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Farmers' perceptions of tree mortality, pests and pest management practices in agroforestry in Malawi, Mozambique and Zambia

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Abstract Pest management research within the context of agroforestry is in its infancy, and it is often difficult to say when a particular pest justifies investment in research to establish facts. Understanding the potentials and drawbacks of farmers' indigenous ecological knowledge (ethnoecology) may form the basis for constructive collaboration between farmers, agroforestry scientists and extension staff. Therefore, the objectives of the study were to (1) assess farmers' knowledge and perceptions of pests, (2) prioritize pest problems that limit tree planting and maize production based on farmers' own criteria and (3) to identify farmers' indigenous pest management practices for priority pests. Data were collected using community meetings, individual interviews and direct observation by the first author. The farmers involved in this study in eastern Zambia had over ten years of experience, while most of the farmers in Mozambique and parts of southern Malawi were new to agroforestry. Farmers perceived insects as the major causes of tree mortality, followed by drought, bush fires and browsing by livestock. Among the biological constraints to maize production, insects (particularly termites and stalk bores) and weeds (particularly *Striga asiatica*) were more important in farmers' minds than crop diseases. Fundamentally, the farmers' perception of the causes of tree mortality and crop pests agreed with researchers' perceptions and the literature. Both termite and witch weed problems were associated with low soil quality, and farmers use various indigenous control practices to control these pests. Some farmers did not know the causes of tree mortality, and hence do not take action. Farmer's perception of tree mortality was found to be a function of operator-specific variables such as sex, level of education and years of experience with tree species.

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Introduction

Smallholder farming systems in southern Africa are characterised by continuous maize cropping, soil erosion, and a shortage of natural, organic sources of soil carbon and nitrogen. Therefore, agricultural research in recent decades has focused on seeking solutions which rely on low-input organic matter technologies such as agroforestry (Snapp et al. 1998). Agroforestry practices have been widely promoted for replenishing soil fertility and improving maize yields in smallholder agriculture in southern Africa (Kwesiga et al. 2003). Improvements in soil fertility due to agroforestry interventions can at the same time affect soil biota populations (Sileshi and Mafongoya 2006) and have negative or positive impacts on crop pests (Sileshi and Mafongoya 2003; Sileshi et al. 2005). The introduction of certain tree crops in the system also can provide alternate food for many pests. Recently, both farmers and researchers have expressed considerable concern over pest and disease problems on agroforestry species in southern Africa (Kwesiga et al. 1999; Sileshi et al. 2000).

Though integrated pest management (IPM) is widely acclaimed as the most appropriate strategy for smallholder farmers, implementation has proved difficult, exposing not just mistaken assumptions about farmer behaviour but also formidable technical constraints (Orr and Ritchie 2004). Within the context of agroforestry, progress in IPM research has also been hindered by lack of information on the key pest problems (Boa 1998). It is often difficult to say when a particular pest justifies investment in research to establish facts and develop management practices. It is helpful if there is general agreement that the problem is serious enough, and there is demand for research (Boa 1998). Donors, national and international research institutions and non-governmental organizations (NGOs) emphasize on transparent methods of priority setting, and there has been growing pressure to show research results to justify expenditure.

One of the major constraints to establishing such priorities is the lack of adequate information about farmers' knowledge, perceptions and practices in pest management (Morse and Buhler 1997). The current philosophy in pest management is that if scientists have to work with farmers to improve crop protection and production, they should value farmers' indigenous technical knowledge systems (ethnoscience) and recognise farmers' constraints (Altieri 1993; Morse and Buhler 1997). The concept of indigenous pest management knowledge relates to the way in which local people view and understand their environment and how they structure, code, classify, interpret and apply meaning to their experience (Altieri 1993; Nkunika 2002; Price 2001). The strong point of farmers' indigenous knowledge systems is that it is the product of frequent observation of crops during the whole cropping season, and it comprehends continuities within the diverse landscape and vegetation. Practices and principles grounded in the theory of ethnoecology are often used for capturing farmers' pest management knowledge and practices (Altieri 1993; Björnsen Gurung 2003; Guimarães and Mourão 2006; Price 2001; Price and Björnsen Gurung 2006). Ethnoecological knowledge may be understood as spontaneous knowledge, culturally referenced, learned and transmitted through social interactions and that are targeted at resolution of daily routine situations (Toledo 1992; Guimarães and Mourão 2006).

A growing body of literature suggests that many farming communities have a thorough knowledge of the history, biology and bionomics of pests that affect their crops (Altieri 1993; Björnsen Gurung 2003; Nyeko et al. 2002; Nyeko and Olubayo 2005; Price 2001; Price and Björnsen Gurung 2006). Farmers not only could identify the pests affecting their crops, but they could also rank them according to the degree of damage they cause to crops (Altieri 1993; Nyeko and Olubayo 2005). There are also many areas in which farmers' knowledge about pests is deficient or the knowledge itself has drawbacks (Björnsen Gurung 2003; Nyeko and Olubayo 2005; Price and Björnsen Gurung 2006). Understanding the potentials and drawbacks of farmers' indigenous pest management knowledge may form the basis for constructive collaboration between farmers, agroforestry scientists and extension staff. Therefore, the objectives of this study were to (1) assess farmers' knowledge and perceptions of pests, (2) prioritize pest problems that limit tree planting and maize production based on farmers' own criteria, and (3) to identify farmers' indigenous pest management practices for priority pests.

