these technologies contribute to rural household of subsistence farmers in terms of food security and livelihoods improvement in two districts of Malawi. The study shows that fertilizer tree technologies increase crop production and provide additional income to households through sources such as sale of agroforestry tree seed and fuelwood. The choice of the technologies is driven by the size of the land holdings and more benefits are associated with large land holdings. While fertilizer tree technologies contribute to the reduction in hunger months, this is usually compromised at the household level by the inability to achieve livelihood security, absorb and cope with shocks and overall improved welfare.

Keywords Fertilizer tree technologies · Adoption · Food security · Households · Livelihood security

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Introduction

Agriculture is the primary livelihood strategy for 85% of the rural population in developing regions (Dixon et al. 2001). In Africa, and particularly southern Africa, the main constraint to agricultural productivity is soil nutrient deficiency, especially nitrogen and phosphorous (Sanchez et al. 1997; Scoones and Toulmin 1999). The situation in Malawi presents a unique challenge to improvement of agricultural productivity. The country relies heavily on agriculture, which contributes 36.3% of the GDP and 90% of all foreign exchange earnings. The smallholder agricultural sector is responsible for approximately 70% of the country's agricultural output while the estate sector makes up the remaining 30% (Harrigan 2008). Increasing populations, decreasing land holdings, declining soil fertility, and declining maize yields have led to chronic food insecurity for the majority of Malawi's rural poor. According to Sanchez (2002), Malawi's food deficit is directly related to poor crop production, rather than inadequate distribution. There is simply not enough food being produced.

Agroforestry research in southern Africa region has focused on soil improving agroforestry technologies and the adoption and scaling-up of these practices is the main thrust of the ongoing research (Akinnifesi et al. 2008). These agroforestry technologies are currently commonly termed 'fertilizer tree systems'. Fertiliser tree systems involve soil fertility replenishment through on-farm management of nitrogen-fixing trees (Mafongoya et al. 2006). The different fertiliser tree systems that have been developed and promoted in southern Africa in the last two decades include sequential tree fallow, annual relay intercropping, Gliricidia intercropping and biomass transfer and these have been described extensively in literature (Akinnifesi et al. 2008, 2010).

Recent research has explored the role of various cultural, environmental, political, and economic factors that affect the adoption and scaling-up of these agroforestry technologies (Ajayi et al. 2007a; Keil et al. 2005; Phiri et al. 2004; Thangata and Alavalapati 2003) with the aim of understanding the complex interplay of biophysical and socio-economic factors that influence farmer adoption. These studies have led to a greater understanding of farmer decision making and have allowed research and extension personnel to evaluate dissemination efforts to better facilitate farmers and increase the numbers of adopters. However, despite the amount of both biological and socio-economic research being done, there is little information both globally and regionally regarding how fertilizer tree technology adoption affects farmer livelihood decisions (Ellis et al. 2003; Sunderlin et al. 2005). For example, Place et al. (2007) conducted an extensive survey on the impacts of fertilizer tree technologies on the rural poor in western Kenya and found that adoption increased social capital of some farmers but also that the increased productivity of an adopting farmer could stir up jealousy among non-adopters. Furthermore, they concluded that the full potential of fertilizer tree technologies to reduce poverty may not be realized if farmers do not have the initial resources to fully implement and maintain the system. Thus, there is a need for more research into the long term effects of fertilizer tree technology adoption on livelihoods and sustained poverty relief.

Research needs to explore beyond improved fallow technologies, maize yields and adoption rates to investigate the resulting livelihood impacts of fertilizer tree technologies. With the current emphasis on scaling-up agroforestry adoption, it is important to revisit farmers who are well-established in their use of agroforestry systems to investigate how (or if) the technologies have facilitated any shift in their livelihoods that would indicate progress along the path of wealth creation and a permanent migration out of poverty. This study investigated the linkages between fertilizer tree technology use and poverty reduction in farming households of central and southern Malawi by assessing food security, asset status, and household income generating activities. The research focused on four specific objectives: (i) evaluate changes in food security resulting from increased yields associated with fertilizer tree technology adoption; (ii) determine if there is a pattern of fertilizer tree technology adoption and changes in household assets; (iii) determine if fertilizer tree technology adoption has allowed households to diversify their income generating activities; (iv) determine if fertilizer tree technology adoption has an effect on the household's level of vulnerability and its ability to absorb and cope with various household and environmental shocks.

