UC Santa Cruz
UC Santa Cruz Previously Published Works

Title

Comparing agroforestry systems' ex ante adoption potential and ex post adoption: on-farm participatory research from southern Malawi

Permalink

https://escholarship.org/uc/item/17r2w1g4

Journal

Agroforestry Systems: An International Journal incorporating Agroforestry Forum, 79(2)

ISSN

1572-9680

Authors

Sirrine, Dorothy
Shennan, Carol
Sirrine, J. Robert

Publication Date

2010-06-01

DOI

10.1007/s10457-010-9304-0

Peer reviewed

Comparing agroforestry systems' ex ante adoption potential and ex post adoption: on-farm participatory research from southern Malawi

Dorothy Sirrine · Carol Shennan · J. Robert Sirrine

Abstract Agroforestry (AF) systems have been the focus of numerous research and development projects in southern Africa, yet their adoption rate generally remains low. Employing on-farm, participatory research techniques in southern Malawi, we compared the suitability of three AF-based systems that relay crop the dominant staple, maize (*Zea mays*), with the perennial legumes *Sesbania sesban*, *Tephrosia vogelii*, and *Cajanus cajan* (pigeonpea). Our secondary objective was to compare two methodologies employed to investigate AF adoption: farming systems based ex ante adoption potential and ex post adoption analysis. Nineteen percent of farmers preferred *S. sesban*, 26% *T. vogelii*, and 55% pigeonpea. Between 2001 and 2003, *S. sesban* adoption ranged from 3 to 6%, *T. vogelii* from 16 to 20%, and pigeonpea from 76 to 100%. Pigeonpea and *T. vogelii* were primarily preferred and adopted for their immediate livelihood benefits—a secondary food source in the case of pigeonpea and a fish poison in the case of *T. vogelii*. Though *S. sesban* was the most promising in terms of biophysical impacts, many farmers found it labor intensive and its lack of immediate livelihood benefits was a deterrent to adoption. With food insecurity a pervasive hardship in the region, farmers will likely continue to focus on satisfying immediate livelihood needs before prioritizing longer-term soil-quality improvement techniques. Both ex ante adoption potential and ex post adoption analysis contributed distinct and valuable data, and relying on either exclusively would have limited our understanding of the AF systems.

Keywords *Sesbania sesban* · *Tephrosia vogelii* · *Cajanus cajan* (pigeonpea) · Agroforestry adoption · Malawi · Food security

D. Sirrine (✉)
10555 S. Timberlee Dr., Traverse City, MI 49684, USA
e-mail: dorothy.sirrine@gmail.com

C. Shennan
Environmental Studies Department, University
of California, 1156 High St., Santa Cruz, CA 95064, USA

J. R. Sirrine
Michigan State University Extension, 8527 E.
Government Center Dr., Suite 107, Suttons Bay,
MI 49682, USA

Introduction

Food insecurity has been pervasive in Malawi (Chinsinga 2005) and has been fundamentally attributed to low and declining agricultural productivity (Devereux 2002). Though the Malawian government reinitiated fertilizer subsidies in 2005, the future of such subsidies is uncertain considering their high costs (Dorward et al. 2008) and recent reports of political turmoil and budget crises (UN IRIN 2008). Furthermore, despite fertilizer subsidies, southern

Malawi is expected to experience food production deficits and food insecurity in the coming season based on a prolonged drought (FEWS NET 2010). Agriculture remains an important avenue for improving food security for the majority of the rural population in Malawi (Peters 2006), since 85% of the population consists of smallholder farmers. Agroforestry (AF) systems that incorporate leguminous nitrogen (N)-fixing trees into the dominant cropping system, maize (*Zea mays*), have been investigated in Malawi (see Chirwa et al. 2006; Ikerra et al. 2001; Snapp et al. 1998 for examples) as a means of improving soil quality and maize yields.

Indeed, AF is extensively promoted throughout southern Africa by government extension agencies and NGOs (Kwesiga et al. 2003; Pye-Smith 2008), is widely utilized in development projects (Franzel and Scherr 2002), and was prioritized by the Malawian government as an essential component of their National Agricultural Agenda (NAC) (WAC 2005). Despite AF's scientific potential and prominence within the agricultural development arena, its rate of adoption has generally been low (Mercer and Snook 2004); this has also been the case in Malawi (ICRAF 1997 from Thangata and Alavalapati 2003). In order for AF systems to realize their full scientific potential, it is imperative to discern how and why farmers make long-term land use decisions (Mercer 2004). Yet in Malawi, the vast majority of AF research has been biophysical in nature. The adoption studies that have occurred (Blatner et al. 2000; Gladwin et al. 2002; Thangata et al. 2002; Thangata and Alavalapati 2003) focus on relatively few AF species and/or techniques (i.e. improved fallows). Thus the scope of socioeconomic and cultural influences on AF adoption, and AF systems' impacts on farmers' livelihoods, has been largely overlooked. Adoption potential studies would be particularly useful in Malawi because there has been substantial on-farm AF research (see Harawa et al. 2006; Kanyama-Phiri et al. 1998) and promotion of AF systems in the region.

There are two predominant methodologies used to evaluate AF adoption: farming systems based ex ante adoption potential and ex post adoption studies (Mercer 2004). Farming systems based ex ante adoption potential studies employ *participatory* research techniques to evaluate AF systems' feasibility, profitability, and acceptability. The studies generally take place simultaneous with the on-farm testing stage or soon thereafter (Franzel and Scherr 2002) to determine whether experimental systems are appropriate for farmers' needs, abilities, and circumstances (Mercer 2004). Ex ante adoption potential studies that incorporate farmer assessment are rare, as they are often viewed as overly subjective (Franzel and Scherr 2002). Ex post adoption studies typically investigate the relationship between actual adoption behavior and socioeconomic and agroecological variables using binary choice regression models (Mercer 2004) after farmers have had an opportunity to adopt a new cropping systems. They rely on actual, as opposed to potential, adoption events, and enable researchers to determine which characteristics are statistically associated with adoption. However, as Ajayi et al. (2003) point out, adoption often doesn't hold a direct relationship to such characteristics but rather is the result of interaction between many different factors that may operate at various scales (e.g. household, macroeconomic). Mercer (2004) suggests that complimentary use of ex ante and ex post methodologies could be extremely useful in AF investigations.

