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Assessing the adoption potential of agroforestry practices in sub-Saharan Africa

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Abstract

This paper reviews the application of various types of on-farm trials and methods for collecting and analysing data needed to assess the adoption potential of agroforestry practices. The review is based on farmers' and researchers' experiences in seven case studies in three countries of sub-Saharan Africa assessing the biophysical performance, profitability and acceptability of agroforestry practices. Assessments of adoption potential are key elements of a participatory, farmer-centered model of research and development. They improve the efficiency of the technology development and dissemination process, help document the progress made in disseminating new practices, demonstrate the impact of investing in technology development, provide farmer feedback for improving research and extension programmes, and help to identify the policy and other factors contributing to successful technology development programmes as well as the constraints limiting the achievements. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Agroforestry practices have considerable potential for helping to solve some of Africa's main land-use problems (Sanchez, 1995; Cooper et al., 1996). Agroforestry trees can supply farm households with a wide range of products for domestic use or sale, including food, medicine, livestock feed, and timber, and environmental and social services such as soil fertility, moisture conservation, and boundary markers.

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At numerous sites throughout sub-Saharan Africa, researchers and farmers have conducted participatory surveys to identify farmers' problems and needs and have selected agroforestry practices to test in on-farm trials. These trials, and the analyses that researchers and farmers conduct together, form the basis for determining whether farmers will adopt the practices on a wider scale. Adoption potential is defined as the likelihood of uptake of a new technology or practice when required information and material are made available to the farmer. Assessing the adoption potential of a practice involves determining its biophysical performance, its profitability, and its acceptability to farmers. The assessment has several objectives: improving the efficiency of technology generation, measuring the effectiveness of technology dissemination, understanding the role of policy in adoption, and demonstrating the impact of investment in technology development (CIMMYT, 1993).

There is an extensive literature on conducting on-farm trials and assessing the adoption potential of technologies concerning annual crops (e.g. Ashby, 1990; CIMMYT, 1993; Stroud, 1993) but little is available on agroforestry or other 'natural resource management' and 'sustainable agriculture' practices. Approaches developed for annual crops are not necessarily appropriate for agroforestry for various reasons: agroforestry system complexity and variability (in terms of objectives, components, management, and ecological interactions), the longer period required for farmer and researcher assessment, and poor understanding of farmers' agroforestry strategies (Scherr, 1991a).

The objective of this paper is to review the application of (1) various types of on-farm trials used to assess the adoption potential of agroforestry practices and (2) selected methods for collecting and analysing data needed for the assessments. The review is based on research conducted jointly by staff of the International Centre for Research in Agroforestry (ICRAF) and of national agricultural research institutes in seven case studies in three countries (Table 1). The case studies involve farmers' experiences of testing agroforestry practices and the biophysical performance, profitability and acceptability of these practices.

The assessment of adoption potential is an integral part of a farmer-centered approach to research and development (Fig. 1). The discussion in this paper follows the components of the approach.

1. First, we examine the evolution of approaches used to assess the adoption potential of agricultural practices.
2. We then define a framework for assessing the adoption potential of agroforestry practices, highlighting the use of three types of on-farm trials and their main features.
3. Next, we present specific methods for assessing adoption potential and how the assessments can be used for determining the boundary conditions for practices, that is the biophysical and socioeconomic circumstances that determine whether the practice is likely to be adopted.[1]

[1] The concept 'boundary conditions' complements the term 'recommendation domain,' commonly used in farming systems research. A recommendation domain is a roughly homogenous group of farmers with similar circumstances for whom we can make more or less the same recommendation (Byerlee and

Table 1
Main characteristics of the study areas and agroforestry practices examined in this paper[a]

	Yaounde area, central Cameroon	Chipata area, eastern Zambia	Maseno area, western Kenya	Embu area, central Kenya
Altitude (m)	600–900	900–1200	1500	1300–1800
Rainfall (mm)	Bimodal, 1500	Unimodal, 1000	Bimodal, 1600–1800	Bimodal, 1200–1500
Soil type	Ferralitic	Alfisols	Nitosols	Nitosols
Population density (km^{-2})	5–30	25–40	300–1000	450–700
Main crops	Cassava, cocoa, plantain	Maize, groundnuts	Maize, beans, vegetables	Coffee, maize, beans
Livestock types	Goats	Zebu cattle, goats	Zebu cattle, goats	Improved dairy cattle
Area cultivated per farm (ha)	6	1.2–3.2	0.5–1.5	1–2
Agroforestry practices examined	Improved tree fallows for improving soil fertility	Improved tree fallows for improving soil fertility	Improved tree fallows and hedge-row intercropping for improving soil fertility, upper-storey trees for wood	Fodder trees, upper-storey trees for wood
Main tree species in above practices	*Cajanus cajan, Calliandra calothyrsus*	*Sesbania sesban, Tephrosia vogelii*	*Sesbania sesban, Tephrosia vogelii, Crotelaria grahamiana, Calliandra calothyrsus, Leucaena leucocephala*	*Calliandra calothyrsus, Grevillea robusta*

[a] Sources: Duguma and Franzel (1996); Franzel et al. (1996); Kwesiga et al. (1999); Swinkels et al. (1997).

4. Finally, we examine how assessments of adoption potential fit into a farmer-centered model of the research-development continuum, and conclude with some thoughts on future priorities.

As stated above, agroforestry and other 'sustainable agriculture' and natural resource management practices share many features, such as their greater spatial and temporal complexity as compared to annual crop practices. Thus, many of the lessons learned from on-farm agroforestry research should be relevant to other natural resource management innovations in sustainable agricultural development.

Collinson, 1980). Recommendation domains are defined in the early stages of the research process and technologies are sought which are appropriate for them. Once a technology is found that benefits farmers at particular sites in a recommendation domain, it is useful to try to assess that technology's boundary conditions.