Methods

Data collection

The study was conducted in Rural Development Programmes in two districts of Malawi, Kasungu (S 13°2′0″, E 33°29′0″) in the Central region and Machinga (S 14°58′00″, E 35°31′00″) in the Southern region. The sites, communities, and individual households were selected using purposive sampling strategies (Babbie and Mouton 2001) based on information provided by the project staff and local extension officers. In total, 131 household interviews were conducted, 65 from Kasungu and 66 from Machinga. Farmers were selected on the basis of length of agroforestry use; having been adopters of the fertilizer tree technologies for at least 5 years.

Data analysis

Household characteristics such as number of household members and landholding size were summarized using descriptive statistics. Frequency tables and descriptive statistics were used to identify and evaluate trends in the agroforestry technologies use, crop production, shocks, assets, and income. Sign and Signed Rank Non-parametric (also called Wilcoxon Matched Pairs test) analysis was used to test for a change in the crop yield and asset variables between pre- and post-adoption (Clewer and Scarisbrick 2006). The test for equality of proportions was used to examine the probability of an increase in income amount, number and type of income sources, and maize yields as a result of the technologies adoption. Logistic regression was used to identify which continuous input variables caused significant changes in the odds for the response variables. Chi-square analysis test was used to determine if there was an influence of the addition of agroforestry related activities on both the amount and number of sources of household incomes.

Results

Household characteristics

The average household size was 6.5 members and the majority of households (80.9%) were headed by men (Table 1). All households were subsistence farmers and diversified their livelihoods through crop sales and off-farm labor wages. The average farm size in Kasungu was 1.88 ha of which 0.28 ha was under fertilizer tree technologies. In Machinga, farm sizes were significantly smaller (t value $= 1.75$, $P < 0.01$), averaging 0.91 ha. Consequently, area under fertilizer tree technologies was also significantly smaller in Machinga than Kasungu (t value $= 4.81$, $P < 0.01$), averaging 0.16 ha.

Household use of fertilizer tree technologies

In general, respondents had adopted at least one of the fertilizer tree technologies for a period of 5 years (Table 2). There were no significant differences in years since adoption between the sites either by technology or by maximum years since adoption. The most frequently reported technology in both districts was intercropping (86%), followed by relay cropping (50%) and biomass transfer (50%). Only 35% of the respondents reported using improved fallows.

In Kasungu, 66% of respondents cited *Tephrosia vogelii* Hook.f. as the preferred agroforestry species for intercropping followed by *Gliricidia sepium* (Jacq.) Kunth (26%) (Table 3). Those practicing intercropping in Machinga predominantly used *Leucaena leucocephala* (Lam.) de Wit (34%), followed by Tephrosia (31%). *Sesbania sesban* (L.) Merr was the preferred species for relay cropping at both sites, followed by Gliricidia in Kasungu and *Senna* spp. in Machinga. Approximately 79% of those using improved fallows in Kasungu and 69% in Machinga favored Tephrosi*a*. This was followed by Gliricidia in Kasungu (10%) and Leucaena (19%) in Machinga. Sesbania and Gliricidia were the two most commonly grown species for biomass transfer systems at both sites. However, in Kasungu 73% of those using biomass transfer reported using Sesbania followed by Gliricidia (28%) while in Machinga Gliricidia was the preferred species (77%) followed by Sesbania (12%) and Senna (12%).

Table 1 Household average characteristics

Household size	Kasungu[a] 6.4	Machinga 6.5	*P* value 0.77
% Male headed households	80	81.8	
Farm size (ha)*	1.9	0.9	<0.01
Area under fertilizer trees (ha)*	0.3	0.2	<0.01

* Indicates a significant difference between site values

[a] *Figures* in *brackets* are standard deviations

Benefits and challenges of fertilizer tree technologies

Of those practicing intercropping, improved soil fertility was the main benefit identified at both sites (Table 4). Both Kasungu (45%) and Machinga (30%) residents who used relay cropping identified construction materials as the most important benefit. For Kasungu adopters of improved fallows, 28 and 24% identified seed production and increased yields as the greatest benefits, respectively. While in Machinga, increased yields was the most commonly reported benefit (31%) followed by improved soil fertility and fodder production (19%). In Kasungu, 58% of those using biomass transfer reported that wood for construction materials was the greatest benefit. In Machinga, 31% of the respondents reported that construction materials and improved soil fertility were the greatest benefit to biomass transfer (Table 4).