Materials and methods

The study areas

The study was conducted in the "Chinyanja triangle" covering central and southern Malawi, northwest Mozambique and eastern Zambia (Fig. 1). The area is

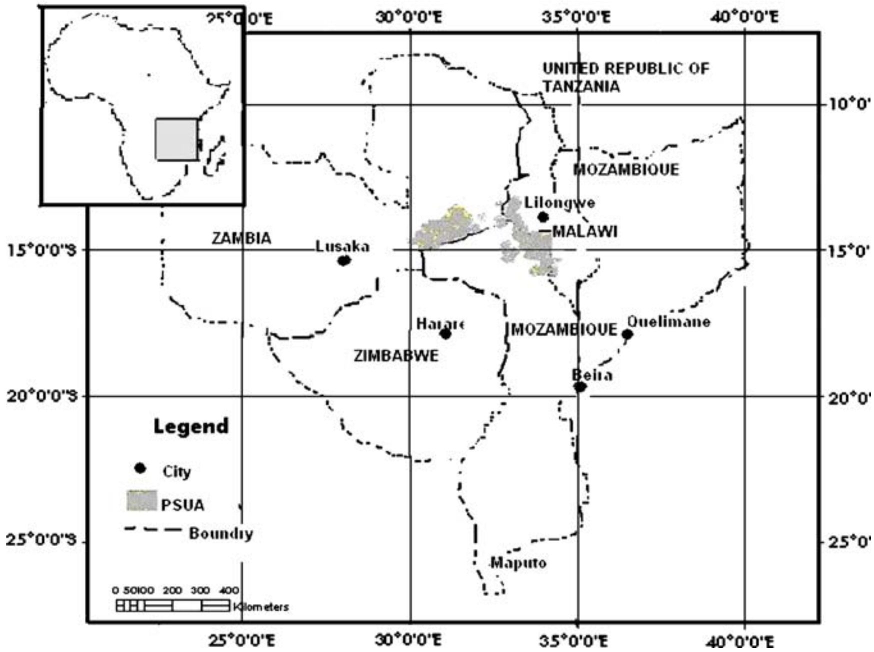

Fig. 1 Location of the Chinyanja triangle and the pilot scaling up areas (PSUAs)

named after the predominant language (Chinyanja/Chichewa) spoken in that area. Chinyanja belongs to the Nyanja group of Bantu languages. It is spoken in Malawi (where it is known as Chichewa) and in Zambia and Mozambique (where it is known as Chinyanja). This language is also spoken in Zimbabwe and Tanzania. Studies on the classification of Bantu languages indicate that Chichewa is probably one of the dialects of Chinyanja. Over 65% of Malawians have functional literacy in Chichewa, while 42 and 4% of Zambians and Mozambicans understood Chinyanja (Mchombo 2007). The majority of the people in the study area belonged to the Chewa and Ngoni ethnic groups. For example, in the sample of 87 households interviewed in 2005 in eastern Zambia, the Ngoni and Chewa accounted for 50 and 45.4%, respectively. The Tumbuka, Nsenga and Kunda ethnic groups constituted less than 5%.

Degradation of natural resources, poverty, malnutrition and HIV/AIDS are widespread in the study area. For example, in Malawi and Zambia, the productivity of maize, which is the staple food crop, has drastically declined. Some 60–85% of rural households in the Chinyanja triangle lacked access to food for three to four months per year (Akinnifesi et al. 2006). An estimated one in five in Zambia, one in seven in Malawi, and one in eight in Mozambique are living with HIV/AIDS (UNAIDS 2002).

The Chinyanja triangle is the target area where the project "Accelerating impact of agroforestry technologies on smallholder farmer livelihoods in southern Africa" is being implemented. The basic units of extension in which the agroforestry project was implemented were designated as pilot scaling up areas (PSUAs) selected based on existing production and marketing potentials, levels of vulnerability to food insecurity and poverty, existing extension staff competences and performance and level of local participation and innovation. At the beginning of the project, a local change team consisting of farmers, traditional leaders, frontline extension staff and technical extension staff was formed in every PSUA. The change teams undertook practical, field-based, modular training courses on various aspects of agroforestry, and they in turn, provided training to other farmers in the project area. The survey described here was conducted after 2 years since the change agents were trained.

The data collection methods

The data collection methods employed here were community meetings and free interviews, direct observation, and application of semi-structured questionnaires to farmers. This participatory multi-method approach was employed to overcome some of the limitations of traditional survey research and participatory rural appraisal (PRA) methods. This combination of methods was also assumed to illicit a complementary understanding of the emic (insider—in this case farmer) and etic (outsider—in this case the scientist) perspectives (Guimarães and Mourão 2006; Price 2001).

Farmer community meetings

Farmer community meetings and PRA-like exercises were conducted in April and May 2004 in a total of 12 out of the 23 PSUAs in the project area; 5, 3 and 4 in Malawi, Mozambique and Zambia, respectively (Table 1). During the community meetings in 2004, guiding questions were asked during each session to stimulate discussion and generate information comparable across the PSUAs in a consistent manner. First the agroforestry tree species planted and the major problems impinging on establishment of trees were identified by participants. Then these problems were ranked in priority order wherever consensus could be reached during the meeting. However, sometimes such consensus could not be reached as a result of differences in perception among participants. In such cases, the reason for disagreement was recorded. Participants were then asked how they cope with the problems they faced. The whole exercise took about four to five hours depending on the size of the group and intensity of debate.

In August 2005, farmer communities in six agricultural camps (a sub-division of districts used as extension units) in Chipata, Chadiza and Katete districts of eastern Zambia were involved in a PRA-like exercise. The districts and camps were selected because they were focal agroforestry research areas in eastern Zambia (Kuntashula and Mafongoya 2005) for over a decade. Four agricultural camps (Kalichero, Kalunga, Sanjika and Kaphinde) in Chipata district where farmers have the longest experience, one camp each in Katete (Kafunka) and Chadiza (Kapachi) were included. The meetings were organized by the front-line extension officers (known as Agricultural Camp Officers in Zambia), and PRA-like exercises were conducted. All participants were farmers who practiced agroforestry on average 6.2 years (standard error 0.32, median 6.0 years). The PRA methods used were pair-wise ranking of