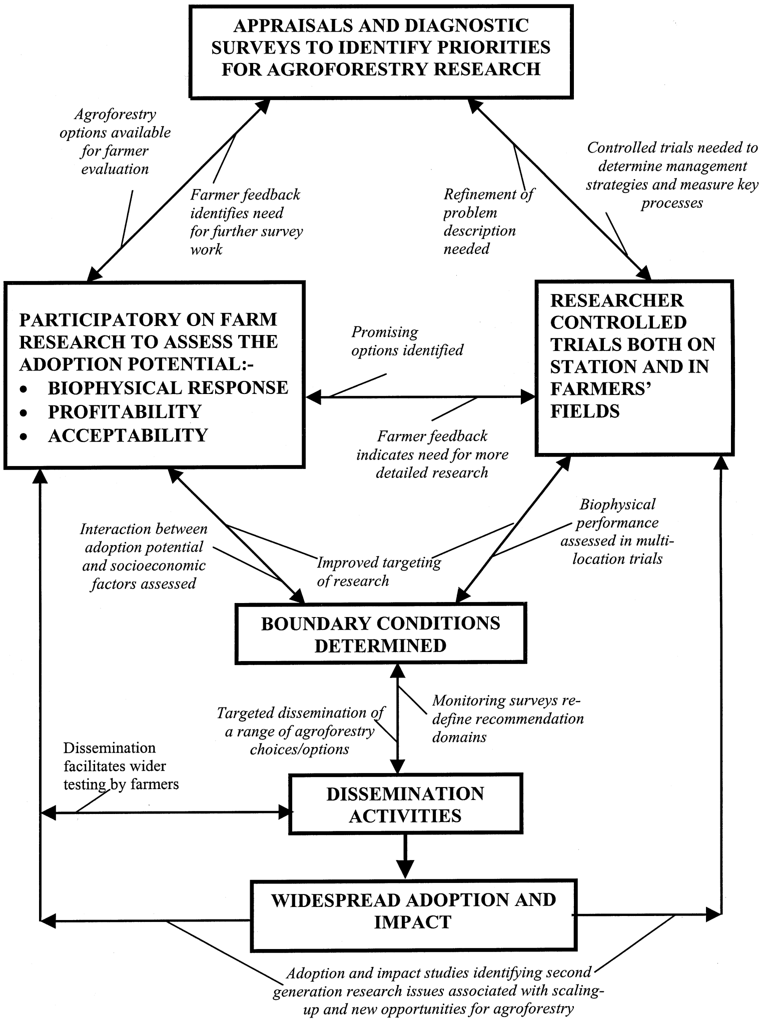

Fig. 1. Flow diagram of decisions and activities in farmer-centred agroforestry research and extension.

2. Evolving approaches to assessing adoption potential

During the 1970s, assessments of adoption potential focussed on biophysical variables such as a new crop variety's potential to increase yields per hectare (Byerlee and Franzel, 1993). Where technologies involved new crop varieties and associated practices and biophysical circumstances were fairly homogenous, as for rice varieties in the irrigated areas of southeast Asia, the approach achieved considerable success. But in Africa where farming systems were often more complex, more subsistence-oriented and more variable, the biophysical approach was found wanting. In the 1980s, farming systems research emphasized the need to determine adoption potential based on the priorities and circumstances of farmers (Norman, 1980). Researchers tested new practices under farmers' conditions but research protocols for on-farm trials still tended to be drawn up by researchers, following consultation with farmers (Zandstra et al., 1981).

Participatory approaches in the late 1980s and 1990s highlighted empowering farmers to choose the technologies they wanted to test and then to design and implement the research themselves (Chambers et al., 1991; Haverkort et al., 1991; Rocheleau, 1991; Scherr, 1991a). There was considerable experimentation with adapting both researcher-led and participatory on-farm research methods to agroforestry (Scherr, 1991b, c). During the 1990s, the case studies examined in this paper were initiated with an explicit view to using participatory on-farm trials to understand the adoption potential of agroforestry practices. Furthermore, it was realised that on-farm research offers researchers, extensionists, policy makers and farmers an opportunity to learn important lessons about achieving effective dissemination of agroforestry practices, as well as feedback on further research priorities.

3. Objectives and types of on-farm trials

Much of the information for determining the biophysical performance, profitability and acceptability of agroforestry comes from on-farm trials. The nature of a trial depends on its objectives. Assessment of biophysical performance requires biophysical data on the products and services that the technology is planned to produce. These are likely to change with different adaptations of the technology as might occur if farmers were asked to manage them. To prevent such possible variation, trials designed to assess biophysical performance should be controlled in order to replicate specific technology designs. The trials should also be implemented in a way that farmers' willingness and ability to establish and maintain the trials does not affect the outcome. Thus, trials to assess biophysical performance need a high degree of researcher control in both design and implementation.

The assessment of profitability requires biophysical data (to estimate returns), that must be generated from standardised experiments. However the financial analysis[2] also requires realistic input estimates, of which labour poses most difficulties. Realistic data can only be obtained if farmers manage the trials to their own standards. Thus profitability objectives require trials in which researchers have considerable input into the design but farmers are responsible for implementation. The objectives of assessing feasibility and acceptability require data on farmers' assessments and adaptations of the technology. These can only be assessed if farmers are left to experiment with little researcher involvement.

There are many different ways of classifying on-farm trials (Okali et al., 1994). However, the differing requirements of the objectives of biophysical performance, profitability and acceptability mean it is helpful to classify trials according to the

[2] Financial analysis refers to analysis of profitability from the farmers' perspective; economic analysis to profitability from society's perspective (Gittinger, 1982).

balance of researcher and farmer involvement in their design and implementation. The classification outlined below involves three types of trials and draws upon that of Biggs (1989).

3.1. Type 1 trials, designed and managed by researchers

These trials are simply on-station trials transferred to farmers' fields. They are useful for evaluating biophysical performance and require the same design rigour as on-station research with regard to treatment and control choice, plot size, replication and statistical design. In the case studies reviewed, these trials often replaced on-station trials. Researchers found that because the trials took place on farmers' fields, they were more representative of the range of farmers' biophysical conditions, such as soil type, field management history, flora, and fauna, than were on-station trials. Type 1 trials were also found essential to confirm that promising results obtained on-station could be duplicated under a wider set of biophysical conditions. But type 1 trials were usually more expensive and more difficult to manage than on-station trials; in western Kenya they involved renting land from farmers, guarding the trials, and bringing labourers from the station to implement them (Shepherd et al., 1994). Farmers' assessments were not a main objective of these type 1 trials but, as with on-station trials, it was useful to get farmers' feedback on the different treatments in a systematic manner (Sperling et al., 1993; Franzel et al., 1995).

3.2. Type 2 trials, designed by researchers but managed by farmers

Here, farmers and researchers collaborate in the design and implementation of the trial. The trial is labelled 'researcher-designed' because it follows the conventional scientific approach to conducting an experiment: one or more test treatments are laid out in adjacent plots and compared to a control treatment or several controls. In the case studies, researchers and farmers collaborated in the design of the trials and each farmer agreed to follow the same prototype or chose one of several possible prototypes, so that results could be compared across farms. Farmers were responsible for conducting all of the operations in the trial. Usually plots were large, ranging from 200 m^2 to 400 m^2, and unreplicated on each farm. When analysing the data, farmers were considered as replicates because researchers were looking for patterns of response that were consistent across farms.

In type 2 trials, reliable biophysical and socioeconomic data over a broad range of farm types and circumstances were sought. The trials were also useful for assessing farmers' reaction to a specific practice and its suitability to their circumstances. Farmers were encouraged to visit each other's trials and to conduct group field days to assess the practice at different stages of growth.

