The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research

Frank Place
Ralph Roothaert
Lucy Maina
Steven Franzel
Judith Sinja
Julliet Wanjiku

The World Agroforestry Centre, an autonomous, non-profit research organization, aims to bring about a rural transformation in the developing world by encouraging and enabling smallholders to increase their use of trees in agricultural landscapes. This will help to improve food security, nutrition, income and health; provide shelter and energy; and lead to greater environmental sustainability.

We are one of the 15 centres of the Consultative Group on International Agricultural Research (CGIAR). Headquartered in Nairobi, Kenya, we operate six regional offices located in Brazil, Cameroon, India, Indonesia, Kenya, and Malawi, and conduct research in eighteen other countries around the developing world.

We receive our funding from over 50 different investors. Our current top ten investors are Canada, the European Union, Finland, Ireland, the Netherlands, Norway, Denmark, the United Kingdom, the United States of America and the World Bank.

The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research

Frank Place
Ralph Roothaert
Lucy Maina
Steven Franzel
Judith Sinja
Julliet Wanjiku

Titles in the Occasional Papers series aim to disseminate information on Agroforestry research and practices and stimulate feedback from the scientific community. Other publication series from the World Agroforestry Centre include: Technical Manuals and Working Papers.

Correct citation: Place F, Roothaert R, Maina L, Franzel S, Sinja J and Wanjiku J. 2009. The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research. ICRAF Occasional Paper No. 12. Nairobi: World Agroforestry Centre.

Published by the World Agroforestry Centre
World Agroforestry Centre
United Nations Avenue
PO Box 30677, GPO 00100
Nairobi, Kenya
Tel: +254(0)20 7224000, via USA +1 650 833 6645
Fax: +254(0)20 7224001, via USA +1 650 833 6646
Email: icraf@cgiar.org
Internet: www.worldagroforestry.org

ISBN: 978-92-9059-275-4

Editor: Peter Fredenburg
Layout: Abel Belachew
Cover Design: Reagan Sirengo
Cover photo: Charlie Pye-Smith

Contributors

Frank Place
Head of the Impact Assessment Office
World Agroforestry Centre
Nairobi, Kenya

Ralph Roothaert
Fund Manager
Maendeleo Agricultural Technology Fund
FARM-Africa
Nairobi, Kenya

Lucy Maina
Lecturer
Department of Sociology
Kenyatta University
Nairobi, Kenya

Steven Franzel
Principal Agricultural Economist
World Agroforestry Centre
Nairobi, Kenya

Judith Sinja
Research Associate
World Agroforestry Centre
Nairobi, Kenya

Julliet Wanjiku
Research Associate
ILRI
Nairobi, Kenya

Abstract

The objective of this study is twofold, to demonstrate (1) the effects of fodder shrubs on milk production and their value at the household and regional level and (2) the contribution of research by the World Agroforestry Centre toward strengthening the impact of fodder shrubs. The study is a synthesis of previous studies related to dissemination, adoption and impact combined with two new analyses, one quantitatively measuring the impact of the shrubs through econometric analysis and the other a qualitative analysis to better understand constraints on adoption and gender issues related to participation and control of benefits from fodder shrubs. Among the study findings are that fodder shrubs have been widely adopted in East Africa, by an estimated 205,000 smallholder dairy farmers by 2005. Women were active in planting shrubs, as monitoring found almost half of planters to be women. Several studies have confirmed that shrubs do have an impact on milk production. While feeding trials have found that 1 kilogram of calliandra increases milk production by 0.6–0.8 kilograms, a new survey of farmers' perceptions in Kenya found the effect to be about half as large after controlling for the effects of breeds, season and other feeds. Whether the effect is the lower or higher estimate, the overall impact of the shrubs in terms of additional net income from milk is high, at US$19.7 million to $29.6 million in Kenya alone over the past 15 years.

Acknowledgements

The authors are grateful to Charles Nicholson and Lydia Kimenye, who reviewed a draft of this paper and provided rich and insightful comments and suggestions that we incorporated as best we could.

Abbreviations

AFRENA	Agroforestry Research Network for Africa
FGD	focus group discussion
ICRAF	World Agroforestry Centre
ILRI	International Livestock Research Institute
g	Gram
g DM kg^{-1} $BW^{-0.75}$	grams per kilogram of metabolic body weight
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
kg	kilogram
m	Metre
NDFRC	National Dryland Farming Research Centre
PRA	participatory rural appraisal
RRC	Regional Research Centre
SCALE™	System-wide Collaborative Action for Livelihoods and the Environment

Contents

1. Introduction

Milk production grew steadily in East Africa in the 1980s and 1990s. The pace of growth has since accelerated following recent high rates of income growth and urbanization, though exact figures are not easy to verify. Ngigi (2004) reports that milk production increased during the 1990s at an annual rate of 4.1% in Kenya and 2.6% in Uganda. Another estimate suggests that the rate of growth was higher in Uganda, with production having risen from 365 million litres in 1991 to 900 million litres in 2001 (Uganda Investment 2002). One reason for such growth is high domestic consumption. Milk consumption in Kenya is 145 litres per person per year, which is among the highest rates in the developing world (SDP 2006), spurring an estimated 4 billion litres of production in 2003 (Export Processing Zones Authority 2005). Although only about 35% of milk production is marketed, at a retail price of US$0.75 or more per litre, the Kenya dairy sector is estimated to generate $2 billion dollars per year (Strategic Business Partners 2008).

Much of market demand has been met by smallholder dairy farmers, typically with 1–3 cows on farms measuring 0.5–1.5 hectares. The International Livestock Research Institute (ILRI) reports that by 2006 there were approximately 1.8 million smallholder dairy farmers in Kenya (SDP 2006). Evidence is less precise for other countries, but there are at least several hundred thousand smallholder dairy farmers in the neighbouring countries of Ethiopia, Rwanda, Tanzania and Uganda. Most smallholder farms are in highland areas more than 1,200 meters above sea level, where two rainy seasons prevail and can support year-round feed-production systems. Despite such impressive growth in numbers of farmers and cattle and overall production, milk productivity per cow remains very low. In intensive production systems with improved cattle, average milk yields per cow are just 7–8 litres per day, despite the potential of farmers' breeds to produce at least three times that much (Reynolds et al. 1996).

It has been argued that the scarcity and low quantity of feed resources are major constraints on improving the productivity of dairy animals in sub-Saharan Africa (Winrock International 1992, Lanyasunya et al. 2001, Mapiye et al. 2006). Feeding regimes consist of bulk feeds such as natural and improved grasses (e.g., napier) and protein-rich supplements. Among these supplements, several have been available for a long time, including manufactured concentrates (e.g., dairy meal) and a host of crop by-products such as sweet potato vines and bean leaves. More recently, research and development have been devoted to testing additional high-protein feed legumes such as desmodium and a variety of shrub species. These supplements provide high concentrations of protein and other nutrients that can significantly improve animal health and increase the productivity of dairy animals, especially of milk. The homegrown options provide cheaper alternatives to concentrates, which are effective but costly. Whereas fodder trees and shrubs are known to be a key source of feed for ruminants in the drier areas of Africa, their use in the more intensive dairy systems of the East African highlands was rare until the late 1980s. At that time, several fodder shrub species (especially *Leucaena leucocephala*) were introduced to farmers in the Kenya highlands. However, little was known about how management affected shrub growth and sustainability in a highland agro-ecological zone, how different proportions of fodder shrubs in the diet affected milk yield from the dairy cattle breeds found in the region, how the shrubs could best be grown on the small farms of the region, and how best to multiply seed and establish shrubs on farms. With all of these knowledge gaps, the International Centre for Research in Agroforestry (ICRAF, since renamed the World Agroforestry Centre but retaining the old abbreviation) developed in 1991 a research programme in collaboration with the Kenya Agricultural Research Institute (KARI) and the Kenya Forestry Research Institute (KEFRI) at the KARI research centre at Embu, on the southeastern slopes of Mount Kenya.

This paper aims to describe the research undertaken by ICRAF and its partners on fodder shrubs and the dissemination processes that unfolded in East Africa, followed by an analysis of the adoption and impact of fodder shrubs in the region. The paper is structured as follows. Section 2 sets the research in a conceptual model and describes the methods used in this paper. Section 3 presents a summary of research undertaken by ICRAF and its partners, which is divided into technology development and scaling up. Section 4 presents data and analyses on the dissemination and adoption of fodder shrubs in the region. Section 5 is devoted to an analysis of the impacts of the technology on milk production and income, mainly at the household level, but also presenting estimates of impact at nationally and regionally. Section 6 focuses on gender-differentiated adoption and impact, and section 7 briefly discusses other impacts of the technology that have been documented but not fully analyzed. Finally, section 8 contains a summary and conclusion.

2. Conceptual framework and methodology

2.1 Conceptual model

Although fodder shrubs have multiple benefits for milk production, animal health and soil conservation, ICRAF research and eventual scaling up in East Africa was motivated mainly by demand for quality dairy feed to increase milk production in the smallholder dairy farming systems of the region.

Milk productivity, production and income in a given agro-ecology are affected by many factors amenable to research, such as

1. animal breed
2. animal health
3. animal feed
4. markets for milk and milk products
5. consumer awareness and demand
6. overall policy regulation and support

Many of these research areas are the domain of institutions with mandates for livestock, such as ILRI. However, a number of plant-research organizations have engaged in research on feed systems, as feed is a primary product or by-product of many plants. Several centres of the Consultative Group on International Agricultural Research (CGIAR) investigate the fodder or stover potential of their mandated crops. Within the category of animal feed, ICRAF identified several areas for research that required attention, as detailed in figure 2.1.

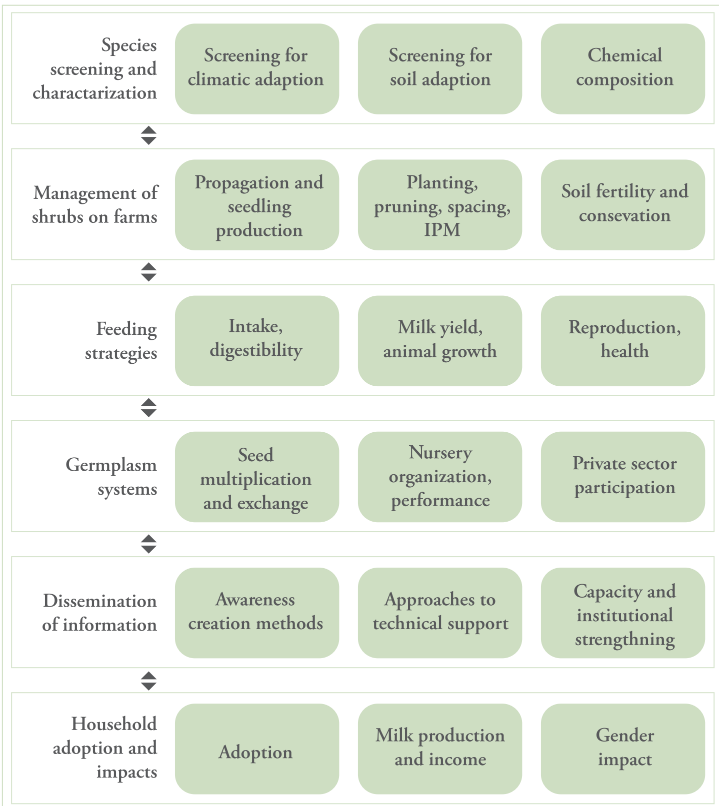

Figure 2.1: Fodder shrub research areas undertaken by the World Agroforestry Centre.

IPM = integrated pest management.

The research areas are expected to lead to several observable effects on smallholder dairy farms, as described in table 2.1.

Table 2.1: Expected effects of fodder shrub research areas on smallholder dairy farmers

Research area	Main outputs	Expected outcomes on farm
Species identification	Calliandra was most promising species in highlands, but others identified in all dairy zones	Types of shrubs found on farms
Shrub management	Determined that 500 shrubs are optimal to feed one cow daily throughout the year	Number of shrubs planted on farm
Feeding strategies	Found that 2 kilograms of dry shrub feed per day was recommended to provide an additional litre of milk	Amount of shrubs fed to dairy animals
Seed systems	Most species require nursery establishment; formalization of private seed dealers and marketing of seed	Numbers of planters of fodder shrubs
Dissemination of information	Farmer-to-farmer dissemination was active and the means to support this identified	Numbers of organizations and farmers involved in dissemination and number of adopters
Adoption and impact	On-farm impacts from shrubs similar to those on station; diffusion was rapid, but planting and feeding levels less than recommended	Feedback into improving technology development and dissemination approaches

This study cannot attribute observed impacts to the specific research areas, as that would require full monitoring of how specific outputs were taken up, translated into changed actions by organizations such as extension services, and then transmitted to farmers. Although some of the reported studies do examine different parts of the impact pathway, the focus of the research is on the economic impacts of fodder shrubs occurring at the farm level along with a full description of ICRAF's supporting research role. Further, the value of the centre's research, as distinct from other research or the scaling up of fodder shrubs, cannot be determined objectively. Rather, the case will be made that ICRAF played a clear role in developing fodder shrubs as a viable technology in East Africa, that it played a further catalytic action-research role in its scaling up, and that the resulting on-farm benefits have been significant.

A summary of the results of the research on species screening and characterization, shrub management, and feed strategies are presented in chapter 3. Research related to seed systems and information dissemination, adoption and impact is the focus of this report and is thus given much more attention, forming the basis of chapters 4, 5 and 6.

2.2 Methods used in the study

This impact assessment draws on previous studies of the adoption and impact of fodder shrubs and newly generated and analyzed empirical data that has not previously been published. Many studies relevant to assessing the impact of fodder shrubs have been conducted by ICRAF, KARI and hosted students, most notably for Kenya, but also including Rwanda, Tanzania and Uganda.

Most of the studies were undertaken in central Kenya, where the process of technology dissemination is the most mature and advanced. Kenya has been the main focus of research because it has the largest number of farmers adopting shrubs for the primary purpose of obtaining fodder. Thus, the collection and analysis of new data were also conducted in Kenya. The sites selected were Embu and Maragua districts in Central Province, where many farmers have used fodder shrubs for many years.

In the two main highland study districts of central Kenya, population density is typically over 500 people per square kilometre (CBS 1994). Agriculture is the main activity in the area, with the main cash crops being coffee at medium to low altitudes and tea at higher elevations. Dairy production is an important farm enterprise, second only to tea, coffee and other cash crops in economic importance (Staal et al. 1997). In terms of cash flow, dairying is more advantageous than most cash crops because payments for milk are generally monthly or daily. High population density keeps farm sizes small in central Kenya, with average holdings of 0.9 – 2.0 hectares (ha) per household (Murithi 1998, Mwangi 1999, Staal et al. 1997) continuing to shrink as they are subdivided. Thus, the number of dairy animals per farm is low, usually 1–3 animals.

These new analyses focused on three knowledge gaps: (1) a quantitative assessment of the impact of fodder shrubs on milk yields after controlling for all the other types of feeds in different feeding strategies used by farmers (and controlling for breed and season), (2) an understanding of the constraints on adopting the planting of shrubs and its impact, and (3) how women benefit from the technology. Similar questions had been addressed by ICRAF research in the past (e.g., Place 1998), but, because the technology has now been on farm for many more years, additional study was merited.

The methods of qualitative information collection and household surveying are described in more detail below. The methods used in the previous research that is cited are briefly described in section 3 and again where specific results are reported in later sections.

2.2.1 Qualitative study methods

The qualitative study (Maina 2009) was designed to capture information on the actual impact of the introduced fodder shrubs on livelihoods, welfare and household dynamics. In particular, it sought to understand why fodder shrubs were adopted and contributing well in some circumstances and not in others, with particular attention to gender dimensions. The first step was to identify localities where the fodder technologies had been introduced so that various aspects of technology impact could be studied. In the end, the localities selected for study were Manyatta, Nembure and Runyenjes in Embu District and, in Maragua District, Gatituini, Kagunduini, Kaguthi, Kahaini and Makumbi.

Being mainly a qualitative study, the survey utilized qualitative tools of data collection. These included community workshops, participatory rural appraisal (PRA) methods to allow classifying respondents by type, focus group discussions, case studies, and then discussions with key informants. To some extent the different methods were used to confirm the information acquired on the same topics (e.g., perceptions of the impacts of fodder shrubs and gender participation in using the fodder shrub technology). But the methods also had their own unique contributions. The community workshops brought out the range of ways in which shrubs were used, the range of impacts that were perceived and the constraints on their use. This information fed into both the design of the household surveys and subsequent qualitative methods. The PRA methods and the key informant discussions were used to better understand the trajectory of farming in the area, how the role of dairy was changing, and what the potential for dairy and fodder shrubs was likely to be. They also helped to identify different types of respondents for follow-up case studies or focus group participation. The focus group discussions and case studies both aimed to probe more deeply into the uptake of the technology, its use and its impacts, especially as they played out among different types of individuals—women, men, youths, etc.