We were able to simultaneously employ farming systems based ex ante adoption potential and ex post adoption analysis methods due to the presence of a decade-long on-farm participatory research project investigating three AF systems in southern Malawi. The unusually long on-farm research timeframe allowed farmers to both adopt novel AF systems and provide researchers with useful feedback on the AF systems' impacts on farmers' livelihoods. Due to southern Malawi's high population density and limited smallholder landholding size, 0.2–0.5 ha per family (Harawa et al. 2006), researchers have focused specifically on relay cropping AF species with maize (Harawa et al. 2006; Kanyama-Phiri et al. 2000; Snapp et al. 2002) rather than using rotations or improved fallows. Therefore, the AF species, *Sesbania sesban*, *Tephrosia vogelii*, and *Cajanus cajan* (pigeonpea), were annually replanted to minimize trees' competitive effects with maize. Given the challenges of producing green manure quantities adequate to improve soil quality on small landholdings (Snapp et al. 2002), we also investigated the benefits of integrating small amounts of inorganic fertilizer with the relay crops. There are no publications on the adoption of *S. sesban* or *T. vogelii* in Malawi despite their prominence in biophysical

research and development projects. Although pigeonpea was historically cropped in the region (Chirwa et al. 2003), Snapp et al. (2003) suggest its role has been under-investigated and potentially overlooked despite its use as a secondary food source and fuelwood.

Our primary objective was to compare the suitability of the three AF systems for smallholder farmers based on the systems' acceptability to farmers, boundary conditions, and actual adoption. Our primary hypothesis was that pigeonpea would be the most widely preferred and remain the most widely adopted of the three AF species because it offers the greatest immediate livelihood benefits in the form of a secondary food crop, whereas the other two AF species offer no known unique secondary benefits. We also hypothesized that *S. sesban* preference and adoption would be minimal due to higher labor requirements, and perhaps unfamiliarity. Specific hypotheses for relationships between socioeconomic/agroecological characteristics (i.e. landscape and gender) and farmer preference and adoption are specified in the "Results and discussion" section, and were generally related to vulnerability and food security. Our secondary objective was to compare the usefulness of farming systems-based ex ante adoption potential and ex post adoption methodologies by contrasting their efficacy and the quality of results each generated.

Methods

Physical characteristics of study site

The study, conducted as an on-farm, farmer/researcher-designed and managed project, was initiated by researchers at University of Malawi's Bunda College of Agriculture in 1994 and continued with our participation through 2004. Participating farmers were located in villages within the Songani watershed (15°19′S/35°24′E), which is located approximately 15–20 km north of Zomba—a municipality of roughly 80,000. There is a unimodal rainfall pattern in southern Malawi, with the wet season occurring between October and May. Average annual rainfall in the study area is 1,150 mm (Kamanga et al. 1999). The soils are mainly classified as Alfisols and Ultisols (Eswaran et al. 1996). They are typically well-drained

loamy sands, with nitrogen (N) as the most limiting nutrient (Snapp 1998). Since agriculture is increasingly spreading onto hillsides and steep slopes in this region (Banda et al. 1994), our research included farmers with plots at three different landscapes: (1) dambo (less than 12% slope and poorly drained), (2) dambo margin (less than 12% slope and well drained), and (3) hillside (greater than 12% slope) (Kamanga et al. 1999).

Farmer recruitment and socioeconomic characteristics

Forty-eight farm families, or households, were recruited for the initial project, selected at random along six transects spaced 0.6 km apart. Prior to farmer selection, researchers from the University of Malawi Bunda College of Agriculture held community meetings to ascertain farmers' assessments of local agricultural constraints and opportunities. After problems were collaboratively prioritized, farmers and researchers determined potential solutions that could be assessed and facilitated through agricultural research, and that seemed most feasible for farmer adoption. Most farmers selected for the project decided to participate. Eight households were no longer participating in the project by 2004, and six others were either too old or ill to consistently participate in *all* components of the socioeconomic data collection.

The ethnicity of participating farmers was predominantly Yao, with a minority from Chewa and Ngoni ethnic groups. Forty-one percent of the households participating in the socioeconomic analyses were female-headed households (FHHs), defined as households where women are divorced, widowed or separated from their husbands (Bezner Kerr 2005). FHHs generally comprise 25% of Malawi's households, but are more prominent in rural and impoverished areas such as southern Malawi (NEC 2000). Additional descriptive data on participating households can be found in Table 1.

Description of AF systems

All three AF species in this study are short-lived deciduous shrubs of the family Leguminosae. *S. sesban* generally grows between 4 and 8 m tall, while *T. vogelii* and pigeonpea are typically 1.3–3 m

Table 1 Socioeconomic and agroecological characteristics of project participants

Continuous variables	Mean	Standard deviation	Range	R
Age of farmer (years)	49	14	26–77	37
Residents per household	6.5	2.5	2–11	34
Categorical variables	1	2	3	R
Participants sex (1 = female, 2 = male)	67% (37)	33% (18)	NA	55
Head of household (1 = husband and wife present, 2 = female headed household, 3 = male only)	59% (23)	41% (16)	0% (0)	39
Well-being status (1 = wealthiest, 2 = middle income bracket, 3 = poorest)	38% (15)	31% (12)	31% (12)	39
Formal employment (1 = yes, 2 = no)	23% (9)	77% (30)	NA	39
Size of landholdings per household (1 = smallest, 2 = medium, 3 = largest)	9 (29%)	12 (39%)	10 (32%)	31
Landscape (1 = dambo, 2 = dambo margin, 3 = hillside)	29% (11)	42% (16)	29% (11)	38
Landholding size (1 = smallest, 2 = medium-sized, 3 = largest)	29% (9)	39% (12)	32% (10)	31

R Number of responses, which varies based on whether the variable represents cases for households, or husbands and wives, *NA* not applicable

tall (Bunderson et al. 1995). Farmers used woody portions from all three species for fuelwood. Both *T. vogelii* and pigeonpea were cultivated in southern Malawi prior to the project's inception, though we were unaware of *T. vogelii*'s presence and role in the region. *T. vogelii* contains a toxic compound called *tephrosin*, and historically had been used to poison fish for consumption. This fish-poisoning practice was outlawed during the colonial period, and despite its occasional use, appears to remain banned (Nsiku 2001). Farmers had not used the species as a green manure.

Pigeonpea is a perennial grain legume as well as an AF species. It is the most common species intercropped with maize in southern Malawi (Chirwa et al. 2003). While farmers did incorporate pigeonpeas' leafy biomass, this occurred after the leaves had senesced and fallen to the soil. As part of the project management, researchers incorporated fresh leafy biomass from the AF species into the soil. As a result, farmers had to forego a second and much smaller dry pigeonpea harvest.