Table 1 Profile of farmer involved in the community meetings in 2004 and 2005

Year	Country	Region	District	PSUA/Camp	Women	Men	Started AF in the area
2004	Malawi	Southern	Balaka	Mpilisi	10	12	1998
		Central	Mchinji	Chiosya	2	2	2002
		Central	Kasungu	Santhe	8	8	1998
		Southern	Dedza	Kanyama	1	2	2002
		Southern	Ntcheu	Ntcheu	11	5	2002
	Mozambique	Northwest	Angonia	Matewere	23	47	2002
		Northwest	Angonia	Nkhami	0	6	2002
		Northwest	Tsangano	Mapanje	28	24	2002
	Zambia	Eastern	Katete	Chitasa	23	37	2002
		Eastern	Chipata	Mafuta	4	11	2002
		Eastern	Katete	Chataika	10	7	2002
		Eastern	Petauke	Mondola	4	6	2002
	Total				124	167	
2005	Zambia	Eastern	Katete	Kafunka	15	18	1993
		Eastern	Chipata	Kalichero	15	15	1991
		Eastern	Chipata	Kalunga	20	14	1991
		Eastern	Chipata	Sanjika	13	19	1995
		Eastern	Chipata	Kaphinde	10	31	1996
		Eastern	Chadiza	Kapachi	12	22	1996
	Total				85	119	

problems and direct matrix ranking by a group of farmers. Groups of female and male farmers were separated and conducted the ranking exercise. The participants elected a moderator, and the discussion and ranking was entirely done by each group. Apart from recording the process, scientists and technicians were not involved in the ranking. At the end of the exercise, the male and female groups were reunited and the results were analysed with the help of the scientists and technicians. The technicians spoke fluent Chinyanja/Chichewa and acted as facilitators. The whole exercise took about 2–4 h.

Individual interviews

In August 2005, individual interviews were conducted side by side with the community meetings that took place in the six agricultural camps of eastern Zambia. The individual interviews were restricted to farmers in these camps because farmers have practiced agroforestry for over a decade and hence expected to be more familiar with pests affecting trees. The individual interviews with experienced farmers were designed to supplement results from community meetings. It is believed that group discussions often tend to produce a synchronised 'chorus line' of mutually agreed responses failing to capture the individual nature of farmer decision-making and variation in pest management practices (Orr and Ritchie 2004). It is easier to capture this diversity by talking to farmers individually rather than in large, heterogeneous groups. Therefore, additional information, approaching the subject from an etic perspective, was gathered using formal data collection methods.

In most cases, individual interviews with randomly selected farmers were conducted. In some cases, the interviewees were suggested by other members of the community (considering the experience of the individuals in agroforestry). This technique of selecting interviewees by members of the communities has been termed 'snow ball' method (Balley 1982). For this purpose, a semi-structured questionnaire was used. A total of 89 farmers (48% men and 52% women) were interviewed. About 63, 17 and 20% of the respondents were from Chipata, Chadiza and Katete districts, respectively (Table 1). The profile of respondents is presented in Table 1.

Direct observation

After the community meetings, the first author visited fields of volunteer farmers, and noted the general state of the trees/crop in terms of insect damage and disease problems. With the help of guided tours, fields where major pest problems occurred in the past season were also observed. Direct observation was applied as a way to get better understanding and description of pests, factors that increased pest problems and farmers pest control techniques. Specimens of pests that attacked the trees and crops were also collected with the help of farmers, and the vernacular names of pets were recorded.

Data analysis

The qualitative information gathered during the community meetings was summarized and tabulated. The data on biological constraints and insect pests of trees and maize was subjected to nonparametric test (Kruskal–Wallis one-way analysis of variance) to see if differences existed between men and women's ranking and among the different constraints. The data from individual interviews conducted in the agricultural camps were tabulated and analysed using generalized linear models (GLM) (Lawless 1987) based on the following assumptions. Farmers' propensity to plant different species of trees was assumed to be a function of farmer-specific characteristics. A Poisson generalized linear regression (Lawless 1987) was used to relate the number (N_i) of species planted by the ith farmer to each of the predictor variables individually or in combination. The dependent variable N_i was assumed to have a Poisson error distribution with parameter λ_i which, in turn, depends on the explanatory variables according to the log-linear function. The independent variables were farmer's age, sex, level of education, household head, ethnic group, size of land-holding, duration of land holding, years of experience of agroforestry, which have been widely used as predictors of farmers' agroforestry adoption (Pattanayak et al. 2002). Maximum likelihood estimates of parameters of the models were obtained using PROC GENMOD of the SAS system (SAS Institute Inc 2003).

In characterizing farmers' perception of tree mortality and causes of tree mortality, a GLM assuming binomial/multinomial error distribution of

Table 2 Tree species planted in agroforestry, methods of tree establishment in the field and sources of planting material mentioned by the respondents involved in the interview in eastern Zambia in 2005

Variable	Main use	Method of establishment	Respondents (%)
Tephrosia vogelii Hook f.	Soil fertility and pesticide	Direct-seeded	23.6
Gliricidia sepium (Jaq.) Walp.	Soil fertility	Potted or bare-rooted	20.1
Sesbania sesban (L.) Merrill	Soil fertility	Potted or bare-rooted	18.9
Cajanus cajan (L.) Millsp	Food and soil fertility	Direct-seeded	17.7
Tephrosia candida DC	Soil fertility	Direct-seeded	4.3
Strychnos cocculoides Bak.	Fruits	Potted	3.5
Senna siamea (Lam.)	Fuel wood and medicine	Potted	1.6
Uapaca kirkiana Müll. Arg.	Fruits	Potted	1.2
Ziziphus mourtiana Lam.	Fruits	Potted	1.2
Jatropha curcas L.	Oil production	Potted	1.2
Acacia crassicarpa A. Cunn	Fuel wood	Potted	1.2
Sclerocarya birrea (Rich.) Hochst	Fruits	Potted	0.8
Azadirachta indica A. Juss	Medicinal value	Potted	0.4

farmer responses was used. We hypothesized that a farmer's perception of tree mortality, the probability that he/she will recognize the cause of mortality and will take action against it is a function of farmer-specific explanatory variables such as age, sex, level of education and years of experience with tree species and their method of establishment. The perceived causes of tree mortality were used as dependent variables and farmers' sex, level of education and years of experience as explanatory variables. Parameters of the cumulative logit model were estimated using the LOGISTIC procedure of SAS.

