R6549

FINAL TECHNICAL REPORT

Phase 1 (1996-2001)
Investigation of factors affecting the nutritive value of *Calliandra calothyrsus* as fodder for ruminants

Phase 2 (2001-2006)
Scaling up the promotion of calliandra and other fodder shrubs in East Africa

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Table of Acronyms

ADF	Acid detergent fibre
AFRENA-ECA	Agroforestry Research Network for Africa – East and Central Africa
CIAT	International Centre for Tropical Agriculture (Centro Internacional de Agricultura Tropical), Cali, Colombia
CBO	Community-based organisation
CT	Condensed tannin
DM	Dry matter
DOMD	Dry organic matter digestibility
FORRI	Forestry Resources Research Institute, Uganda
HPLC	High performance liquid chromatography
ICRAF	World Agroforestry Centre (formerly International Centre for Research in Agroforestry), Nairobi, Kenya
ILRI	International Livestock Research Institute, Addis Ababa and Nairobi
ISAR	Rwanda Agricultural Research Institute (Institut des Sciences Agronomiques du Rwanda), Butare, Rwanda
IVDMD	*In vitro* dry matter digestibility
KARI	Kenya Agricultural Research Institute, Kenya
NDF	Neutral detergent fibre
NGO	Non-governmental organisation
NPV	Net present value
OFI	Oxford Forestry Institute
SARI	Selian Agricultural Research Institute, Arusha, Tanzania

Executive Summary

Previous FRP-funded projects (R4485, R5728) carried out range-wide provenance collections of *Calliandra calothyrsus* Meissn. ("calliandra") in Central America (R4485) and evaluated them in multi-locational agronomic trials throughout the tropics (R5728). R6549 Phase 1 built on this foundation by comparing two of the highest-yielding provenances, Patulul and San Ramón, in terms of their quality as animal fodder, using a combination of laboratory analyses and feeding trials with small ruminants in Kenya (KARI[1], Embu) and Colombia (CIAT[2], Palmira). The laboratory evaluations included estimation of crude protein, acid and neutral detergent fibre, tannins and digestibility. The effects on these traits of provenance, as well as management (cutting frequency) and season, were estimated using freeze-dried samples from an on-station agronomic trial in Embu. Both the agronomic trails and the feeding trials in Kenya also included the local land race ("Embu") of calliandra. The effect of site was evaluated by comparing material of the two provenances grown on a fertile site (Palmira) and on an acid-infertile one (Quilichao) in Colombia. The comparison was made both by laboratory analysis and by a feeding trial with sheep.

In parallel with this, the effect of drying was investigated by comparing freshly harvested, freeze-dried and air-dried (at 30°C) leaf samples of both provenances, grown in a greenhouse in the U.K. (Reading University). Fresh and dried material was also compared in feeding trials in both Kenya and Colombia.

The principal findings from Phase 1 were:

- ☆ Calliandra can be fed fresh or dry. Drying was previously thought to reduce quality, particularly digestibility, but this was not supported by our research.
- ☆ Cutting every six weeks or every twelve weeks produces similar amounts of leaf biomass, but the longer cutting interval also provides additional small diameter wood suitable for fuel.
- ☆ Patulul provenance is of significantly higher nutritive value than San Ramón, but is of similar quality to the Embu land race.
- ☆ Fodder quality is reduced in calliandra grown on acid infertile soils.
- ☆ The two provenances showed major differences in the structure of their condensed tannins. This was the first report of major intra-specific variation in tannin structure in any fodder species.

In Phase 2, the project's emphasis shifted to scaling up the adoption of calliandra and other fodder shrubs in East Africa, at the same time ensuring that the outputs from Phase 1 were disseminated as widely and effectively as possible. Our research on the scaling up process included studies of adoption in Rwanda and of farmer-to-farmer dissemination in Kenya; assessment of the economic impact of calliandra in Kenya and Uganda; documentation of farmers' experiences in Uganda and Tanzania; and a study of the market for calliandra seed in Kenya. In parallel with these studies the project facilitated the scaling up process directly, in collaboration with a wide range of partners.

In the final two years of the project, four more outputs were added. To capture the experiences and lessons from our scaling up activities, we produced a decision support tool and extension manual for extension providers in East Africa. We also attempted to quantify the effectiveness of different extension approaches through a questionnaire survey of extension providers in the four countries. Additional studies investigated the factors which make a farmer an effective disseminator, and assessed the potential of fodder leaf meal production, processing and marketing to improve rural livelihoods in Tanzania.

[1] Kenya Agricultural Research Institute
[2] International Centre for Tropical Agriculture

Foreword

R6549 comprised two phases. These were substantially different: Phase 1 (1996-2001) consisted mainly of bio-physical, on-station research on factors affecting the nutritive value of the leguminous shrub *Calliandra calothyrsus* ('calliandra') when used as a fodder for ruminants. The research included feeding trials in Embu, Kenya (with KARI) and Cali, Colombia (with CIAT), as well as laboratory analysis of leaf samples from both countries, both in-country and in the U.K. (at the University of Reading, Agriculture Faculty Analytical Laboratory).

In contrast, the research under Phase 2 comprised a series of socio-economic studies associated with adoption and impact of fodder shrubs (including, but not limited to, calliandra), and issues associated with the scaling up of their uptake by smallholder farmers. In this phase the geographic focus of the project also shifted, becoming focused on the East African region and including four countries: Kenya, Uganda, Tanzania and Rwanda. The principal partner in Africa for this phase was the World Agroforestry Centre (ICRAF), although we also developed partnerships in our scaling-up activities with a wide range of partners including governmental, non-governmental and community-based organisations.

Because the two phases of the project were so different, the research activities, outputs and contribution of the outputs are presented in two parts, one for each phase, to make for better continuity when reading the report. However the overall project purpose and background are largely common to both phases so are presented for the project as a whole, at the beginning of the report. The logical frameworks for both phases are included as Appendix 1.

Most of the outputs have been written up in detailed reports and/or scientific papers. Rather than repeat all the detailed information in this report, we present summaries here and refer throughout to the more detailed documents which are collected together as the Annex in the box file which accompanies this report.

Background

Fodder shrubs have the potential to have a substantial impact on the livelihoods of smallholder dairy farmers in the tropics, particularly in high potential sub-humid areas where land holdings are too small for extensive grazing systems. Without fodder shrubs, the only feed available on the farm during the dry season is dry grass and crop residues such as sweet potato vines and maize or sorghum stover, most of which are of poor quality. Some farmers alleviate this problem by buying dairy concentrate (dairy meal), but this is of variable quality and too expensive to be used by the poorer farmers. By growing their own high-protein fodder shrubs on the farm, instead of buying dairy meal, farmers can immediately save money, whilst those who could not previously afford supplements can achieve substantial increases in milk production for income and/or family consumption, by improving the nutrition of their animals.