Table 2 Percent of respondents reporting fertilizer tree technologies and the associated number of years in use

Technology	Kasungu			Machinga			Whole sample		
	%	*n*	Mean years (SD)	%	*n*	Mean years (SD)	%	*n*	Mean years (SD)
Intercrop	85	55	4.5 (1.5)	94	62	4.9 (1.3)	86	113	4.7 (1.4)
Relay crop	45	29	4.4 (1.2)	56	37	4.7 (1.5)	50	66	4.6 (1.4)
Improved fallow	45	29	4.9 (1.3)	24	16	4.8 (1.4)	34	45	4.8 (1.3)
Biomass transfer	62	40	5.2 (1.5)	39	26	4.9 (1.4)	50	66	5.1 (1.4)

Note: % = percent of respondents reporting use; *n* = number of respondents reporting use; mean years = average number of years the respondent has been using the technology

Table 3 Percent (%) of respondents from Kasungu (K) and Machinga (M) using agroforestry species for various fertilizer tree technologies

Species	Intercropping		Relay cropping		Improved fallow		Biomass transfer	
	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga
Tephrosia vogelii	66	31	0	3	79	69	0	0
Faidherbia albida (Delile) A.Chev.	7	27	3	0	0	0	0	0
Leucaena leucocephala	0	34	0	14	3	19	0	0
Gliricidia sepium	26	0	10	8	10	6	28	77
Sesbania sesban	2	5	86	57	7	6	73	12

Table 4 Percent (%) of respondents who identified various benefits to fertilizer tree technologies in Kasungu and Machinga

Benefit	Intercropping		Relay cropping		Improved fallow		Biomass transfer	
	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga
Soil fertility	60	63	21	22	17	19	18	31
Seed sale	18	5	3	0	28	13	5	0
Construction material	13	8	45	30	21	6	58	31
Yield improvement	6	11	14	22	24	31	8	12
Fuelwood	2	7	14	5	0	6	13	15
Fodder	0	5	0	5	3	0	0	0
Good crop quality	0	2	3	16	0	6	0	12
Other	2	0	0	0	7	0	0	0

In Kasungu, labor requirements were the most frequently identified challenge to intercropping (33%) followed by a lack of training (22%, Table 5). Browsing was identified as the biggest challenge to intercropping by 29% of those using the technology in Machinga, followed by labor requirement (23%). Browsing and pests were the most commonly identified challenges for relay cropping in Kasungu, with 31 and 24% of users identifying these challenges, respectively. In Machinga, labor demands (24%), followed by a lack of training and the lag time between technology implementation and the resulting effects on crops (16%) were the challenges most commonly associated with relay cropping. At both sites, lag time, followed by jealousy from neighbors were the two most noted challenges to improved fallows. Similarly, lag time and lack of training were the most commonly identified challenges to biomass transfer at both sites.

Table 5 Percent (%) of respondents who identified various challenges to agroforestry technologies in Kasungu and Machinga

Challenge	Intercropping		Relay cropping		Improved fallow		Biomass transfer	
	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga
Labour	33	23	3	24	3	6	13	15
Training	22	11	10	16	7	19	20	23
Land area	15	10	14	14	14	19	5	19
Pests	11	7	24	5	3	0	10	0
Jealousy	9	11	7	5	31	19	8	12
Browsing	7	29	31	5	3	6	15	0
Lag time	4	3	10	16	35	31	28	27
Seed	0	3	0	0	3	0	3	0
Other	3	0	0	14	0	0	0	4

Shocks and coping strategies

There was a significant ($P < 0.05$) crop loss in Kasungu (91%) compared to Machinga (33%). There was also a significant difference in the number of respondents reporting theft ($P < 0.05$) accounting for 43% of respondents in Kasungu compared to only 15% in Machinga (Table 6). Labor shortage significantly affected 55% of the respondents in Kasungu while illness affected more than 50% of the respondents at both sites. Hunger was the most frequently reported shock and was significantly higher ($P < 0.05$) in Machinga (86%) than in Kasungu (48%).

Table 6 Percent of respondents reporting various shocks

Shock	Kasungu	Machinga	Whole sample
Hunger*	48	86	–
Crop loss*	91	33	–
Illness	62	53	57
Death	5	0	2
Theft*	43	15	–
Structure loss*	11	0	–
Labor shortage*	55	20	–
Job loss*	8	0	–

* Indicates a significant difference (Fisher's exact P value < 0.05) between the sites and means could not be pooled

Selling physical assets was the most common coping strategy for all shocks (Table 7). In response to hunger, both sites resorted to selling assets (>90%); and in Kasungu selling labor was an equally important response (90.3%). Interestingly, migration and selling labor accounted for 53–55% of the response in Machinga district. In Kasungu, selling assets was also used as a response to loss of crops by 71% of the farmers. When faced with illness, selling physical assets was again the most important coping strategy at both sites (96%); while selling crops was another important coping strategy in for nearly 80% of the respondents in Kasungu.