3.3. Type 3 trials, designed and managed by farmers

In type 3 trials, farmers were briefed about new practices through visits to field stations or on-farm trials. They then planted and experimented with the new practices as they wished. They were not obliged to plant in plots or include control treatments. Researchers monitored the farmers' experiments, or a subsample of them, focusing on their assessment of the new practice and their innovations. In addition, farmer-to-farmer visits and meetings were useful so that farmers could compare their experiences and innovations. Any farmers experimenting with a new practice could be said to have a type 3 trial, regardless of whether they obtained planting material and information from researchers, other facilitators, or other farmers. The 'hands-off' approach in these trials, which assumes that farmers know best how to test a new practice on their own farms, is supported by some in the literature while others emphasize training farmers to conduct trials following scientific principles, such as replication and non-confounding of treatments (Okali et al., 1994).

3.4. Suitability of trial types for meeting objectives

The suitability of the different trial types for differing objectives is summarized in Table 2. Suitability involves both the appropriateness of the trial for collecting the information and the ease with which it can be collected. Biophysical measurements were most meaningful in type 1 and 2 trials; they were less useful in type 3 trials because each farmer may have managed the practice in a different manner. Type 2 trials were well-suited for collecting parameters (e.g. labour use) for financial analysis; such data were difficult to collect in type 3 trials because plot size and management varied. The data collected in type 1 trials were less relevant to farmer circumstances; yield response to new practices was biased upward and labour use, measured using labourers hired by researchers and working on small plots, was found to be unrepresentative of farmers' labour use.

Type 3 trials were critical for identifying farmers' innovations and farmers' assessments were more accurate in type 3 trials for several reasons. Because farmers controlled the experimental process, they were likely to have more interest and information about the practice. Furthermore, because in type 3 trials farmers usually had less contact with researchers, their views of a technology were less influenced by researchers' views. Finally, whereas it was often necessary to provide inputs to farmers in type 2 trials to ensure that results were comparable across farmers, no inputs, with the possible exception of planting material, were provided in type 3 trials. Thus farmers' views in type 3 trials were more likely to be sincere than in type 2 trials, where positive assessments may simply have reflected the farmers' interest and satisfaction in obtaining free inputs.[3] For example, in the hedgerow intercropping trial to increase soil fertility in western Kenya, 50% of the farmers claimed that hedges increased crop yields whereas technicians noted

[3] In fact, providing free inputs to farmers is also disadvantageous because they may (1) promote a dependency relationship between facilitator and farmer instead of a partnership, (2) set an unfortunate precedent for other facilitators who come later and do not have the resources for offering inputs, and (3) create conflict because inputs cannot be provided to all. Positive assessments may also reflect farmers' interest in interacting with researchers.

Table 2
The suitability of Type 1, 2 and 3 trials for meeting specific objectives[a]

Information types	Type 1 trial: researcher-designed, researcher-managed	Type 2 trial: researcher-designed, farmer-managed	Type 3 trial: farmer-designed, farmer-managed
Biophysical response	H	M	L
Profitability	L	H	L
Acceptability			
Feasibility	L	M	H
Farmers' assessment of a particular prototype[b]	L	H	M
Farmers' assessment of a practice[b]	L	M	H
Other			
Identifying farmer innovations	0	L	H
Determining boundary conditions	H	H	H

[a] H, high; M, medium or variable; L, low; 0, none. The suitability involves both the appropriateness of the trial for collecting the information and the ease with which the information can be collected.

[b] By particular prototype, we mean a practice for which experimental and non-experimental variables are carefully defined. For example, a prototype of the practice improved fallows would include specific management options such as species, time of planting, spacing, etc.

yield increases on only 30% of the farms; the technicians claimed that the difference was due to farmers trying to please researchers (Swinkels and Franzel, 1997).[4]

3.5. Continuum and sequencing of trial types

The different types of trials are not strictly defined; rather they are best seen as points along a continuum. For example, it was common for a trial to fit somewhere between type 2 and type 3, as in the case where farmers agreed to test a specific protocol (type 2) but over time, individuals modified their management of the trial (type 3). For example, in the hedgerow intercropping trial in western Kenya, farmers planted trials in a similar manner but many later modified such variables as the intercrop, hedge pruning height and frequency (Shepherd et al., 1997).

The types of trials are not necessarily undertaken sequentially; researchers and farmers may decide to begin with a type 3 trial, or to simultaneously conduct two types of trials. For example, in central Kenya, researchers began their fodder tree research with type 3 trials because much was already known about the growth of the trees in the area (Franzel et al., 1996). In central Cameroon, farmers planted both type 2 and type 3 trials; type 2 trials to test a particular prototype (improved tree fallows, for two seasons, to improve soil fertility) and type 3 trials either to extend their plantings or to test a modification of the practice, such as tree fallows for longer than two seasons (Degrande, 1997). Type 2 and 3 trials often generated

[4] Only 14% actually expanded their hedges, which suggests that the technicians were right.

questions about biophysical factors that could be then best evaluated through type 1 on-farm or on-station trials. For example, in western Kenya, several researcher-managed trials to explore specific aspects of improved fallow function and design were set up following farmer-managed trials (Swinkels et al., 1997).

3.6. Complexity and types of trials to use

It is tempting for researchers to try to use the same trial to meet several different objectives. However this can lead to conflict, compromising the ability to meet any of the objectives in a rigorous manner. For example, researchers assessing the adoption potential of hedgerow intercropping in western Kenya wanted to use a type 2 on-farm trial to collect information on biophysical responses and farmer assessment. They allowed the farmers to modify the trial as they wished, and because of the resulting variation, were unable to identify factors determining the practice's effects on crop yields. They concluded that researchers and farmers would be better off conducting separate type 1 trials for biophysical data and type 3 trials for socioeconomic assessment rather than a single type 2 trial that tried to do both (Shepherd et al., 1997; Swinkels and Franzel, 1997).

Across the case studies, it was found that the more complex the trial or technology, the less effective a type 2 approach was likely to be for both biophysical and socioeconomic assessments. 'Complexity' involves the number and diversity of components (intercropping trees and crops, as opposed to trees or crops in pure stand), long-term cycle of the technology (3+ seasons) as opposed to single-season cycles, the period of evaluation, and the size of the trial (whether it takes up more than 10% of a farmers' cultivated area). In a trial comparing annual crop varieties, it is often possible to combine biophysical and socioeconomic objectives because, according to the above definition, the trial is not complex. However, most agroforestry trials are complex and thus different trial types are needed to meet the differing objectives. The overall lesson from the case studies was that no type of trial was 'better' than another type; determining which type was best depended on the participants' (researchers' and farmers') objectives and the particular circumstances.

4. Management of on-farm trials

The case studies offer important lessons in the areas of management of on-farm trials, particularly concerning farmer and technology selection, trial control plots, and the need to integrate adaptive research and dissemination.