The Central American leguminous shrub *Calliandra calothyrsus* ("calliandra") showed particular promise in the East African highlands in initial trials during the 1980s and 1990s. However the early research on this species used land race material of unknown origin, so there was scope to improve both yield and quality through judicious selection of appropriate provenances, as well as through improvements in the recommendations on utilisation. These are the issues that Phase 1 of R6549 sought to address.

Previous FRP-funded research projects managed by OFI (R4485, R5728) carried out range-wide exploration and seed collection of calliandra provenances in Central America, and tested these provenances in a pantropical network of trials. The provenances were evaluated in terms of biomass production but this did not give any insights into variation in quality as animal fodder. It would not have been feasible to test the whole set of provenances for quality traits, as this requires costly and time-consuming laboratory analyses and feeding trials. However there was a clear need to ensure that provenances selected for promotion as fodder, on the basis of leaf biomass production, were also suitable in terms of nutritive value. This was the rationale for the element of R6549 which addresses the issue of provenance differences in fodder quality: the two provenances selected for evaluation, Patulul from Guatemala and San Ramón from Nicaragua, were identified as among the most productive across a range of sites in the previous trial network.

With regard to utilisation, previous research in Kenya and elsewhere had evaluated different management options (cutting height and frequency) but only using local land race material of unknown origin (though in fact, the Embu land race which was used for most of this research in Kenya was shown by isozyme studies under R5728 to be closely related to the Santa Maria de Jesús provenance from Guatemala, quite close to Patulul). It was important to test whether the high-yielding provenances proposed for wider dissemination would respond to cutting regimes in the same way as the Embu land race, and also whether their nutritive value would be affected by variation in site quality.

The final important aspect of nutritive value to be addressed by Phase 1 of R6549 was the issue of the effect of drying the leaves on their quality. Early research in Australia had suggested that calliandra needed to be fed fresh, as drying was found to reduce voluntary intake and digestibility[1]. This became the standard recommendation to farmers on how to feed calliandra, even though some more recent research had failed to replicate the earlier Australian findings[2]. Again, the genetic origin of the material used in these earlier studies was unknown, so a possible explanation might have been that different provenances responded differently to drying, and this needed to be tested.

Phase 2 of R6549 was concerned principally with issues relating to scaling up the uptake, adoption and application of fodder shrub technologies in the East African region. An important and widely-recognised constraint to the impact of research is the difficulty of bridging the gap between research agencies and extension providers so that recommendations arising from research are effectively disseminated. At the time that Phase 2 was designed (2001) the popularity of calliandra

[1] Palmer, B. & Schlink, A.C. (1992). The effect of drying on the intake and rate of digestion of the shrub legume *Calliandra calothyrsus*. Tropical Grasslands **26**, 89-93.

[2] e.g. Hove, L., Topps, J.H., Sibanda, S. & Ndlovu, L.R. (2001). Nutrient intake and utilisation by goats fed dried leaves of the shrub legumes *Acacia angustissima, Calliandra calothyrsus* and *Leucaena leucocephala* as supplements to native pasture hay. Animal Feed Science and Technology **91**, 95-106.

had spread in Kenya from Embu to other parts of central Kenya[1], and calliandra was also starting to be used for fodder to a significant degree in other parts of the region, including the Lake Victoria Basin (western Kenya and southern Uganda) and the area around Mt. Kilimanjaro in northern Tanzania. However, the number of smallholder dairy farmers using the technology was still a small fraction of those who could potentially benefit. There was a need for research on aspects of the scaling up process which would allow extension to be targeted more effectively, and this was the principal rationale for Phase 2.

[1] Wambugu, C., Franzel, S., Tuwei, P. & Karanja, G. (2001). Scaling up the use of fodder shrubs in Central Kenya. Development in Practice **11**, 487-494.

Project Purpose

The project purpose, as stated in the logical framework for Phase 1 was: *Strategies to improve seasonal availability of livestock feeds in high potential areas developed and promoted. This purpose will be addressed with specific reference to Calliandra calothyrsus, and strategies to optimise its fodder value.* For Phase 2 it was: *Strategies for improved sustainable livelihoods and income generation for forest and tree dependent poor people in the Forest/Agriculture Interface developed and promoted.*

Phase 1 was designed to increase the benefits that farmers could derive from the use of calliandra as fodder. It addressed both the advantage that could be gained from selection of improved genetic (provenance) material, and optimising the quality of the fodder by correct site selection, harvesting method and post-harvest treatment. The research consisted of a combination of on-station feeding trials and laboratory analysis of leaf samples from research stations in Kenya and Colombia. As described under *Contribution of Outputs* below, this research did yield valuable recommendations for improved utilisation of calliandra. However, Phase 1 had no budget specifically for dissemination activities, apart from the project maturity workshops, and the results were initially published in the scientific literature (see Annex) rather than in extension materials aimed at extensionists and/or farmers. The need for a more proactive approach to dissemination of the findings came out clearly in the project maturity workshop held in Kenya. This was the constraint addressed by Phase 2, through a combination of activities designed to improve the capacity of extension partners in the region to deliver accurate advice on fodder technologies, and new socio-economic research into the scaling up process.

Phase 2 initially comprised five outputs. It is important to note here that when Phase 2 was designed, there was an emphasis in the DFID Renewable Natural Resources Research Strategy (which at that time was temporarily, but significantly, re-named the Renewable Natural Resources *Knowledge* Strategy) on promoting the use of research already completed[1]. Accordingly, the part of Phase 2 designed in 2001 (Outputs 1-5) comprised a mixture of new research (Outputs 1, 2, 3 & 5), and activities to widen the recommendation domain and improve the utilisation of calliandra and other fodder trees in line with the findings from Phase 1 (Output 4). The scope of the project was widened in Phase 2 to cover four countries in the region (Kenya, Uganda, Tanzania and Rwanda), as well as other fodder shrub species, though the main emphasis was still on calliandra.

During the course of Phase 2, we were asked by FRP to add additional outputs to the project. Output 6 was a decision support tool: its purpose was to draw together the project's accumulated knowledge and experience, both about fodder shrubs themselves and about the dissemination process, into a single volume which would be attractive and accessible to extension providers at all levels and even to farmers directly. Outputs 7-9 were additional socio-economic research studies into aspects which we had identified as researchable constraints requiring further investigation: the mechanism of farmer-to-farmer dissemination (Output 7); the scope for developing the market for fodder leaf meal (Output 8), and factors affecting the impact of extension (Output 9).

[1] See FRP Revised Strategy document of 26 January 2000, e.g. Sections 2.10 and Figure 1.

Research Activities: Phase 1 (1996-2001)

The research activities are described separately for each of the outputs listed in the logical framework (Appendix 1). The findings relating to each output are summarised in the *Outputs* section which follows this one.