There were no significant differences between sites in relation to theft coping strategies. When recovering from theft, 79% chose to sell physical assets, 63% hired out labor, and 50% sold crops (Table 7). Labor shortages were dealt with through the sale of assets in both Kasungu and Machinga; and

Table 7 Percent (%) of respondents employing various coping strategies in response to shocks in Kasungu and Machinga

Coping strategy	Hunger		Crop loss		Illness		Theft		Labor shortage	
	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga	Kasungu	Machinga
Selling assets	90	100	71	36	98	100	79	80	89	100
Selling labor	90	53	0	0	3	0	68	50	0	0
Migration	0	55	0	5	3	3	0	20	0	0
Selling crops	19	2	0	0	80	20	46	60	77	4

selling crops was also an important coping strategy in Kasungu.

Sale of crop produce and sources of income

A Student's *t* test revealed that households from Kasungu showed a significantly more diverse income portfolio than those from Machinga ($P < 0.01$). The average number of income generating activities for any given month in Kasungu was 7.83 (±1.03) while in Machinga the average number of activities for a given months was 4.67 (±0.98). Overall, crop sales (non-vegetables) were the most frequently reported (92%) and highly valued source of income (Table 8).

Table 8 Percent of respondents for the for the various income sources

	Machinga ($n = 66$) %	Kasungu ($n = 65$) %	Whole sample ($n = 131$) %
Income source			
Sell crops	96	89	92
Off-farm wages	71	91	81
Sell wood	33	72	53
Sell AF seeds	6	80	43
Tobacco	44	40	42
Sell vegetables	12	48	30
Sell maize	3	52	28
Sell crop seeds	0	11	5
Other	0	3	2
Pension[#]	0	2	1
Sell other[#]	0	2	1

[#] Indicates only one household reported this sources of income

This was followed by off-farm wages (81%) and the selling of fuel and/or construction wood (53%), agroforestry seeds (43%), tobacco (42%), vegetables (30%) and maize (28%).

Since adoption, 50% of the respondents reported an increase in the number of income sources while 47% said the number of sources had remained the same. While overall there was no significant increase in the number of income sources from pre- to post-adoption; separate analysis by district showed that 86% of respondents in Kasungu reported that there was a significant ($P < 0.05$) increase in the number of income sources following fertilizer tree technologies adoption (Table 9).Similarly, only households from Kasungu showed a significant increase ($P < 0.05$) in the amount of income (Table 9).

In trying to identify the influence of fertilizer tree technology adoption on income, there was no significant probability that this increase was the result of any *single* agroforestry related activity. Among those reporting an increase in the number of sources of income, agroforestry seed/seedling sale was the only *single* activity found to make a significant contribution; which when combined with sale of fuelwood and crops were responsible for 100% of the reported increases in the number of income sources.

General perception of fertilizer tree technologies

Farmers mentioned the need for some form of additional support, such as training or access to inputs (75%), followed by the desire for new agroforestry species (24%), and field trips (22%) (Table 10). Additionally, a significantly higher percentage of respondents from Machinga (88%)

Table 9 Test for equality of proportions showing changes in number of income sources and income amount from pre- to post-adoption in Kasungu and Machinga

	% Reporting ($n = 65$) Kasungu		% Reporting ($n = 66$) Machinga		% Reporting ($n = 131$) whole sample	
	Number	Amount	Number	Amount	Number	Amount
Increase	86	74	17	46	51	60
Stayed the same	12	23	82	53	47	38
Decreased	2	3	2	2	2	2
$\hat{p}_i$	0.862	0.738	0.167	0.455	0.51	0.595
P value	<0.01	<0.01	2.0	1.539	0.793	0.029

Tests the hypothesis that the probability that a household would report an increase was the same as the probability that the household would report no increase. Ho:$P_{increase} = 0.5$; H1:$P_{increase} \neq 0.5$

Table 10 Percent of responses in various concluding comments categories

Comment	Kasungu ($n = 65$)	Machinga ($n = 66$)	Whole sample ($n = 131$)
New species	26	23	24
Support*	62	88	–
Field trips	20	24	22
Markets	11	7	8
Satisfied	8	2	5

* Indicates a significant difference (Fisher's exact P value < 0.05) between the sites and means could not be pooled

identified the need for support compared to those from Kasungu (62%, $P < 0.05$).

Perceived support needs were divided into the following categories: education and training; more agroforestry seeds; access to clean water; agricultural inputs such as fertilizer and tools; and support during hunger periods, in the form of either food or cash.