Finally, the farmers had no prior experience cultivating *S. sesban*. It had no known secondary uses beyond fuelwood. Earlier on-farm biophysical trials with participating farmers indicated *S. sesban* had the greatest positive impacts on maize yields (Kamanga et al. 1999). *S. sesban* required more labor than pigeonpea and *T. vogelii* because it could not be

planted from seed due to a low germination rate. Thus *S. sesban* plants were grown in a nursery and transplanted roughly two months after maize planting, whereas both *T. vogelii* and pigeonpea were direct-seeded.

Experimental design and management

The project encompassed two distinct experimental phases (phase 1 from 1995 to 2000 and phase 2 from 2001 to 2004), which primarily differed in the rate and timing of inorganic fertilizer application. In 1995, four 15 × 15 m rainfed plots were established at each of the participating household's fields. Each household's field was a replicate and the experimental plots remained fixed in the same location for the remainder of both project phases. *S. sesban*, *T. vogelii*, and pigeonpea were individually relay-cropped with maize into one of the plots, while the fourth plot remained as a maize control. We cut and incorporated non-woody portions of the green manure legume species into the soil, typically in late September or early October. Researchers performed fertilizer application, much of the labor related to legumes (sowing, transplanting, and incorporation), and harvested maize from subplots. Farmers performed land preparation, sowed maize, weeded, and harvested maize outside of experimental subplots.

Data collection

Ex ante adoption potential data collection

Our ex ante adoption potential analysis was closely based on Franzel et al.'s (2002) framework for investigating the adoption potential of agroforestry practices, which assesses six different factors. Here we evaluate the four primarily socioeconomic factors: (1) feasibility and acceptability, (2) boundary conditions (additional circumstances such as market opportunities that allow or prohibit the AF practices to be profitable, feasible, and acceptable to farmers), (3) lessons for effective dissemination, and (4) feedback to research and extension. We evaluated the other two factors, biophysical performance and profitability, in Sirrine (2008) and will refer to these when appropriate. Data were collected through farmer interviews, focus groups, participant observation, and a wealth ranking exercise. Most activities took place with a translator proficient in both Chichewa (the regional language) and Chiyao (the local language).

Semi-formal farmer interviews were carried out in 2001 and 2003. The 2001 survey was employed to determine baseline data, such as demographic data and farmers' experience with the legumes. The 2003 preference survey was designed to obtain farmers' in-depth assessments of the AF systems. We first prompted farmers to summarize their experiences with the three different systems. We then obtained information such as farmers' preferred AF system(s), and farmers' perceptions of the AF systems labor requirements, secondary benefits, impacts on food security, biophysical performance, and variability. Husbands and wives were interviewed separately for both interviews. Forty-seven individual farmers were interviewed in 2001 and fifty-one in 2003, which represented 87 and 94% of the potential study population, respectively.

In 2004, we held four focus groups that included 5–9 farmers. The primary goal of the focus groups was to inform farmers of the research results; however we also obtained insights into cropping systems' impacts on farmers' livelihoods. Participant observation was based on our presence in the field between 2001 and 2004. While present, we participated in all field operations with the project research assistants and oftentimes alongside farmers. The methods for our participatory wealth-ranking exercise are described in detail in Sirrine (2008). Briefly, three community members aided researchers in categorizing farmers into three distinct socioeconomic categories (wealthiest, middle income bracket, and poorest) based on locally relevant indicators of well-being and/or vulnerability. The validity of the results was confirmed through home visits.

Ex post adoption analysis data collection

We performed adoption surveys in 2001 and 2003 to collect information on adoption and intensity of cropping of the three AF systems in farmers' fields. We carried out 34 surveys in 2001, interviewing husbands and wives together since they generally farm the same plots of land. In 2003, the adoption survey was combined with the preference survey, thus we interviewed 51 farmers. Though heads of households were interviewed separately, data were only reported for each household. We interviewed the complete population in 2001 and 94% in 2003. When inquiring about adoption and intensity of cropping, we asked farmers to exclude the presence of the AF species in the experimental plots, thus referring to "on-farm off-plot adoption". The first adoption survey also requested farmers to recall on-farm presence and intensity of any of the three AF species prior to the inception of the project's experimental phase in 1995.

Data analysis

We investigated adoption and intensity of cropping chronologically using farmer recall for 1994, and actual adoption results for 2001 and 2003. We calculated conditional distributions for both farmer preference and adoption based on socioeconomic and agroecological characteristics. The small number of cases (participating households in this case) prohibited the use of logistical regression models (e.g. probit or logit models). Additionally, descriptive statistics accurately describe the results because our data represent a census (nearly complete representation of farmers) rather than a sample, and we are not making inferences for the larger regional population since they were not participants in the on-farm project. Qualitative data from surveys, focus groups, and participant observation were drawn upon for

multiple purposes. Foremost, we used farmer feedback to facilitate our understanding of the quantitative results, and to determine which factors farmers emphasized in their decision-making process. Qualitative results also enabled us to further refine our questions and methodological approaches, allowing our research to proceed in an iterative manner.

Results and discussion

General AF system preference and adoption

Ninety-two percent of farmers interviewed in 2003 stated an AF system preference. Of those, 19% of farmers preferred *S. sesban*, 26% preferred *T. vogelii*, and 55% preferred pigeonpea (Fig. 1). As we had hypothesized, farmers primarily preferred pigeonpea because it offers a secondary food source or *ndiwo* (loosely translated as a relish that is eaten with the staple maize porridge). Many participants also mentioned the versatile nature of pigeonpea—"it is multipurpose as we can get more maize, more ndiwo, more firewood, and it also improves soil quality". Farmers reported that they preferred *T. vogelii* for its secondary use as a fish poison, enhanced soil quality, and low labor requirements. *S. sesban* was preferred for enhanced soil quality, increased maize yields, and larger growth compared to the other two legumes.

Pigeonpea adoption was 100% at the project's inception (based on farmer recall), fell to 76% in 2001, and was nearly 100% again by 2003 (Fig. 2), indicating its prominent role in the region. Respondents indicated that the decline in pigeonpea cropping in 2001 was the result of the 2000/2001 famine
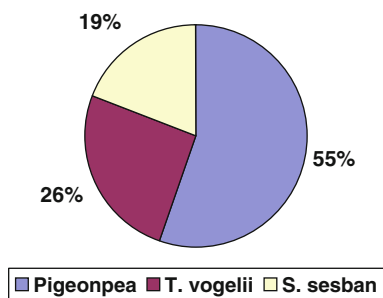
during which they consumed much of their pigeonpea seed and lacked the funds to purchase additional seed. As one farmer reported, "a lot of farmers do not save seed because they are eating it, and there is seed at the market but they cannot buy it due to lack of money". The intensity of pigeonpea cropping in farmers' fields fell from 49% at the project's inception to 39% by 2003. Yet, intensity of pigeonpea cropping was substantially higher than *T. vogelii* and *S. sesban* at all time frames (Fig. 3).