4.1. Farmer and technology selection

A common approach to on-farm technology testing has been to identify a relatively small number of farmers in many different villages who are willing to undertake experiments. This approach can be useful when key socioeconomic or biophysical factors such as farm size or soil type vary mainly across villages. An alternative approach, used in the case studies in Zambia, western Kenya, and Cameroon, is to concentrate efforts in a relatively few contrasting but representative sites, which we refer to as the village approach. The key feature of this approach is that all villagers are given equal access to information and germplasm, thus encouraging wider participation. As such, it was found to be most appropriate for type 2 or type 3 trials. The advantages of the village approach were found to be:

1. a reduction in monitoring costs per farmer through higher concentration of farmers;
2. a wider participation ensuring that different household types are involved in testing and development;
3. a possibility of studying inter-farm linkages and larger scale effects (e.g. pest and disease outbreak, income from labour hiring) which require identification prior to wide dissemination; and
4. the mitigation of intra-village jealousies and improved interaction with researchers.

Researchers also noted a disadvantage to the approach: the more or less equal distribution of information and high participation rates made the study of farmer-to-farmer diffusion processes more difficult. To summarize, the ‘scattered farmer’ and ‘village’ approaches each have their advantages and the degree to which one is favoured over another depends on the technology being tested, the type of information sought, and the degree of variation in local conditions.

The case studies used a range of different methods for selecting farmers, including extension staff (Zambia, central and western Kenya), volunteers in farmer meetings (Cameroon) and farmer groups (western Kenya). The different methods may lead to large variation in the types of farmers that are involved in the research and their interest. In western Kenya, the farmers selected by extension staff were found to have a much higher proportion of males and wealthy persons than their surrounding communities (Obonyo, 2001). Ndufa et al. (1995) found that working with farmers in groups was extremely effective, because the group approach sustained farmers’ interest and because members shared information and planting material. These findings concur with those of Heinrich (1992) and van Veldhuizen et al. (1997). Ndufa et al. (1995) also found that group members were not necessarily representative of the farmers interested in the technology and that it was necessary to influence the selection process so that a representative sample of farmers participated in the on-farm trials.

Providing farmers with different options to test was a key feature of the trials, because different farmers had different circumstances and preferences, because farmers wanted to diversify, and because any single option could have failed. For example, in Zambia, farmers selected among six improved fallow practices in on-farm trials. Some farmers preferred the options that economised on land and labour but gave a relatively low yield response, while others preferred the practices with high land and labour requirements but giving greater yield response (Franzel et al., 1999).

The numbers of trials and farmers varied greatly among sites and was determined by the specific objectives as well as the number and resources of facilitators.

Researchers usually began on a small scale, with fewer than 10 farmers in the first season, in order to learn from the experience. In the second season, they modified the trial and expanded to 20–100 farmers, to allow stratification according to differences in farmers' circumstances and strategies. The numbers of type 3 trials were often much higher; ranging up to over 1000 in Zambia. There, researchers coordinated the monitoring of small samples of farmers, 35 to 110, depending on the objective of the monitoring and available staff and resources (Franzel et al., 1999).

4.2. Trial control plots

In the case studies, farmers were not as interested in the comparison between the test and the control plot as were the researchers. For example, in the hedgerow intercropping trial in western Kenya, farmers agreed to compare the effects on maize yields of a plot with hedges and a plot without hedges, otherwise treating the two plots in the same manner. Later, researchers found that only 11% of the farmers concurred with this approach; 40% sought to compare the hedges with another soil fertility amendment such as animal manure or fertiliser, which they applied only to the control plot. For 38%, the main evaluation method was to compare present yields with past yields on the hedge plots (Swinkels and Franzel, 1997). Others have reported similar complications (Reynolds et al., 1991; Versteeg and Koudokpon, 1993). Where farmers do want to compare test and control plots in type 2 trials, the exact comparison should be one that they are interested in. In many cases, different controls will be relevant for different farmers.

4.3. Adaptive research and dissemination teams

Participatory on-farm research and dissemination are closely linked. Therefore, in all of the case studies, research, extension, non-governmental organisations (NGOs) and farmer groups established partnerships called Adaptive Research and Dissemination Teams (ICRAF, 1997, pp. 207–209). The teams planned, implemented, and evaluated on-farm research, training and dissemination activities. In Zambia, for example, 75 representatives of research, extension, NGOs and farmer groups met once or twice per year to review progress and plan activities for testing and disseminating improved fallows and other soil fertility measures (Kwesiga et al., 1997). The teams have had the following impacts (Cooper, 1999):

1. reduced cost of conducting on-farm research as field-based extensionists and NGOs establish and monitor on-farm trials;
2. enhanced breadth of input into and relevance of the research;
3. expanded range of sites under experimentation with relatively little additional cost;
4. partners increasingly well-informed on key aspects of technology options and better placed to disseminate technologies and respond to farmer feedback; and

5. partners have developed a sense of involvement, enthusiasm, and ownership of promising innovations.

5. Assessing adoption potential

This section focuses on methods for assessing profitability and acceptability, as methods for assessing biophysical performance in on-farm trials are covered elsewhere (Hildebrand and Russell, 1996; Mutsaers et al., 1997). The methods used in each case study for assessing profitability and acceptability are shown in Table 3.

5.1. Profitability

Greater financial benefits may arise through increased biophysical productivity or through reduced input costs. Researchers assessed biophysical productivity and financial net benefits by comparing results on treatment plots with those on control plots, which represented farmers' current practices. Financial analyses were based on the costs and returns that farmers faced. Partial budgets were drawn up for those practices that had limited impacts on the costs and returns of an enterprise, as in the case of fodder trees for dairy cows in central Kenya (Franzel et al., 1996). A partial budget is a technique for assessing the benefits and costs of a practice relative to not using the practice. It thus takes into account only those changes in costs and returns that result directly from using a new practice (Upton, 1987). Where a practice had substantial effects, as for hedgerow intercropping, enterprise budgets were used (Swinkels and Franzel, 1997). Detailed information on labour use among participating farm households was collected using a range of methods, including farmers' recall just after a task was completed and monitoring of work rates through observation. Prices were collected from farmers and from local markets.

Financial analyses often calculate returns to only one resource, land, ignoring the fact that labour and capital are far greater constraints than land in many farming systems. Thus, we calculated the net returns to land, which was relevant for farmers whose most scarce resource was land and the net returns to labour, relevant for those who lacked household labour. Net returns to capital for agroforestry practices were often extremely high or infinite because little or no capital was used in implementing them. This finding explained the attractiveness of many of the options because the alternatives, for example, fertiliser to improve crop yields or dairy meal concentrate to increase milk yields, were very expensive for farmers.