In each of the two selected districts, the study started off with a community workshop attended by farmers from the target areas. The main purposes of the meetings were to establish rapport with the community, explain the study objectives and

refine some research questions. After that, the team conducted more specific focus group discussions (FGDs), PRAs and case studies. Three FGDs were carried out in each of the two districts.

With regard to respondents targeted for the study, the community workshop meetings combined farmers from different localities and community groups. In Maragua, 39 farmers attended the meeting. In Embu, the general meeting was attended by 42 farmers, 26 of whom had adopted the fodder shrub technology. In both cases, staff from the district livestock office attended the meetings.

To enhance entry into and cooperation from the community, district livestock officers were contacted and requested to inform the communities about the study. Further, community workshops attempted to bridge the gap between researchers and farmers. In these workshops, the study objectives were shared with the farmers, along with the type of information that was sought and the methods that would be employed in gathering information. The meeting helped to gather crucial data covering broad contextual topics as well as specific topics related to fodder shrubs through guided discussions and PRA.

The FGDs carried out in this study targeted diverse types of respondents. In both Maragua and Embu, one FGD included men, women and youths. A second FGD had men only and a third exclusively targeted women. This categorization was done to elicit views that would ordinarily not have been forthcoming from mixed groups. The FGDs each had 10–15 respondents who were all dairy farmers and predominantly adopters of the shrub technology.

Further PRA exercises were carried out with farmers after the general meeting and FGDs. The PRA aimed to elicit key information from farmers using the following techniques:

1. diagramming livestock resource flow;
2. eliciting the proportions of various feed resources in diets;
3. developing a gender activity calendar; and
4. wealth ranking to show (a) the number of wealth classes in the area, (b) differences among the households in the sub-location in terms of their well-being, (c) the causes and indicators of these differences, and (d) analysis of the cultivation and use of fodder trees across different wealth classes.

Further, 10 in-depth case studies targeted households with certain characteristics that were purposefully selected to provide additional information considered crucial to filling gaps that arose. Specifically, the case study respondents were selected to represent variation in the following factors:

1. proximity to dairy and processing plants,
2. gender of family head,
3. farmer livelihood types and income class,
4. early and late adoption of the technology,
5. large- and small-scale farming,
6. multiplicity and limitations of livelihood options,
7. proximity to water resources,
8. farmer education, and
9. subsistence and commercial farming.

Livestock officers and other local key informants helped to identify households that could provide contrasting case studies based on the criteria above.

Finally, two key informant interviews were carried out with livestock field officers in both areas to elicit background information pertaining to the introduction, adoption (planting and use) and sustainability of the introduced fodder shrubs among farmers. All the sources of information above have been analyzed and compared to give a comprehensive picture of the impact experienced by farmers at the household level and to show the main hindrances to positive impacts in both areas of study and among the various categories of farmers.

2.2.2 Household surveys on feeding regimes and milk production

The formal household surveys took place in the same districts and divisions as did the FGDs, engaging 240 farmers. The sampling method used to draw the study sample was stratified random sampling. This involved first identifying dairy farmer groups whose members had been exposed to fodder shrubs in both districts, Embu and Maragua. Lists of farmers in groups from two divisions in Maragua who were thought to have planted the fodder shrubs were used to randomly select 45 farmers from each to provide a reasonable number of actual adopters of shrubs. Likewise, another list from three divisions of Embu District was used to select another 90 farmers as potential adopters of shrubs. Planters of shrubs were oversampled because the study was intended to assess the impact of fodder shrubs, thus requiring a significant number of users.[1] Another 15 farmers in every division who were not

[1] As such, the data cannot be used to infer the rate of adoption of shrubs.

adopters were randomly picked by the enumerators. The non-adopters selected were the 4th neighbour on the right of the road from every 3rd selected adopting household, giving an additional 30 farmers per district. In practice, many of the purported planters did not manage to plant and use the shrubs at the time of the survey. Some replacement with other group members was made, but others were retained and added to the number of control households who did not use fodder shrubs. This means that the data are not representative in terms of the proportion of adopters or numbers of shrubs per adopting farmer. However, this strategy was followed as the main purpose of the study was to analyze the impact of shrubs on milk production in varied field conditions, and a large number of users was necessary to enable statistical analyses that could identify the impact while controlling for other factors. Previous studies had collected more representative information on the numbers of fodder shrubs planted.

The inclusion of users and non-users of fodder shrubs was meant to provide a rich set of different feeding strategies from which calculations of the quantitative effects of fodder shrubs (as well as effects from other feeds) could be determined. The surveys elicited detailed information on the number and types of cows, the different feeding strategies used for each cow in both the wet and dry season, the quantity of different feeds used in those feeding strategies, and the number of days each feeding strategy was used. The enumeration team weighed common units of feeds used to enable converting all reported proportions into kilograms. To complement this information, recall of average daily milk yields from each of these strategies (and farmer estimates of the milk yield increase with and without different high protein feeds) was obtained. Many other household and farm variables were enumerated, but the results reported herein relate to the feeding types and quantities and milk yields. In summary, the data were collected from a single recall, which obviously has its limitations, but the intention was to identify average or typical milk yields resulting from different feeding regimes, while controlling for breeds and seasons. The assumption was that the feeding regimes of a given household were sufficiently small in number and consistently used to allow average feeding and milk production levels to be recalled.

3. ICRAF fodder research partnerships, themes and investments

3.1 Main partners

ICRAF set up the Agroforestry Research Network for Africa in 1986. The East African regional programme under the network covered the highlands of Burundi, Kenya, Rwanda, Tanzania and Uganda. In each country, ICRAF was hosted by and collaborated with national agricultural research and forestry institutes: KARI and KEFRI in Kenya, the National Agricultural Research Organization and the Forestry Research Institute in Uganda, the Selian Agricultural Research Institute in Tanzania, Institut Scientifique Agricole de Rwanda in Rwanda, and Institut Scientifique Agricole du Burundi in Burundi.

The National Agroforestry Research Project was started in Embu in 1991 as a joint activity of ICRAF, KARI and KEFRI. The project brought the first on-farm testing of fodder shrubs in the highlands of East Africa, following up earlier species screening on station. In the early 1990s ICRAF, KARI, KEFRI, Oxford University and the Natural Resources Institute assessed *Calliandra calothyrsus* genetic resources, improvement and fodder quality. During 1999–2000, a project implemented through the Systemwide Livestock Program of the CGIAR helped farmers to plant calliandra across seven districts of central Kenya. This project, implemented by ICRAF, ILRI and KARI, also introduced other fodder legumes, including desmodium (Franzel et al. 2002).

As research moved from farm-level management to seed and dissemination systems, ICRAF research broadened to involve other research partners such as Egerton University, University of Nairobi, Makerere University, University of Rwanda, Sokoine University, University of Florida, CAB International and the Academy for Educational Development.

On the development side, the centre worked closely with extension programmes in each country and with a number of development non-governmental organizations (NGOs) and community organizations such as the Dairy Goat Association of Kenya, Dairy Development Board, VI Agroforestry Program, Heifer Project International and Africare. This collaboration was expanded to working with other types of civil society organizations such as churches, as well as directly with the private sector (e.g., Limuru Milk Processors and Farmchem (Kenya)).

3.2 Research themes

ICRAF and its partners were active in several research areas. As shown in figure 2.1, the six broad research areas could be classified as (1) species characterization and identification, (2) on-farm establishment and management of technology, (3) animal feeding strategies, (4) germplasm systems, (5) information dissemination, and (6) household impact. Studies in each area yielded results that fed into development processes. Examples are the identification of appropriate species for different agroclimatic zones, recommendations for establishing and managing shrubs on farm, feeding recommendations for dairy cows and other livestock, and improved methods for more cost-effective scaling up.

Some of the more salient research outputs related to the development of fodder shrub technology are presented in more detail below as evidence of ICRAF's role in past research. The presentation of research related to scaling up and impact is given much more attention in sections 4–6 because the results in those studies provide much of the documentation of impact from the technology.

3.2.1 Research related to fodder shrub technology development

3.2.1.1 Species identification and characterization

ILRI and KARI initiated research on fodder shrubs in the late 1980s along the Kenyan coast. The initial systematic screening of fodder trees in Kenya was undertaken independently by the National Dryland Farming Research Centre (NDFRC) at Katumani, Regional Research Centre (RRC) at Mtwapa on the coast, and Agroforestry Research Network for Africa (AFRENA) at RRC sites in Embu in central Kenya and Maseno in western Kenya. This involved planting different species and provenances across a number of locations, applying common management (e.g., pruning frequency), and assessing characteristics such as shrub survival and growth and leaf biomass production following pruning. Before the initiation of systematic screening studies, *Leucaena leucocephala* was regarded as an appropriate fodder for smallholder farms in central, western and coastal Kenya (Mureithi et al. 1994). The screening studies by RRC at Mtwapa, NDFRC at Katumani and AFRENA in Embu and Maseno increased the diversity of fodder tree species potentially suitable for the smallholder farms in different agro-ecological zones. AFRENA and ICRAF played key roles in this by spearheading research in the highlands, identifying nine species with high potential (e.g., demonstrating high survival and production of biomass after repeated pruning) from among screening trials of some 69 accessions of 37 agroforestry species (Niang 1991, Roothaert and Paterson 1997).

Among fodder shrubs, *Calliandra calothyrsus* was a key species screened across many locations in East Africa. Since the mid-1990s, when calliandra was disseminated more widely, several other species have been tested and disseminated. In Kenya, *Leucaena trichandra*, an exotic species; *Morus alba* (mulberry), a naturalized species; and *Sesbania sesban*, an indigenous species, were widely tested but their uptake has not been as significant as that of calliandra. In Rwanda, calliandra and *Leucaena diversifolia*, also an exotic, are the most common species. In Uganda, these same two species and sesbania are widely grown. In Tanzania, calliandra and *L. leucocephala* are the most widely used species.

Research included testing different provenances of calliandra, which turned out to be the most attractive species for farmers. The Embu landrace, which had been used in early dissemination work, a few local trials and other research on calliandra, was germplasm of unknown genetic origin. So the research team formally tested the growth and nutritive values of different provenances, notably Patulul and San Ramón. Among the results was that the Patulul provenance was significantly more nutritious than San Ramón and of similar quality to the Embu landrace (Hess et al. 2006, Stewart et al. 2006).

3.2.1.2 Nursery and tree establishment research

All priority fodder species become established and grow better when raised in a nursery and transplanted as seedlings. Seeds are planted in nurseries and, after about 3 months there, transplanted on the farm with the onset of the rains. Experiments on seedling production have confirmed that the seedlings may be grown 'bare-root', that is, raised in seedbeds rather than by the more expensive and laborious method of raising them in polythene pots (O'Neill et al. 1997). Bare-root seedlings are cheaper to produce but sometimes have lower survival rates after transplanting, especially when rainfall is low or the distance from the nursery to the farm field is great (Wambugu et al. 2006).

3.2.1.3 On-farm management of fodder shrubs

The first on-farm shrub-management research trials in the highlands, where the vast majority of dairy cows are, were initiated by scientists of ICRAF, KARI and KEFRI in the Embu area. They were designed by researchers but managed by farmers. The trials assessed three promising species—*Calliandra calothyrsus*, *Sesbania sesban* and *Leucaena leucocephala*—to assess performance and determine preferred locations for planting the shrubs. Because of the limited size of the farms, farmers and researchers focused on integrating the shrubs into existing cropping systems rather than planting them in monoculture blocks. Two of the species, sesbania and *L. leucocephala*, performed poorly. Sesbania did not withstand frequent pruning, and *L. leucocephala* was attacked by psyllids (*Heteropsylla cubana*). Calliandra performed well, and farmers preferred the following locations and planting arrangements for it:

1. Planted in hedges around the farm compound. Hedges are a common feature of homesteads in central Kenya and have traditionally been planted to relatively unproductive, non-browsed species to prevent free-range livestock from destroying them. But livestock is now confined, and there is great potential for replacing unproductive hedges with fodder hedges (Thijssen et al. 1993).

2. Planted in hedges along contour bunds and terrace edges on sloping land. The shrubs thus help conserve soil and, when kept well pruned, have little effect on adjacent crops.

3. Intercropped in lines with napier grass. Results from intercropping experiments show that introducing calliandra into napier grass has little effect on grass yield when one row of shrubs is intercropped with 4 rows of napier grass (Nyaata et al. 1998).

4. Planted in lines between upper-storey trees. Many farmers plant *Grevillea robusta*, a tree useful for timber and firewood, along their boundaries. Fodder shrubs may be planted between the trees in the same line (NARP 1993).

Under normal growth, calliandra shrubs are ready for first pruning for fodder 9–12 months after transplanting, and pruning is carried out 4–5 times per year (Roothaert et al. 1998). Leafy biomass yield per year rises as pruning frequency decreases and cutting height increases, but then the yields of any adjacent crops will be constrained by shading (ICRAF 1992). One recommended cutting option is in the range of 4–6 prunings per year at 0.6–1.0 metres (m) high, which yields roughly 1.5 kilograms (kg) of dry matter (4.5 kg of fresh biomass) per tree per year, planted at two to three trees per metre in hedges under farmers' conditions. Thus a farmer would need about 500 shrubs to feed a cow throughout the year at a rate of 2 kg of dry matter per day, providing about 0.6 kg of crude protein. A typical farm of 1.5 ha could easily accommodate 500 shrubs without replacing any existing crops. For example, the farm would have available about 500 m of perimeter and several hundred meters in each of three other niches: along terrace edges or bunds, along internal field and homestead boundaries, and in napier grass plots. As shrubs are planted at a spacing of 50 centimetres, only 250 m would be needed to plant 500 of them (Paterson et al. 1998). The establishment and growth of shrubs in each of these niches has been found to be good, and indeed farmers use them all.

3.2.1.4 Animal feeding research

On-farm feeding trials have confirmed the effectiveness of calliandra as a supplement to a basal diet. In feeding trials, 1 kg of dried calliandra, which is 24% crude protein and 60% digestible when fed fresh, about matched the digestible protein of 1 kg of dairy meal, which is 16% crude protein and 80% digestible (Paterson et al. 1998). Both feeds increased milk production by about 0.75 kg under farm conditions, but the response was variable, depending on such factors as the health of the cow and the quantity and quality of the basal feed (Paterson et al. 1998). Koech (2005) found that a sample of 20 farmers in Embu District reported an average response of 0.8 kg of milk from feeding 1 kg dry weight of calliandra. Paterson et al. (1999) reported that the effects of modest inputs of calliandra and dairy meal were additive, suggesting that the two feeds were nutritionally interchangeable. Unfortunately, data are unavailable for constructing a response curve to show the effect of varying quantities of calliandra on milk production. Calliandra was also found to increase the milk production of dairy goats (Kiruiro et al. 1999), though Tuwei et al. (2003) found that its effectiveness in boosting goat milk yield was much below that of dairy meal, comparing 1 kg dry weight of each.

Some practical guidelines for using combinations of feeds with calliandra have been published in extension materials, such as by Roothaert et al. (1998), Wambugu (2001), Wambugu (2002) and Wambugu et al. (2006). Among these guidelines, research by Stewart et al. (2000) found that calliandra could be fed fresh or dry. Drying was previously thought to reduce quality, particularly digestibility, but this was not supported by further research. Cutting every 6 or 12 weeks produces similar amounts of leaf biomass annually, but the longer cutting interval provides additional small sticks suitable for fuel.

3.2.2 Scaling up, adoption and impact research

As technology-development research matured and positive results were obtained, ICRAF and its partners focused more research on scaling-up processes, technology adoption and impact to identify constraints and improve dissemination strategies. The research questions addressed by the various studies are in table 3.1, along with a brief description of research methods and links to key references. The results of the studies are presented in the following sections.