Sixteen percent of farmers recalled that they had adopted *T. vogelii* prior to the project's onset, rising to 20% by 2003 (Fig. 2). *T. vogelii* cropping intensity was 12% prior to initiation of the research project and fell slightly by 2003 (Fig. 3). Only 3 and 6% of farmers had adopted *S. sesban* in 2001 and 2003, respectively. Moreover, the cropping intensity of *S. sesban* in the adopters' fields was relatively low-less than 10% in both 2001 and 2003. Additional labor
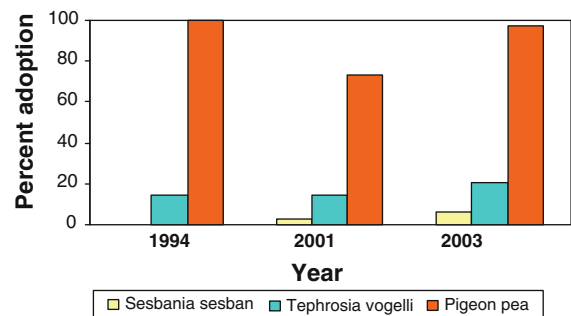
Fig. 2 Percent of AF species adoption by participating farm families ($N = 34$)

Fig. 1 Percent of farmers preferring AF species based on 2003 preference survey. $N = 51$ however four farmers had no preference, thus the pie chart incorporates $N = 47$
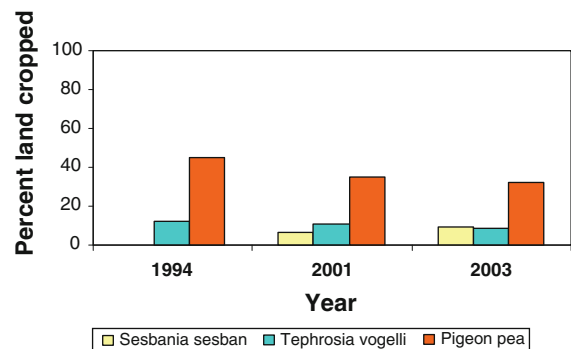
Fig. 3 Percent of farmers' land cropped to AF species (cropping intensity). *n* varies based on the number of farmers who have adopted the AF species

requirements were frequently cited as an impediment to *S. sesban* adoption, as was unfamiliarity with its germination requirements.

AF system preference and adoption by socioeconomic and agroecological characteristic

Socioeconomic (or wealth) rank

Because of immediate livelihood needs, we hypothesized the poorest farmers would not replace pigeonpea with non-food legumes, in spite of the potential for greater long-term soil quality benefits. It often takes 3–6 years for AF systems to improve soil quality (Franzel and Scherr 2002) and the poorest farmers would be least capable of accepting this trade-off. Although 50% of the poorest farmers preferred pigeonpea, 40% preferred *T. vogelii* (Table 2), the highest *T. vogelii* preference of any vulnerability category. Interviews uncovered that several of the poorest farmers either sold *T. vogelii* biomass to fishermen for cash or personally used *T. vogelii* as a fish poison. Thus immediate livelihood benefits were highly influential in the poorest farmers' AF system preference, only those benefits weren't as expected given the lack of prior knowledge of *T. vogelii*'s use as a fish poison. Yet, the poorest were more likely to adopt (or continue to crop) pigeonpea than *T. vogelii* or *S. sesban* (Table 3), indicating it played an important role in their livelihoods.

We hypothesized that the wealthiest farmers would prefer *S. sesban* because of its ability to improve maize yields in on-farm trials where the farmers had participated (Kamanga et al. 1999; Sirrine 2008). Even wealthier Malawian households generally strive to be self-sufficient in maize production due to its highly variable market price. However, 50% of the wealthiest farmers preferred pigeonpea, 22% preferred *T. vogelii*, and 28% preferred *S. sesban*. While the wealthiest farmers had the highest *S. sesban* preference and adoption rates (Table 2), a 28% preference rate was quite low. This may be because most of Malawi's population, particularly in the south, was quite poor (NEC 2000) (our wealth rankings are only relative to the project's population), and vulnerable to fluctuations in food availability and maize prices. We found that even many of the wealthiest farmers rely upon pigeonpea for household food security. In fact, their rate of pigeonpea cropping dramatically increased from 46 to 100% after the 2001/2002 famine (Table 3).

Farmers in the middle-income bracket were the most likely to prefer (Table 2) and adopt pigeonpea (Table 3), and the least likely to prefer and adopt *T. vogelii*. We found that there was a strong social stigma against the use of *T. vogelii* as a fish poison. It was viewed as "old-fashioned", perhaps because it had been previously banned by colonial powers. Wealthier farmers who preferred and adopted *T. vogelii*, often did so as a border, pesticide, and a source of fish-poison for grandchildren. Additionally, multiple farmers feared that cropping *T. vogelii* would attract thieves to their fields, who would steal not only *T. vogelii* but also other crops.

Gender

We hypothesized that women would be more likely to prefer pigeonpea because it offers an additional food source, and females in Malawi are more likely to be impoverished than males (NEC 2000). Additionally, women are often responsible for food crop production and preparing family meals (Uttaro 2002). Sixty-three percent of females preferred pigeonpea compared to 40% of men (Table 2). Women predominantly reported that they preferred pigeonpea because it was an additional food source for the family. We also repeatedly heard, from both genders, that most men did not like pigeonpea, but rather preferred to consume "good ndiwo like meat and fish". In fact, pigeonpea was often stereotyped in this region as food for women and children. A few women also reported that pigeonpea sales were particularly advantageous because they were able to retain the cash to purchase household items, "women can get money by selling pigeonpea if there is extra, this way we can buy soap and other necessities for the family". Cash income is often limited for women as they are more likely to be involved in informal, lower paying income generating activities (Uttaro 2002).