Results

Agroforestry tree species planted

From the community meetings held in the PSUAs in 2004, it became clear that sesbania (*Sesbania sesban* (L.) Merrill), tephrosia (*Tephrosia vogelii* Hook f. and *Tephrosia candida* DC), pigeon pea (*Cajanus cajan* (L.) Millsp), gliricidia (*Gliricidia sepium* (Jaq.) Walp.) and some *Acacia* species were the major tree species planted by farmers. Farmers also regard *Faidherbia albida* (Del.), *Senna siamea* (Lam.) and *Senna spectabilis* (DC) as valuable agroforestry trees in Kasungu, Balaka and Nchewu districts in Malawi. Farmers liked these species because they provide firewood, poles, timber and medicines besides improving soil fertility (Table 2). Farmers also said *Senna* species are not damaged by termites and goats. The community meetings held in the three districts of eastern Zambia in 2005 revealed that tephrosia, gliricidia, sesbania and pigeon pea were the species most respondents planted (Table 2).

According to the results of the individual interview 34.5, 58.3 and 6.9% of the respondents have been practicing agroforestry <5 years, 6–10 years and >10 years, respectively. Farmers on average planted three species of trees. Over 57% of the respondents had planted those tree species that are direct-seeded (e.g. *Tephrosia* spp. and pigeon pea), while about 21% planted species that can be either bare-rooted or potted (e.g. sesbania and gliricidia). The majority of the farmers had longer experience of planting sesbania than any of the tree species (Fig. 2). However, the planting of gliricidia and tephrosia has increased sharply since 1996. Farmers' level of education ($\chi^2 = 7.29$; $P < 0.05$) and experience ($\chi^2 = 9.85$; $P < 0.01$) were the significant determinants of farmers' propensity to plant more tree species. Those who had secondary school education had planted more number of species compared with those who had no education or only primary school education. Similarly, those farmers who had over 10 years of experience had planted more species than those with shorter experience.

Farmers' perception of problems affecting trees and maize in agroforestry

Farmers mentioned various constraints to planting tree in the PSUAs and the agricultural camps. However, the major ones were pests (particularly termites and defoliator insects such as beetles, grasshoppers and caterpillars), bush fires, drought, labour shortage, browsing by livestock and weeds competition with trees during fallow establishment (Fig. 2; Table 3). Tree diseases were rarely mentioned in the PSUAs as a constraint. In the agriculture camps surveyed in eastern Zambia, both men and women ranked insects as the main problems on trees (Table 3) with only slight variations with camp. Kruskal–Wallis test showed that farmers' ranking of insects is significantly higher ($\chi^2 = 23.02$; $P < 0.001$) than weeds and livestock. Among insects, termites were perceived as the first major causes of tree mortality by farmers in almost all PSUAs and the agriculture camps (Table 3). According to Kruskal–Wallis test, the ranking of insects affecting trees significantly differed ($\chi^2 = 23.26$; $P < 0.0001$), where termites > caterpillars > aphids > beetles (Table 3). The difference between the rankings of men and women's groups was not statistically significant ($P > 0.05$). The data from individual interviews revealed the same pattern where ranking of insects as the main cause of tree mortality was significantly higher than diseases ($\chi^2 = 28.82$; $P < 0.05$).

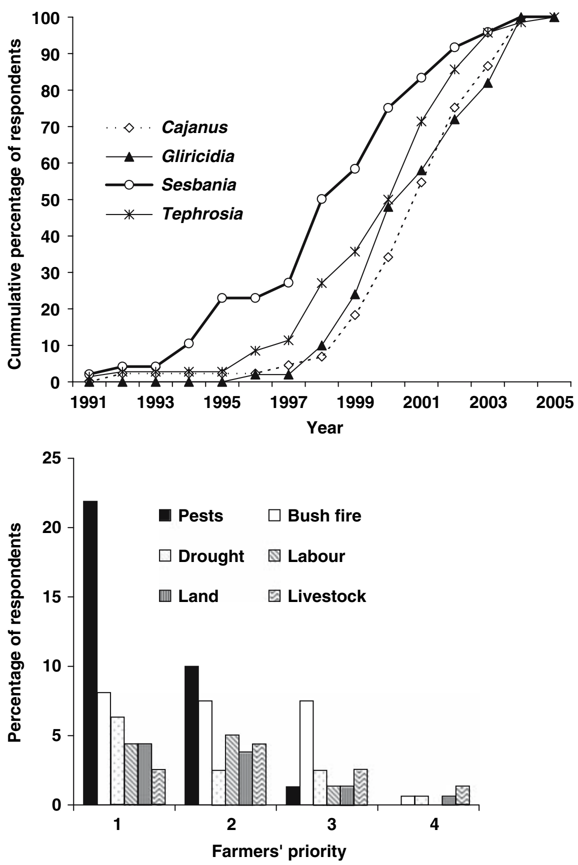

Fig. 2 Cumulative percentage of respondents who planted the four major agroforestry species from 1992–2005 (top) and farmers' constraints (in priority order) in planting the four agroforestry species (bottom) in eastern Zambia

Local people identify the major insect pests with vernacular names, which corresponded mostly to the order or family of a taxon or sometimes to a genus. For example, termites (order Isoptera) are generally called *chiswe/muswe* in Chinyanja. The winged reproductive adults of termites (mainly in the genera *Macrotermes*, *Odontotermes* and *Pseudacanthotermes*) are edible, and these are called *inswa*. Depending on the species, the crop damaging workers of these termites were called *kalanzi*, *magange, gedule* (in eastern Zambia) or *madulila* (in Balaka district of Malawi) while *Microtermes* species were called *kanona* or *kauni.* Generally, grasshoppers (order Orthoptera) are called *vinyoto* or *vikowo* in Chinyanja and *ziwala* in Chichewa. Variegated grasshoppers (*Zonocerus* spp.) are specifically called *anunkadala* in southern Malawi. Aphids (Order Homoptera, family Aphididae) are called *inda*, *nsabwe* (in Chinyanja) or *tsabwe* (in Chichewa). Caterpillars are generally called *vikusi*, *visenda* or *kazola*, which literally means worms or maggots. However, caterpillars that attack maize (e.g. stalk borers) are specifically called *kapuche*.