Table 3.1: Scaling up, adoption and impact studies on fodder shrubs in East Africa

Research question	Research methods
How effective are the different information-dissemination approaches, methods, and materials	Quantitative study of the usefulness of information from different sources (Wambugu 2006). Quantitative analysis of fodder shrub stakeholder organizations to determine trends in collaboration among them (Acharya et al. 2007)
In farmer-to-farmer dissemination, who are these disseminators, how active are they, and what motivates them?	Quantitative analysis of randomly selected users of fodder shrubs and assessment of numbers of farmers trained and motivations (Franzel and Wambugu 2007)
How can germplasm supply be made more self sustaining and private oriented?	Qualitative study using key actors in value chain (Technoserve 2003)
Are all types of groups trained on nursery development equally likely to understand and implement information on fodder shrubs?	Quantitative analysis of seedling production performance across different types of farmer groups (Place et al. 2004)
How many farmers have planted fodder shrubs and use them as feed?	Quantitative monitoring by organizations involved in disseminating fodder shrubs and researcher validation (Franzel and Wambugu 2007). Direct quantitative monitoring of adopters from projects (Stewart et al. 2006). Quantitative analyses of farmer-to-farmer dissemination processes (Franzel and Wambugu 2007)
Which types of farmers (e.g., women) are planting shrubs and why?	Quantitative adoption studies sampling those planting shrubs and those who have not (Sinja et al. 2004). Quantitative assessment of early planters to measure the extent of expansion or dis-adoption over time (Gerrits 2000)
What effect do the shrubs have on milk production?	Quantitative studies of fodder planters on the number of trees planted, amount of feed given and milk response (Mawanda 2004, Koech 2005, Franzel and Wambugu 2007). Quantitative study of fodder users' and non-users' feed strategies and milk production and an econometric assessment of relationships (this study)
What effects do the shrubs have on other welfare indicators?	Qualitative assessment from focus group and case study analyses (Maina 2009)
How are fodder shrub impacts distributed across different types of households or individuals?	Qualitative focus group discussions with men and women separately (Maina 2009). Qualitative case studies with households of different types (Maina 2009). Quantitative monitoring of gender of nursery group members and planters of shrubs in projects (Stewart et al. 2006). Quantitative regressions of planting of fodder shrubs in Kenya (Wanjiku and Place 2007)

The research thus involves a range of questions and methods, with respondents ranging from development organizations to nursery groups and farmers. Though the studies took place in different years and at different sites, they provide valuable insights into the different components of scaling up and impact.

As noted above, most of the research has been conducted in Kenya, mainly because fodder feeding is the primary purpose of planting leguminous shrubs there for almost all farmers. In other countries, such as Uganda, the primary purpose was often initially soil conservation or fertility. Thus, while the shrubs were very often also used for fodder, they were not managed in similar ways. Research results are presented from around the region, but the more rigorous analyses have been done in Kenya, and much of the impact analysis relates to Kenya alone. Similarly, much of the adoption and impact work pertained to the effects of feeding calliandra to dairy cows. Again, the reason for this is that calliandra has been the overwhelming species of choice among adopters so far.

ICRAF and its partners undertook several studies to assess the extent of adoption, focusing initially on central Kenya, where the technology spread earliest. A key activity was to coordinate the regular monitoring of the total number of households with fodder shrubs and the number of new planters created by development organizations promoting the practice. Of particular interest was how to use the data collected to estimate the total number of adopters. It was found that there was significant variation in the interest and capability of different organizations to collect reliable information. Further, the organizations were unable to track diffusion outside of their mandated geographical areas.

To complement the information received from the fodder shrub disseminator organizations, ICRAF and its partners conducted a number of household surveys. These had multiple purposes. One was to fill gaps where information from other sources was out of date, inaccurate or imprecise. Another was to better understand farmer-to-farmer diffusion processes and the number of farmers reached through these informal channels and therefore possibly under the radar of development partners. Given the difficulty in arriving at an accurate number of adopters, ICRAF researchers applied various methods to measure the extent of adoption of fodder shrubs, including surveys to estimate the extent of uptake and diffusion (see Franzel et al. 2005). The results of these analyses are given in section 4.2 below.

Shortly after significant scaling up began, it was recognized that some farmers were learning about the technology from other farmers. Hence, ICRAF conducted formal research to measure the significance of this farmer-to-farmer dissemination. Other scaling-up research included analyses of how dissemination partners in Kenya were connected, how different types of groups managed the task of producing fodder shrub seedlings in nurseries, and the constraints on more private sector involvement in the seed sector.

Results from all these studies have been integrated into subsequent development projects, including one funded by the United States Agency for International Development in Kenya using the Academy for Educational Development's System-wide Collaborative Action for Livelihoods and the Environment (SCALE™) approach and an ongoing project funded by the Bill and Melinda Gates Foundation in Kenya, Rwanda and Uganda called East Africa Dairy Development.

3.3 Moving from knowledge to action

ICRAF's role in research has gone beyond that captured in sections 3.1 and 3.2, as it also translated research results into outcomes, moving from knowledge to action. ICRAF's strategy and philosophy, the context of the sector into which the technology fits, and the collaboration among partners in Kenya and the larger region all contributed to positively influence the process of dissemination and adoption.

ICRAF has always had a strong impact orientation. While that is true for the CGIAR as a whole, ICRAF has positioned itself well for moving from knowledge to action through the establishment of long-term research programmes in priority countries, enabling it to address the various developmental constraints and research challenges faced as innovations are increasingly adopted. ICRAF has long used on-farm research to test technology, and fodder shrubs have been no exception. Within the East Africa programme, fodder research was identified as a priority research area with a flagship site in Embu, Kenya, and satellite research conducted in other regional research sites. Fodder tree research was also conducted in southern and western Africa. The team assembled for fodder shrub research included social scientists, and the continuous leadership of an agricultural economist and an extension specialist was key to facilitating the wider dissemination of the technology. Project concepts were conceived

with research and development partners to scale up dissemination and conduct research on the scaling-up process. Several projects proposals were successful in attracting funds. This had a snowball effect in terms of creating awareness among other organizations, including farmer organizations who increased demand for knowledge.

As noted above, several attributes of the technology itself facilitated its scaling up. Three key characteristics were its low cost of establishment, relatively short wait for benefits when compared with other tree products, and clear income benefits. The income benefits reflected that dairy is a profitable and growing sector in Kenya and the region. Profits are made throughout the value chain, motivating all actors to improve efficiency and productivity.

The ease with which partners—from investors to researchers, development organizations and farmer groups—came together was also a key factor. The success of the dairy sector likely contributed enormously to this collaboration, as there was mutual interest among investors and development organizations in making a difference. The inclusion of research institutions in the partnership was welcomed by others because the technology itself was not well known among development practitioners. Perhaps most important, however, was the ease of involving farmer groups, as dairy production was a very attractive catalyst for group formation, from small community groups up to national associations. This greatly facilitated the raising of awareness and the ease of entry of project staff, development organizations, and extension personnel into beneficiary communities. As described below, these entry points have had multiplier diffusion effects through farmer-to-farmer dissemination.

3.4 Costs of research

ICRAF conducted fodder shrub research throughout its East Africa AFRENA programme beginning in the late 1980s. Species screening trials were held in Burundi, Kenya, Rwanda, Tanzania and Uganda. Feeding trials were also conducted at most of these sites. However, the hub of fodder research was at the KARI research site at Embu, where a number of researchers and students were based for a decade. At that site, specialized research hypotheses on animal nutrition, health and reproduction, species' establishment, nursery management, farm management, and dissemination strategies were tested. Thus, the bulk of the research effort and expenditure was at the Embu site. Although ICRAF formally closed down research in Embu in 2000, further joint research-and-development projects on scaling up continued in Kenya and the larger region.

ICRAF invested an estimated $4.71 million in fodder shrub research and scaling up in East Africa over 1988–2007. This figure includes all staff and operating costs in the East African field sites of ICRAF as well as some backstopping support from headquarters. Much of this was funded by restricted grants, with unrestricted ICRAF funds as supplement, notably for staff time. This underestimates the total amount devoted to fodder shrub research in the region, as national partners also allocated funds for this. Further, ILRI allocated funds for research on feeding systems, including high-quality feeds. It is impossible to provide a reliable estimate of these additional research investments. Lastly, one should not overlook the amounts spent on disseminating fodder shrubs in the region. Some of these funds were factored into project costs, as the funds were managed by ICRAF or close partners, but other efforts by NGOs, government extension agents and farmers themselves have not been included in the calculation.

4. Dissemination and adoption of fodder shrubs in East Africa

4.1 Dissemination pathways, approaches and research

As noted above, fodder shrubs are homegrown, requiring little or no cash investment or land taken away from producing food or other crops. The only inputs required are seed and minimal amounts of labour, which farmers are usually willing to provide. But, like many agroforestry and natural resource management practices, growing fodder shrubs is knowledge intensive, requiring management practices with which most farmers are unfamiliar, such as raising seedlings in a nursery, pruning trees on farm and feeding the leaves to livestock (Franzel and Wambugu 2007). In recognition of these potential constraints, the dissemination process entailed three components: awareness creation, technology management training and access to germplasm. The specific methods and approaches used in dissemination changed somewhat over the years as new partnerships brought in new ideas and research discovered differences in the effectiveness of tested methods.

Three general dissemination phases can be distinguished in East Africa: (1) local scaling up from the Embu research site and a few other sites in Kenya and Uganda (1995–1999); (2) wider awareness creation and pilot site extension in Kenya, Rwanda, Tanzania and Uganda (1999–2004); and (3) the System-wide Collaborative Action for Livelihoods and the Environment (SCALE™) approach in Kenya, with a focus on central Kenya (2005–2007). A more recent dissemination project, East Africa Dairy Development, was launched in Kenya, Rwanda and Uganda in late 2008, too recently to be included in this study.

The dissemination approaches and methods used for each of the three components are summarized in table 4.1. Generally, dissemination evolved from highly localized processes, in which researchers played a strong catalytic role, into one in which a number of intermediaries, including private sector actors and civil society organizations, played larger roles. In terms of awareness creation, early methods involved ICRAF disseminating extension materials at infrequent events and through a limited number of partners. By 2005, the media was actively promoting the technology, many new organizations such as churches were transmitting information about fodder shrubs, and the private sector became more organized and active

Table 4.1: Dissemination approaches used to scale up fodder shrubs in Kenya

Phase 1: Local dissemination from Embu	**Methods used**
Awareness creation	Posters and pamphlets
Technical support	Direct training of farmers, groups and local extension agents
Access to germplasm	Provided by project
Phase 2: Dissemination in East Africa through pilot sites	
Awareness creation	Management manuals produced; moderate use of newspapers and radio; promotion at agricultural shows and events; sensitization of non-governmental organizations (NGOs) and extension systems
Technical support	Dissemination facilitators training farmer groups; NGOs and extension agents; farmer trainers supported and farmer-to-farmer dissemination promoted

Table 4.1: Dissemination approaches used to scale up fodder shrubs in Kenya (continued)

Access to germplasm	Organizations and projects buy seed from the Kenya Forestry Research Institute (KEFRI) or from producers and dealers in western Kenya and provide it to new areas; training on seed collection, bulking and storage and nursery management
Phase 3: SCALE™ Approach	
Awareness creation	Intensive use of newspapers, television, and radio; active sensitization of wide range of organizations, including milk processors and church groups; establishment of communication support office
Technical support	Linking new demand for knowledge to existing farmer trainers
Access to germplasm	Facilitating establishment of private seed dealer association; connecting buyers and sellers

SCALE™ = System-wide Collaborative Action for Livelihoods and the Environment.

in promoting awareness. These organizations attended awareness events or otherwise met with dissemination facilitators to learn more about the technology. They then passed on the information to farmers at gatherings or by distributing leaflets at milk collection points.

Regarding access to seed, there was a similarly marked transition in approaches. In the early days, ICRAF, KEFRI and NGOs acted as intermediaries, buying seed from a few producers or dealers in western Kenya and making it available to new communities, mostly in central Kenya. As a complement to this, small exchanges and sales were emerging within communities. Eventually, the demand for seed grew to the point that a more organized, formal and private sector effort was needed. The private seed sector was developing but became more independent and empowered with the formation of the private Kenya Association of Tree Seed and Nursery Operators. With improved communications, this network was better able to respond to germplasm demand arising from many quarters.

Also improving seed access was training on nursery production. Over the years, the most success has been achieved by training farmer groups and using group nurseries as training sites (Wambugu et al. 2001). This was found to be more cost effective in terms of knowledge diffusion and effective in generating seedlings that could be planted by farmers, as the shrub species did not exist in private nurseries. For example, in 1999–2000 a small development project was able to train over 2,600 farmers and establish 250 nurseries by training 150 groups in Kenya (Wambugu et al. 2001). Place et al. (2004) studied nursery management and performance among farmer groups and found that all types of groups, regardless of their main objective, performed well in raising and planting out seedlings. This suggested that dissemination efforts did not need to be confined to certain types of groups.

The potential of the private sector to meet demand for fodder shrubs was studied (Technoserve 2003). A study of the calliandra seed market in Kenya found that the private sector in western Kenya was effective in providing seed for sale to such institutional buyers as projects and NGOs but not to farmers. In central Kenya, these institutional buyers supplied farmer groups with free seed. There appears to be insufficient incentive for the private sector to undertake calliandra seed distribution to farmers, probably because so much seed is given away for free. An important lesson is that the biggest reason behind the lack of available seed is the lack of knowledge among seed producers in western Kenya about relatively strong farmer demand for seed in other parts of the country. Second, information is lacking about calliandra as feed in western Kenya, suppressing demand for seed. One recommendation was to help seed dealers form an association to share information, improve access to seed and lobby policy makers. As it turned out, this came to fruition in later years as an outcome of the fodder shrub research programme.

In terms of technology management training, approaches have perhaps evolved more slowly as this still requires dedicated time and effort. Various projects have funded field technicians to help train farmers, farmer groups, NGOs and extension agents. The cadre of trained staff has been able to train others in turn in their mandated regions. Likewise, farmers themselves are active trainers and seed providers and have greatly multiplied the number of farmers adopting fodder shrubs. These two methods have worked well to

expand the number of trained farmers in areas where the trainers reside. But they have not been effective in bridging geographical distances and reaching new communities.

A study by Wambugu (2006) assessed the frequency of farmers using different information sources and evaluated the usefulness of their information from the perspective of farmers in central Kenya. Table 4.2 shows that a variety of sources were frequently accessed by farmers, including print and electronic media, researchers, extension agents, organized demonstrations or tours, farmer groups, and individual farmers. The perceived usefulness varied by source. The farmers found the information received from researchers, educational tours, demonstrations and farmer group meetings to be the most useful of all. Of less importance was information received from nurseries, seed dealers or electronic media.

Table 4.2: Sources of extension information on fodder shrubs in central Kenya

Source of extension information	Number of respondents reporting the source	Rating of usefulness (% of respondents)		
		Low	Medium	High
Visits by other farmers	45	16	29	56
Nursery operators and seed dealers	23	52	30	17
Farmer group meetings	73	3	15	82
Farmer association and cooperative meetings	26	35	19	46
Field days, demonstrations and village meetings	53	13	15	72
Educational tours	60	10	18	72
Workshops and seminars	26	23	31	46
Electronic media	53	36	46	18
Print media (newspapers, magazines, pamphlets, posters, etc.)	51	18	29	53
MOA and MOLD extension visits	68	16	27	57
NGO visits	18	28	33	39
Research agents visits	84	6	11	83
Private company visits	3	33	0	67
Agricultural shows	4	25	25	50
Experimentation	3	0	67	33

MOA = Ministry of Agriculture, MOLD = Ministry of Livestock Development, NGO = non-governmental organization.
Source: Wambugu 2006.

In terms of what has worked well and why in the region as a whole, a few lessons have been learned. Five elements appear to be critical for the successful dissemination of the practice, according to Franzel and Wambugu (2007), as follows:

1. **Large NGO promoters.** In Rwanda and Uganda, a few large international NGOs facilitated the dissemination of fodder shrubs to many thousands of farmers, accounting for over half of farmers planting in the two countries. Large NGOs were also important in facilitating the spread of the practice in Kenya and Tanzania. Some of the NGOs employed hundreds of extension staff and thus had significant reach. Many promoted dairy production and wanted to ensure that their farmers had sufficient feed for their cows. Others primarily promoted agroforestry and were interested in helping farmers plant more trees for a range of purposes, including the provision of fodder and fuelwood and controlling soil erosion. An advantage of NGO promoters is that they often have sufficient resources to follow through with their target communities and farmers. For example, in central Kenya, it was found that farmers visited by NGOs received an average of 8.5 visits per year (Wambugu 2006).

2. **Civil society campaigns.** The dissemination approaches mentioned above involve extension providers, seed vendors and farmers, but a much broader set of partners can add significant value in promoting a new technology such as fodder shrubs. The System-wide Collaborative Action for Livelihoods and the Environment (SCALE™) methodology brings civil society stakeholders together to plan and implement campaigns to promote new practices (AED 2004). By engaging with a wide range of stakeholders representing all aspects of a given system (in this case, dairy production), SCALE™ generates change across many levels and sectors of society, using a combination of social change methodologies including advocacy, mass communication and social mobilization. Experience with the SCALE™ approach in central Kenya highlights the effectiveness of civil society campaigns as complements to more conventional extension programmes. Religious leaders, the media (radio, TV and publications), private input suppliers, local government administrators and dairy companies each have a critical role to play in awareness creation that generates demand from farmers for more in-depth training. The SCALE™ approach draws these various actors together into a unitary planning process, enhancing the synergy of their individual efforts and aligning processes and systems for awareness creation, more formal training and germplasm access. A study by Istrate et al. (2007) showed that SCALE™ significantly increased the number of actions of and between key stakeholders involved in the dairy feed sector, including those providing training or seed.