S. sesban was only preferred by 13% of women (Table 2). Many suggested *S. sesban* was too labor intensive, in part because it often grew larger than the other AF species. As one female farmer stated during a focus group, "*S. sesban* requires more labor than

Table 2 Farmer preference of AF species from 2003 preference survey based on socioeconomic and agroecological characteristics

Socioeconomic and/or agroecological characteristic[a]	S. sesban (%)	T. vogelii (%)	Pigeon pea (%)	R
Gender				
Male	33	27	40	15
Female	13	25	63	32
Female-headed household				
Yes	21	14	64	14
No	18	31	50	32
Socioeconomic status				
Wealthiest	28	22	50	18
Middle income bracket	19	6	75	16
Poorest	10	40	50	10
Age				
26–38	33	33	33	12
39–53	6	19	75	16
54–77	24	24	53	17
Household size				
1–4	17	33	50	6
5–8	26	26	48	23
9–12	9	9	82	11
Landholding size				
Smallest	29	14	57	7
Medium-sized	12	12	76	17
Largest	19	38	44	16
Formal employment				
Yes	22	22	56	9
No	20	15	65	20
TA/chief	100	0	0	2
Landscape				
Dambo	38	8	54	13
Dambo margin	16	21	63	19
Hillside	8	33	58	12

[a] Percentages were based upon the number of responses for each category *within* a socioeconomic or agroecological characteristic

R Number of responses, *TA/chief* traditional authority or village chief

the others, like making a nursery bed that requires more construction, and women are always busy doing more of the house chores than men. When *S. sesban* finds favorable conditions it grows very big giving women problems during incorporation because it is hard to cut". Adoption could not be investigated

strictly by gender since married couples typically cultivated their plots together.

Female-headed households (FHHs) and male-headed households (MHHs)

We hypothesized that FHHs would prefer and adopt pigeonpea more than MHHs because FHHs are disproportionately poor (NEC 2000). Sixty-four percent of FHHs preferred pigeonpea, 14% preferred *T. vogelii*, and 21% preferred *S. sesban* (Table 2). FHHs did prefer pigeonpea more than MHHs, again primarily because it provided a food source. Although many men voiced their dislike of pigeonpea's taste, there was no evidence that males influenced the decision to plant pigeonpea (Table 3).

Though FHHs were more likely to prefer pigeonpea than MHHs, they were less likely to crop pigeonpea in both 2001 and 2003 (Table 3). Ferguson (1994) found that land-limited, resource-poor, female farmers in Malawi often couldn't save seed from season to season because they either consumed or sold it shortly after harvest. FHHs participating in this project also had difficulty saving seed, "…I don't have any seeds—I cannot manage to save because I use it all for ndiwo…I don't have money to buy seeds [at the market]". Interestingly, MHHs more readily adopted all of the AF species compared to FHHs, with the exception of *S. sesban* in 2003 (Table 3). It is possible that MHHs were able to plant a wider diversity of species because they typically have extra labor and land resources compared to FHHs (Anderson 2002). Also, cash-generating activities such as selling surplus maize yields, which were most improved by *S. sesban* and secondarily by *T. vogelii* (Kamanga et al. 1999; Sirrine 2008), were typically associated with males (Uttaro 2002).

Landscape

We hypothesized that hillside farmers would have greater pigeonpea preference and adoption rates than dambo and dambo margin farmers because a high percentage of poor farmers reside at this rocky, erosion-prone landscape. Moreover, since none of the AF systems had a beneficial impact on maize yields on the hillside (Sirrine 2008) we assumed pigeonpea, with its secondary food benefits, would be even more attractive. While hillside farmers were more likely to

Table 3 Ex post farmer adoption of AF species in 2001 and 2003 based on socioeconomic and agroecological characteristics

Socioeconomic and/or agroecological characteristic[a]	2001				2003			
	S. sesban (%)	T. vogelii (%)	Pigeon pea (%)	R	S. sesban (%)	T. vogelii (%)	Pigeon pea (%)	R
Female-headed household								
Yes	0	7	67	15	7	13	93	15
No	5	21	79	19	6	29	100	17
Socioeconomic status								
Wealthiest	8	15	46	13	17	33	100	12
Middle income bracket	0	10	100	10	0	0	100	11
Poorest	0	20	80	10	0	33	89	9
Average HH age								
26–38	17	17	50	6	13	13	88	8
39–53	0	14	86	14	7	29	100	14
54–77	0	15	69	13	0	18	100	11
Household size								
1–4	20	20	40	5	17	17	100	6
5–8	0	16	79	19	6	29	100	17
9–12	0	13	75	8	0	14	100	7
Landholding size								
Smallest	0	25	63	8	0	11	89	9
Medium-sized	0	8	85	12	0	40	100	10
Largest	10	20	60	10	22	22	100	9
Formal employment								
Yes	11	11	78	9	14	29	100	7
No	0	19	76	21	5	24	95	21
TA/chief	0	0	33	3	0	0	100	3
Landscape								
Dambo	0	11	78	9	0	50	88	8
Dambo margin	7	13	73	15	14	14	100	14
Hillside	0	20	70	10	0	10	100	10

[a] Percentages were based upon the number of responses for each category within a socioeconomic or agroecological characteristic. Additionally, farmers may have adopted more than one, or none, of the AF systems, so percentages will typically not add up to 100

R Number of responses, TA/chief traditional authority or village chief

prefer pigeonpea compared to the other AF systems, their pigeonpea preference (58%) was very similar to that of dambo (54%) and dambo margin (63%) farmers (Table 2). Multiple hillside farmers explained to us that baboons from the adjacent forest stole their pigeonpea and they often yielded very little pigeonpea grain as a result. Still, only 8% of hillside farmers preferred S. sesban, suggesting that immediate livelihood benefits, whether from T. vogelii or pigeonpea, were important mediating factors. Pigeonpea had a much greater adoption rate than T. vogelii and S. sesban (Table 3) at all three landscapes,

suggesting that it continues to play an important role for hillside farmers despite theft from baboons.

Formal employment, landholding size, age, and household size

We hypothesized that farmers with formal employment would prefer and adopt S. sesban, to maximize maize yields, and those without formal employment would be more likely to prefer and adopt pigeonpea. However, the majority (56%) of formally employed farmers preferred pigeonpea, slightly less then the

65% of farmers without formal employment (Table 2). All formally employed farmers had adopted pigeonpea in 2003. Thus it is clearly part of their livelihood strategy. Nonetheless, *S. sesban* was primarily adopted by farmers with formal employment (Table 3) who generally hire ganyu to perform extra labor.

We expected farmers with larger landholdings to prefer *S. sesban* under the assumption they would have the physical space in their fields to include non-food crops that improved soil quality. Though farmers with larger landholdings were not more likely to prefer *S. sesban* than farmers with the smallest landholdings (Table 2) they were the only farmers to actually adopt *S. sesban* (Table 3), suggesting that landholding size may be an important barrier to adoption. Farmers offered very little qualitative feedback on the relationship between landholding size and the AF systems, with the exception of farmers with smaller landholdings who suggested their limited landholdings made it difficult to save seed.