OUTPUT 1: EFFECTS OF ENVIRONMENT, MANAGEMENT AND PROVENANCE ON NUTRITIVE VALUE OF CALLIANDRA FORAGE DETERMINED WITH RESPECT TO:
(A) UTILISATION BY RUMINANTS.
(B) CRUDE PROTEIN (CP), ORGANIC MATTER (OM), IN VITRO AND IN SACCO DIGESTIBILITY.

Output 1 was designed to test the hypothesis: *Nutritive value of calliandra is influenced by one or more of the following: (a) provenance (b) site, (c) post-harvest treatment (fresh/dry), (d) cutting interval, (e) season.* Output 1a comprised on-station feeding trials with sheep and goats by CIAT in Palmira, Colombia and KARI in Embu, Kenya. The CIAT trials compared the two provenances (Patulul and San Ramón), grown on two sites (Palmira, a fertile site and Quilichao, an acid infertile one) and fed fresh and dry in short-term metabolic trials. The experiments at Embu were longer-term production trials estimating the effects of provenance on growth rate in lambs and milk yield in dairy goats. Output 1b involved laboratory analyses of samples from field trials in Kenya and Colombia, to examine the effects of provenance, site, cutting frequency and season. In Colombia the samples came from the same plots as were used in the feeding trials. In Kenya, a separate 'agronomic trial' was established specifically to examine the effects of cutting management and season, and the interaction of these with provenance. Three provenances were included in the agronomic trial: Patulul, San Ramón and the local Embu land race. The laboratory analyses were carried out at the University of Reading, CIAT and the University of Nairobi.

(a) Effects of environment, management and provenance on utilisation by ruminants

Feeding trials at CIAT

1. Effect of provenance and drying of Calliandra on intake and digestion in sheep fed a low quality grass[1]

Before embarking on a full intake trial, a short-term intake experiment was carried out to ensure that the fresh and dried treatments of the two provenances were palatable enough to be consumed in sufficient quantities by the animals in the main experiment. In this initial experiment, edible forage (leaf and thin stems) of Patulul and San Ramón provenances was fed to eight sheep receiving a basal diet of *Brachiaria* grass. A 4 x 4 Latin Square design was used. Each provenance was offered either fresh or sun-dried in the morning and afternoon, and the animals were allowed to consume the forage for 30 minutes. The recorded intake was transformed to dry matter intake per hour per unit of body weight. In this initial palatability test, short-term intake of *Calliandra* was low regardless of provenance or post-harvest treatment, with the amount consumed ranging from 27% to 33% of that offered. However, intake was similar in all four treatments, so we were able to continue with the full intake and digestibility trial.

In the main experiment, eight African hair sheep housed in metabolism crates and fed a basal low quality grass (*Brachiaria humidicola)* were allocated to the following treatments, again arranged in a 4 x 4 Latin Square design:

T1: Dry calliandra, San Ramón provenance
T2: Fresh calliandra, San Ramón provenance
T3: Dry calliandra, Patulul provenance
T4: Fresh calliandra, Patulul provenance

The animals were fed 100 g of dry matter per kg of metabolic weight[2] per day, of which the low quality *Brachiaria* grass comprised 60% and the calliandra 40%. Each experimental period lasted

[1] This trial corresponds to trial C2 in the Project Memorandum.
[2] Metabolic weight = (live weight)$^{0.75}$

14 days, of which seven were for adjustment and seven for measurements. These included intake, digestibility and nitrogen (N) utilisation.

2. Effect of provenance and site quality on intake and digestion in sheep fed a low quality grass[1]

This study has been published as:
Lascano, C., Avila, P. and Stewart, J. (2003). Effect on intake, digestibility and nitrogen utilisation by sheep fed with Calliandra calothyrsus Meissner with different tannin structure. Archivos Latinoamericanos de Producción Animal ***11(1)****: 1-7.* This paper is included in the Annex[2], and provides a fuller account of the experiment than is given here.

The second trial at CIAT used six African hair sheep, housed in metabolic cages and fitted with ruminal and duodenal cannulas. Each was assigned to one of four treatments, in an unbalanced simple crossover design with four experimental periods, so that each animal received all four treatments over the course of the experiment. Each experimental period lasted 17 days: seven days' adjustment period and ten days' data collection. The treatments comprised a sole diet of sun-dried calliandra leaves, of one of two provenances harvested from two sites with contrasting soil fertility, as follows:

T1: San Ramón provenance grown in Quilichao (infertile soils)
T2: Patulul provenance grown in Quilichao (infertile soils)
T3: San Ramón provenance grown in Palmira (fertile soils)
T4: Patulul provenance grown in Palmira (fertile soils)

The foliage was sun-dried for 48 hours before feeding (complete drying was necessary because the material from Quilichao had to be transported to Palmira for the trial). The use of dried forage was considered justifiable in view of evidence from the first trial that drying had no significant effect on intake. The animals were offered 50 g of dry matter per kg of metabolic weight per day. The calliandra was fed a sole feed, even though this is not an approach recommended to farmers, because this was more likely to reveal any differences between the treatments. Intake was estimated by weighing the offered and refused feed daily, and dry matter digestibility by collection and weighing of all faeces. Nitrogen utilisation was assessed by measuring nitrogen in ruminal and duodenal fluid samples as well as in the offered feed and the faeces.

This trial also relates to Output 3 (*Relationship between tannin structure and function investigated*), because differences between the four treatments in tannin content and structure were also investigated (see Output 1b, below) and these were related to the treatment differences observed in the feeding trial. This is discussed further under Output 3.

Feeding trials at KARI- Embu

These feeding trials differed from those at CIAT in that they provided direct measures of effects on animal production, whereas the CIAT trials used fistulated animals, fed for shorter periods, to look in more detail at metabolic effects.

Accounts of the feeding trials in Embu have been published in:
Tuwei, P.K., Kang'ara, J.N.N., Mueller-Harvey, I., Poole, J., Ngugi, F.K. & Stewart, J.L. (2003). Factors affecting biomass production and nutritive value of Calliandra calothyrsus leaf as fodder for ruminants. Journal of Agricultural Science ***141****: 113-127.*
This paper is included in the Annex[3], and provides a fuller description of the experiments than is given here.

[1] This trial corresponds to trial C1 in the Project Memorandum.
[2] R6549-FTR-Phase 1-Lascano et al 2003
[3] R6549-FTR-Phase 1-Tuwei et al 2003

1. Effect of provenance, drying and seasonal (wet/dry) diet on intake and live weight gain in growing lambs fed calliandra as a supplement.

This experiment was conducted as two separate feeding trials. The first took place in the wet season (October-December), and the basal feed was fresh Napier grass (*Pennisetum purpureum*), while the second was in the dry season (February-April), with maize stover as the basal feed. This reflects a typical feeding regime for smallholder dairy farmers in the Embu area.