Data for a single period are usually inadequate for evaluating the performance of an agroforestry practice. Therefore, cost-benefit analyses, also called investment appraisals (Upton, 1987), were developed for estimating costs and benefits over the lifetime of an investment. Average values for costs and returns across a sample of farmers were used to compute net present values. Also, net present values were calculated for each individual farm based on its particular costs and returns. This latter method allowed a better understanding of the variation in returns and thus the risk of the practices. In some cases, such as in the improved fallow trials in western

Table 3
Types of assessments conducted in analyses of the profitability and acceptability of selected agroforestry practices

Practices	Profitability				Acceptability							
	Partial budget	Enterprise budget	Sensitivity analysis	Farm model	Resource budget	Evaluation of quality of practice	Survey of farmer problems	Farmer assessment survey	Risk assessments	Monitering expansion	Matrix scoring	Decision trees
Hedgerow inter-cropping, western Kenya[a]		*	*	*	*	*	*	*	*	*		*
Improved fallows, eastern Zambia[b]		*	*	*	*	*	*	*	*	*		
Improved fallows, western Kenya[c]		*	*	*	*	*	*	*	*			
Improved fallows, central Cameroon[d]		*	*	*			*	*		*		
Agroforestry trees, western Kenya[e]						*	*	*		*	*	
Fodder trees, central Kenya[f]	*		*		*	*	*	*	*	*		
Boundary planting, central Kenya[g]	*	*	*				*	*	*	*	*	

[a] Shepherd et al. (1997); Swinkels and Franzel (1997).
[b] Kwesiga et al. (1999); Franzel et al. (1999).
[c] Swinkels et al. (1997).
[d] Degrande (1997).
[e] Franzel et al. (2000).
[f] Franzel et al. (1996).
[g] Tyndall (1996).

Kenya, it was not possible to assess yield responses, because farmer management varied greatly between the control and treatment plots and among farms. But it was still possible to calculate the post-fallow yield increases required to break even, that is, to cover the costs of planting and maintaining the improved fallows, under different assumptions. The analysis thus provided useful information about profitability before the yield response of the practice was known (Swinkels et al., 1997).

Whereas cost-benefit analyses are useful for determining the net present value of an enterprise that has costs and returns over many years, they do not show the increase in annual income generated. To assess increases in annual income, farm models were developed in which the farm was partitioned, to contain specified portions of land devoted to each phase (corresponding to a season or year) of the technology. For example, in the model of improved fallows in Zambia, the farm was assumed to have equal portions of area in each of the practice's four phases: planting of the improved fallow (year 1), maturing of the fallow (year 2), the first post-fallow maize crop (year 3), and the second post-fallow maize crop (year 4; Table 4). The net returns of this farm were compared to two other farms having the same amount of labour (the main constraining resource), one planting fertilised maize continuously without fallow and the other planting unfertilised maize continuously without fallow. The model was thus useful for estimating the impact of improved fallows on annual net farm income and maize production (Franzel et al., 1999).

5.2. Acceptability

In the case studies, acceptability was found to depend on a range of criteria in addition to financial profitability, such as risk, compatibility with farmers' values and difficult-to-quantify benefits that were often omitted from economic analyses, such as a tree's ornamental value or its value in providing a boundary marker (Tyndall, 1996). The acceptability of a technology also depends on its feasibility from the farmers' point of view, and its value to them. Apparent constraints, such as labour bottlenecks that are cited when farmers attach a low value to an activity, may disappear when the farmers' perception of the value increases. Thus, the feasibility of a technology is dependent upon the technology's perceived value.

Farmers' ability to plant and maintain agroforestry practices was found to depend on three factors: (1) their available resources (land, labour, and capital), (2) whether they had the required information and skills, and (3) whether they were able to cope with any problems that arose. Several tools were used in the case studies for assessing the feasibility of a practice. Resource budgets were assembled to compare the needs of a new practice with the needs of the farmers' other enterprises. For example, Fig. 2 shows that labour requirements for pruning hedgerows coincided with peak season labour use in western Kenya. This tool helped explain farmers' difficulty in pruning hedges in a timely manner, required to prevent competition with adjacent crops (Swinkels and Franzel, 1997).

Another means of assessing feasibility was to evaluate the quality of the practice as planted and maintained by the farmer. This assessment often involved both quantitative data, such as survival rates of planted seedlings, and qualitative ratings,

Table 4
Farm models comparing net returns to labour per year of a 1.44-ha farm in eastern Zambia using *Sesbania sesban* improved fallows with farms cultivating continuous maize, with and without fertiliser[a]

Practice	Farm using improved fallows (farm adds 0.36 ha of improved fallow per year)				Farm with unfertilized maize (1.2 ha cultivated)				Farm with fertilized maize (0.92 ha cultivated)			
	Area (ha)	Work-days $year^{-1}$	Maize production kg $year^{-1}$	Net returns $year^{-1}$ (ZKw)		Work-days $year^{-1}$	Maize production kg $year^{-1}$	Net returns $year^{-1}$ (ZKw)		Work-days $year^{-1}$	Maize production kg $year^{-1}$	Net returns $year^{-1}$ (ZKw)
Fallow, 1st year	0.36	45	0	−1316	Maize	120	1157	159,827	Maize	120	4077	442,985
Fallow, 2nd year	0.36	2	0	2880								
Maize 1st post-fallow year	0.36	35	1359	216,704								
Maize 2nd post-fallow year	0.36	38	650	98,575								
Total	1.44	120	2008	316,843								

[a] Household is assumed to have only 120 workdays available during the cropping season for maize production; the amont needed to manually cultivate 1.2 ha maize without using fertiliser. Improved fallows are 2 years in length and are followed by 2 years of maize crops. As over 80% of cultivated area is under maize and most households do not own livestock, the model roughly approximates the farm as a whole. \$1.00 US = 1,683 Zambia Kwacha (ZKw), 1998. Source: Adapted from Franzel et al. (1999).

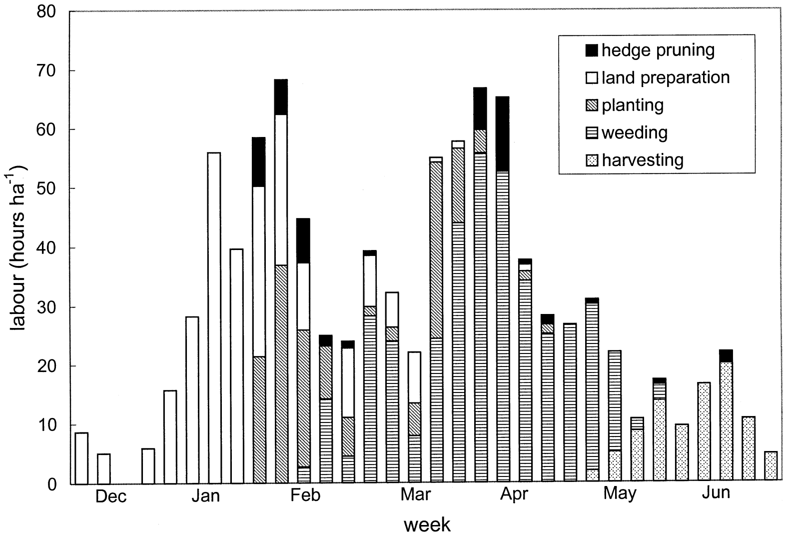

Fig. 2. Labour profile of pruning and cropping activities in long rains 1992 by hedgerow intercropping trial farmers. Cropping labour is mean of 126 maize/sorghum plots of 31 farmers. Pruning labour is mean of 31 hedge plots of same 31 farmers. Labour includes both household and hired labour.

such as farmers' assessments of the amount of biomass produced in an improved fallow. Both were used in assessing the feasibility of improved fallows in Zambia (Franzel et al., 1999).