We hypothesized that younger farmers would be more likely to adopt *S. sesban* than older farmers based on a greater willingness to experiment with new cropping systems, a longer planning horizon (Thangata and Alavalapati 2003), and perhaps a more reliable and healthy labor source. The youngest farmers were evenly split in their preference for the three AF systems, which, when compared to project-wide AF system preference, does indicate increased preference *S. sesban*. Additionally, only the youngest and middle-age group of farmers adopted *S. sesban,* suggesting age was an important boundary condition.

We were surprised to find that the largest households, in terms of number of residents, were far more likely to prefer pigeonpea than the other two AF species (Table 2). We had expected the opposite since larger households would presumably have more labor available, as required for the *S. sesban* system. It's possible that larger households were more dependent on pigeonpea because there were more mouths to feed. We did not quantify the number of household members that contributed to agricultural labor on the family's landholdings. Given the prevalence of ill relatives (HIV/AIDS and TB) and orphans being cared for by relatives, it is possible that larger households do not necessarily have greater labor resources in Malawi. In actuality, it was the

smaller households that adopted the majority of *S. sesban* and *T. vogelii* (Table 3), which may include younger households who are more likely to experiment.

Boundary conditions

Profitability represents one important boundary condition. An earlier distributional profitability analysis (Sirrine 2008) determined that pigeonpea was generally the most profitable of the systems, primarily because of its benefits as a secondary food source. The analysis also indicated that the poorest farmers were least able to profit from the AF systems. The cropping systems were more profitable for the wealthiest farmers, in part, because they generally had higher yields than the poorest farmers *regardless* of fertilizer regimes. The poorest farmers typically had low-quality, rocky, and erosion-prone hillside landholdings. These findings are consistent with previous distributional agricultural economic analyses that suggest the benefits of new agricultural technologies are often realized by farmers who can mobilize the necessary resources, and these technologies typically offer fewer benefits for women and poor farmers (von Braun 2003). In fact, none of the AF systems significantly increased maize yields on the hillside landscape (Sirrine 2008), indicating that landscape is also an important boundary condition. Secondary uses, such as firewood or ndiwo, may be the main benefits at this landscape.

The ability to afford fertilizer also played a role in limiting feasibility. The poorest farmers, and many of the middle income bracket farmers, could not afford appreciable amounts of fertilizer. Earlier findings demonstrated that fertilized AF systems had significantly higher maize yields (Sirrine 2008), indicating that the wealthiest farmers are best positioned to benefit from increased maize yields derived from AF systems that integrate fertilizer.

Market boundary conditions included the lack of marketable *S. sesban* products. The availability of a market for *T. vogelii* biomass as a fish poison, rather than a green manure, may inspire its adoption with few soil quality benefits. The local market for pigeonpea appeared to remain steady. Although *T. vogelii* and *S. sesban* seed were typically not readily available in the market, farmers felt they could obtain it from farmers in the community or from researchers.

Pigeonpea seed was consistently available in the market, but not always affordable for the poorest farmers.

We learned that the additional labor requirements associated with *S. sesban*, constructing and planting a nursery, and subsequent transplanting of seedlings, fell during the peak season for labor requirements during the maize cropping cycle. At this time, many of the poorest farmers are involved in informal labor (*ganyu*) working on wealthier farmers' lands (Alwang and Siegel 1999). It would be difficult for these farmers to forego the immediate income or food assistance associated with ganyu work. As a result, it appears that *S. sesban*-based systems were not feasible for the poorest farmers.

Lessons and recommendations for effective dissemination, extension, and policy

One of the most important lessons for dissemination is to recognize that farmers may face serious tradeoffs if adopting *S. sesban* or *T. vogelii*. Because of high planting densities in the area, most farmers will have to practice substitutive as opposed to additive intercropping. *S. sesban* and *T. vogelii* were typically planted between maize stations, in the same location as pigeonpea or other intercropped species such as common beans, squash, and groundnuts. Farmers would likely have to forego a food crop (whether pigeonpea or another), in order to plant quantities of AF species sufficient to obtain higher maize yields. If the government, researchers, NGOs, and others are interested in encouraging farmers to adopt the legumes that provide the greatest biophysical benefits, they may need to provide farmers with short-term incentives or subsidies. This would be of particular importance for poorer households.

Feedback to extension and research

Additional trials on the timing of incorporation for the three AF systems would be beneficial. Many farmers felt that the legume biomass was being incorporated too late to be beneficial to the following season's maize crop. Farmers managed their own pigeonpea slightly different than the project. They typically incorporate fallen, predominantly senesced biomass when preparing ridges for the upcoming maize planting. However a portion (the proportion varied greatly between farms) of the biomass produced by pigeonpea was usually left on the plant and not threshed and incorporated. Farmers manage their pigeonpea in this manner because they obtain a second much smaller dry harvest of pigeonpea after most leaves have dropped. Stripping remaining biomass from the trees while it is fresh is necessary for maximum soil quality benefits, because during leaf senescence nutrients are mobilized to other parts of the plant. This technique would also decrease the likelihood of N immobilization (Sakala et al. 2000).

A promising area for future research is to determine if incorporating green pigeonpea biomass and foregoing the second pigeonpea harvest would increase maize yields. Advantageously, the pigeonpea harvest comes after the maize harvest so such a system could be flexible enough to allow farmers to forego the second pigeonpea harvest if the maize harvest was sufficient. Or, if the maize harvest was poor and farmers were concerned about food security for the upcoming year, they could choose to incorporate the senesced leaves and obtain the second harvest of pigeonpea.

Local socioeconomic research is needed to investigate the potential impacts of increased maize yields resulting from non-food legumes on the food security of women and children given the current prominence of pigeonpea in their diet. An increased emphasis on the role of interdisciplinary teams, or individuals broadly trained in social and agricultural sciences, will be essential to accurately assess constraints and limitations to adoption, and prioritize areas for future research. The fields of Farming Systems Research and Agroecology, as well as the Sustainable Livelihoods Framework (DFID 2001), all provide strong foundations for such research.

Comparison of ex ante adoption potential and ex post adoption analyses

We found that farming-systems based ex ante adoption potential and ex post adoption analyses methodologies resulted in feedback that was often complementary, yet at other times conflicting. Further examination of conflicting results often led to unexpected and important insights. For example, ex ante adoption potential data indicated that the adoption potential for pigeonpea in FHHs was higher than that for MHHs, since FHHs were more likely to prefer pigeonpea (Table 2).