The two trials were intended to have the same design, with five treatments:

T1: Basal feed + concentrate (dairy meal)
T2: Basal feed + fresh Patulul/Embu mixture
T3: Basal feed + wilted Patulul/Embu mixture
T4: Basal feed + fresh San Ramón
T5: Basal feed + wilted San Ramón

In the second (dry season) trial, however, treatment T5 had to be omitted because of shortage of San Ramón leaf material. Moreover, in the second trial it was not possible to feed the supplements *ad libitum*, because voluntary intake of the maize stover basal feed was so low that the intake of calliandra or concentrate had to be limited to a maximum of 50% of the total diet. Because the lambs ate all the supplement they were offered, it was not possible to measure voluntary intake of supplement in this trial.

The two trials used the same 40 lambs, divided into five groups of eight so as to give a similar mean live weight in each group. The treatments were randomly allocated to the five groups. The animals were individually penned. Each trial comprised 14 days' adaptation period followed by ten weeks of data collection. There was a rest period of four weeks between the two trials. The amount of feed offered was adjusted weekly to give a 10% surplus over the previous week's consumption. The response variables in both trials were voluntary intake (of basal feed, supplement and total) and live weight gain. In addition to estimating the overall treatment effects, using ANOVA, the significance of the following orthogonal contrasts was tested: dairy meal v. calliandra; fresh v. wilted; Patulul/Embu v. San Ramón; and the interaction between provenance and wilting. In the second trial, non-orthogonal contrasts were necessary because of the missing treatment: dairy meal v. calliandra; fresh Patulul/Embu v. fresh San Ramón; and fresh Patulul/Embu v. wilted Patulul/Embu.

2. Effect of provenance and drying on intake and milk production in lactating dairy goats fed calliandra as a supplement.

This experiment was conducted at the end of the long rains (June-August). It comprised the same five treatments as the wet season trial in Experiment 1, but in this experiment intake and milk yield were measured in 16 lactating cross-bred dairy goats. An unbalanced crossover design was used, with three periods, each comprising a 14-day adaptation period followed by seven days of data collection. The goats were individually penned throughout the experiment. As in Experiment 1, both the basal feed and the supplement were offered *ad libitum*, with the amount offered adjusted every week to the previous week's intake plus 10%. The response variables were voluntary intake and milk yield.

(b) Effects of environment, management and provenance on crude protein, organic matter, and *in vitro* and *in sacco* digestibility

Analysis of samples from trials in Colombia

Freeze-dried leaf material of the two provenances Patulul and San Ramón, grown on the contrasting sites Palmira (fertile soils) and San Ramón (acid infertile soils) were analysed to estimate the effects of site and provenance, and their interaction. Samples of immature and mature edible material from each provenance, harvested at the two sites, were analysed for *in vitro* dry matter digestibility, crude protein, fibre (neutral and acid detergent fibre), and level and types of

condensed tannin (using the butanol-HCl spectrophotometric assay[1]). The relative proportions of cyanidin and delphinidin in the products of the butanol-HCl reaction were estimated by high performance liquid chromatography (HPLC), using a method developed at CIAT. This gives basic information about structural differences between the proanthocyanidins from different treatments, in terms of their constituent subunits, since the assumption is made that the proportions of procyanidin and prodelphinidin in the proanthocyanidins is the same as that of their respective end-products, cyanidin and delphinidin, in the butanol-HCl reaction.

Protein precipitation activity (astringency) of purified condensed tannins from the two provenances was determined using a radial diffusion assay, which is based on the ability of tannins to bind to protein (bovine serum albumin)[2]. As explained above, the findings on tannins also relate to Output 3 (*Relationship between tannin structure and function investigated*) as the same material was also used in the second feeding trial at CIAT, described under Output 1a above. The study is described in more detail in Lascano *et al* (2003), which is included in the Annex[3].

Analysis of samples from trial in Kenya

The agronomic trial at the KARI Regional Research Centre in Embu was designed to test the effects of cutting frequency (6- and 12-weekly harvesting) and season on biomass production and nutritive value of three provenances, Patulul, San Ramón and the Embu land race. Like the feeding trials in Kenya described above, the analyses of samples from the agronomic trial are described in Tuwei *et al.* (2003) (see Output 1a) so only a summary of the methods is given here.

The trial layout was a randomised complete block design with 4 replications, and split plots for the two cutting intervals. Each subplot contained 36 (6x6) plants at 1m x 1m spacing, of which the central 25 were measured and sampled. An initial uniformity cut (to 1 m height) was carried out 6 months after planting, followed by eight biomass harvests every 6 weeks for the next year. The 6-week frequency treatments were cut at every harvest, and the 12-week ones at the 2nd, 4th, 6th and 8th harvests. An additional, 9th harvest was used for chemical analysis only (biomass was not measured) to give compositional data spanning a full year. Biomass was defined as dry matter of edible (leaves and shoot tips) and woody material. Leaf samples from each harvest were freeze dried and sent for analysis to the University of Reading.

Crude protein, neutral detergent fibre, and IVDMD were estimated using standard techniques (see Tuwei *et al.,* 2003 for details). Extractable and bound condensed tannin content was estimated using the butanol-HCl assay, and the spectrophotometric readings were calibrated to tannin concentration by constructing a standard curve using semi-purified tannin standards for each provenance separately. In addition, the structure of these tannins was investigated by comparing the ratio of prodelphinidin to procyanidin using HPLC. This last part of the analysis relates to Output 3, allowing us to interpret the results of the feeding trials (see Output 1a) with reference to differences in tannin structure between the provenances.

The analysis of the data required a split-plot analysis of variance, owing to the complexity of the experimental design. The main plot was cutting frequency and the sub-plot was provenance. The AREPMEASURES procedure (Genstat 5, 1998) was used to analyse changes in treatment effect over time. This carries out an ANOVA on the repeated measurements and checks the assumptions required (i.e. symmetry of the variance-covariance matrix).

The analysis examined the data in terms of pairs of harvests, i.e. comparing each 12-weekly harvest with the two 6-weekly harvests carried out in the same period. For biomass, the production from the 6-weekly cuts was summed to compare with the biomass from the 12-weekly cut (because cumulative totals are of interest). For all the other variables, mean values from each pair of 6-weekly cuts were compared to the 12-weekly values. This analysis provided information not only

[1] Terrill, T.H., Rowan, A.M., Douglas, G.B. and Barry, T.N. 1992. Determination of extractable and bound condensed tannin concentrations in forage plants, protein concentrate meals and cereal grains. J. Sci. Food Agric. **58**: 321-329.
[2] Hagerman, A.E. 1987. Radial diffusion method for determining tannin in plant extracts. Journal of Chemical Ecology **13**: 437-449.
[3] R6549-FTR-Phase 1-Lascano et al 2003

about the effects of cutting frequency and provenance, and interactions between them, but also how these may change over time.

OUTPUT 2: EFFECTS OF DRYING *CALLIANDRA* LEAVES ON DEGRADABILITY, AND THE ROLE OF TANNINS IN THESE EFFECTS, INVESTIGATED.