Over 54% of the farmers who have been planting sesbania mentioned insect as the most important causes of mortality, while 25% did not know the cause (Fig. 3). Drought, fire and diseases were mentioned by 10, 6 and 4% of the respondents. Farmers perceived termites, leaf beetles, grasshoppers (*Zonocerus* spp.) and caterpillars as the most important insect pests of sesbania. About 35% of them mentioned termites, specifically *kalanzi* (31% of respondents), *magenge* (29%) and kanona (3%). Direct observation revealed that leaf beetles (family Chrysomelidae) including *Mesoplatys ochroptera* Stål, *Ootheca bennigseni* Weis and *Exosoma*

Table 3 Farmers' ranking[a] of biological constraints in general and insects specifically to growing trees in agroforestry and maize crop during the community meeting in eastern Zambia in 2005

Constraints	Plant	Pest category	Chinyanja/Chichewa name	Women	Men
General	Trees	Insects	*Tudoyo*	1.7	1.5
		Weeds	*Wudzo, undzu*	2.7	2.0
		Disease	*Matenda*	1.7	2.5
		Animals	*Ziweto*	3.2	4.0
	Maize	Weeds	*Tudoyo*	1.7	1.7
		Insects	*Wudzo, udzu*	1.7	2.0
		Disease	*Matenda*	3.2	3.2
		Animals	*Ziweto*	3.5	3.2
Insects	Trees	Termites	*Chiswe*, *muswe*	2.0	1.5
		Caterpillars	*vikusi*, *visenda*, *kazola*	2.3	3.2
		Aphids	*Nsabwe*, *inda*	2.5	3.2
		Beetles	*Kambuyembuye*, *tununda*	3.3	2.5
		Grasshoppers	*Vinyoto*, *vikowo*, *viwala*	4.5	4.3
	Maize	Termites	*Chiswe*, *muswe*	1.2	1.0
		Caterpillars	*Kapuche*	1.8	2.0
		Grasshoppers	*Vinyoto*, *vikowo*, *viwala*	3.3	3.5
		Aphids	*Tsabwe*, *inda*	3.5	3.7
		Beetles	*Tununda*	4.7	4.8

[a] Ranking: 1 is highest and 5 is lowest

sp., which are called *kambuyembuye/mbuyembuye* are widely distributed in the study area.

Those farmers who planted pigeon pea perceived insect (51% of respondents) as the first major cause of mortality in eastern Zambia, while 40% did not know what caused mortality (Fig. 3). Some 44% of the respondents said termites caused mortality in pigeon pea, where *magenge* and *kalanzi* each were mentioned by 31% of the respondents. The other pests of pigeon pea included wilt disease, flower feeding beetles and pod-borers. Direct observation revealed that the flower feeding beetles are *Mylabris* and *Coryna* spp., while the pod-borers are *Helicoverpa armigera* (Hubn) and *Maruca testulalis* (Geyer).

Farmers who had experience with gliricidia perceived insects (30% of respondents) and drought (22% of respondents) as the major causes of mortality. About 40% of the respondents did not know what caused mortality (Fig. 3). Farmers recognized termites, aphids, beetles and white maggots (probably *Diaecoderus* larvae) as major pests of gliricidia. *Magenge*, *kalanzi* and *kanona* were mentioned by 31, 25 and 18% of the respondents, respectively, as the major kinds of termites attacking gliricidia.

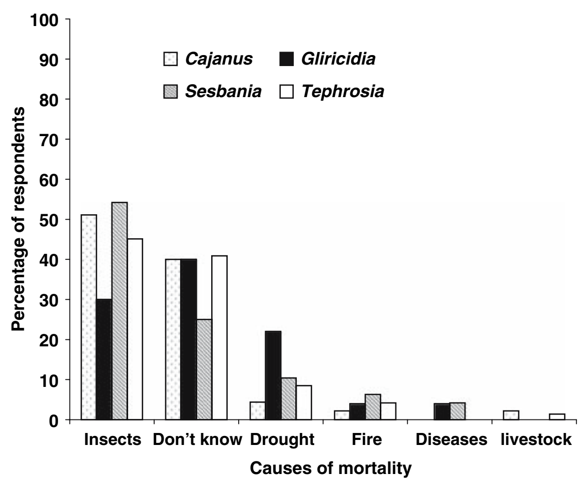

Fig. 3 Farmers' perception of the major causes of mortality in *Sesbania sesban*, *Cajanus cajan*, *Gliricidia sepium* and *Tephrosia* species in eastern of Zambia

Among the farmers who planted *Tephrosia* species, 41% did not know what caused mortality, while 45, 9 and 4% perceived insects, drought and fire as the major causes of mortality (Fig. 3). Some 42% of the respondents mentioned termites, of which *magange* (37%) and *kalanzi* (34%) were the major kinds of termites known to them. Very few farmers mentioned other insects and wilt disease.

Other non-specific insects mentioned by farmers included soil-dwelling grubs that affect most of the tree seedlings. Soil-dwelling grubs included larvae of Scarabaeidae, Curculionidae and Chrysomelidae locally called *bundzi*. White grubs were mentioned by farmers in Kanyama, Matewere and Mondola as damaging the roots of sesbania and gliricidia. Farmers also mentioned many other localized problems as causes of tree mortality. These included poor tree management including late planting, general neglect and failure to weed.

Among the problems that affect maize crops, low soil fertility, insects (particularly termites and stalk borers), weeds (particularly the witch weeds *Striga asiatica* (L.) Kuntz) and livestock were mentioned most frequently in the PSUAs and agricultural camps. Analyses of the pair-wise ranking performed in the agricultural camps showed that insects and weeds are more important ($\chi^2 = 17.56$; $P < 0.001$) in farmers' minds than diseases and livestock. Statistical tests on farmers' ranking of major insect groups showed that termites were more important ($\chi^2 = 50.93$; $P < 0.001$) than caterpillars (including stalk borers), grasshoppers and aphids. Witch weed is called *kaloyi* (literally meaning syphilis of the land) or *kawfiti* (the witch). In some areas, *Kawfiti* may mean either *S. asiatica* or *Alectra vogelii* Benth. Farmers associated witch weed problems with infertile sandy soils (locally called *mchenga*), while *katondo* (red soils) and *mkanda* (dark clay soils) were perceived to have less problem. Many farmers did not understand the biology of witch weed, and some even thought witch weed is the cause of low soil fertile. To control witch weed, farmers used various indigenous practices, including crop rotation and manure application (Table 4).