Researchers conducted surveys using informal interviews and questionnaires to obtain farmers' assessments of practices and problems. For example, in Zambia, farmers noted beetles as their main problem affecting *Sesbania sesban* improved fallows; technicians found that weeds were also a critical problem (Table 5). These assessments provided quantitative evidence of the frequency and intensity of the problems.

Risk was assessed by (1) measuring variability in the returns of individual farmers, (2) conducting minimum returns analysis (CIMMYT, 1988), in which the average of the lowest 25% of the net benefits of each treatment were compared, and (3) conducting informal group interviews with farmers. Sensitivity analyses were conducted to assess the effect of changes in key parameters, such as input–output coefficients, the discount rate, or prices of inputs and outputs. These were useful for assessing the stability of the results.

In the case studies, asking farmers whether a practice was acceptable did not prove to be very useful; nearly all farmers gave positive assessments probably because they felt that criticising a practice would be insulting to the researcher. Rather, acceptability was best ascertained by examining whether farmers continued using or expanded use of a practice following a trial and whether neighbouring farmers took it up. For example, Franzel et al. (1996) assessed the numbers of fodder trees farmers had planted on their own, 3 years after completion of an on-farm trial. Important indicators of acceptability included the number of times farmers

Table 5
Problems that farmers faced in growing improved fallows in type 3 trials, eastern Zambia, 1996[a]

Problems	Number of farmers having as main problem (%)		Number of farmers mentioning problem[b] (%)		No. of farms where technicians observed problems not mentioned by farmers (%)	
	Sesbania sesban	*Tephrosia vogelii*	*Sesbania sesban*	*Tephrosia vogelii*	*Sesbania sesban*	*Tephrosia vogelii*
Mesoplatys beetles	16 (38)	0	17 (40)	0	0	0
Drought at planting	5 (12)	1 (5)	9 (21)	1	0	0
Termites	3 (7)	0	7 (17)	0	0	0
Browsing	1 (2)	1 (5)	1 (2)	1	0	0
Weeds	1 (2)	0	3 (7)	0	7 (17)	5 (24)
Poor germination	0	4 (19)	0	5 (24)	0	0
Waterlogging	0	2 (9)	0	4 (19)	0	0
Late planting	0	0	0	0	4 (10)	2 (10)
Competition	0	0	0	0	2 (4)	0
No problems	16 (38)	13 (62)	16 (38)	13 (62)	29 (69)	14 (66)
Total No. of farmers	42 (100)	21 (100)	42 (100)	21 (100)	42 (100)	21 (100)

[a] Source: Franzel et al. (1999).
[b] Percentages do not sum to 100 and numbers of farmers do not sum to total numbers because some farmers mentioned more than one problem.

expanded their planted area, numbers of trees planted and area planted per expansion, and numbers of farmers to whom the original experimenters gave or sold planting material.

But using continued use or expansion as a proxy for acceptability was also found to be problematic, for three reasons. First, in some cases, farmers were interested in expanding but were unable to do so because they lacked access to critical information or inputs. Second, some farmers may have continued using a practice not because they liked it but because they expected to receive other benefits, such as free inputs, employment, or social benefits from having researchers visit their farms. Third, agroforestry practices take a long time to evaluate and it was reasonable to assume that a farmer needed to experience the full cycle of a technology (4 years in the case of improved fallows in Zambia) before deciding whether to continue using it. Any expansion that took place before the end of the cycle could arguably have been called an expansion in testing rather than an indication of acceptability.

Assessments of farmers' preferences among alternative options can provide useful feedback for research and extension, especially when they are quantified. For example, in western Kenya, farmers used an indigenous board game, *bao*, to score upper-storey trees on criteria important to them (Table 6). Branches of each tree were laid out on the ground next to each row of the board and for each criterion, farmers rated the species by putting one to five seeds in the pocket next to each branch — five being a high rating and one being a low rating. In contrast to questionnaires, which farmers find tedious, the *bao* game can be used for collecting quantitative data on farmers' evaluations in an accurate, entertaining, yet statisti-

Table 6
Farmers' mean ratings of species on a scale of 1–5, using *bao* game, on growth characteristics, intended uses, and preference for future planting, 30 months after planting, western Kenya[a]

Species	Ratings (standard deviation)[b]					% Farmers rating 4 or 5 for future planting
	Speed of growth	Biomass production	Compatability with crops	Fodder	Firewood	
Grevillea robusta	4.4 (0.9)	–	4.0 (1.3)	–	4.1 (1.0)	73
Casuarina junghuhniana	3.2 (1.1)	–	4.5 (0.7)	–	–	46
Leucaena leucocephala	–	3.4 (0.8)	3.8 (1.8)	4.0 (1.4)	3.8 (1.0)	29
Leucaena diversifolia	–	3.7 (0.9)	3.6 (1.6)	3.4 (1.5)	3.8 (0.7)	24
Calliandra calothyrsus	–	4.9 (0.2)	3.3 (1.8)	4.1 (1.3)	4.1 (1.1)	41
Eucalyptus spp	4.3 (1.0)	–	1.4 (0.9)	–	3.6 (1.2)	27

[a] Source: adapted from Franzel et al. (2000).
[b] Data based on 37 persons interviewed — 1 is poor and 5 is excellent.

cally rigorous manner (Franzel et al., 1995). It also allows farmers to visually assess their ranking and perhaps, upon reflection, make changes.

Hierarchical decision trees were used to model complex decisions, such as whether or not to expand the use of hedgerow intercropping in western Kenya (Fig. 3). This method was useful for explaining the decisions that farmers made by breaking them down into a series of sub-decisions and mapping each farmer's decision path along the branches of the tree (Gladwin, 1989).

Farmer workshops were also held to find out farmers' views on the technologies and their potential impacts (Kristjanson et al., 2001). To facilitate the exchange of information, farmers were split into small working groups, each addressing a specific issue. The workshops provided information on important effects of practices, "invisible effects" such as secondary effects on other enterprises, indicators that farmers would use to evaluate the impact of adoption, and clarification of possible constraints to adoption. Whereas, in many cases, the information provided by farmers in these workshops was what researchers might have anticipated, in several instances important new information was obtained. For example, a key finding in the Zambia workshop was that many farmers intended to use improved fallows not so much to increase the total amount of maize they produced, but rather to increase maize yields and reduce the area they devoted to maize, freeing up land for growing cash crops.