3. **Facilitated seed flows.** Poor seed availability was a key constraint in many areas. As calliandra, the main species, produces relatively little seed, farmers need to be trained to collect, maintain and treat it before planting. An assessment of the seed market chain found that a few private seed vendors in western Kenya were effective in providing seed to big institutional suppliers such as NGOs but were ineffective at reaching farmers, particularly in central Kenya, where the greatest number of potential adopters were. Following the study, ICRAF and its partners used their experiences to help seed vendors in central Kenya form an association to forge links with seed providers in western Kenya and make seeds available in small packets for sale to farmers in central Kenya. Over 8 months in 2006, 43 seed vendors sold over 1 tonne of seed, which is sufficient for about 33,000 farmers and a quantity much greater than they had sold previously. A thriving private seed market is key to sustainable growth in the number of farmers using fodder shrubs.

4. **Dissemination facilitators.** Dissemination facilitators are extension specialists who are knowledgeable about fodder shrubs and whose principal function is to promote their use among extension providers and support them with training, information and access to seed. Dissemination facilitators are employed by international organizations such as ICRAF or national agricultural research institutes such as the National Agricultural Research Organization in Uganda or the Selian Agricultural Research Institute in Arusha, Tanzania. With few exceptions, they were employed through donor-financed projects designed to promote fodder shrub adoption. The dissemination facilitators proved to be highly effective. In central Kenya, for example, over a 2-year period, a dissemination facilitator helped 22 organizations and 150 farmer groups comprising 2,600 farmers establish 250 nurseries and plant over a million fodder shrubs (Wambugu et al. 2001).

5. **Farmer-to-farmer dissemination.** Survey results showed that farmers played a critical role in disseminating seed and information to other farmers. A survey of 94 farmers in central Kenya randomly selected from among farmers who had planted fodder shrubs 3 years before the study revealed that 57% had given out both planting material (seeds or seedlings) and information to other farmers (Franzel and Wambugu 2007). On average, those giving out planting material gave it to 6.3 other farmers (see table 4.3). They accessed planting material in a variety of ways, from their own or group sources, and in seed and seedling form. The most common form of germplasm transmission was seed from the disseminator's own farm (to an average of 2.0 other farmers per disseminator), followed by seedlings from either the disseminator's own nursery (to an average of 1.6 farmers) or from the group's nursery (to an average of 1.1 farmers). Of special interest were five 'master disseminators' among the sample farmers, who were responsible for two-thirds of all farmer-to-farmer dissemination. These disseminators did not differ from other farmers in any appreciable way, as they included both males and females and represented a range of ages, levels of education and farm size.

Farmers receiving planting material from other farmers had fairly high rates of success in planting, as 75% were found to have fodder shrubs. One disturbing trend was that, while women accounted for 43% of adopters and 37% of farmers disseminating to others (table 4.3), they accounted for only 25% of farmers receiving planting material (table 4.4). The full effectiveness of knowledge transmission through farmer-to-farmer dissemination has not yet been explored, meriting further study to fully understand the role that farmers can play in diffusion. It is clear that they have an important role to play in awareness creation and catalyzing testing by other farmers, given the results observed and the fact that they are not formally paid for these services.

Table 4.3: Farmer-to-farmer dissemination of fodder shrub planting material in central Kenya

	% of group members giving out planting material to non-members			Mean number of new farmers receiving planting material		
Source of planting material	**% of male members**	**% of female members**	**Total % of members**	**Male farmers**	**Female farmers**	**Farmer total**
Individual group members						
Seedlings from group nurseries via individual members	28	38	32	0.6	1.8	1.1
Seedlings from individual group member nurseries	17	10	14	2.6	0.3	1.6
Seed from individual group members' own shrubs	22	20	21	3.1	0.7	2.0
Seed from the group through individual group members	9	8	9	0.6	0.2	0.4
Wildings from individual members	15	5	11	0.3	0.1	0.2
Groups						
Seedlings from group nurseries			71	0.6	0.0	0.5
Seed from a group			28	0.7	0.0	0.5
Total	61	48	55	8.5	3.1	6.3

Source: Franzel and Wambugu 2007.

Table 4.4: Recipients of planting material by gender in central Kenya

	Recipients of planting material (number [%])		
Source of planting material	**Men**	**Women**	**Total**
Individual group members			
Seedlings farmers received from group nursery	45 (75)	15 (25)	60 (100)
Seedlings from farmers' own nurseries	33 (80)	8 (20)	41 (100)
Seed from farmers' own shrubs	26 (87)	4 (13)	30 (100)
Wildings	7 (87)	1 (13)	8 (100)
Seed from farmers who got seed from group	9 (64)	5 (36)	14 (100)
Groups			
Seed or seedlings from group nurseries	39 (68)	21 (32)	60 (100)
Total	159 (75)	54 (25)	213 (100)

Source: Franzel and Wambugu 2007.

Sinja (2006) studied the social and spatial relationships between farmer disseminators and recipients of calliandra or desmodium feeds (see table 4.5). Planting materials were given mostly to farmers who were described as (in order of importance) friends, relatives or neighbours. The recipients were located relatively near the first-generation farmers, with 84% living less than 5 kilometres from the first farmer). But the data suggest that the relationship of the recipient to the disseminator—that is, friendship and family ties—is a more important influence on dissemination than is being physically close as neighbours. Sinja (2006) then used a probit model to identify characteristics that were related to the decision to actively share calliandra germplasm with other farmers among 168 farmers in central Kenya. A farmer with responsibility in a group or the community is more likely to give out germplasm, as may be expected. Farmers with larger farms and more livestock, and those further from main roads, were more likely to share germplasm with other farmers. Other variables such as age, gender and education of household head were not significant. Stewart at al. (2006) found no strong evidence of relationships between household or individual characteristics and dissemination activities. Thus, farmer disseminators were generally found to emerge from various conditions and were not confined solely to an elite group.

Table 4.5: Relationship of first- and second-generation users of calliandra and desmodium feeds in central Kenya

Relationship between first and second farmer	(%)	**Mean distance (standard deviation)**
Neighbour	21	1.5 (1.87)
Relative	26	3.5 (3.94)
Friend	49	0.5 (6.79)
Other (e.g., visitors or no relationship)	5	4.2 (10.43)
Distance from first farmer (kilometres)		
0–5	84	2.0 ± 1.9
5–10	10	8.3 ± 1.6
≥10	5	22.0 ± 12.3

Note: Number of new farmers is 168.
Source: Sinja 2006.

Maina (2009) found that focus group discussions held with farmers indicated that farmer participation during the introduction of the shrub technology in some locations in Embu and Maragua had not been sufficient and was possibly responsible for the lack of awareness, knowledge and adoption. The adoption of fodder shrub technology in the areas studied when they were first introduced was highly dependent on membership in groups, particularly dairy groups. Group participants noted that many farmers not involved initially did not see the need to adopt or use the technology and have hence remained marginalized. Most farmers interviewed in both locales of the study reported that they were inclined to adopt the technologies but require more sensitization and follow-up to enable them to clearly interpret what is required and the type of potential to be realized.

4.2 Adoption

In this section, two topics are explored in detail. The first is calculating the number of adopters of fodder shrubs in East Africa. The methodology used and numbers reported are from an earlier study by Franzel and Wambugu (2007). The second sub-section draws on several other studies that analyzed household and farm variables associated with the planting of fodder shrubs, mainly in Kenya.

4.2.1 The patterns of adoption

The uptake of fodder shrubs has been substantial. By 2006, about 10 years after dissemination began in earnest, 224 organizations were counted across Kenya, Rwanda, northern Tanzania and Uganda promoting fodder shrubs, and about 205,000 farmers had fodder shrubs that they had successfully planted (table 4.6). The estimated figure is derived from data submitted by development organizations involved in promoting fodder shrubs. This data was first validated using follow-up discussions with field experts and some spot visits. Because not all key development organizations submitted information, and expansion had taken place in some new areas, the data received from the organizations was adjusted upwards as appropriate. These adjustments were based on various methods, such as assigning 'average' dissemination and adoption figures to organizations that did not report and taking into account the mandate area and size of the organization (and in some cases building upon past records submitted), as described in the following paragraph.

In Kenya, data in the 'our records' column of table 4.6 are from four random sample surveys and reports from 23 organizations, mostly in 2004–2005. Data in the 'rough estimate' column include 'conservative' numbers in areas with fodder shrubs for which we have no data (e.g., the coast, Kisii and Machakos) and increases in Central and Eastern provinces since 2003 surveys. In Uganda, data in our records are from surveys in 2003 and 2005, in which 44 organizations reported on the number of farmers planting fodder shrubs. Data in rough estimate include numbers in areas not covered in the survey and 16 organizations that were unable to report on numbers of farmers. Many of the organizations promoted fodder shrubs primarily for soil conservation. In northern Tanzania, data in our records are from 14 organizations in Arusha and Kilimanjaro and estimates of the number of collectors, planters, processors and users in Tanga. Data in rough estimate are of farmers in Mbeya, Mwanza, Shinyanga, Tabora and other parts of the country where fodder shrubs are promoted. Finally, in Rwanda, data in our records are from 11 of the organizations that promoted fodder shrubs from 2000 to 2005. In rough estimate, we estimate that each of the other 44 organizations that bought seed helped 100 farmers to plant. Many of the organizations promoted fodder shrubs primarily for soil conservation.

The number of shrubs reported by the organizations during 2003–2005 averaged 71–236 per farmer, depending on the country (236 in Uganda, 180 in Rwanda, 165 in Kenya and 71 in Tanzania). There was considerable variation among farms and across sites within countries. Farmers receiving information and seed from other farmers (second-generation farmers) generally had fewer shrubs than those directly contacted by extension, research or project staff (Stewart et al. 2006). For example, three-quarters of second-generation adopters had planted fewer than

Table 4.6: Farmers planting fodder shrubs in Kenya, Rwanda, northern Tanzania and Uganda by 2005

Country	Number of organizations promoting fodder shrubs	Our record of the number of farmers planting	Rough estimate of additional farmers planting	Total
Kenya	60	51,645	30,000	81,645
Uganda	80	77,369	5,000	82,369
Northern Tanzania	15	17,519	10,000	27,519
Rwanda	69	9,590	4,400	13,990
Total	224	156,123	49,400	205,523

Source: Franzel and Wambugu 2007.

100 shrubs in Kenya (Stewart et al. 2006). A follow-up study in western Kenya and northern Tanzania, where fodder shrubs were recently introduced, found an average of 102 and 117 shrubs per farm (Stewart et al. 2006). A study in Rwanda found that most farmers opted to take fewer than 100 shrubs when given the chance to test them (Dusengemungu 2002). However, Stewart et al. (2006) report that more significant planting of shrubs occurred among households covered by project staff or NGOs, such as in southwest Uganda, where the average number of shrubs planted was 317, or in Byumba, Rwanda, with 301 per household.

These studies indicate that adoption was well below the 500 shrubs needed to feed a single dairy cow each day throughout the year. The likely reasons that the number of shrubs planted per farm was low compared with feed requirements are threefold:

1. Many farmers adopt incrementally, have planted only recently and want to see how the shrubs perform before adding more.

2. Many farmers partly adopt, applying several different strategies to obtain protein supplements (herbaceous legumes, dairy meal, etc.) to better manage the risk of relying on a single strategy.

3. In Rwanda and Uganda, the shrubs have been adopted mainly for soil conservation, as intensive dairy production systems are just emergent, so the target number for a farmer may not correspond to the number recommended for feeding.

However, the planting of shrubs as measured in the field may not represent the final adoption level of households. Studies have found that farmers establish fodder shrubs incrementally, across several plantings. This is for various reasons, such as observing performance before committing to a significant investment, selecting niches on farm, or the difficulty in accessing sufficient seed or seedlings numbers. Franzel et al. (2003b) used data from 45 farmers selected randomly from a group of very early testers of calliandra in central Kenya to investigate planting and expansion patterns among farmers. Table 4.7 shows that 37 of the 45 farmers expanded from their initial planting, and about half of that number expanded at least one more time. The average number of shrubs planted increased each time, indicating that farmers gained interest in investing in the technology. Over the few years up to 1995, the number of trees planted by all sample farmers increased from about 3,780 to 10,541.

In another study in Kabale District of Uganda carried out in 1999, Gerrits (2000) observed that, out of the 88 surveyed farmers who had planted calliandra 2 years previously, the average number of trees planted per household was 260, ranging from as few as 10 to as many as 2,650. During expansion planting, the average number of trees per household was 168 for the second planting and 136 trees for the 3rd and 4th planting. By the time of the survey, the average number of trees per farm was 321, indicating the expansion of fodder trees on the farms.

4.2.2 Understanding adoption patterns

Franzel and Wambugu (2007) interviewed representatives of 70 organizations promoting fodder shrubs to determine the most important factor explaining their achievements in disseminating fodder shrubs. The most important factor, according to these organizations, with a mean score of 4.1 out of 5.0, was that fodder shrubs generally 'met the needs' of farmers. Other key reasons for success were that the fodder shrubs were profitable, effective extension approaches were used, and partnerships with other organizations facilitated success. Less important factors,

Table 4.7: Farmers' expansion of calliandra plantings in Embu, Kenya, by 1995

Planting	Number of farmers	Average number of trees per planting
Initial planting	45	84
1st expansion	37	85
2nd expansion	16	97
3rd and 4th expansion	8	129

Source: Franzel et al. 2003b.

according to these organizations, included long-term commitment by key players, farmers' commercial orientation, farmers' skill level, the availability of training materials and backstopping from research. That training materials and research support were less important is very telling, suggesting that they are not necessary to help farmers plant fodder shrubs. Franzel and Wambugu (2007) argue that many of the reasons for the spread have to do with the technology itself, its attractiveness to farmers, the socioeconomic environment and, in particular, the rapid growth of the smallholder dairy industry in the region.

Wanyoike (2004) used a tobit model to identify household factors associated with the planting of fodder shrubs from among 300 households in Embu, central Kenya. The results showed that farmers' level of formal education, degree of commercialization of their dairy enterprise (proportion of milk sold), perception that calliandra could enhance productivity, receipt of extension services and participation in on-farm trials of fodder trees positively related to the number of calliandra trees they planted. On the other hand, age, size of household, and size of landholdings were not related to adoption. The study concluded that access to extension and participation in on-farm trials were significant in fostering adoption on male-managed farms and those jointly managed, with both men and women making decisions.

Sinja et al. (2004) analyzed data from a random sample of 131 farm households in four districts in central Kenya to examine the effect of farmer characteristics and perceptions on the number of fodder shrubs (mainly calliandra) planted. Using a tobit model, they found that the amount of household labour and farm size positively influenced the investment in fodder shrubs, suggesting that land and labour constraints were present. However, education, off-farm income, and social status did not have a significant effect on the level of shrub planting. Importantly for educational efforts, farmers who perceived that calliandra increased productivity without taking land out of other crop production invested more significantly in calliandra.

The results reported by Wanyoike (2004) and Sinja et al. (2004) are consistent in indicating that diverse types of individuals, by gender, age and social group, plant shrubs. However, there are conflicting results in terms of the effects of landholding size, labour availability and education. Further investigation of the issue is needed across more locations to better understand and support dissemination efforts. Results in both regressions show that perceptions are important and that perceived constraints, such as on land use, can be effectively dealt with through increased training on viable niches for the shrubs.

In a broader study that measured different types of trees on 920 farms across 15 districts in Kenya, Wanjiku and Place (2007) used tobit regressions to examine the effect of meso and household factors on existing tree stocks on farms. They found that the quantity of legume shrubs (used for fodder and/or soil fertility) was related to meso-level variables of proximity to major roads (+), temperature (–) and altitude (–), suggesting that there was an effect of access to markets or extension and that the shrubs were common in middle altitudes, where temperatures are cool. Other meso-level variables such as soil type, rainfall and population density were not related to the number of fodder trees on farm. Among household variables, farm size negatively related to the number of shrubs, suggesting that larger farms opted more for purchased substitutes like fertilizer and dairy concentrates. The age of the household head was positively linked to the number of shrubs, but other household characteristics like education, gender of household head, and asset measures were not strongly linked. The numbers of timber trees, coffee or tea shrubs, and fruit trees were often more strongly linked to meso- and household-level factors.

Maina (2009) discussed issues of adoption of both the planting of shrubs and their use in community workshops, focus groups and case study discussions. One of the motivations for trying fodder shrubs was the high price of alternative quality feeds. Dairy feed prices had been escalating recently, as noted by farmers in community workshops. It was reported that prices for most feeds had more than doubled within the previous year, with a bag of dairy meal selling at 1,500 Kenyan shillings, up from 850; maize germ at 1,000 shillings per bag, up from 650; bran at 650 shillings per bad, up from 220; chicken waste at 350 shillings per bag, up from 200; and sunflower and/or cottonseed cake at nearly 20–40 shillings per kilogram. In terms of constraints, it was apparent from the workshops that farmers believed that the amount of work involved in laying the nursery bed initially discouraged some from participating in fodder shrub experimentation. Reports from interviewed livestock officers reflected reluctance on the part of most farmers not initially involved in early dissemination efforts to adopt the technologies. Other problems affecting adoption included wastage during transplanting, plant desiccation in dry weather, parasite infestation, the need for farmers to contribute

financially to setting up nurseries, small landholdings, lack of follow-up and limited knowledge about the shrubs among farmers not present at the introductory stage.