Farmers' pest management practices

The majority of farmers made no efforts to control insects such as beetles, aphids, caterpillars and grasshoppers. Some farmers hand-picked and destroyed insects such as grasshoppers, beetle larvae while others applied insecticides recommended for control of cotton pests. Farmers used various methods to control termites (Tables 4 and 5) and witch weeds (Table 4). The most commonly mentioned methods for managing termites were (1) planting cuttings of *Euphorbia tirucalli* L. (locally called *nkadzi* or *mududzi*) in termite-infested fields or applying its finely chopped branches in planting holes, (2) digging the termite mound and destroying the queen, (3) applying wood ash in planting holes, (4) applying crushed fruits of *Swartzia madagascareinsis* Desv in planting holes, (5) applying leaf concoctions of neem (*Azadirachta indica* A. Juss) or *Tephrosia vogelii* and (6) applying pork or meat to attract predatory ants. In addition, farmers avoided earthing-up the soil when weeding or reduced the weeding to minimum in order to reduce termite damage on maize crops (Table 5).

Farmers' indigenous practices of witch weed control included (1) applying manure, (2) rotation with food legumes and (3) planting legume trees such as *S. sesban* (Table 4). In order to reduce browsing by goats, farmers sprayed the tree with goat droppings or cow dung. Farmers also said there are traditional rules regarding control of livestock. However, these rules worked only during the cropping season.

Determinants of farmers' knowledge and perception of tree pests

Results of the logistic regression showed variation of farmers' perception of tree mortality with the tree species ($\chi^2 = 7.76$; DF = 3; $P < 0.05$) in the agricultural camps in eastern Zambia. Over 42% of the farmers perceived mortality in gliricidia as high. Some 40% of these did not know the cause of mortality, while 30 and 22% viewed insects and draught as causes of gliricidia mortality, respectively. Damage by diseases and fire was mentioned by less than 5% of the respondents. The probability of a farmer perceiving gliricidia mortality as high or low differed significantly with their method of establishment ($\chi^2 = 12.68$; DF = 2; $P < 0.001$), and the model gave 59.1% correct classification. About 58% of the farmers perceived mortality in sesbania as moderate to high. Close to 25% of these did not know the cause of mortality, while 54.2, 10.4 and 6.3% view insects, draught and fire as important causes of sesbania mortality, respectively.

Farmer's perception of tree mortality was also found to be a function of operator-specific variables such as sex, level of education and years of experience with tree species. The probability of a farmer perceiving sesbania mortality as high or low differed

Table 4 Farmers' indigenous management practices for the top three pests mentioned in the PSUAs in 2004

PSUA	Pest (Chinyanja/Chichewa name)	Tree/crop attacked	Control practices
Mplisi	Termites (*chiswe*)	Trees and crops	Dig mound and destroy queen
	Termites (*madulila*)		Plant *Euphorbia tirucali*
	Grasshoppers (*anunkadala*)	Most trees	Hand-pick and kill
			Apply insecticides
Chiosha	Termites (*chiswe*)	Both	Avoid earthing-up
	Wilting of seedlings	Pigeon pea	Early planting in the nursery
	Witch weed (*kawfiti*)	Maize/groundnut	Apply manure
			Plant leguminous species
Santhe	Termites (*chiswe*)	Trees and crops	None
	Beetles (*nunda*); grubs (*mputsi*)	Sesbania	None
	Witch weed	Maize	Plant leguminous species
Kanyama	Black maggots (*mputsi*)	Sesbania	None
	White grubs	Tree seedlings	None
	Witch weed (*kawfiti*)	Maize, beans	None
Ntcheu	Termites	Trees	None
	Black grubs (*mputsi*)	Sesbania	Hand-pick and killing
	Witch weed	Maize	Crop rotation
Matewere	Termites (*chiswe*)	Pigeon pea, maize	Plant *Euphorbia tirucali*
	White grubs (*bunzi*)	Tree seedlings	Spray *Tephrosia* extract
	Witch weed (*kawfiti*)	Maize	Plant leguminous species
Nkhami	Witch weed (*kawfiti*)	Maize, groundnut	Apply manure
Mapanje	Termites (*chiswe*)	Most trees	Apply pork or meat to attract ants
			Apply *Euphorbia tirucali*
	Grubs (*mputsi*)	Sesbania	None
	Witch weed (*kawfiti*)	Maize	None
Chitasa	Termites (*chiswe*)	Pigeon pea	Apply insecticides
	Beetles (*tununda*)	Sesbania	Apply insecticides
	Witch weed (*kaloyi*)	Maize	Crop rotation
Mafuta	Termites (*chiswe*)	Pigeon pea	None
	Beetles (*tubuyembuye*)	Sesbania	Apply insecticides
	Pod borers (*vingongo*)	Pigeon pea	None
	Witch weed (*kaloyi*)	Maize, groundnuts	None
Chataika	Termites (*chiswe*)	All trees	Spray *Tephrosia* extract
	Beetles (*nunda*)	Sesbania	Apply Foskill
	Witch weed (*kawfiti*)	Maize	Apply manure; crop rotation
Mondola	Termites (*chiswe*)	Pigeon pea	Plant *E. tirucali* in field
	Beetles (*tununda*)	Sesbania	Apply *Tephrosia* extract
	Witch weed (*kaloyi*)		Apply manure; crop rotation

significantly (Table 6) with sex ($\chi^2 = 4.22$; DF = 1; $P < 0.05$) and operator experience ($\chi^2 = 8.71$; DF = 2; $P < 0.05$), and the model with sex and farmer experience gave 58.9% correct classification. The probability of a farmer perceiving disease and fire as a cause of mortality in gliricidia and sesbania was lower than that for insects.