Output 2 was concerned specifically with the effect of drying on nutritive value, since the standard recommendation for calliandra at the time was that should be fed fresh; it was thought that the quality would be reduced by drying or even wilting the leaves. To test this hypothesis, the two provenances, Patulul and San Ramón, were grown in a greenhouse to examine the effect of drying the leaves on their nutritive value. A full account of this work has been published in: *Stewart, J.L., 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.* This paper is included in the Annex[1], and provides a fuller description of the study than is given here.

Thirty plants of each of the two provenances (Patulul and San Ramón) were raised under controlled conditions in a greenhouse at the Plant Environment Laboratory, Department of Agriculture, University of Reading. Leaf samples for analysis included material from all 30 plants to capture all available genetic variation. Four post-harvest treatments were compared: fresh, air-dried (in an oven at 30°C), freeze-dried, and fresh-frozen at -20°C. These treatments were included to enable us to:

- compare fresh and air-dried fodder, as these are the options available to farmers. If provenances were affected by drying to different extents, this could be an important selection criterion;
- see whether freeze-dried material adequately represents fresh leaves, as is generally assumed by researchers;
- compare the effects of long-term storage (12 months) on air-dried, freeze-dried and fresh-frozen leaf.

Freshly harvested leaf of the two provenances was compared with freeze-dried and air-dried material in terms of extractable and bound CT and IVDMD. In addition, crude protein, fibre (ADF, NDF) and astringency were estimated in freeze- and air-dried samples only. The effect of long-term storage on each sample type was evaluated after 12 months' storage in terms of CT content and structure (procyanidin:prodelphinidin ratio), and IVDMD.

All the analyses were carried out using standard procedures, including a modified version of the butanol-HCl assay for condensed tannins (see Stewart *et al.,* 2000 in the Annex[1] for details). The spectrophotometric readings were converted to tannin concentrations using semi-purified standards prepared separately for each provenance. The standards were extracted from leaf extracts on a Sephadex LH-20 column. Protein binding activity (astringency) was estimated using a radial diffusion assay with haemoglobin.

OUTPUT 3: RELATIONSHIP BETWEEN TANNIN STRUCTURE AND FUNCTION INVESTIGATED.

There were no activities associated exclusively with Output 3. Insights into the relationship between the chemical structure of condensed tannins and their function in ruminant nutrition came from several of the experiments described above: these are discussed below under *Outputs.*

[1] R6549-FTR-Phase1-Stewart et al 2000

OUTPUT 4: RESULTS FROM OUTPUTS 1-3 USED TO FORMULATE IMPROVED UTILISATION STRATEGIES, AND DISSEMINATED THROUGH REGIONAL WORKSHOPS AND APPROPRIATE EXTENSION MEDIA.

The recommendations for improved utilisation of calliandra which arise from the results of Outputs 1-3 are discussed in *Contribution of Outputs* below. Here we summarise the main dissemination activities associated with Phase 1 of the project.

The project's findings and recommendations were discussed at project maturity workshops in Costa Rica and Kenya, as well as at the project maturity workshop of a related FRP project (R6535) in Indonesia.

Project maturity workshop in Costa Rica

A three day project maturity workshop was held in Costa Rica in May 2000. CIAT has a regional remit in tropical agriculture, and one of the promotion pathways identified at the outset of R6549 was the Tropileche consortium, a CIAT-ILRI project to develop improved feeding systems for dual purpose (milk/beef) cattle in tropical Latin America, based on forage legumes. Tropileche was CIAT's principal promotion pathway for calliandra in Latin America. It was active in the seasonally dry (Pacific) zone of Costa Rica, and in Peru. In addition, a CIAT project was starting in Costa Rica, Honduras and Nicaragua, with German (BMZ) funding. Both initiatives involved on-farm validation and promotion of research results through close collaboration with participating farmers.

The workshop participants were chosen on the basis of involvement with these projects. In Costa Rica, the Ministry of Agriculture and Livestock, MAG[1] is involved in management of the collaboration with farmers in both Tropileche and the BMZ project. In Honduras and Nicaragua, both governmental organisations[2] and NGOs[3] are involved. The rest of the participants are involved with calliandra research and/or promotion of other forage legumes in Central America (e.g. CATIE[4], Costa Rica; CONSEFORH[5], Honduras; ICTA[6], Guatemala). In addition, a representative of CIAT[7], Bolivia as invited as an observer, because of this institution's long experience of working with calliandra and other forage legumes.

The workshop was held in Costa Rica rather than Colombia because Pacific (seasonally dry) Central America is seen as the most suitable niche for calliandra within the region. However, there is no traditional use of tree fodder in this area, and research is still at the stage of on-farm testing of various species.

The workshop comprised three parts: presentations by participants about their experiences with calliandra (day 1); a field visit to two farms participating in the Tropileche project (day 2); and working groups to define necessary actions for the future (day 3). The working groups were formed on a country-by-country basis, and concentrated on on-farm research and promotion. The outcomes of the workshops discussions are summarised under *Outputs* below.

Project maturity workshop in Kenya

A three-day project maturity workshop was held in Nairobi in June 2000. The theme of the workshop was "*Calliandra calothyrsus*: moving forward in research and dissemination on fodder trees". There were 24 participants from Kenya, Uganda, Tanzania and Rwanda, representing national research institutes, international research centres and non-governmental organisations.

[1] Ministería de Agricultura y Ganadería
[2] Dirección de Ciencia y Technología Agropecuaria (DICTA) in Honduras, Instituto Nacional de Technología Agropecuaria in Nicaragua
[3] Servicios Técnicos de Desarrollo Sostenible (SERTEDESO) in Honduras, Proyecto de Desarrollo Sostenible Agropecuaria (PRODESA) in Nicaragua
[4] Centro Agronómico de Investigación y Enseñanza
[5] Conservación y Silvicultura de Especies Forestales de Honduras
[6] Instituto de Ciencia y Tecnología Agrícolas
[7] Centro de Investigación Agrícola Tropical

The participants included agroforesters, forage agronomists, animal nutritionists, animal scientists, economists and extension specialists. The objectives of the meeting were to:

1. Review the results of the KARI/OFI project on the use of calliandra as a fodder
2. Assess progress and set priorities for research and dissemination of calliandra and other fodder trees in eastern and southern Africa since the Bogor conference, 1996
3. Develop concept notes to submit to donors for calliandra and other fodder tree research and dissemination

On the first day, participants gave presentations about their experiences with calliandra. Those in the morning mainly concerned the results of the DFID-financed project, as well as calliandra dissemination in the Embu area. In the afternoon, the current status of calliandra and other fodder tree research and promotion was presented for each of the other countries represented. On the morning of the second day, participants went on a field visit to several farms growing calliandra for fodder, which was a useful opportunity for informal discussions about calliandra utilisation. The afternoon was spent identifying important research and dissemination needs, first individually then in groups. On the third day, working groups produced an outline concept note encapsulating the most pressing of the issues identified the previous day. Thus a participatory process was used to set research and dissemination priorities and to draft an outline of a concept note for a project proposal. This process is described further in the *Outputs* section.