5.3. Sources of variation in adoption potential

The farm and household characteristics that were tested most frequently in the case studies for their association with testing and continued use of a practice included gender, household type, wealth level, farm size, soil type and soil nutrient status. These were investigated by testing the statistical association between individual variables and performance, as in Zambia, where similar proportions of male and female

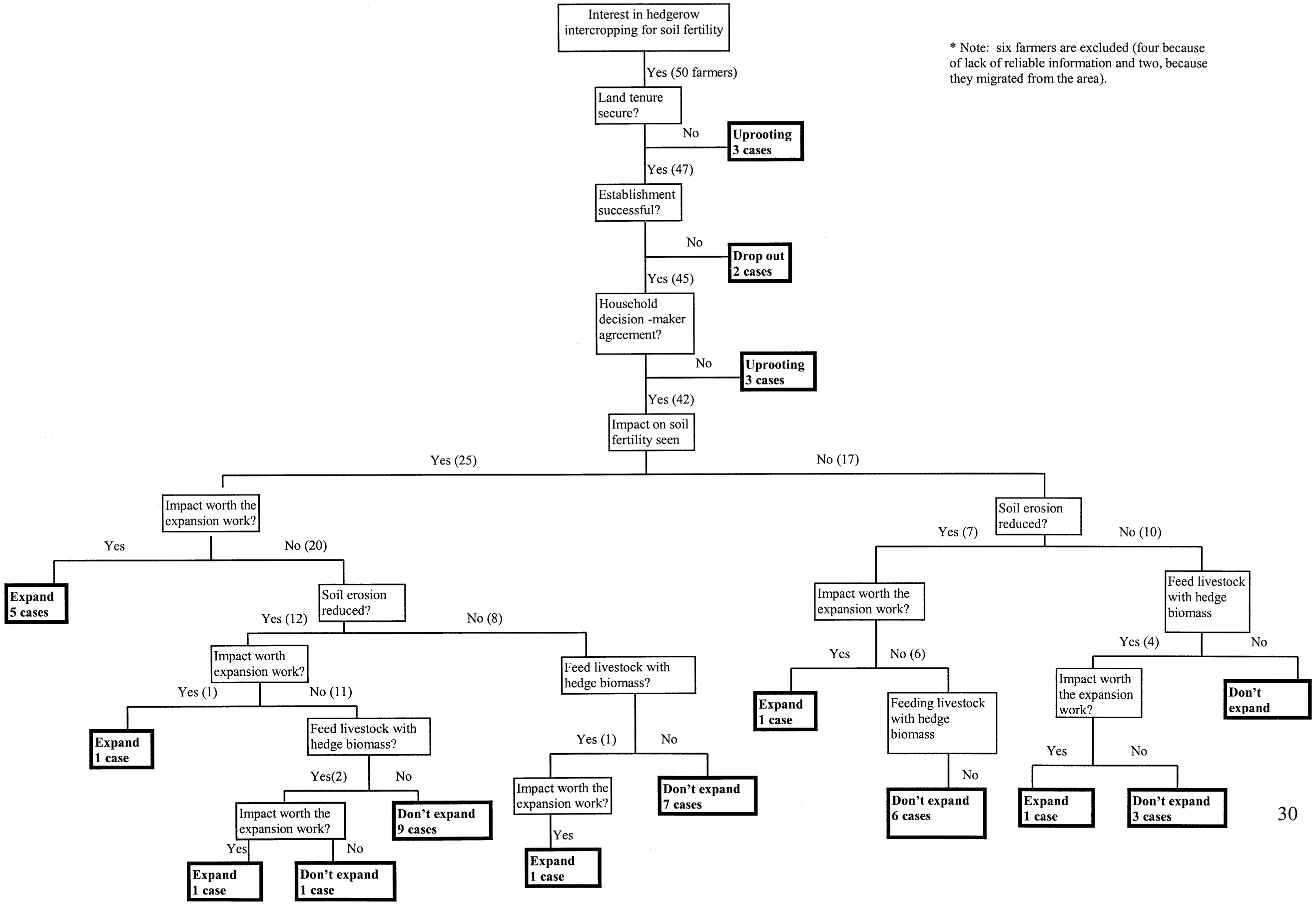

Fig. 3. Decision tree: expansion of hedgerows by trial farmers.

households were found to be testing improved tree fallows (Franzel et al., 1999). In western Kenya, multiple regression was used to assess the relative importance of selected variables affecting farmers' preferences among upper-storey trees (Franzel et al., 2000). The small number of farmers that could be monitored in a type 2 trial, usually less than 50, limited the degree to which factors affecting adoption potential could be rigorously examined.

5.4. Farmer innovations and feedback

Farmer innovation and feedback have played an important role in modifying the extension messages shared with farmers and in identifying 'second-generation' research issues for enhancing adoption potential. For example, whereas type 1 and type 2 trials on improved fallows in Cameroon, Zambia, and Kenya were started with the main food staple, maize, farmers began testing them, on their own, on higher-value crops such as tomato, kale, and sunflower. Some farmers at all three sites began establishing improved fallows by mixing trees with crops during the first cropping season, instead of planting the trees in pure stands, as researchers did. Intercropping and planting fallows for crops other than maize have now become popular options at all three sites and researchers and farmers are collaborating in conducting research to refine these options (Franzel, 1999). No formal method is effective for identifying farmers' innovations, rather they are identified through intensive interaction between researchers and farmers.

The case studies also demonstrated the importance of feedback to policy makers for enhancing adoption potential (Place and Dewees, 1999). In all of them, germplasm availability was a critical constraint; mechanisms for improving its availability are critical. Studies are needed to better understand farmer-to-farmer diffusion processes and methods for decentralised production and distribution of seed. In Zambia, free grazing of livestock during the dry season, and the damage it caused to young trees, has constrained some farmers from planting improved fallow species and some localities are now trying to restrict grazing. Assessments of these experiences could be helpful in assisting other communities to find ways to meet the needs of both livestock grazers and farmers wanting to plant improved fallows.

5.5. Selection of methods

The case studies did not all use the same techniques for assessing adoption potential (Table 3). In fact, no standard approach can be outlined; rather, the selection of activities was driven by critical information gaps, identified jointly by researchers, extensionists and farmers, in technology design and in understanding boundary conditions. The choice of methods thus depended on several factors.

1. *The resource requirements of the practice*. Hedgerow intercropping had relatively high labour requirements. Thus, researchers decided to measure the labour requirements of the practice and compare them with the seasonal and total labour requirements of the household.

2. *The impact of the practice on farming enterprises*. Enterprise budgets were needed to assess profitability when a new practice, such as improved fallows, had an important impact on the costs, returns, and management of an enterprise. But for practices that had less impact, such as substituting fodder trees for a purchased protein concentrate in a dairy enterprise, a partial budget sufficed for determining profitability.
3. *The size of the sample*. Where few farmers were testing a practice (for example, only 20 farmers tested improved fallows in western Kenya), tests of association between farmers' characteristics and use of the practice could be conducted but the results were not statistically convincing.
4. *Availability of staff and resources*. The availability of scientists of different disciplines, support staff, and resources was also critical.