Farmers perceived mortality as low in the direct-seeded species such as pigeon pea (34.0%) and tephrosia (21.4%). Some 52.3 and 45.7% of the

Table 5 Farmers' indigenous termite management practices mentioned during group meetings held in eastern Zambia in 2005

District	Camp	Tree/crop attacked	Indigenous control practices
Katete	Kafunka	Maize	Plant *nkadzi* (*Euphorbia tirucali*) in maize fields
		Trees	Apply *mchelekete* (*Swartzia*) leaves
		Both	Dig the termite mounds and destroy the queen
Chipata	Kalichero	Both	Apply Tephrosia or Neem concoction
		Maize	Avoid earthing-up in maize fields when weeding
		Maize	Minimum weeding (2 or 3 times only)
		Both	Dig the termite mounds and destroying the queen
		Both	Apply wood ash around crops/trees
	Kalunga	Maize	Avoid earthing-up in maize fields when weeding
		Maize	Plant *nkadzi* or *mududzi* (*E. tirucali*) in field
		Tree	Apply *mchelekete* (*Swartzia*) leaves
	Sanjika	Maize	Plant *nkadzi* or *mududzi* (*E. tirucali*) in field
		Maize	Avoid earthing-up in maize fields when weeding
		Trees	Clean weeding
		Trees	Apply wood ash or lime in planting holes
		Trees	Apply *mchelekete* or *kasokosoko* (*Swartzia*)
	Kaphinde	Trees	Apply wood ash or lime in planting holes
		Trees	Apply *mchelekete* or *kasokosoko* (*Swartzia*)
		Maize	Plant *nkadzi* or *mududzi* (*E. tirucali*) in field
		Maize	Avoid earthing-up in maize fields when weeding
Chadiza	Kapachi	Maize	Avoid earthing-up in maize fields when weeding
		Maize	Plant *nkadzi* or *mududzi* (*E. tirucali*) in field
		Trees	Apply wood ash
		Both	Dig the termite mound and destroying the queen

farmers viewed insects as the causes of mortality in pigeon pea and tephrosia, while about 40.9 and 41.4% did not know the causes of mortality in pigeon pea and tephrosia, respectively. The probability of farmers' perceiving mortality of these species was not significantly influenced with any of the farmer-specific variables entered in the model (Table 7). The probability of farmers ranking insects and drought as equally important causes of pigeon pea and tephrosia mortality is higher than is fire (Table 7).

Discussion and conclusions

Farmers perceived insects as the first major causes of tree mortality, followed by drought, bush fires and browsing by livestock. Fundamentally, the farmers' perception of the causes of tree mortality and crop pests agreed with researchers' perceptions. Among insects, termites were perceived as the most important pests of both trees and maize crops. This is consistent with evidence from literature (Nkunika 1994; Nyeko and Olubayo 2005). For instance, the damage due to termites on forestry and agroforestry trees in parts of Zambia ranges from 19–78% (Nkunika 1994). Similarly, Ugandan farmers ranked termites as the most serious problems in growing trees (Nyeko and Olubayo 2005). Termites are also one of the major problems in crop production in the study area (Wightman and Wightman 1994; Munthali et al. 1999; Orr and Ritchie 2004; Sileshi et al. 2005) accounting for 20–30% of pre-harvest loss in maize in parts of Zambia and Malawi (Nkunika 1994; Munthali et al. 1999). Termite damage to trees and crops is more pronounced during drought years and or prolonged dry spells during the crop season (Sileshi and Mafongoya 2003; Sileshi et al. 2005; Orr and Ritchie 2004). Other soil-dwelling insects

Table 6 Logit-linear modelling of respondents' perception of tree mortality and significance of respondent-specific covariates in eastern Zambia in 2005

Species (number of respondents)	Parameter	Parameter estimate	Pr > χ^2
Gliricidia (28 female; 22 male)	Mortality low	−0.54	0.1038
	Mortality moderate	0.40	0.2131
	Mortality high (reference)	0.0	–
	Method bare-rooted	−0.31	0.4370
	Method direct seeded	−1.14	0.0079
	Method potted (reference)	0.0	–
Sesbania (25 female; 23 male)	Mortality low	−0.28	0.5702
	Mortality moderate	0.89	0.082
	Mortality high (reference)	0.0	–
	Sex female	0.65	0.0355
	Sex male (reference)	0.0	–
	Experience <5 years	−2.05	0.0036
	Experience 5–10 years	0.003	0.9947
	Experience >10 years (reference)	0.0	–
Pigeon pea (26 female; 18 male)	Mortality low	−0.09	0.7631
	Mortality moderate	0.66	0.0382
	Mortality high (reference)	0.0	–
Tephrosia (43 female; 27 male)	Mortality low	0.46	0.0581
	Mortality moderate	1.30	<0.0001
	Mortality high (reference)	0.0	–

[a] Parameter held as a reference category

such as white grubs and other beetle larvae were also perceive as important in the mortality of many tree species. Larvae of Curculionidae (e.g. *Diaecoderus* spp.) have been reported to damage maize, groundnut (Wightman and Wightman 1994; Sileshi and Mafongoya 2003) and trees such as sesbania (Sileshi and Mafongoya 2003) in southern Africa.

Among the tree-specific pests, beetles were perceived by farmers as important causes of mortality in sesbania. Leaf beetles such as *M. ochroptera*, *O. bennigseni* and *Exosoma* sp. can inflict substantial damage to sesbania in Malawi and Zambia (Mchowa and Ngugi 1994; Sileshi et al. 2000, 2002). However, beetles rarely cause tree mortality although beetle damage is aggravated if planting is done late (Sileshi et al. 2002). According to farmers the main problems affecting pigeon pea were wilt disease, flower beetles and pod borers. This is in agreement with research findings. In the study area wilt disease (particularly *Fusarium* wilt) has been reported to cause up to 75% plant mortality in Malawi (ICRISAT 1986; Orr and Ritchie 2004). Research has shown that blister beetles (*Mylabris* and *Coryna* spp.) and pod-borers (*H. armigera*, *M. testulalis*) can cause up to 80% reduction in grain yield (ICRISAT 1986). Farmers perceive aphids as pests of gliricidia. The groundnut aphid (*Aphis craccivora* (Koch)) and bean aphid (*Aphis fabae* Scop.) cause leaf and flower damage to gliricidia throughout the region. Farmers did not mention any major problems on *Tephrosia* species.