Project maturity workshop in Indonesia

A third workshop was held jointly with FRP project R6535 (Joanne Chamberlain) in Bogor, Indonesia in November 2000. This was a training workshop, with the theme *Calliandra seed production and utilisation.* The reason for R6549 to participate in this workshop (which was initiated by R6535) was to disseminate our findings from R6549 more widely: although Indonesia is not part of the target area of the project, it is another area of the tropics where calliandra is important as fodder and where our findings would be applicable.

There were 31 invited participants at the workshop, which was facilitated by ICRAF-SE Asia (James Roshetko, Mulawarman). They comprised a mixture of researchers and representatives of NGOs.

The aims of the workshop were:

1. to highlight recent FRP-funded research results in relation to calliandra seed production and utilisation (with special reference to fodder);
2. to provide the opportunity for Indonesian partners to share their experience in relation to calliandra seed production and utilisation; and
3. to identify what type of extension material is appropriate to disseminate the information from 1 and 2 above.

The workshop ran over a period of three days and involved a mixture of presentations, group discussions and a field visit. The workshop began with an introduction to the FRP-funded work and why the workshop was taking place. The focus of the first day was on utilisation of calliandra, and presentations were made by Janet Stewart (OFI) on the findings of R6549, Budi Tangendjaja (Research Institute for Animal Production, Bogor), I Wayan Karda (University of Mataram) and James Roshetko (ICRAF/Winrock). The second day was on reproductive biology and seed production, with training sessions by Joanne Chamberlain on the findings of R6535, and a presentation by Nurhayati Purwantari (Research Institute for Animal Production, Bogor). These sessions were accompanied by an abstract or information leaflet. The third day involved a field visit to the Research Institute for Animal Production in Ciawi, just outside Bogor. Discussions were held in a plot of calliandra planted for fodder production, but which may be converted into a seed production area. After returning to Bogor, the material in the new seed production manual (R6535) was reviewed.

Group discussions were conducted every afternoon, following the day's presentations. The working groups covered three main areas (one for each day) and then presented their results to the whole group:

1. Calliandra utilisation in Indonesia and the identification of knowledge gaps/constraints
Four working groups, one composed of researchers, and three with NGO representatives.
2. Designing seed production areas of calliandra
Three working groups, split on a regional basis.
3 Needs assessment for new training/extension materials
Three working groups, split on a regional basis.

Topic (1) was the only one with substantial input from R6549. The key points from the discussion of this topic are presented in the *Outputs* section.

Outputs: Phase 1 (1996-2001)

OUTPUT 1: EFFECTS OF ENVIRONMENT, MANAGEMENT AND PROVENANCE ON NUTRITIVE VALUE OF *CALLIANDRA* FORAGE DETERMINED WITH RESPECT TO:
(A) UTILISATION BY RUMINANTS.
(B) CRUDE PROTEIN (CP), ORGANIC MATTER (OM), *IN VITRO* AND *IN SACCO* DIGESTIBILITY.

(a) Effects of environment, management and provenance on utilisation by ruminants

Feeding trials at CIAT

1. Effect of provenance and drying of Calliandra on intake and digestion in sheep fed a low quality grass[1]

The results shown in Table 1 indicate that total (grass + calliandra) dry matter intake did not change with provenance or drying. However, dry matter digestibility was higher when Patulul provenance was fed, either fresh or dried. Thus intake of digestible nutrients (data not shown) was higher when Patulul was fed as a supplement as compared to San Ramón. Edible forage of San Ramón harvested in Palmira and Quilichao was shown to have lower digestibility than Patulul. In contrast, the concentration of extractable condensed tannins was significantly higher in Patulul. The lower digestibility of San Ramón was correlated with fibre content and not with concentration of extractable tannins.

Table 1: Intake and digestibility by sheep fed a low quality grass and supplemented with two provenances of *Calliandra calothyrsus* fed dry and fresh[1].

Item	Dry *Calliandra* (San Ramón)	Fresh *Calliandra* (San Ramón)	Dry *Calliandra* (Patulul)	Fresh *Calliandra* (Patulul)	SE
DM Intake (g/kg of BW/day)	23.2	24.1	24.7	24.4	0.59
DM Digestibility (%)	57.1b	54.9b	60.9a	59.0a	1.41

[1] animals were fed a low quality grass basal diet (60%) and supplemented with 40 % legume
[a, b] means are different (P <0.05)

2. Effect of provenance and site quality on intake and digestion in sheep fed a low quality grass[2] (see Lascano *et al.* (2003) in the Annex[3] for a full account)

The results of this feeding trial are summarised in Table 2. There was no significant interaction between provenance and site, so only the main effects are presented.

In contrast to CIAT Experiment 1 (above), where the calliandra was fed as a supplement to *Brachiaria* grass, intake of San Ramón was significantly higher than that of Patulul when fed as a sole feed in this experiment. However, the digestibility of Patulul was significantly higher, and these differences cancelled one another out so that the intake of digestible dry matter did not differ significantly between the two provenances. It is notable that the total intake was much lower than in Experiment 1, indicating the relatively low palatability of calliandra when fed as a sole feed.

[1] This trial corresponds to trial C2 in the Project Memorandum.
[2] This trial corresponds to trial C1 in the Project Memorandum.
[3] R6549-FTR-Phase 1-Lascano et al 2003

Table 2 also shows that, although the digestibility of the two provenances was not significantly affected by the site on which they were grown, intake was significantly higher for the material grown on the more fertile, less acid site (Palmira) and this was reflected in higher intake of digestible dry matter of material from this site.

Table 2: Intake and digestibility of *Calliandra calothyrsus* fed to sheep housed in metabolism crates and supplemented with extracted cassava meal[1].

Item	Site Effect		Provenance Effect		SEM
	Quilichao	Palmira	San Ramón	Patulul	
Intake of DM (g/kg of BW/day)	6.7 b	10.6 a	10.2 a	7.1 b	0.55
Digestibility of DM (%)	57.8 a	53.7 a	51.7 b	59.8 a	2.10
Digestibility of NDF (%)	50.1 a	50.9 a	45.5 b	55.6 a	3.60
Intake of Digestible DM (g per kg of BW^{-1} d)	3.6 b	5.4 a	5.1 a	4.0 a	0.37

a, b, c for each main effect, values in the same row with the same letters are not different (P<0.05)
[1]4 g/ kg of BW^{-1} d of extracted cassava meal was fed via rumen cannula to each sheep

The effects of provenance and site on N utilisation are shown in Table 3. These data again show higher nutritive value for material grown at Palmira. The results regarding San Ramón are complex to interpret. Although they suggest higher quality, in terms of N utilisation, for San Ramón relative to Patulul, this is counteracted by the lower digestibility of San Ramón.

Table 3: Nitrogen (N) utilization by sheep housed in metabolic crates and fed two provenances of *Calliandra calothyrsus* grown in contrasting sites[1].