Hence, Maina (2009) suggested that membership in community groups using the technology was likely to lead to better adoption of the technologies and translate into other advantages. However, it should be noted that there was suspicion of exploitation that discouraged some farmers from joining community groups or cooperative societies. Farmers recounted several instances in which community groups had failed to meet their objectives after leaders embezzled money contributed by farmers.

The results from all the quantitative adoption studies indicate that adoption opportunities for the fodder shrubs are not narrowly defined by ecological zone, market access or household characteristics. Rather, there seems to be at this stage interest in planting and evaluating fodder shrubs in a range of conditions. Further, evidence from a range of studies suggests that participation in learning activities related to fodder shrubs, often through groups, has been important to their successful uptake (Wambugu et al. 2001, Franzel and Wambugu 2007).

5. Impacts of fodder shrubs

5.1 Impacts on growth, health and productivity from researcher trials

5.1.1 Impact on growth, health and productivity of cattle

Feeding trials, mainly on farm, have been conducted to assess animal production characteristics such as growth rates, milk production levels and fertility when cattle, sheep and goats were fed tree fodder.

The effect of leucaena supplementation to change the live weight of grazing steers has been investigated in Tanzania. Sixteen grazing Tanzania shorthorn zebu steer were allocated four different diets of supplementary feeds containing different levels of leucaena leaf meal. The animals grazed on relatively poor-quality pastures of natural vegetation during the dry season in a semi-arid climate. With increasing intake of leucaena leaf meal at 0.4, 0.6 and 0.8 kg of dry matter per day, growth rates increased accordingly, at 0.02, 0.14 and 0.26 kg per day, respectively. Without leucaena supplementation, steers lost 0.3 kg per day. These results show the importance of leucaena supplementation for cattle under pastoral systems during the dry season, when normal grazing commonly is insufficient to maintain body weight.

In a literature review, Roothaert and Paterson (1997) compared the nutritive value of several common fodder tree species such as *Leucaena leucocephala*, *Calliandra calothyrsus*, *Sesbania sesban*. Among the three, *S. sesban* had the highest dry matter digestibility, low acid detergent fibre levels and average crude protein content, which gave it high nutritive value overall. The disadvantage of *S. sesban* is that it does not survive when intensively pruned. Calliandra tends to score lower in nutritive value assessments but ranks high with respect to pruning tolerance.

Anti-nutritive properties in calliandra caused by polyphenolic compounds, commonly known as tannins, have been reported by many authors (e.g., Kaitho 1997, Dzowela et al. 1997). These compounds also have positive effects in animal feeds, as they protect proteins from microbial degradation in the rumen and enable direct absorption in the intestines. For highly productive dairy cows, this can be an advantage for milk production.

There is some disagreement over whether calliandra may be dried without compromising its nutritive value. Palmer and Schlink (1992) discovered that the nutritive value of calliandra is lower in wilted and dried material than in fresh fodder. It is possible that the polyphenolics bind with organic matter during drying. But, in a collaborative experiment by ICRAF, KEFRI, KARI, and Oxford Forestry Institute in Embu, Kenya, Tuwei et al. (2003) examined the effects of provenance and fresh-versus-dried calliandra on the growth rates of sheep and the milk production of goats and found otherwise. Results of feeding fresh and dried calliandra in combination with napier grass were not consistent. Sheep had higher calliandra and total dry matter intake when the calliandra was dried, but it did not affect the live weight gains. When calliandra was fed to sheep in combination with maize stover, the intake of calliandra and the total intake was not affected, but sheep gained more weight with dried calliandra. Drying calliandra had no effect on milk production when fed in combination with napier to goats. The Patalul and Embu provenances were superior to the San Ramón provenance in terms of live weight gains. The study showed that the existing landrace in Kenya is highly suitable as fodder.

On-farm feeding trials have confirmed the effectiveness of calliandra as both a supplement to the basal diet and a substitute for dairy meal. A study in Embu showed that harvesting and feeding 2 kg of dry calliandra per day as a supplement to the normal diet increased milk production by about 450 kg per year, an increase of about 10% over base milk yields (ICRAF 1998).

Assessing calliandra as a substitute for dairy meal, the trials found that 1 kg of dry calliandra (or 3 kg of fresh) had about the same amount of digestible protein as 1 kg of dairy meal, and both increased milk production by roughly 0.60–0.75 kg under farm conditions (Roothaert et al. 2003, Paterson et al. 1998). In Tanzania, 30 grazing crossbred dairy cattle were selected from farmers' herds and randomly placed in five groups with different supplement feeds (Kakengi et al. 2001). The experiment showed that there was a linear relationship between the amounts of leucaena leaf meal the cows were fed and their milk yield: the more leucaena leaf meal provided, the higher the milk yield. A level of 2.6 kg of leucaena leaf meal with 1.8 kg of cottonseed husks gave similar milk yields as a manufactured 1.8 kg cottonseed cake. Kabirizi (2009) found that adding 1 kg of calliandra daily to a diet of napier, lablab and homemade concentrate increased the daily milk production of a cow by 0.7 litres.

Studies in Embu suggest that fodder shrubs can replace commercial concentrates within the normal range of feeding of commercial concentrates (2.0–4.0 kg per day) at a ratio of 3.0 kg of fresh material (0.8–1.0 kg dry matter equivalent) to 1.0 kg dairy meal with 16% crude protein (Paterson et al. 1999). There was also an indication that fodder slightly increased the butterfat content of milk, though this does not translate to higher prices received for it.

5.1.2 Impact on growth, health and productivity in small ruminants

In traditional systems, goats and sheep more commonly feed on tree fodders than do cattle (e.g., Roothaert and Franzel 2001). Goats are natural browsers when left grazing in shrubland, but sheep also consume browse voluntarily in significant amounts. In many parts of the tropics, fodder trees and shrubs are actively harvested by farmers and fed to small ruminants. Dairy goats are a rapidly growing enterprise in East Africa, and dissemination efforts are underway to make fodder shrubs available to dairy goat producers (Kaburia 2006). When used as supplements to low-quality diets, tree fodder increases live weight gain and milk and wool production (Devendra 1990, Djogo 1994, Roothaert et al. 1998).

In the AFRENA programme of ICRAF, Niang et al. (1996) carried out a feeding experiment with 30 young local bucks in the highlands of Rwanda, at 2,500 m above sea level. The bucks were fed basal diets of the grass *Setaria splendida* (4 kg fresh per animal per day) and a daily supplement (2 kg fresh) of one of the following fodder trees: *Mimoca scabrella*, *Chamaecytisus palmensis, Alnus acuminate, Acacia koa, Acacia Koaia, Acacia melanoxylon, Acacia mearnsii* or *Hagenia abyssinica*. The control was a diet of setaria grass only. In all cases, total daily feed intake was significantly increased by the addition of fodder shrubs, with values ranging from 53.5 grams per kilogram of metabolic body weight (g DM kg^{-1} $BW^{-0.75}$) with grass + *A. acuminata* to 70.3 g kg^{-1} $BW^{-0.75}$ with grass + *M. scabrella*. The diets with *M. scabrella*, *A. koaia*, *A. koa* and *C. palmensis* gave comparable results in terms of total feed intake.

In another experiment at the same location, the live weight gain of 24 bucks was monitored when fed on three different diets: 100% setaria, setaria + 45% mimosa, and setaria + 55% mimosa. Feeding of mimosa significantly increased the live weight gain of the goats. On setaria alone, the animals gained 31 grams per day, while on 45% mimosa they gained 47 grams and on 55% mimosa 51 grams. Ebong et al. (1999) also recorded positive growth gain in goats as a result of feeding calliandra as a supplement.

Positive results when supplementing grass basal feeds with fodder trees were also obtained for sheep by Mpairwe et al. (1998) in Uganda. Four rams were fed napier grass hay *ad libitum* and supplemented with dried gliricidia leaves at 0, 4, 8 and 12 g of dry matter per kilogram of live weight per day in a 4 × 4 Latin square design. In this experiment, supplementation did not affect total dry matter intake in a significant way; animals simply ate more napier at lower gliricidia levels. The maximum total dry matter intake was 71 g DM kg-1 BW0.75. Gliricidia supplementation affected live weight gain, with average growth rates for the grass-gliricidia diets ranging between 71 and 89 g per day, compared with a growth rate of 18 g per day on grass alone. The recommended supplementation rate was 8 g of dried gliricidia per kilogram of live weight, which corresponds to about 1 kg of fresh gliricidia leaves for a sheep weighing 40 kg.

Very high levels of dry matter intake of calliandra-napier mixtures were recorded by Tuwei et al. (2003). Sheep consumed as much as 112 g DM kg^{-1} $BW^{-0.75}$, of which 37% was wilted calliandra, and gained 79 g per day in live weight. When fed fresh calliandra, sheep consumed 93 g DM kg^{-1} $BW^{-0.75}$, of which 32% was calliandra, and gained 90 g per day.

5.2 Impact on household milk production and economic value

The impact of fodder shrubs on milk production was already analyzed, in a sense, by feeding trials

documented in section 5.1. Those trials provide the most rigorous controls to enable distinguishing the additional effect of feeding with shrubs. Those results found that 1 kg of dry equivalent of fodder shrubs increased milk production by 0.6–0.8 kg.

These trials standardized feeding regimes despite being conducted on farm, where farmers use a range of different feeding strategies depending on their access to different feeds. So this section draws on two additional sources of information.

The first is a variety of farmer surveys conducted in 2001–2006 that aimed to produce partial budget analyses, soliciting information on the additional costs and benefits associated with fodder shrub production and use. These provide an estimate of the number of shrubs used along with estimated milk increases from their use. The number of shrubs used is an important variable to identify, as it determines the number of days a farmer can benefit from additional milk production. The second source of information is a new survey in 2008 not previously reported that surveyed 230 dairy farmers in Embu and Maragua districts in Kenya. These were experienced dairy farmers belonging to dairy groups, and a subset used fodder shrubs. For each farmer, each cow, and both the rainy and dry season, all feeding strategies were enumerated along with the number of days and the resulting milk yields from each. The unique aspect of this data was the recognition that fodder shrubs are used in different amounts and in different feed combinations, and that fodder shrub effects on milk may therefore be conditional on other feeds used. The survey generated a large number of different observations (more than six per household), and econometric analysis was used to identify the marginal effect of the shrubs, controlling for other feeds.

5.2.1 Partial budget analysis of milk production and income impacts in East Africa

Impacts on milk income are derived from two strategies adopted by farmers that use fodder shrubs. In the first, farmers increase milk yields by using fodder shrubs as a complement to the existing diet, with fodder shrubs becoming the only high-protein feed or else complementing other high-protein feeds. In the second, farmers may use fodder shrubs as a substitute for other quality feeds, in particular purchased concentrates. Here, the farmer may be attempting to maintain milk yields at lower input cost.

Several farmer surveys have found both strategies to be practiced in the field. Three sets of analyses follow. The first two draw upon field research conducted over 2002–2006 that assessed the marginal impact of fodder shrub feeding practices in Kenya and Uganda, as reported in Franzel and Wambugu (2007). The third draws on field research in Kenya in 2008 that aimed to investigate the marginal returns from various high protein feed strategies, including combinations of available options.

The partial budget analyses are based on parameters given in table 5.1 of the costs of establishment, feeding, dairy meal and labour wages, as well as farm gate prices for milk. Ranges are given for wages and prices because they vary across the region. The calculated net income for a farmer planting and using 500 shrubs (in table 5.2) was further calculated by using the daily feed amounts and milk responses from table 5.1. However, the net income figures based on the actual numbers of shrubs planted were validated through household surveys. Indeed, the ratio of actual fodder trees over the recommended 500 was found to be a close predictor of the ratio of actual net income generated over that generated under full adoption.

Scenario 1:
Calliandra used as a substitute for dairy meal. Some farmers use calliandra instead of dairy meal, perceiving the benefits of calliandra to be the money they save by not buying dairy meal. The costs and benefits of feeding a cow 6 kg of fresh calliandra (equivalent to 2 kg of dried calliandra) per day can be compared with the costs and benefits of feeding 2 kg of dairy meal, which has about the same quantity of digestible protein and gives roughly the same milk output. Assuming this substitution rate, we compare

1. the benefit of using calliandra, that is the money saved by not purchasing and transporting the equivalent quantity of dairy meal for protein, with

2. the cost of using calliandra, that is planting, cutting and feeding it.

Beginning in the second year after planting 500 calliandra shrubs, a farmer's net income increases by about US$101 to $122 per cow per year by using calliandra as a substitute for dairy meal. The increases in income vary by site because of differences in labour requirements and prices, particularly for milk (tables 5.1–5.4).

Table 5.1: Selected coefficients and prices used in the economic analysis

Item coefficients	Value
Calliandra quantity per cow per day (equivalent to 2 kg dry)	6 kg fresh
Dairy meal quantity per cow per day	2 kg
Milk output per day from 1 kg dry calliandra	0.62 litres
Calliandra leafy biomass yield per tree in year 1	None
Calliandra tree biomass yield per tree per year, years 2–5	1.5 kg (dry)
Shrubs required to feed 1 cow per year	500
Labour for planting calliandra	20–28 shrubs per hour
Labour for cutting and feeding calliandra	30–40 minutes per day
Prices (US$)[a]	
Dairy meal	0.16–0.17 kg^{-1}
Seedling cost of production (bare-rooted)	0.50–0.96 100 $shrubs^{-1}$
Labour wage rate (3/4 of rate farmers pay casual labour)	0.51–0.79 day^{-1}
Milk price (farm gate)	0.13–0.33 $litre^{-1}$

[a]Because coefficients and prices often vary by site, values are presented as ranges. Milk output from calliandra is from on-farm trials as reported by Paterson et al. (1998); 2003-04 exchange rates: US$1 = 1,881 Ugandan shillings = 76-80 Kenyan shillings.

Source: Franzel and Wambugu 2007.

Table 5.2: Partial budget of using calliandra as a supplement to increase milk production in Kisumu area, Kenya, 2004

Year	Additional costs (US$)		Additional benefit (US$)		Net benefit (US$)
1	Shrub seedlings	2.85			
	Planting labour	3.01			
	Subtotal	5.86		0.00	–5.86
2–10	Cutting & feeding labour	9.16	450 kg milk	124.02	114.86

Net present value at 20% discount rate = $380.93 per year

Net benefit per year after year 1 = $114.86

Annualized net benefit treating establishment costs as depreciation = $112.90

Note: Base model farm has 500 calliandra shrubs and one dairy cow that consumes a basal diet of 80 kilograms of napier grass per day and produces 10 kilograms of milk per day.

Table 5.3: Partial budget of using calliandra as a substitute for dairy meal in milk production in Kisumu area, 2004

Year	Additional costs (US$)		Additional benefit (US$)		Net benefit (US$)
1	Shrub seedlings	2.85			
	Planting labour	3.01			
	Subtotal	5.86		0.00	–5.86
2–10	Cutting & feeding labour	9.16	Saved dairy meal cost Saved dairy meal transport Interest on capital freed up Subtotal	123.83 6.48 1.09 131.39	122.23

Net present value at 20% discount rate = $416.11

Net benefit per year after year 1 = $122.23

Annualized net benefit treating establishment costs as depreciation = $120.27

Note: Base model farm has 500 calliandra shrubs and one dairy cow that consumes a basal diet of 80 kilograms of napier grass per day and produces 10 kilograms of milk per day.

Table 5.4: Net return per household per year using fodder shrubs, by location and strategy

Location	Strategy	Net return for full adopter with 500 shrubs	Mean number of shrubs per farmer in sample	Net return for farmer with mean number of shrubs (US$ per year)
Embu, Kenya, 2003	Substitution	101	358	72
	Supplementation	62	358	44
Kisumu, Kenya, 2004	Substitution	122	130	32
	Supplementation	115	130	30
Makono, Uganda, 2003	Substitution	112	280	63
	Supplementation	93	280	52
Kabale, Uganda, 2003	Substitution	102	560	114
	Supplementation	72	560	81
Mean	Substitution	109	332	72
	Supplementation	85	332	56
Grand mean		97	332	64

Note: Net returns per year are earned beginning in the second year after planting, when farmers start feeding fodder shrubs to their dairy cows. In some of the areas (e.g., Kisumu), samples were random, while in others (e.g., Kabale and Embu), farmers with many trees were purposely selected.
Source: Franzel and Wambugu 2007.