However, based on the ex post adoption analysis, we found MHHs were more likely to adopt pigeonpea (Table 3). By following up on these results in an iterative manner (through additional interviews, focus groups, and literature reviews), we uncovered evidence that poorer farmers, and FHHs in particular, were often not able to save pigeonpea seed from season to season due to hunger and small landholdings.

Relying exclusively on either method would have resulted in significant information gaps on the feasibility of AF system adoption. Based on the more commonly employed ex post adoption analysis, researchers would not have uncovered farmers' preference of *T. vogelii* for its secondary benefits as a fish poison, or how gender influenced preference of pigeonpea (Table 2). In the latter case, it was not possible to investigate gender using ex-post adoption analysis methods because husbands and wives generally cultivated the same plots. This highlights a limitation of ex post adoption analysis in any geographical region where husbands and wives farm together. Head-of-household would not have provided an adequate proxy for gender because of obscuring socioeconomic factors such as the increased vulnerability of FHHs. The use of closed-ended interviews designed to determine a singular relationship between adoption and distinct socioeconomic and agroecological characteristics presents a challenge vis a vis understanding the complex interactions between socioeconomic and agroecological characteristics. Ex ante adoption potential analysis allowed us to investigate barriers that were *locally* relevant and would not likely have been predicted prior to developing ex post binary choice regression models (e.g. theft of pigeonpea by baboons at the hillside landscape).

Likewise, relying exclusively on ex ante adoption analysis would have also resulted in only a partial understanding of AF adoption potential. For example, farmers' preference for pigeonpea at the hillside landscape was relatively low (Table 2), suggesting it played a minimal role in their livelihoods. In actuality there was a high rate of pigeonpea cropping at the hillside landscape, where 100% of farmers had cropped it by 2003 (Table 3). Additionally, it is possible that ex ante adoption potential enables participants to provide researchers with feedback they believe the researchers want to hear. For instance, we found it curious that both TAs, or

chiefs, preferred *S. sesban* (Table 2) but neither adopted it (Table 3). *S. sesban* had been proposed by researchers as a promising option for farmers at early community meetings, and this certainly could influence farmers' feedback to researchers. Ex post adoption analysis has two additional unique strengths. It was useful for uncovering end-of-the-line incentives and barriers to adoption (as in the case of pigeonpea seed affordability for the poorest farmers) because it represented *actual* adoption events. Also, ex post adoption studies typically employ logistical regression models that allow researchers to determine the *strength* of relationship between socioeconomic or agroecological associations and AF system adoption (we didn't have enough cases to perform a binary-choice regression model).

Conclusion

Farmer AF system preference and adoption was generally based on immediate livelihood benefits rather than long-term soil quality or maize yield improvements. Pigeonpea had the highest preference and adoption rates primarily based on its ability to provide an immediate secondary food crop, while *T. vogelii* was primarily adopted and preferred for its use as a fish poison. Socioeconomic and agroecological factors influenced farmers' AF system preference and adoption. Wealthier, younger, and farmers with greater landholdings were more likely to adopt *S. sesban*, which had the greatest biophysical and maize yield improvements. In terms of gender, women emphasized the importance of pigeonpea within household food security provisioning. The substitution of pigeonpea, or other food crops, with non-food soil quality ameliorating crops may negatively impact short-term food security. Farmers' vulnerability was not always a reliable indicator of AF system preference and adoption because multiple unpredictable, locally relevant circumstances dictated the interplay between the AF systems and farmers' livelihoods.

Farming systems based ex ante adoption potential analysis enabled us to uncover unforeseen locally relevant factors, which would not have happened if we relied solely upon ex post adoption analysis. Yet ex post adoption analysis had unique strengths—it uncovered many end-of-the-line barriers to adoption, such as seed availability, and generally allows

researchers to determine the strength of relationships between adoption and socioeconomic and/or agro-ecological factors. We found using the two methodologies iteratively added tremendously to our understanding of the AF systems' roles in and impacts upon farmers' livelihoods.

References

Ajayi OC, Franzel S, Kuntashula E, Kwesiga F (2003) Adoption of improved fallow technology for soil fertility management in Zambia: empirical studies and emerging issues. Agrofor Syst 59:317–326

Alwang J, Siegel PB (1999) Labor shortages on small landholdings in Malawi: implications for policy reforms. World Dev 27(8):1461–1475

Anderson A (2002) The effect of cash cropping, credit and household composition on household food security in southern Malawi. Afr Stud Q 6(1–2). http://web.africa.ufl.edu/asq/v6/v6i1a7.htm. Accessed April 13, 2006

Banda AZ, Maghembe JA, Ngugi DN, Chome VA (1994) Effect of intercropping maize and closely spaced leucaena hedgerows on soil conservation and maize yield on a steep slope at Ntcheu, Malawi. Agrofor Syst 27(1):17–22

Bezner Kerr R (2005) Informal labor and social relations in northern Malawi: the theoretical challenges and implications of ganyu labor for food security. Rural Sociol 70(2):167–187

Blatner KA, Bonongwe CSL, Carroll MS (2000) Adopting agroforestry: evidence from central and northern Malawi. J Sustain For 11(3):41–69

Bunderson WT, Bodnar F, Bromley WA, Nanthambwe SJ (1995) A field manual for agroforestry practices in Malawi. Malawi Agroforestry Extension Project, Publication No. 6, Lilongwe, Malawi

Chinsinga B (2005) The clash of voices: community-based targeting of safety-net interventions in Malawi. Soc Policy Adm 39(3):284–301

Chirwa PW, Black CR, Ong CK, Maghembe JA (2003) Tree and crop productivity in gliricidia/maize/pigeonpea cropping systems in southern Malawi. Agrofor Syst 59(3):265–277

Chirwa PW, Black CR, Ong CK, Maghembe J (2006) Nitrogen dynamics in cropping systems in southern Malawi containing *Gliricidia sepium*, pigeonpea and maize. Agrofor Syst 67:93–106

Devereux S (2002) The Malawi famine of 2002. IDS Bull 33(4):70–78

DFID (Department for International Development) (2001) Sustainable livelihoods guidance sheets. DFID, London. http://www.livelihoods.org/info/info_guidancesheets.html. Accessed January 21, 2006

Dorward A, Chirwa E, Boughton D, Crawford E, Jayne T, Slater R, Kelly V, Tsoka M (2008) Towards 'smart' subsidies in agriculture? Lessons from recent experience in Malawi. Natural resources perspectives 116. Overseas Development Institute, UK