Item	Site Effect		Provenance Effect		SEM
	QUILICHAO	Palmira	San Ramón	Patulul	
N intake, g d^{-1}	6.7 b	12.4 a	10.8 a	8.3 b	0.67
Duodenal N, g d^{-1}	12.5 b	18.6 a	18.6 a	12.5 b	1.26
Faecal N, g d^{-1}	5.7 b	9.7 a	9.1 a	6.2 b	0.38
[2]Apparently absorbed N, g d^{-1}	6.9 b	8.9 a	9.5 a	6.3 b	0.10
[3]Ruminal escape dietary N, g d^{-1}	5.5 b	9.5 a	11.0a	4.0 b	1.30
Ruminal escape N, % of N intake	77.2 a	79.0 a	99.0 a	57.2 b	13.90

[1] 4 g/ kg BW/d of extracted cassava meal was fed via rumen cannula to each sheep
a, b for each main effect, values in the same row with the same letter are not different (P<0.05)
[2]Duodenal N – Faecal N
[3]Ruminal escape dietary N = N flow to the duodenum – (Bacterial N flow + Endogenous N) where: Endogenous N = 2.2 g N per kg of DM intake

Feeding trials at KARI- Embu
(see Tuwei *et al* (2003), in the Annex[1], for a full account of the results of both trials)

1. Effect of provenance and seasonal (wet/dry) diet on intake and live weight gain in growing lambs

The results of the two trials are summarised in Tables 4 and 5. The tables show the treatment means as well as the significance both of the treatment main effects and the various contrasts.

[1] R6549-FTR-Phase 1-Tuwei et al 2000

Table 4: *Mean intake (dry matter) and live weight gain of lambs fed Napier grass supplemented with fresh or wilted calliandra, or commercial concentrate (Trial 1). Standard errors in brackets*

Supplement	% of supplement in diet (DM)	Voluntary intake of Napier grass (g/kg $(BW)^{0.75}$)	Voluntary intake of supplement (g/kg $(BW)^{0.75}$)	Total voluntary intake (g/kg $(BW)^{0.75}$)	Average daily live weight gain (g)	Feed efficiency (total diet) (g LWG/g total intake)	Feed efficiency (supplement) (g LWG/g supp. intake)
Commercial concentrate (dairy meal)	21.4	60.3 (3.79)	16.4 (1.44)	76.7 (4.11)	112.8 (6.97)	0.130 (0.0054)	0.616 (0.0207)
Fresh calliandra: Patulul/Embu	32.4	63.1 (3.79)	30.2 (1.44)	93.3 (4.11)	90.1 (6.97)	0.090 (0.0054)	0.282 (0.0207)
Fresh calliandra: San Ramón	29.9	75.7 (3.79)	32.3 (1.44)	108.0 (4.11)	55.8 (6.97)	0.050 (0.0054)	0.173 (0.0207)
Wilted calliandra: Patulul/Embu	37.3	70.4 (3.79)	41.8 (1.44)	112.2 (4.11)	79.1 (6.97)	0.064 (0.0054)	0.176 (0.0207)
Wilted calliandra: San Ramón	32.6	80.9 (3.79)	39.1 (1.44)	120.1 (4.11)	56.8 (6.97)	0.047 (0.0054)	0.143 (0.0207)
Overall *P*-value		0.002	<0.001	<0.001	<0.001	<0.001	<0.001
***P*-values for contrasts:**							
Calliandra vs dairy meal		0.007	<0.001	<0.001	<0.001	<0.001	<0.001
Fresh vs wilted calliandra		0.108	<0.001	<0.001	0.481	0.009	0.002
Patulul/Embu vs San Ramón		0.004	0.826	0.009	<0.001	<0.001	0.002
Fresh/wilted vs provenance		0.785	0.109	0.413	0.397	0.070	0.045

Table 5: *Mean intake and live weight gain of lambs fed maize stover supplemented with fresh or wilted calliandra, or commercial concentrate (Trial 2). Standard errors in brackets*

Supplement	% of supplement in diet (DM)	Voluntary intake of maize stover (g/kg $(BW)^{0.75}$)	Intake of supplement (fixed) (g/kg $(BW)^{0.75}$)	Total intake (g/kg $(BW)^{0.75}$)	Average daily live weight gain (g)	Feed efficiency (total diet) (g LWG/g total intake)	Feed efficiency (supplement) (g LWG/g supp. intake)
Commercial concentrate (dairy meal)	53.0	33.2 (1.10)	37.4 (1.22)	70.6 (1.77)	59.7 (4.49)	0.072 (0.0052)	0.138 (0.0104)
Fresh calliandra: Patulul/Embu	52.7	35.5 (1.03)	39.5 (1.14)	75.0 (1.66)	26.1 (4.2)	0.032 (0.0048)	0.061 (0.0097)
Fresh calliandra: San Ramón	54.3	33.7 (1.03)	40.1 (1.14)	73.8 (1.66)	3.6 (4.2)	0.005 (0.0048)	0.008 (0.0097)
Wilted calliandra: Patulul/Embu	51.7	35.2 (1.03)	37.7 (1.14)	72.9 (1.66)	42.7 (4.2)	0.051 (0.0048)	0.099 (0.0097)
Overall *P*-value				0.347	<0.001	<0.001	<0.001
***P*-values for contrasts:**							
Calliandra vs dairy meal				0.115	<0.001	<0.001	<0.001
Fresh Patulul/Embu vs wilted Patulul/Embu				0.380	0.010	0.009	0.009
Fresh Patulul/Embu vs fresh San Ramón				0.626	0.001	<0.001	<0.001

In the wet season trial with Napier grass as the basal feed, intake of the two provenances (San Ramón and Patulul/Embu) did not differ significantly, but intake of Napier grass was higher when supplemented with San Ramón, resulting also in significantly higher total intake. However, live weight gain was much higher with Patulul/Embu (whether fresh or wilted), so the feed efficiency (expressed as g live weight gain per g dry matter intake) was also significantly higher for Patulul/Embu.

For both provenances, the intake of wilted material was higher than for fresh leaves, to the extent that total intake was also significantly higher even though intake of Napier grass was not affected by wilting the calliandra. Wilting had no effect on live weight gain, however, so the feed efficiency was higher with fresh leaves. There was no significant interaction between provenance and wilting.

In the dry season trial, with maize stover as the basal feed, the three calliandra treatments (fresh San Ramón, fresh Patulul/Embu and wilted Patulul/Embu) all gave similar total intake, but the fresh San Ramón treatment gave very poor live weight gain compared to the Patulul treatments.

Previous research[1] had suggested that 1 kg DM of calliandra was roughly equivalent in its effect on animal production to 1 kg of dairy meal. In both trials, however, dairy meal gave much greater weight gain, and hence higher feed efficiency, than equivalent amounts of calliandra. This suggests that the recommendation of 1:1 substitution of calliandra dry matter for dairy meal should be treated with caution.