Scenario 2:
Calliandra used to supplement basal diet. Here, calliandra is fed in addition to the existing basal diet, which may or may not include dairy meal. The cow's diet thus remains the same except that calliandra is added. The farmer does not view calliandra as a substitute for dairy meal or for any other component of the cow's diet but rather as a supplement. We compare

1. the benefit of using calliandra, that is the value of the extra milk produced, with

2. the costs of planting, cutting and feeding calliandra.

Beginning in the second year after planting 500 calliandra shrubs, a farmer's net income increases by about $62 to $115 per year by using calliandra as a supplement for dairy meal (table 5.4). As above, the increases in income vary by site and are particularly sensitive to differences in milk prices.

5.2.2 Econometric analysis of milk production and income impacts in Maragua and Embu

5.2.2.1 Descriptive analysis

The number of households surveyed was 242, of which 208 were headed by males and 32 by females. The mean household size was 6 people. Most household heads had a secondary school education, followed in frequency by a primary school education. The mean farm size of the surveyed households was 1.2 ha. The mean number of cattle per household was 1.8, with a standard deviation of 1.2. The mean number of milking cows per household was 1.6, with a standard deviation of 0.9.

The reported percentage of farmers in Embu and Maragua using various feeds for cattle was highest for napier (87%), followed by grass (62.8%) and banana leaves (66.1%). Another popular feed was crop residues (51%) during the dry season, when other feeds were scarce (table 5.5).

Among the high-protein feeds (concentrates, calliandra or desmodium in our case), concentrate alone was the most popular feeding strategy, used by 73% of farmers. Concentrate in combination with shrubs was the second most popular strategy, practiced by 40% of farmers in the study area. Note that the use of desmodium by sample farmers was low, with just 12 households during the rainy season, as shown in table 5.6. Most households fed shrubs in combination with concentrate, as shown in tables 5.6 and 5.7. Almost half the households feeding shrubs did so without concentrate or desmodium. The survey elicited the number of days during lactation in which cows were fed the different diets. As with other information, answers were based on recall, capturing differences for each dairy animal by season. The number of days farmers fed shrubs exclusively was much lower than the number of days they fed shrubs in combination with concentrate.

Table 5.5: Bulk feeds usage by season

Bulk feed type	Season	Number of households	% of all households
Napier	Rainy	192	79.3
	Dry	211	87.2
Grass	Rainy	152	62.8
	Dry	131	54.1
Banana leaves	Rainy	132	54.5
	Dry	160	66.1
Crop residues	Rainy	75	31.0
	Dry	125	51.7
Sweet potato vines	Rainy	84	34.7
	Dry	70	28.9
Banana stems	Rainy	45	18.6
	Dry	64	26.4
Hay	Rainy	10	4.1
	Dry	10	4.1

Table 5.6: High-protein feed usage by season

Feeding strategy	Season	Number of households	% of all households	Mean no. of days among users	Median no. of days among users
Concentrate alone	Rainy	165	68.2	114.6	91
	Dry	177	73.1	122.7	100
Shrubs alone	Rainy	41	16.9	53.7	21
	Dry	39	16.1	46.6	20
Desmodium alone	Rainy	3	1.2	8.0	7
	Dry	2	0.8	2.0	2
Concentrate and shrubs	Rainy	86	35.5	84.1	30
	Dry	96	39.7	59.3	40
Concentrate and desmodium	Rainy	4	1.7	12.3	14
	Dry	3	1.2	9.7	13
Shrubs and desmodium	Rainy	1	0.4	150.0	150
	Dry	1	0.4	60.0	60
All three feeds	Rainy	9	3.7	34.2	24
	Dry	9	3.7	59.1	24

Table 5.7: Fodder shrubs feeding patterns, by season

Feeding strategy	Season	Number of households	Mean number of shrubs day^{-1} among users	Standard error
Shrubs alone	Rainy	53	5.0	0.06
	Dry	49	4.7	0.07
Shrubs and concentrate	Rainy	105	3.4	0.02
	Dry	103	3.4	0.03
Shrubs and desmodium	Rainy	2	1.3	0.70
	Dry	3	2.5	0.80
Shrubs, concentrate and desmodium	Rainy	10	2.4	0.20
	Dry	9	2.4	0.30

In all, 126 households in the sample had planted shrubs and, among them, the median number of shrubs planted was 202 (the mean was slightly over 450 as a few households had planted very large numbers of shrubs). Of these, 121 households had fed fodder shrubs to their dairy cattle during 2008.

The mean total milk production per household per day during the rainy season was 15.6 kg , with a standard deviation of 14.1 kg and a median of 12 kg. In the dry season, the mean total milk production per household was 13.0 kg, with a standard deviation of 13 and a median of 10 kg.

The mean daily milk production per cow was 9.6 kg across all seasons, breeds and feeding strategies. It was lowest when none of the high-protein feeds were given (7.9 kg), higher when fodder shrubs alone were given (9.1 kg), when dairy meal was given alone (10.3 kg), and when dairy meal and shrubs were both given (11.1 kg). Simple calculations were done to determine the productivity ratio of milk increase over high-protein feed using kilograms for both variables. Where concentrates were used alone, the productivity ratio was 1.36, or an additional 1.36 kg of milk per 1 kg of concentrate. For shrubs alone, the ratio was 0.66, and the ratio for shrubs and concentrates together (where the shrubs and concentrates were added together without adjustment) was 1.00. We also calculated the correlation between the quantity of shrubs used and the resulting milk increase when shrubs were used alone and found it to be significant, at 0.31. However, there was definitely a decreasing marginal impact because the correlation between the quantity of shrubs and the productivity ratio was negative, at –0.43.

5.2.2.2 Econometric analysis

With 240 households in the survey holding on average 1.6 milking cows and often applying different feeding strategies during the rainy and dry seasons, there were more than 16,400 distinct feeding observations recorded for which information on daily feeds and milk production were enumerated. However, after discarding some observations with apparent data errors and/or gaps, 1,431 observations across 218 households were used in the regression analysis. Because there were multiple observations for each household, a fixed effect model was used to control for managerial and other effects observed at the household level. Both daily milk production and the log of daily milk production were used as dependent variables in different models. Among the explanatory variables were the daily quantities of all feeds used, including basal feeds and high-protein feeds. As these differ by feeding strategy, a household may, for example, use one amount of concentrate alone but a different amount when concentrate is used with shrubs. Likewise, the amounts can vary across season for the same household. Other variables included a dummy to distinguish the rainy season from the dry season and dummy variables for three types of improved cattle, with the least-improved breeds as the base case.

For the high-protein feeds, different specifications were used to check for best fit. The tested specifications included (a) actual amounts; (b) actual amounts and a squared term (a quadratic specification); (c) a combination of a binary variable and actual amount; and (d) a combination of a binary variable, the actual amount and a squared term. Qualitatively, the results from (a) and (b) are not different in terms of the shrub effects. As will be seen below, model (b) indicates that shrubs have a linear and not a quadratic effect. Models (c) and (d) also gave significant effects for shrubs that are more difficult to interpret for reasons noted below. We therefore report and focus on the results of models (a) and (b) for the total milk amount (non-logged), as shown in table 5.8.

The F values for all the regressions are very high and significant, and adjusted r-squares from the regressions are 0.15–0.17, which, while not being poor, are also not high for the number of observations. This undoubtedly reflects the difficulties encountered in recall surveys, where nuances of input–output relations cannot be fully reflected in 'average' response data. Farmers' perceptions of quantities of specific feeds are also challenged by the collection and mixing of different feeds. We present the results pertaining to the non-shrub variables first. Note that the small number of observations where desmodium was applied means that we do not feel the results for that variable can meaningfully present the effects of desmodium.

Among the basal feeds, napier, grass and hay had positive effects on milk yield. This validates the importance of napier in a cow's diet and explains its widespread adoption in the country. Other basal feeds turned out to have either an insignificant effect or, in the case of sweet potato vines, a negative relationship to milk yields, suggesting that they may be used mainly during times when napier is not available and when milk production is therefore lower. These results need to be followed up more closely by other studies, as it was not very easy to collect quantitative information on basal feeds, which were fed in bulk. On the other hand, quantifying the amounts of concentrates and shrubs was made easier by more standard feeding methods and the smaller amounts involved.

The quality of dairy cattle breed also had a clear impact on milk yield, with an expected diminishing effect as the degree of improvement diminished. Purebreds had the largest impact, followed by crossbreeds of over 50%. The effect of a purebred as opposed to a local animal was on the order of 5.6 kg of milk per day (model [a]), after controlling for feed, season and other variables. So the importance of breed improvement programmes is clearly found in the data. Similarly large effects were found across seasons. Milk yields in the rainy season were 1.2 kg higher than in the dry season, over and above differences in feeds, which were controlled for. This can be explained by the fact that the nutritive value of basal diets such as napier grass is usually higher during the rainy season than in the dry season in terms of higher digestibility and protein content (Roothaert and Paterson 1997). It may also be that water availability and animal health are both better in the wet season.

In terms of the high-protein feeds, concentrates had the strongest effect on milk yields, with 1 kg boosting milk yields by 0.58 kg in model (a). However, the marginal impact was even greater with low inputs of concentrates, as indicated by the coefficient estimates in the quadratic model (b). The marginal effect decreased as more concentrates were fed, as shown by the negative sign on the squared term, and this was expected. But the effect remained strong over the range most commonly used by farmers. It would appear that farmers were very familiar with the use of concentrates and provided productive amounts of it to their cattle.

Fodder shrubs also had a positive effect, but it was weaker than that of concentrates and, unlike that of

concentrates, followed a linear pattern. Model (a) showed a marginal effect of 1 kg of fodder leaves to be 0.117 kg of milk. Model (b) suggested a slightly higher marginal impact of shrubs throughout most of the range of fodder shrub feeding values. Using the mean value of fodder shrubs fed (5), model (a) predicted an increase in milk production of 0.58 kg. The results for models (c) and (d) are worth discussing. In model (c) the dummy for use of shrubs was positive and significant with a value of 0.78, while the coefficient estimate for the quantity of shrubs was negative, but insignificantly so. In model (d), the dummy variable was again positive and significant, but a difference was that the quantity of shrubs was significantly negative, while that on the squared term was positive and significant. The lower additional effect of fodder shrubs compared to concentrates on milk yield can be explained by the bulkiness of shrub fodder. When animals are fed larger amounts of shrub fodder, their capacity to consume dry matter becomes a factor limiting total nutrient intake. Substitution of basal diets with shrub fodder then takes place, reducing the amount of nutrient intake from the basal diet. In addition, both of these results suggested that there was a significant amount of noise or variability around the linear relationship observed in models (a) and (b). Model (c) in fact suggested that the quantity of shrubs used per se was not highly linked to milk yields. These patterns were quite distinct from the results for concentrates and hinted at much less farmer familiarity with how best to use the shrubs as part of feeding systems. Of course, this was to be expected, as shrubs had only recently been adopted.

Table 5.8: Results from regressions to measure the effect of different feeds on milk production at Embu and Maragua, Kenya

	Total milk production per day (kilograms)			
	Model (a)		Model (b)	
Variable	**Coefficient estimate**	**t-stat**	**Coefficient estimate**	**t-stat**
Napier	0.0127	2.22	0.0126	2.24
Grass	0.0197	2.47	0.0189	2.42
Banana leaves	–0.0026	–0.33	–0.0023	–0.30
Crop stover	0.0092	0.88	0.0115	1.11
Sweet potato	–0.0229	–2.00	–0.0237	–2.10
Banana stem	0.0180	0.62	0.0165	0.58
Hay	0.1069	2.21	0.1051	2.21
Concentrate amount	0.5825	13.35	1.1591	12.76
Concentrate amount squared			–0.0941	–7.25
Shrub amount	0.1171	3.13	0.1459	1.74
Shrub amount squared			–0.0053	–0.57
Desmodium amount	0.3688	1.76	0.5045	1.24
Desmodium amount squared			–0.0373	–0.48
Rainy season	1.2791	7.41	1.2945	7.65
Purebred	5.6185	9.36	5.5732	9.48
Cross above 50%	3.4108	4.73	3.3796	4.78
Cross at 50%	2.8623	3.70	2.8389	3.75
Constant	3.4905	5.67	3.2472	5.37
Number of observations	1,431		1,431	
Significance of F	0.00000		0.00000	
Adjusted r-square	0.150		0.154	

5.2.2.3 Calculation of the impact of shrubs on household income

Recognizing the significance of the fodder shrub variables in the regression results, the coefficient estimates from the regression results in table 5.8 were used to calculate the impact of shrubs. This was done by calculating predicted daily milk production with shrubs using the coefficients on the shrub variables and without the shrubs, setting the level of shrubs equal to zero. The difference was then the effect of the actual amount of fodder shrubs used on the daily milk production of a particular cow for a particular season and feeding strategy that involved fodder shrubs. We used the simple model in which the high protein feeds were entered as linearly related to milk production, so the marginal impact of shrubs was 0.117 kg of milk per kilogram of fresh shrubs. From this, three further steps were taken.

First, it was necessary to multiply this daily figure by the number of days for which the different feeding strategies were used. The median number of days per year in which fodder shrubs were used was 70, while the mean was 119 among those who fed fodder shrubs. Using the actual amounts in each feeding observation gave a total milk-production effect for a given cow, season and feeding strategy.

Second, these were aggregated at the household level to generate a value of total milk production increase per household (which can also be done by season). Finally, this amount was multiplied by the farm gate price for milk, which was 20 shillings, or about $0.26, per litre. The median annual gross income effect from the fodder shrubs per household using shrubs was calculated to be 1,236 shillings, or $17.16, and the mean was 2,905 shillings, or $40.35. To arrive at a net income figure, the costs of establishment and feeding had to be deducted. We calculated these costs using the labour and cost values from table 5.1. Given the number of shrubs in our sample, the average establishment cost was just about $2.50 and could be amortized to $0.50 per year. Annual cutting and feeding costs amounted to about $5.00 per year, using the mean number of feeding days and daily feeding amounts, giving a total of $5.50 in costs per year. Thus the average increase in net income per household per year was about $34.85, with the median being lower at $11.66.

These figures are less than those reported in the last column of table 5.4. One reason could be that the shrub effect on milk yields is estimated to be lower in our study (0.7 litres of milk from 2 kg of dry fodder, as compared with 0.6–0.8 litres of milk from just 1 kg of dry fodder in table 5.1). Another reason could be the number of days feeding shrubs, which we found to be only 119 on average among the households we assessed for fodder shrub impact.

5.3 Importance of milk income to households

This section draws largely from Maina (2009). Using community workshops held with farmers, the study established that, in both districts, dairy cattle farming was cited as the most valued source of livelihood in terms of its profit, dependability and utility. The highest ranked advantage associated with dairy farming was milk for home consumption and income, followed in order by manure production, direct income from the sale of livestock, meat, self employment, resource for bride wealth and prestige, and biofuel.

In essence, the advantages of dairy farming are tied to its dependability and reliability as a source of income. For most farmers, the assurance of a daily income from milk sales is an important feature in their livelihood. This explains why some farmers preferred to sell their milk to brokers, because, though brokers paid less than the local processing plant, their payment was received promptly upon delivery. This ready cash could be used to purchase immediate needs such as food.

Farmers under study largely acknowledged reaping benefits from growing fodder shrubs. “I stopped using dairy meal, hence saving the money I used to spend on dairy meal to meet other costs,” said one. “Fodder shrubs have also helped increase the production of milk, thus increasing my income. They have also increased soil fertility on my farm.”

“I don’t buy dairy meal any more, so I save money, hence increasing my income,” said another. “At times I also sell calliandra and manure, thus increasing my income.”

For most farmers, additional income augmented the money available to meet family needs such as paying school fees, including secondary school and university fees; purchasing food to improve the nutrition of children; furnishing homes; and buying clothing and other domestic items. In one case, such income went to buying more land, while in several cases the money came in handy for paying casual workers employed on the farm to pick tea, plough the land or look after livestock.

Although income from different sources is often pooled to make specific expenditures or investments, some farmers were able to identify examples of uses of the additional income generated from improved milk production. In two cases, such income went to paying contributions to community groups, while in another it helped buy agricultural inputs. For one farmer, the money came in handy for paying the medical bills of a sickly relative. Only in four instances out of 20 farmers was there no additional income, and this was mainly attributed to the small number of trees planted. In this regard, farmers acknowledged that more income would be forthcoming if they could plant more fodder. However, small landholding was a major hindrance.

5.4 Cumulative fodder research costs and benefits

This section builds on the previous sections to quantify the extent and degree of fodder shrub adoption in Kenya and East Africa, along with the benefits per farmer, by (1) estimating the annual and cumulative milk benefits to all farmers using the technology and (2) comparing the benefits against the research costs incurred. In determining the aggregate annual and cumulative benefits, we used ranges of estimates to account for the imprecision of exact numbers of adopting farmers, the range of intensity of adoption (planting and use), and the range in the value of milk impacts due to varying milk yield effects found under different studies.