Eswaran H, Almaraz R, Van den Berg E, Reich P (1996) An assessment of the soil resources of Africa in relation to productivity. World Soil Resources, Soil Survey Division, USDA Natural Resources Conservation Service, Washington DC, 20013

Ferguson A (1994) Gendered science: a critique of agricultural development. Am Anthropol 96:540–552

FEWS NET (Famine Early Warning System Network) (2010) Malawi food security update, February 2010. http://www.fews.net/docs/Publications/Malawi_FSU_February_2010_final.pdf. Accessed March 10, 2010

Franzel S, Scherr SJ (2002) Introduction. In: Franzel S, Scherr SJ (eds) Trees on the farm: assessing the adoption potential of agroforestry practices in Malawi. CABI Publishing, Wallingford

Franzel S, Scherr SJ, Coe R, Cooper PJM, Place F (2002) Methods for assessing agroforestry adoption potential. In: Franzel S, Scherr SJ (eds) Trees on the farm: assessing the adoption potential of agroforestry practices in Malawi. CABI Publishing, Wallingford

Gladwin CH, Peterson JS, Uttaro R (2002) Agroforestry innovations in Africa: can they improve soil fertility on women farmers' fields? Afr Stud Q 6(1–2). http://web.africa.ufl.edu/asq/v6/v6i1a10.htm. Accessed April 13, 2006

Harawa R, Lebmann J, Akinnifesi F, Fernandes E, Kanyama-Phiri G (2006) Nitrogen dynamics in maize-based agroforestry systems as affected by landscape position in southern Malawi. Nutr Cycl Agroecosyst 75:271–284

Ikerra ST, Maghembe JA, Smithson PC, Buresh RJ (2001) Dry-season sesbania fallows and their influence on nitrogen availability and maize yields in Malawi. Agrofor Syst 52(1):13–21

Kamanga BCG, Kanyama-Phiri G, Minae S (1999) Intercropping perennial legumes for green manure additions to maize in southern Malawi. Afr Crop Sci J 7(4):355–363

Kanyama-Phiri G, Snapp S, Minae S (1998) Partnership with Malawian farmers to develop organic matter technologies. Outlook Agric 27(3):167–175

Kanyama-Phiri G, Snapp S, Kamanga B, Wellard K (2000) Towards integrated soil fertility management in Malawi: incorporating participatory approaches in agricultural research. Managing Africa's Soil No. 11. IIED-Drylands Programme, London

Kwesiga F, Akinnifesi FK, Mafongoya PL, McDermott FH, Agumya A (2003) Agroforestry research and development in southern Africa during the 1990s: review and challenges ahead. Agrofor Syst 59(3):173–186

Mercer DE (2004) Adoption of agroforestry innovations in the tropics: a review. Agrofor Syst 61–62:311–328

Mercer E, Snook A (2004) Analyzing ex-ante agroforestry adoption decisions with attribute based choice experiments. In: Alavalapati JRR, Mercer DE (eds) Valuing agroforestry systems. Kluwer, Dordrecht, pp 237–256

NEC (National Economic Council) (2000) Profile of poverty in Malawi, 1998—poverty analysis of the Malawi Integrated Household Survey, 1997–98. Revised version. Poverty Monitoring System, Government of Malawi, Lilongwe, Malawi

Nsiku E (2001) The use of fishers' knowledge in the management of fish resources in Malawi. In: Haggan N, Brignall C, Wood L (eds) Putting fishers' knowledge to work. Conference proceedings held at the Fisheries Centre, University of British Columbia during August 27–30, 2001. http://www.fisheries.ubc.ca/publications/reports/11-1/17_Nsiku.pdf. Accessed January 29, 2008

Peters P (2006) Rural income and poverty in a time of radical change in Malawi. J Dev Stud 42(2):322–345

Pye-Smith C (2008) Farming trees, banishing hunger. How an agroforestry programme is helping smallholders in Malawi to grow more food and improve their livelihoods. World Agroforestry Centre, Nairobi

Sakala WD, Cadisch G, Giller K (2000) Interactions between residues of maize and pigeonpea and mineral N fertilizers during decomposition and N mineralization. Soil Biol Biochem 32:679–688

Sirrine D (2008) Agroforestry, soils, and food security: interdisciplinary on-farm research linking sustainability and livelihoods. Doctoral dissertation, Department of Environmental Studies, University of California, Santa Cruz

Snapp SS (1998) Soil nutrient status of smallholder farms in Malawi. Commun Soil Sci Plant Anal 29:2571–2588

Snapp SS, Mafongoya PL, Waddington S (1998) Organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa. Agric Ecosyst Environ 71(1–3):185–200

Snapp SS, Kanyama-Phiri GY, Kamanga B, Gilbert R, Wellard K (2002) Farmer and researcher partnerships in Malawi: developing soil fertility technologies for the near-term and far-term. Exp Agric 38(4):411–431

Snapp SS, Jones PB, Minja EM, Rusike J, Silim SN (2003) Pigeonpea for Africa: a versatile vegetable- and more. Hortscience 38(6):1073–1079

Thangata PH, Alavalapati JRR (2003) Agroforestry adoption in southern Malawi: the case of mixed intercropping of Gliricidia sepium and maize. Agric Syst 78:57–71

Thangata PH, Hildebrand PE, Gladwin CH (2002) Modeling agroforestry adoption and household decision making in Malawi. Afr Stud Q 6(1–2). http://web.africa.ufl.edu/asq/v6/v6i1a11.htm. Accessed August 20, 2006

UN IRIN (United Nations Integrated Regional Information Networks) (2008) Malawi; subsidizing agriculture is not enough. Africa News, February 5, 2008

Uttaro R (2002) Diminishing choices: gender, small bags of fertilizer, and household food security decisions in Malawi. Afr Stud Q 6(1). http://www.africa.ufl.edu/asq/v6/v6i1a4.htm. Accessed August 20, 2006

Von Braun J (2003) Agricultural economics and distributional effects. Presidential address at the proceedings of the 25th international conference of agricultural economists, Durban, South Africa, August 16–22, 2003. http://www.iet.ru/afe/conferences/Durban/braun.pdf. Accessed May 28, 2007

WAC (World Agroforestry Centre) (2005) Formalizing agroforestry in Malawi: trees take root in government policy. World Agroforestry Centre, Southern Africa Regional Program. http://www.worldagroforestry.org/news/default.asp?NewsID=6E5F4A43-38BA-47BE-9F8C-58D31E0307A6. Accessed May 31, 2006