5.6. Defining boundary conditions

The boundary conditions of a practice are defined by identifying the variables that are most important in determining who will and will not use the practice. Information on variables affecting biophysical performance, profitability, and acceptability are thus critical. Variables should be easy to identify; otherwise, they will not be useful in distinguishing among farmers or areas.

Biophysical variables used for assessing boundary conditions in the case studies examined in this paper included altitude (a proxy for temperature), rainfall and soil type, depth and nutrient status. Critical socioeconomic variables included wealth, gender, and farm size. The two groups of variables were found to be useful in different ways. Biophysical boundary conditions were often used to exclude a component or practice from particular areas. For example, the fodder tree *Calliandra calothyrsus* did not perform well on acidic soils. Socioeconomic boundary conditions, on the other hand, were used mainly to inform researchers, extensionists, and farmers about the appropriateness of choices. For example, the finding in Kenya and Zambia that well-off farmers tested improved fallows more frequently than did poor farmers led to efforts to identify and alleviate the constraints that the poor faced in testing the technology.

Some boundary conditions were assessed through secondary data, as when it was known that a particular tree species did not perform well outside a certain altitude range. Modelling was also useful, as when the financial analysis of improved fallows in Kenya showed that the practice was profitable, relative to continuous cropping, only when the opportunity cost of labour was above a certain level (Swinkels et al., 1997). But in most cases, assessments were based on empirical data concerning where the practice performed well and who adopted it. Type 1 trials were especially useful for assessing the biophysical boundary conditions of a practice over wide areas. For example, type 1 trials established in four countries of southern Africa confirmed that sesbania improved fallows do not perform well on sandy soils, because of nematode attacks, on shallow soils, because of mortality during the dry season, or in frost-prone areas (ICRAF, 1995, pp. 142–146). For assessing socioeconomic boundary conditions, type 2 and type 3 trials, and the monitoring surveys that followed the trials, provided critical information.

A comparison of the adoption potential of improved fallows in Zambia, western Kenya, and Cameroon has helped refine boundary conditions for the technology (Franzel, 1999). Whereas improved fallows were not expected to have significant adoption potential in areas of high population density (Raintree and Warner, 1986), on-farm testing has demonstrated that that they have considerable potential in the high-population-density areas of western Kenya (Fig. 4). Moreover, the adoption potential was found to increase as the profitability of growing annual crops declined, as crop yields decreased, as the opportunity cost of labour increased, and as access to off-farm income increased (Table 7) (Franzel, 1999).

6. Conclusion

The approach and experiences reported in this paper demonstrate that there are multiple sources of innovation in agroforestry — formal sector researchers, farming tradition, farmer-innovators, and extensionist-innovators. Through shared experiences in on-farm research studies, their complementary strengths can be effectively exploited and integrated, at reasonable cost. The flow diagram of farmer-centered agroforestry research and extension (Fig. 1) that is evolving at the study sites highlights the interactions and synergies among farmers, researchers, and extensionists using the approach. Instead of a linear sequence whereby technology is developed by researchers, then passed to extensionists, and finally to farmers, in the diagram there is continual interaction amongst these groups throughout the process. Input from

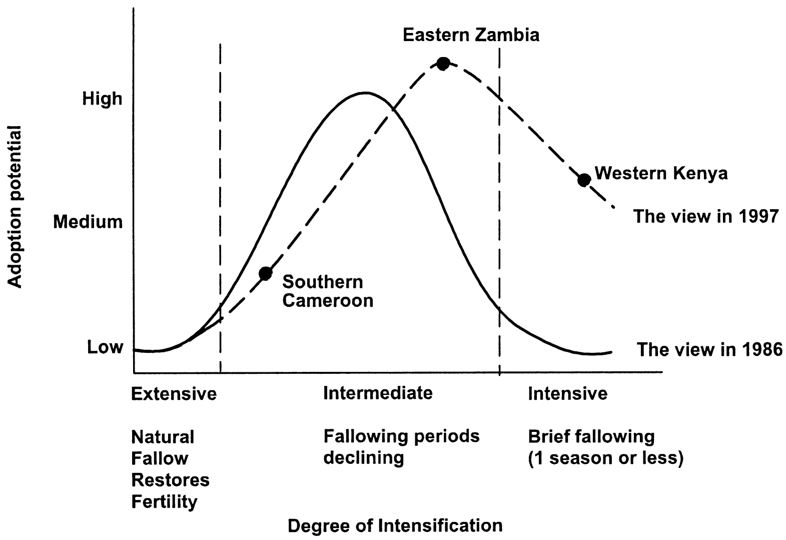

Fig. 4. The adoption potential of improved fallows at different stages of intensification.

Table 7
Farm and household characteristics affecting the adoption potential (feasibility, profitability, and acceptability) of improved tree fallows in central Cameroon, eastern Zambia, and western Kenya[a]

Characteristics	Effect on adoption potential[b]	Strength of effect[c]
Feasibility		
Labour constraints	–	M
Institutional support	+	H
Farmer experience with tree nurseries	+	L
Profitability		
High profitability of growing crops[d]	–	M
High base crop yields[d]	–	M
High opportunity cost of labour[d]	+	M
Acceptability		
Perception of soil fertility problem	+	H
Past investment in soil fertility	+	H
Current fallowing	+	M
Economic importance of annual cropping	+	M
Wealth level	+	M
Gender	0	0
Access to off-farm income	+	M

[a] Source: adapted from Franzel (1999).
[b] +, positive; –, negative; 0 indicates negligible effect.
[c] H, high; M, medium; L, low; 0, none.
[d] Only relevant for the intensive stage, that is, areas of high population density where fallows are brief, one season or less, such as western Kenya.

farmers and extensionists is provided early on, opportunities for early extensionist and farmer innovation and adaptation are encouraged, and implementation on farmers' fields, and hence potential for farmer-to-farmer diffusion, begins much earlier in time. Moreover, building a team of organisations to conduct on-farm research and dissemination together is vastly more effective and efficient than leaving each to work independently on only one element.

The experiences reported also demonstrate the importance of assessing the adoption potential of agroforestry practices. First, such assessments improve the efficiency of the technology development and dissemination process, by feeding back information on farmers' problems, innovations, and preferences to research and extension staff, and policy makers. Second, the assessments help document the progress made in disseminating new practices, demonstrating the impact of investing in technology development and dissemination. Third, because the activities are conducted with partner-institutions, they facilitate interdisciplinary and inter-institutional cooperation. Finally, the assessments help to identify the factors contributing to successful technology development programmes as well as the constraints limiting the achievements.

Future assessments need to take advantage of farmers' increased experience with agroforestry practices; analyses of social, economic, biophysical and ecological impacts will thus be possible at community and regional scales. Improvements in the development of spatially explicit databases and models should permit the use of geographical information systems for assessing the boundary conditions of new technologies. Efforts are also needed to hand over many of the activities in assessing adoption potential to local institutions, such as farmer groups and organisations. The greater control they have over assessing adoption potential, the more responsive technology generation activities will be to their needs and hence the more sustainable they will be over time.

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