Section 3.3 reported that ICRAF spent approximately $4.71 million dollars researching fodder shrubs in East Africa over a 16-year period, noting that this understated the total amount spent on research and dissemination by all partners. Against these costs, we estimated the total benefits accruing to farmers in the region. To arrive at the number of users of shrubs, we approximated the number of adopters (here meaning planters and users of shrubs) over time by interpolating between periods in which the numbers were well known. To provide a first conservative estimate, we used the results from the regression table, which found a lower milk response to shrubs than did previous studies.

We began estimating benefits for the region by looking at Kenya, where the number of adopting farmers was estimated to have increased from 6,000 in 1995 to 20,000 in 2000, after which there was an escalation to 81,645 by 2005. In 2005/2006 a major project was launched in Kenya to scale up fodder shrubs, with over 3 tonnes of fodder shrub seed and more than 500,000 seedlings sold (Acharya et al. 2008). This was estimated to have led to adoption by more than 110,000 additional farmers. We opted for a more conservative estimate of 60,000 additional farmers benefiting by 2008. For a measure of economic impact per household, we began with the annual net impact of $34.85 from the regression analysis in table 5.8. This needed to be adjusted slightly because the sample of households that generated this estimate was not representative of all fodder shrub users.

There were two ways to compare our results with more representative samples in terms of intensity of adoption. One was to compare the mean number of shrubs. The number of shrubs per sample household was higher than the average numbers reported by development partners (450 versus 165), which suggested that we needed to adjust downward our household impact figures considerably. The second approach would have been to compare the number of feeding days in our sample with a representative figure, but unfortunately no such number from a representative sample exists. However, our sample revealed that fodder shrub farmers fed fodder to cows on about 40% of the days in the lactation period of 300 days. Such a feeding regime could be maintained with 200 fodder shrubs, which happens to coincide with our median number of shrubs (202). We felt that the figure of 40% was a good estimate of the adoption rate in our sample. This rate was greater than the 33% adoption intensity implied by the more representative samples from development organization reports (165 fodder shrubs versus a recommended 500). So we adjusted downward the net income figure by 1.19, the additional adoption intensity in our sample as compared with the representative sample of farmers.

The result was an annual impact of $29.29 for each adopting household. Multiplying by the number of fodder shrub users in each year between 1993 and 2008 yielded a nominal (undiscounted) benefit of $19.7 million dollars for Kenya alone. While this appears to be a very plausible estimate, using other parameters would change these results. If, instead of the annual net income value of $29.29, we were to use a net income of $44, which was the figure found in a previous study of the impact of fodder shrub supplementation in central Kenya (table 5.4), the total cumulative benefits in Kenya would rise to $29.6 million. The actual figure may well lie between these two. We can also calculate what may represent the extreme lower and upper bounds. The lowest bound would be defined by adjusting the net income per household from our sample ($40.35) by the ratio of

our average number of shrubs over the global average (450/165). This gives a net annual household income of $12.78 and just $8.6 million of aggregated benefits in Kenya. At the other extreme, if we were to use the higher productivity parameter for fodder shrubs of 0.62 kg of milk per kilogram of fodder from table 5.1, the benefits would soar to $75.20 per household, or $50.6 million in Kenya. This may be interpreted as the potential impact that would have been possible under the given adoption intensity.

It is difficult to extend this analysis to other countries in the region because we do not have clear data on the percentage of shrub planters that regularly use the fodder for feed, nor do we have as much information on adoption and price trends. If, however, we were to assume that just half of those shrub planters fed shrubs to dairy cattle and that they received benefits equal to just two-thirds of those in our more conservative mean estimate of $29.29 per year, the total benefits for 2006 would be approximately $2.4 million.

6. Gender dimensions of impact

Although the rights of women regarding trees are known to be restricted under many communal tenure systems, there was reason to believe that more participation by women could be expected in the case of fodder shrubs. This was because the shrubs are continually pruned and do not become tall trees, and their primary purpose is to provide inputs for dairy farming, in which women are heavily involved. ICRAF and its partners therefore monitored and assessed the extent to which women were involved in planting and managing shrubs and reaping their benefits.

In terms of the numbers of women planting shrubs, Franzel et al. (2003a) found that 60% of planters of fodder shrubs in central Kenya were women. Monitoring with 224 development organizations in 2005 provided validated data similarly pointing to high rates of participation by women. At project sites where gender data were available, the proportion of women planting fodder shrubs was 54% in western Kenya, 43% in central Kenya and 57% along the Uganda lakeshore (Stewart et al. 2006).

Wanyoike (2004) observed in a study of 300 households in Embu, Kenya, that the percentage of households adopting fodder shrubs was about the same for those headed by males and those effectively headed by females, as their husbands lived elsewhere. The rates of planting shrubs ranged from 11% to 21% depending on the administrative division. However, for households headed by women who were divorced, widowed or never married, adoption rates were lower, from 8% to 13%.

A study by Mawanda (2004) in Uganda showed that, in most households, women were the ones who planted and managed calliandra on the farm. The frequency of participation in planting and management by different household members is reported in table 6.1. Women were active in more than half of the cases, roughly the same acting individually or with their husbands.

Table 6.1: Participation in planting and managing calliandra in Uganda

Household member	Planting		Management	
	Frequency	Percent	Frequency	Percent
Wife	25	34	17	23
Husband	22	29	12	16
Wife and husband	18	25	21	28
Wife and/or husband and house helper	0	0	4	6
Daughter and/or son	3	4	6	8
Wife and son	0	0	2	3
Mother of household head	2	3	1	1
Family	2	3	8	11
Hired manager	1	1	0	0
Co-wife	0	0	1	1
Other relatives	0	0	2	3
Total	**73**	**100**	**74**	**100**

Source: Mawanda 2004.

These positive results occurred despite some dissemination approaches not favouring women. Wanyoike (2004) reported that approaches that used in calliandra dissemination in Embu had included on-farm trials, farm visits by extension staff, field days and demonstrations. These methods were biased against women, as their attendance at field days and demonstrations was lower than that of men. Further recall that farmer-to-farmer dissemination tended to disadvantage women. Wanyoike (2004) also found that an additional dissemination approach using women's groups as extension contact points enabled more women to be reached.

None of these quantitative studies addressed the question of whether women actually benefitted from the technology in terms of control over milk and its income, apart from the obvious case in which a woman used fodder shrubs in the absence of her husband. That was one of the reasons for conducting qualitative analyses, to which we now turn.

6.1 Observations from qualitative research

This section is drawn entirely from Maina (2009). In terms of the impact of fodder shrubs on decision-making within households, in some cases, wives acknowledged always being involved in decision making, particularly when it came to intra-household money pooling and deciding what farming activities to undertake. Generally, most women reported that participation or influence in decision-making did not change with changes in incomes. Married respondents were asked whether they had experienced any changes in relationship with their spouses that could be linked to improved incomes related to the fodder technologies. The emerging pattern was that few changes had occurred. This was especially so in the case of spouses who felt that they had always been consulted in decision-making; those who felt that added income should not change relationships but, rather, engender a long-term relationship based on respect; and those who felt that opportunities for earning income had always been there, especially in tea and coffee farming.

Further probing during the women-only focus group discussion revealed that the issue of household decision-making was a thorny one eliciting at times bitter reactions. Most women agreed that, though they did a lot of work on the farm, they received very little income from farming generally. It was also apparent that most men opted to spend income, whenever accrued, on pleasures outside the home. As expressed by the women, most men also happened to own the bank accounts through which tea and milk monies were paid and allocated only a small amount to the household each month. Hence, even in matters concerning growing fodder shrubs and reaping benefits from them, such as through the sale of milk, men were in the more advantageous position.

The focus group discussions provided evidence that women did have leverage over whether to plant fodder shrubs, and most had actually been involved as group members. This was consistent with most farm labour being provided by women, including feeding livestock, milking and delivering produce for sale, among other tasks. Still, male control of income in particular meant that the benefits were limited for most women. In many cases, men felt free to spend the farm income as they wished, including buying liquor and other illicit pleasures. At the same time, it emerged that women did not make major decisions such as when to sell or purchase livestock or how much. The case was different for single women, as they had sole responsibility to make all decisions pertaining to the farm and income.

The community workshops established that male control of income was the case for most families, as most milk registers bore the husband's name, except when women were single or widowed. Further, males took this as their socially ascribed right and tended to see themselves as the custodians of family wealth. However, female participation in community groups and affairs was said to have increased over time, to the point that some women believed themselves capable of liberating themselves from their lowly position through these groups. In this regard, women were beginning to own some resources, such as income from vegetable plots and fruits that they sold directly. There were even a few cases of married women being in charge of income from milk. Apparently, there was also fear that women's increased control of income was responsible for some men's growing reluctance to assume major responsibilities such as paying school fees for their children, transferring such burdens to women.

6.2 Summary

The information gathered from a variety of studies showed that women have been heavily involved in the testing, adoption and wider dissemination of fodder shrubs in East Africa. Major dissemination efforts, often organized through projects or NGOs, have purposefully targeted women to bring about this result. However, there are signs that other dissemination pathways catalyzed by these major efforts, such as further extension efforts and farmer-to-farmer

dissemination, have been biased towards men. This requires further monitoring and evaluation. Women have benefitted from their involvement in increasing the feed resources available on the farm and reducing the time required to forage for feed, especially in the dry season, as they are key suppliers of labour for the dairy enterprise. On the other hand, there are questions as to whether women are able to benefit from the income generated in dairying and from fodder shrubs in particular. They certainly do when they are heads of households with no adult males present. However, qualitative research findings showed that women continued to face difficulties in controlling income earned from the diary cows. Technology introduction did not have a significant impact on women's decision making or control of income.

7. Other benefits

Though fodder shrubs are used mainly as dairy fodder in Kenya, there are other uses and benefits. As cited by farmers in previous studies (table 7.1), other benefits of calliandra include the following:

1. It increases the butterfat content of milk and therefore its creaminess (Paterson et al. 1998).
2. If used as a supplement, it may improve the cow's health and shorten the calving interval.
3. It provides firewood, fencing, stakes, boundary markings and erosion control (Kabarizi et al. 2004).

Maina (2009) reports that farmers mentioned their growing interest in using shrubs for dairy goat production. They indicated using the shrubs to feed rabbits and fish, and that calliandra was an important source of pollen for honey production. For all types of animals, the fodder shrubs were especially important during the dry season, when other sources of fresh feeds were unavailable, saving both costs and time (Maina 2009). In relation to this, one farmer record reported: "I take only a short time to harvest the calliandra leaves, and the trees are so helpful to me when I am in a hurry. I also give them to my rabbits because I don't have time to look for weeds to give them. During hot seasons, the trees don't dry up, so I don't walk for long distances looking for fodder like some of my neighbours."

As dairy production enterprises expand in peri-urban or other densely populated areas, markets for fodder shrubs are likely to develop. A study from Tanzania has found that this is beginning in the Tanga region; Franzel et al. (2007) found that, among the 5,400 dairy farmers in Tanga, Muheza and Pangani districts, 3,290, or 61%, used leucaena leaf meal. About half of these farmers were in the towns of Tanga and Muheza and bought leaf meal to meet their feed needs. This will create further employment for growers, collectors, transporters and traders.

Fuelwood and soil conservation are other important benefits in addition to increased milk production (Franzel et al. 2002). Angima et al. (2002) noted that a combined calliandra-napier grass hedge significantly reduced runoff and soil loss in central Kenya. This was important on slopes of 20% or less. On the other hand, farmers need to be careful in identifying locations for fodder shrubs. As with almost all shrubs, there is potential for competition for light, water and nutrients with other crops if planted too closely.

Table 7.1: Perceived benefits of fodder shrubs in addition to milk production, according to farmers

	% of farmers mentioning benefit in	
Type of benefit	**Embu area, Kenya**	**Kabale area, Uganda**
Firewood	50	78
Soil fertility improvement	48	78
Improvement in animal health	38	5
Soil erosion control	18	4
Improved creaminess of milk (increase in butterfat)	18	6
Fencing	18	76
Revenue from sale of seedlings	13	10
Stakes	9	70

Note: Percentages sum to more than 100 because most farmers mentioned several benefits.
Sources: Koech 2005 and Mawanda 2004.

8. Summary and Conclusions

The primary objective of this study was to assess the impacts of fodder shrubs on milk production and income in East Africa. Other impacts, such as those on animal growth, are also reported. The study found that the fodder shrub technology had spread throughout the region to just over 200,000 smallholder dairy farmers by 2005, from just a couple of thousand a decade earlier. Some of the reasons for such success are that the technology is low cost, relatively easy to use, effective in raising milk yields, and available for use as a substitute for expensive dairy feed concentrates. On the other hand, it was found that the technology requires some technical training, and thus its spread has been greatly facilitated by projects, NGOs and extension staff through group training—as well as, interestingly, by volunteer farmer disseminators. The focus on identifying and training farmer innovators has been found to contribute a large number of additional adopters.

Not all the 200,000 adopters of leguminous shrubs use them primarily for fodder, but most do, including almost all 86,000 adopters in Kenya in 2005. A very significant proportion of the shrub planters are women in households headed by both males and females. Data from project sites indicated that the proportion of women planting fodder shrubs was nearly 50%. However, other studies found that women were less likely to be reached through farmer disseminators, which might have suppressed their presence among fodder shrub users. Further, qualitative research presented in this study suggested that many women still find it difficult to fully benefit from the fodder shrubs in terms of controlling income.

Several studies addressed the economic impact of the fodder shrubs. Partial budget analyses of a range of sites and intensities of use found that, with a milk price of about $0.20 per litre, a farmer with enough shrubs to last throughout the lactation period would earn a net income of between $70 and $120 per cow per year. The actual impacts depended on the number of fodder shrubs and, ultimately, the number of days fodder was fed to the dairy cattle. The number of trees varied from site to site and whether or not a project worked in the area, ranging from around 50 trees per household to over 300.

A new study conducted for this survey attempted to isolate the shrub impacts from those of other feeds through econometric analysis. It found that 6 kg of fresh shrubs had a mean impact of an additional 0.7 kg of milk per day, controlling for other feeds. Farmers in the new study sites fed fodder shrubs between 70 and 119 days (median and mean) and the average annual household income was calculated to be about $35 net of costs. Using a range of values for the impact per household per year, it was estimated that the net benefits accruing to adopters of fodder shrubs in Kenya between 1993 and 2008 was between $19.7 million and $29.6 million. It is more difficult to extrapolate this to other countries in the region, mainly because of the multiple uses of the leguminous shrubs and less certain milk markets.

Additional studies are recommended to improve understanding of the use and impact of fodder shrubs in the region, but especially in Rwanda, Tanzania and Uganda. The technology has been only recently disseminated, so farmers are still learning how to use the fodder shrubs in combination with other feeds. Following up on how impacts through farmer-to-farmer dissemination may differ from those of dissemination by specialized facilitators or projects is important for advising future dissemination efforts. The issue of how women have benefitted from the technology is not fully settled, and qualitative research undertaken in this study indicated that a quantitative follow-up study would be valuable. Finally, several previous studies have identified other benefits from fodder shrubs worth investigating, such as the feeding of the shrubs to other animals including dairy goats, rabbits and chickens, as well as the marketing of fodder shrubs as an enterprise in itself.

References

AED [Academy for Educational Development]. 2004. Going to scale: system-wide collaborative action for livelihoods and the environment. Washington: Academy for Educational Development.

Acharya K, Wambugu C, Karanja E, Arimi H, Booth E, Bender S. 2007. Relationships matter: Using social network analysis to evaluate social capital. In: The Kenyan dairy sector: evaluation of the Agriculture Partnerships for Productivity and Prosperity (AP3) Project. Washington: Academy for Educational Development; Nairobi: World Agroforestry Centre.

Acharya K, Booth B, Wambugu C, Karanja E, Arimi H, Bender S. 2008. How can systems thinking, social capital and social network analysis help programmes achieve impact at scale? Results of a demonstration project in the Kenyan dairy sector. Unpublished report. Washington: Academy for Educational Development; Nairobi: World Agroforestry Centre.

Angima SD, Stott DE, O Neill MK, Ong CK, Weesies GA. 2002. Use of calliandra-napier grass contour hedges to control erosion in central Kenya. *Agriculture Ecosystems and Environment* 91:15–23.

[CBS] Central Bureau of Statistics. 1994. Kenya population census 1989. Nairobi: Ministry of Planning and National Development.

Devendra C. 1990. The use of shrubs and tree fodders by ruminants. In: Devendra C, ed. *Shrubs and tree fodders for farm animals*. Proceedings of a workshop held in Denpasar, Indonesia, 24–29 July 1989. IDRC-276e. Ottawa, Ontario: International Development Research Centre. p. 42–60.