Discussion

There was in general an increase in yield with the use of fertilizer tree technologies. The difference between sites is likely due to the fact that respondents in Machinga cultivate much smaller areas. In this study, respondents only provided information about the rough estimate of the amount of yield increase. There was no baseline information pertaining to yields per hectare so the reported increases cannot be extrapolated to kg per hectare. However, maize yield increases following the introduction of fertilizer tree technologies are consistent with findings from other studies (Ajayi et al. 2007a, b). In this study, it was also difficult to attribute all the yield increases to fertilizer tree technologies since no data was collected on the use of inorganic fertilizers among the respondents. In addition, the current government fertilizer subsidy program supplies 100 kg of inorganic fertilizer to approximately 50% of the smallholder farming sector (Malawi Ministry of Agriculture and Food Security 2008) and it is likely that some of the respondents in this study were recipients of these subsidies. The use of both organic and inorganic fertilizer options are complementary and will contribute to increasing crop yields.

The crop sale as the largest source of income is consistent with the Malawi Baseline Livelihood Profiles (Malawi Vulnerability Assessment Committee (MVAC) 2005). The importance of off-farm wages as a source of income between the months of November and March coincide with the annual food shortages and hunger periods experienced by many subsistence farmers in Malawi. These months are also times of high labor demand as it is during these months that land preparation, land clearing, ridging, and finally planting occur (Malawi Vulnerability Assessment Committee (MVAC) 2005). However, the additional income (either cash or in-kind) from off-farm labor may be more critical to meeting the household's immediate needs. The study found that the adoption of fertilizer tree technologies enhances other income generating opportunities. The differences in the realization of increased income from fertilizer tree technologies at the two sites may be attributed to the fact that farmers in Kasungu were cultivating larger plots; and therefore more respondents used improved fallows and biomass transfer than in Machinga, resulting in more income generating resources available to them. For example, the use of improved fallows requires more land than relay cropping due to the fact that an entire plot is removed from food production for the duration of the fallow. Because the entire fallow area is committed to the growth of the fallow species, the resulting woody biomass yield will be greater in these plots in a plot where woody growth shares the same space as food crops. Therefore, the resulting volume of saleable wood will be greater from an improved fallow than from a relay cropping system.

Despite the gains in food security that may have been brought about by an increase in crop yields, a marked decrease in hunger periods, and in some cases a more diversified income portfolio and asset inventory, there was still an obvious lag in household security, the ability to absorb and cope with shocks, and overall improved welfare. When households live on the margin of survival, livelihood strategies focus more on addressing immediate needs and surviving shocks than progressing out of poverty (Eriksen et al. 2005). The results revealed that when households were able to increase their income, the added income was reinvested into activities that support the household's immediate needs, rather than invested in any form of insurance. The use of various coping strategies provides another indication of a household's vulnerability. Ideally, households would have some form of insurance or "safety net" to rely on in difficult times. However, in the absence of formal security measures, households are likely to sell productive assets, reallocate time to increase income, or a previously non-working member may enter the labor market (Jacoby and Skoufias 1997; Skoufias 2003) in response to unexpected challenges. It is not surprising then that in this study, households at both sites relied heavily on selling assets, crops, and labor as a response strategy.

The reported increases in crop yield support the basic premise associated with fertilizer tree technologies: that they improve soil fertility and results in increased crop yields. Households overwhelmingly identified improved soil fertility as an important and crucial benefit to the technologies. This acknowledgement points to the conclusion that farmers have an understanding of the importance of soil fertility and the currently low soil nutritional status in Malawi. The other benefits identified by farmers, such as the production of saleable seed and wood for fuel or construction, are not surprising and are common benefits identified in other areas in Africa where fertilizer tree technologies are used (Ajayi et al. 2007a, b).

The farmers felt improved access to other resources can help them improve production. Considering the desire for more education and training at both sites, and the perceived lack of formal training and limited access to extension and support staff, group membership may be beneficial to Machinga and Kasungu residents. Group membership and community support play important roles in farm management decision making and the resulting impact on welfare (Ajayi et al. 2003; Place et al. 2007). Furthermore, the networking associated with group membership encourages dissemination of training and education where access to government extension workers is limited. It is apparent that despite the repeated confirmation of the challenges associated with land, labor, seed and training, little has been done to find solutions to these issues.

Conclusion

The study shows that fertilizer tree technologies increase crop production and provide additional income to households such as sale of agroforestry tree seed and fuelwood. The choice of the technologies is driven by the size of the land holdings and more benefits are associated with large land holdings. While fertilizer tree technologies contribute to the reduction in hunger months, this is usually compromised at the household level by the inability to achieve livelihood security, absorb and cope with shocks and overall improved welfare. This may suggest that while food security is paramount to sustaining the livelihoods of smallholder farmers, livelihood security and poverty reduction depend on other factors other than increased food production.

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