In addition to pests, farmers also mentioned other problems such as browsing by livestock, fire, poor tree management including late planting, general neglect and failure to weed as causes of tree mortality. This, confounded with dry spells and the attendant termite attack, could result in high tree mortality. Based on the information from PRA-like exercises, personal interviews and direct observations, we have come to the conclusion that low survival of trees was due to several interacting factors. Tree mortality may be caused by a host of stress factors which may be mutually re-enforcing including damage by insects and pathogens, weed competition, drought, browsing by animals, nutrient

Table 7 Logit-linear modelling of farmers (involved in the interview in eastern Zambia in 2005) perception of major factors that cause tree mortality

Species (number of respondents)	Parameter	Estimate	Pr > χ^2
Gliricidia (N = 50)	Fire	−3.18	<0.0001
	Diseases	−2.44	<0.0001
	No idea	−0.08	0.7774
	Drought	0.85	0.0060
	Insects (reference)	0.0	–
Sesbania (N = 48)	Fire	−2.71	<0.0001
	Diseases	−2.15	<0.0001
	No idea	−0.60	0.0465
	Drought	−0.17	0.5642
	Insects (reference)	0.0	–
Pigeon pea (N = 44)	Fire	−3.38	0.0002
	No idea	−0.27	0.3670
	Drought	−0.09	0.7630
	Insects (reference)	0.0	–
Tephrosia (N = 70)	Fire	−3.11	<0.0001
	No idea	−0.17	0.4738
	Drought	0.17	0.4738
	Insects (reference)	0.0	–

[a] Parameter held as a reference category

N is the number of respondents who planted the tree species

imbalances, water stress or excess, physical damage such as fire, frost, heat, etc.

Among the pests, termites and witch weed were upper most in the minds of farmers who plant maize. Both trees and crops often show poor performance when grown on infertile land. However, the implication of low soil fertility for pest management is often less clear to farmers and often ignored by researchers. Experience in Malawi suggests that smallholder IPM is best viewed in the context of addressing the critical issue of soil fertility (Orr and Ritchie 2004). Even though the role of agroforestry trees in reducing witch weed and termite problems is well established (Gacheru and Rao 1998), very few farmers were aware of it. Both termite and witch weed problems are associated with low soil quality (Sileshi and Mafongoya 2003; Sileshi et al. 2005, 2006). Although some termites are serious pests of crops, they have significant ecosystem functions. Firstly, termites contribute to the tropical ecosystem by providing food and shelter to an extraordinary number of associated organisms. They are also a protein source for humans. Secondly, they play beneficial roles in soil processes in agroforestry by aiding decomposition of organic matter. Because they feed on plant litter and cultivate cellulose-decomposing fungi in their mounds, some termite taxa (e.g. Macrotermitinae) are capable of processing large quantities of litter at up to 80% efficiency (Jones 1990). Thirdly, as ecosystem engineers, they have significant influence on various soil physical and chemical properties. Therefore, they need to be managed in such a way that does not compromise these essential functions.

Managing the soil in ways that conserve and enhance soil quality such as legume fallows using termite tolerant species can reduce the damage by termites and witch weeds (Sileshi et al. 2005, 2006). This should involve testing improved fallows as components of IPM strategies for witch weed and termites. Such strategies are also more likely to win acceptance from farmers because they are linked to general crop management practices. Other promising strategies against termites such as attraction of predatory ants using locally available materials (Table 4) and intercropping with legumes (Sekamatte et al. 2003) need to be tested and promoted in the study area.

Most farmers were aware of insect pest problems on the tree species they planted, where as they were less aware of tree diseases. Nyeko et al. (2002) similarly reported that farmers lacked knowledge of diseases of *Alnus* species in Uganda. In the case of some insect pests, farmers also failed to make the connection between the damaging, soil-dwelling larval stage of the insect (e.g. *Ootheca* spp., *Diaecoderus* sp. larvae) and its above-ground adult stages. Similarly, farmers thought the crop damaging workers of *Macrotermes* spp. (*madulila*) and the winged reproductive adults (*inswa*) are unrelated. Diseases and soil pest are hidden from view and hard to detect until the sudden appearance of damage. Farmer knowledge of causes of tree mortality or crop damage may be deficient when the pest is difficult to observe even though if they are important. Even when damage occurs, symptoms may be misdiagnosed and ascribed to other causes, such as nutrient deficiencies.

The results also suggest that farmers' education level and experience had a positive influence on their planting of agroforestry species and their perception of tree mortality. This is in agreement with Price (2001) who reported that increased knowledge from education is linked to better pest management behaviour. Studies of soil conservation and agroforestry technologies elsewhere have shown that farmers that have been practicing agroforestry are more likely to be aware of different types of agroforestry species, their benefits (Pattanayak et al. 2002) and limitations including susceptibility to pest attack. Agroforestry is a management intensive technology, requiring ability to manage trees properly to achieve optimal results. Lack of proper understanding of the technology may lead to poor management and low tree performance. Therefore, training could improve farmers' tree management knowledge and skills.

The study has also identified a number of indigenous control practices especially for termites and witch weeds. It is tempting to assume that such practices are inherently beneficial. However, some practices may have undesirable effects on crop yields. For example, the farmer practice of not earthing-up termite infested maize fields could lead to a reduction in yield of up to 50% in the absence of termite damage (Orr and Ritchie 2004). Orr and Ritchie (2004) also argue that there is no evidence of reduction in termite damage by planting *E. tirucali*. However, farmers throughout the areas surveyed in Malawi, eastern Zambia and Mozambique believe this practice works. Farmers may use ineffective control practices because of ignorance about the pest in question. Scientists may also raise genuine concerns about the effectiveness of such practices. This in essence justifies the importance of integrating indigenous knowledge and scientific knowledge, as both have strengths and deficiencies and therefore can complement one another. Instead of dismissing local practices as inadequate, their shortcomings need to be identified as a mechanism to generate knowledge. In this way, specific limitations of local practices can be removed and solutions with local relevance may be found. Therefore, as agroforestry technologies are developed and promoted, there is a need to integrate farmers' indigenous ecological knowledge about pest identification and control into the scaling-up process in order to improve pest management.

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