Djogo A. 1994. The use of forage tree legumes in Timor, Indonesia. In: Gutteridge R, Shelton HI, eds. *Forage tree legumes in tropical agriculture*. Wallingford, UK: CAB International. p. 374–380.

Dusengemungu L. 2002. Les facteurs socio-economiques determinants dans l'adoption du Calliandra au Rwanda: cas des provinces de Butare, Gikongoro et Umutara. Unpublished BSc thesis (in French). Butare, Rwanda: Faculté des sciences economiques, sociales et de gestion, Université Nationale du Rwanda.

Dzowela BH, Hove L, Mafongoya PL, Maasdorp BV. 1997. Recent work on the establishment, production and utilisation of multipurpose trees as a feed resource in Zimbabwe. *Animal Feed Science and Technology* 69: 1–15.

Ebong C, Byenkya SG, Ndikumana J. 1999. Effects of substituting calliandra leaf meal for soya bean meal on intake, digestibility, growth and feed efficiency in goats. Journal of *Applied Animal Research* 16:211–216.

Export Processing Zone Authority. 2005. Dairy industry in Kenya 2005. Athi River, Kenya: Export Processing Zones Authority.

Franzel S, Arimi H, Murithi F. 2002. *Calliandra calothyrsus*: assessing the early stages of adoption of a fodder tree in the highlands of central Kenya. In: Franzel S, Scherr SJ, eds. *Trees on the farm: assessing the adoption potential of agroforestry practices in Africa*. Wallingford, UK: CAB International. p. 125–144.

Franzel S, Mawanda G, Aike G. 2005. Estimating the numbers of farmers planting fodder shrubs in East Africa. *Prunus Newsletter* 4:16–17.

Franzel S, Wambugu C. 2007. The uptake of fodder shrubs among smallholders in East Africa: key elements that facilitate widespread adoption. In: Hare MD, Wongpichet K, eds. *Forages: a pathway to prosperity for smallholder farmers*. Proceedings of an international symposium. Ubon Ratchathani University, Thailand: Faculty of Agriculture. p. 203–222.

Franzel S, Wambugu C, Nanok T, Kavana P, Njau T, Aithal A, Muriuki J, Kitalyi A. 2007. The production and marketing of leaf meal from fodder shrubs in Tanga, Tanzania: a pro-poor enterprise for improving livestock productivity. World Agroforestry Centre Working Paper 50. Nairobi: World Agroforestry Centre.

Franzel S, Wambugu C, Tuwei P. 2003a. The adoption and dissemination of fodder shrubs in central Kenya. Agricultural Research and Network (AGREN) Series Paper 131. London: Overseas Development Institute.

Franzel S, Wambugu C, Tuwei P, Karanja G. 2003b. The adoption and scaling up of the use of fodder shrubs in central Kenya. *Tropical Grasslands* 37:239–250.

Gerrits A. 2000. Adoption of calliandra in Kabale District: benefits and constraints. AFRENA Report 132. Kabale, Uganda: Agroforestry Research Network for Africa.

Hess HD, Tiemann TT, Noto F, Franzel S, Lascano C, Kreuzer M. 2006. The effects of cultivation site on forage quality of *Calliandra calothyrsus* var. Patulul. *Agroforestry Systems* 68(3):209–220.

ICRAF [International Centre for Research in Agroforestry]. 1993. *Annual report 1992*. Nairobi: ICRAF.

ICRAF [International Centre for Research in Agroforestry]. 1999. *Annual report 1998*. Nairobi: ICRAF.

Istrate E, Tsvetovat M, Acharya K. 2007. Networks on the ground: rural development in Kenya. *International Journal of Networking and Virtual Organizations* 4(4):383–401.

Kabirizi J. 2009. Integrating Calliandra calothyrusus trees in smallholder crop-livestock farming systems: effect on milk yield and household income. Unpublished paper presented at the second World Congress on Agroforestry held in Nairobi, Kenya, August 2009.

Kabirizi J, Mpairwe D, Mutetikka D. 2004. Testing forage legume technologies with smallholder dairy farmers: a case study of Masaka District, Uganda. Paper presented at a conference held in Entebbe, Uganda, September 2004. Entebbe: National Agricultural Research Organization.

Kaburia B. 2006. Improving information and communication for the smallholder farmers in Kenya (Project R2555, final technical report submitted to UK Department for International Development), Unpublished manuscript. Nairobi: FARM Africa.

Kaitho JR. 1997. Nutritive value of browses as protein supplement(s) to poor quality roughages. PhD thesis. Wageningen Agricultural University.

Kakengi M, Shem MN, Mtengeti EP, Otsyina R. 2001. *Leucaena leucocephala* leaf meal as supplement to diet of grazing dairy cattle in semiarid western Tanzania. *Agroforestry Systems* 52:73–82.

Kiruiro EM, Ouma O, Arimi H. 2000. The potential for improving milk production from dual purpose goats by using *Calliandra calothyrsus* on smallholder farms of the coffee/tea land-use system of Embu District. *Annual report 1999*. Embu, Kenya: Kenya Agricultural Research Institute, Regional Research Centre, Embu.

Koech S. 2005. Socio-economic analysis of fodder legumes: the case of calliandra and desmodium in smallholder dairy farms of Embu District, Kenya. Unpublished MSc thesis. Njoro, Kenya: Egerton University.

Lanyasunya T, Mukisira E, Lokwaleput I, Siamba D. 2001. Factors limiting optimization of smallholder peri-urban dairy herd production in Kenya. In: *Livestock community and development*. Proceedings of the 10th Conference of the Association of Institutions for Tropical Veterinary Medicine held in Copenhagen, Denmark. (Available from http://www.aitvm.kvl.dk/E_periurban/E3Lanyasunya.htm) (Accessed on 16 January 2010)

Maina L. 2009. Socio-economic impact of the introduction of fodder crops in Central Province, Kenya: a case study of Embu and Maragua Districts. Unpublished study. Nairobi: World Agroforestry Centre.

Mapiye C, Foti R, Chikumba N, Poshiwa X, Mwale M, Chivuraise C, Mupangwa J. 2006. Constraints to adoption of forage and browse legumes by smallholder dairy farmers in Zimbabwe. *Livestock Research for Rural Development* 18 (12). (Available from http://www.lrrd.org/lrrd18/12/mapi18175.htm) (Accessed on 22 October 2009)

Mawanda F. 2004. Socio-economic and farmers' perceived environmental impacts of *Calliandra calothyrsus* in Uganda: a case study of Mukono and Kabale Districts. Unpublished MSc thesis. Kampala, Uganda: Makerere University.

Mpairwe D, Sabiiti EN, Mugerwa JS. 1998. Effect of dried *Gliricidia sepium* leaf supplement on feed intake, digestibility and nitrogen retention in sheep fed dried KW4 elephant grass *(Pennisetum purpureum) ad libitum. Agroforestry Systems* 41:139–150.

Mureithi JG, Thorpe W, Tayler SR, Reynolds L. 1994. Evaluation of *Leucaena* accessions for semi-humid lowlands tropics of East Africa. *Tropical Agriculture* (Trinidad) 71:83–87.

Murithi FM. 1998. Economic evaluation of the role of livestock in mixed smallholder farms of the central highlands of Kenya. Unpublished PhD thesis. University of Reading, UK: Department of Agriculture.

Mwangi D. 1999. Integration of herbaceous legumes into napier grass fodder systems in central Kenya: constraints and potential. PhD thesis. University of London.

NARP [National Agro-forestry Research Project]. 1993. National Agro-forestry Research Project. Kenya Agricultural Research Institute (KARI) Regional Research Centre, Embu. AFRENA Report 69. Nairobi: KARI.

Niang A. 1991. General species screening trials. In: Hoekstra DA, Beniest J. Summary proceedings of East and Central AFRENA conference and workshop, 6–12 July 1991. Nairobi: International Centre for Research in Agroforestry.

Niang A, Ugiziwe J, Stygeri E, Gahamanyi A. 1996. Forage potential of eight woody species: intake and growth rates of local young goats in the highland region of Rwanda. *Agroforestry Systems* 34:171–178.

Ngigi M. 2004. Building on successes in African agriculture: smallholder dairy in Kenya. IFPRI Focus 12, Brief 6. Washington: International Food Policy Research Institute.

Nyaata OZ, O'Neil MK, Roothaert RL. 1998. Comparison of *Leucaena leucocephala* with *Calliandra calothyrsus* in napier (*Pennisetum purpureum*) fodder banks. In: Shelton HM, Gutteridge RC, Mullen BF, Bray RA, eds. Leucaena-adaptation quality and farming systems. Proceedings of a workshop held in Hanoi, Vietnam, 9–14 February 1998. ACIAR Proceedings 86. Canberra: Australian Centre for International Agricultural Research. p. 257–260.

O'Neill M, Gachanja S, Karanja G, Kariuki I, Murithi F, Nyaata O, Mwangi J, Tuwei P, Roothaert R. 1997. *National Agroforestry Research Project annual report: March 1996 to March 1997*. AFRENA Report 112. Nairobi: International Centre for Research in Agroforestry.

Palmer B, Schlink A. 1992. The effect of drying on the intake and rate of digestion of the shrub legume Calliandra calothyrsus. Tropical Grasslands 26:89–93.

Paterson RT, Karanja GM, Roothaert RL, Nyaata OZ, Kariuki IW. 1998. A review of tree fodder production and utilization with smallholder agro forestry systems in Kenya. *Agroforestry Systems* 41:2:181–199.

Paterson RT, Kiruiro E, Arimi HK. 1999. *Calliandra calothyrsus* as a supplement for milk production in the Kenya highlands. *Tropical Animal Health and Production* 31:115–126.

Place F. 1998. Embu farmer workshops: Issues related to the adoption, management, use and impact of calliandra fodder feed sources. Unpublished manuscript. Nairobi: International Centre for Research in Agroforestry.

Place F, Kariuki G, Wangila J, Kristjanson P, Makauki A, Ndubi J. 2004. Assessing the factors underlying differences in achievements of farmer groups: methodological issues and empirical findings from the highlands of central Kenya. *Agricultural Systems* 82(3):257–272.

Reynolds L, Metz T, Kiptarus J. 1996. Smallholder dairy production in Kenya. *World Animal Review* 87(2):66–73.

Roothaert RL, Franzel S, Kiura M. 2003. On-farm evaluation of fodder trees and shrubs preferred by farmers in central Kenya. *Experimental Agriculture* 39:423–440.

Roothaert RL, Franzel S. 2001. Farmer's preference and use of local fodder trees and shrubs in Kenya. *Agroforestry Systems* 52(3):239–252.

Roothaert R, Karanja GM, Kariuki IW, Paterson R, Tuwei P, Kiruiro E, Mugwe J, Franzel S. 1998. *Calliandra* for livestock. *Technical Bulletin 1*. Embu, Kenya: Kenya Agricultural Research Institute (KARI), Regional Research Centre, Embu.

Roothaert RL, Paterson RT. 1997. Recent work on the production and utilization of tree fodder in East Africa. *Animal Feed Science and Technology* 69:39–51.

SDP [Smallholder Dairy Project]. 2006. The uncertainty of cattle numbers in Kenya. SDP Policy Brief 10. Nairobi: International Livestock Research Institute.

Sinja J. 2006. A social-economic analysis of preferences for fodder legumes and information flow among farmers: a case study of *Desmodium* and *Calliandra* in central Kenya. MSc thesis. University of Nairobi: Department of Agricultural Economics.

Sinja J, Karugia J, Waithaka M, Miano D, Baltenweck I, Franzel S, Nyikal R, Romney D. 2004. Adoption of fodder legumes technology through farmer-to-farmer extension approach. *Uganda Journal of Agricultural Sciences* 9:222–226.

Staal S, Chege l, Kenyanjui K, Kiari A, Lukuyu B, Njubi D, Owango M, Tanner J, Thorpe W, Wabugu M. 1997. A cross-sectional survey of Kiambu District for the identification of target groups of smallholder dairy producers. KARI-ILRI collaborative project research report. Nairobi: Kenya Agricultural Research Institute; International Livestock Research Institute.

Stewart J, Franzel S, Wambugu C. 2006. *Final technical report phase 2 (2001–2006): scaling up the promotion of calliandra and other fodder shrubs in East Africa*. Unpublished manuscript. Nairobi: Oxford Forestry Institute; World Agroforestry Centre.

Stewart JL, Mould F, Mueller-Harvey I. 2000. The effect of drying treatment on the fodder quality and tannin content of two provenances of *Calliandra calothyrsus* Meissner. *Journal of the Science of Food and Agriculture* 80:1461–1468.

Strategic Business Partners. 2008. Dairy value chain competitiveness assessment and action plan development. Report prepared by the United States Agency for International Development (USAID) Kenya Dairy Sector Competitiveness Program. Nairobi: Land O Lakes.

Technoserve. 2003. *Calliandra calothyrsus*: sustainable planting material distribution and marketing systems. Unpublished report. Nairobi: Technoserve; World Agroforestry Centre.

Thijssen HJC, Murithi FM, Nyaata OZ. 1993. Existing hedges on farms in the coffee based land use system of Embu District, Kenya. AFRENA Report 65. Nairobi: International Centre for Research in Agroforestry.

Tuwei PK, Kan'gara JNN, Muellwe-Harvey I, Poole J, Ngugi FK, Stewart JL. 2003. Factors affecting biomass production and nutritive value of *Calliandra calothyrsusas* browse for ruminants. Journal of *Agricultural Science* (Cambridge) 141:113–127.

Uganda Investment. 2002. Investing in Uganda's dairy industry. Unpublished manuscript.

Wambugu C. 2001. *Calliandra calothyrsus*: nursery establishment and management. Pamphlet 1, *Calliandra calothyrsus* series. Nairobi: International Centre for Research in Agroforestry.

Wambugu C. 2002. *Calliandra calothyrsus*: tree management and utilization. Pamphlet 2, *Calliandra calothyrsus* series. Nairobi: World Agroforestry Centre.

Wambugu C. 2006. Factors influencing the effectiveness of farmers as disseminators of fodder shrubs in the central Kenya highlands. Unpublished report. Nairobi: World Agroforestry Centre.

Wambugu C, Franzel S, Cordero J, Stewart J. 2006. Fodder shrubs for dairy farmers in East Africa: making extension decisions and putting them into practice. Nairobi: World Agroforestry Centre; Oxford Forestry Institute.

Wambugu C, Franzel S, Tuwei P, Karanja G. 2001. Scaling up the use of fodder trees in central Kenya. *Development in Practice* 11:487–94.

Wanjiku J, Place F. 2007. Determinants of tree planting among smallholders in Kenya. Unpublished manuscript. Nairobi: World Agroforestry Centre.

Wanyoike FG. 2004. Dissemination and adoption of improved fodder tree: the case of *Calliandra calothyrsus* in Embu District, Kenya. MSc thesis. University of Nairobi: Department of Agricultural Economics.

Winrock International. 1992. Assessment of animal agriculture in sub-Saharan Africa. Little Rock, Arkansas: Winrock International Institute for Agricultural Development.

Occasional Paper Series

1. Agroforestry responses to HIV/AIDS in East and Southern Africa: proceedings of the HIV/AIDS workshop held in Nairobi 2003.
2. Indigenous techniques for assessing and monitoring range resources in East Africa.
3. Caractérisation de la biodiversité ligneuse dans les zones en marge du desert: manuel de procedures.
4. Philippine landcare after nine years: a study on the impacts of agroforestry on communities, farming households, and the local environment in Mindanao.
5. Impact of natural resource management technologies: fertilizer tree fallows in Zambia.
6. Les haies vives au Sahel: état des connaissances et recommandations pour la recherche et le développement.
7. Improved Land Management in the Lake Victoria basin: final Report on the TransVic project.
8. Intégration du genre dans la mise en oeuvre d'un: programme agroforestier au Sahel: guide pratique des chercheurs.
9. Swiddens in transition: shifted perceptions on shifting cultivators in Indonesia.
10. Evidence for impact of green fertilizers on maize production in sub-Saharan Africa: a meta-analysis.
11. Can organic and resource-conserving agriculture improve livelihoods? A meta-analysis and conceptual framework for site-specific evaluation.
12. The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research.

About the Occasional Paper series

The Occasional Paper is produced by the World Agroforestry Centre to disseminate research results, reviews and synthesis on key agroforestry topics. The manuscripts published in the series are peer reviewed.

Copies could be obtained by contacting the Communications Unit or from the Centre's website at www.worldagroforestry.org.

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

United Nations Avenue, Gigiri • PO Box 30677 • Nairobi, 00100 • Kenya

Telephone: +254 20 7224000 or via USA +1 650 833 6645 • Fax: +254 20 7224001 or via USA +1 650 833 6646

Email: ICRAF@cgiar.org

www.worldagroforestry.org