2. Effect of provenance and drying on intake and milk production in lactating dairy goats fed calliandra as a supplement.

The intake variables estimated were Napier grass (the basal diet), supplement and total dry matter. The response variable was milk yield. These data are presented in Table 6. Analysis of variance, with treatment and period as factors, showed a significant treatment effect for Napier intake (P=0.022) and highly significant treatment effects (P<0.001) for intake of supplement, total intake, milk yield and feed efficiency (grams of milk produced per gram of intake).

In contrast to the feeding trials with lambs, in this experiment provenance had no significant effect on either intake or milk production (P>0.05 for all variables). Wilting had a negative effect on Napier intake (P=0.045) and total intake (P=0.016), the opposite of results reported previously in the literature (see *Background* section). However, milk production was unaffected by wilting (P=0.429).

The orthogonal contrasts showed that while intake of dairy meal (and corresponding total intake) was significantly lower than dry matter intake of calliandra (P<0.001), milk production was significantly higher with dairy meal than with calliandra (P<0.001). Again, this suggests that the previous findings by Paterson *et al.* (1999) were over-optimistic regarding the potential for calliandra to substitute for dairy meal on a (dry) weight-for-weight basis.

[1] Paterson, R. T., Kiruiro, E. & Arimi, H. K. (1999). *Calliandra calothyrsus* as a supplement for milk production in the Kenya Highlands. *Tropical Animal Health and Production* **31**, 115-126.

Table 6: *Intake (dry matter) and milk yield of lactating goats fed Napier grass supplemented with fresh or wilted calliandra, or commercial concentrate. Standard errors in brackets.*

Supplement	Voluntary intake of Napier grass (g/kg $(BW)^{0.75}$)	Voluntary intake of supplement (g/kg $(BW)^{0.75}$)	Total voluntary intake (g/kg $(BW)^{0.75}$)	Average daily milk production (kg)	Feed efficiency (total diet) (g milk/g total intake)	Feed efficiency (supplement) (g milk/g supp. intake)
Commercial concentrate (dairy meal)	87.7 (2.7)	18.4 (0.9)	106.2 (2.8)	0.72 (0.02)	0.51 (0.02)	2.91 (0.08)
Fresh calliandra: Patulul/Embu	102.5 (3.5)	31.0 (1.2)	133.5 (3.6)	0.56 (0.02)	0.34 (0.02)	1.41 (0.11)
Fresh calliandra: San Ramón	99.3 (3.3)	27.1 (1.1)	126.4 (3.3)	0.51 (0.02)	0.30 (0.02)	1.42 (0.10)
Wilted calliandra: Patulul/Embu	94.3 (3.1)	27.5 (1.0)	121.6 (3.1)	0.56 (0.02)	0.35 (0.02)	1.53 (0.09)
Wilted calliandra: San Ramón	93.2 (3.5)	27.0 (1.2)	120.2 (3.6)	0.55 (0.02)	0.34 (0.02)	1.53 (0.11)
Overall *P*-value	0.022	<0.001	<0.001	<0.001	<0.001	<0.001
***P*-values for contrasts: Calliandra vs dairy meal**	0.007	<0.001	<0.001	<0.001	<0.001	<0.001
Fresh vs wilted	0.045	0.124	0.016	0.415	0.267	0.278
Patulul/Embu vs San Ramón	0.530	0.058	0.220	0.201	0.353	0.977
Fresh/wilted vs provenance	0.773	0.162	0.460	0.528	0.610	0.930

(b) Effects of environment, management and provenance on crude protein, organic matter, and *in vitro* and *in sacco* digestibility

Analysis of samples from trials in Colombia

N.B. The results summarised here are discussed in more detail in Lascano *et al* (2003), which is included in the Annex[1].

The results of the chemical analyses in Colombia are summarised in Table 7. Across both sites the two provenances differed significantly with regard to digestibility (IVDMD), fibre (ADF, NDF) and extractable condensed tannin (CT). Patulul provenance had higher digestibility and lower fibre than San Ramón, but higher extractable CT. There was no significant difference in protein content between the provenances. As higher tannin content might normally be expected to reduce digestibility, this suggests that, in calliandra, variation among provenances in fibre content may have a bigger effect on digestibility than variation in tannin content.

Site effects on nutritive value had a somewhat different pattern, with higher protein content and IVDMD in samples from the more fertile site (Palmira). In this case, the difference in digestibility could not be explained by differences in fibre content, as the samples from Palmira contained more fibre than those from Quilichao. Extractable condensed tannin content, however, was significantly lower in the Palmira samples, so here this may be the source of the difference in IVDMD. The difference in CT content between the sites was much more pronounced for San Ramón than for Patulul, resulting in a significant provenance x site interaction for this trait. In contrast, Patulul showed more variation between the two sites in terms of protein content.

Astringency (g of protein precipitated per g of extractable CT) was not influenced by site ($P>0.05$) but varied between provenances: tannins from San Ramón provenance were significantly more astringent ($P<0.05$) than those from Patulul (Table 8). Variation in astringency is discussed further under Output 3.

Table 7: Chemical characterisation of *Calliandra calothyrsus* provenances fed to sheep housed in metabolism crates

Calliandra (provenance and site)	Crude protein (% of DM)	In vitro DM digestibility (%)	NDF (% of DM)	ADF (% of DM)	Condensed extractable tannins (% of DM)	Condensed insoluble tannins (% of DM)
San Ramón -- Quilichao	15.5 b	20.1 c	35.0 a	32.1 a	28.3 b	6.3 a
San Ramón -- Palmira	17.0 a	32.2 b	36.7 a	29.6 a	18.0 c	4.4 a
Patulul -- Quilichao	13.5 c	32.8 b	27.4 b	24.0 b	35.4 a	4.0 a
Patulul – Palmira	18.0 a	39.9 a	31.1 b	24.9 b	33.6 a	3.6 a
SEM	0.4	0.6	0.8	0.9	0.4	0.5
Significance (p) of effects of:						
Provenance	NS	0.0001	0.0001	0.0001	0.0001	NS
Site	0.0001	0.0001	0.01	NS	0.0004	NS
Provenance x Site	0.0036	0.004	NS	NS	0.003	NS

a. b, c Values in the same column with the same letters are not different ($P < 0.05$)

[1] R6549-FTR-Phase 1-Lascano et al 2003

Table 8: Astringency of extractable condensed tannins of calliandra provenances grown in two sites with contrasting soil fertility (mg protein bound/ mg of extractable CT) *

Provenances	Quilichao (infertile soil)	Palmira (fertile soil)
San Ramón	0.90 a	0.97 a
Patulul	0.59 b	0.57 b

* Protein used : Bovine Serum Albumin – pH 5.0
a, b Values with the same letters are not different (P< 0.05)

Analysis of samples from trial in Kenya

N.B. The results summarised here are discussed in more detail in Tuwei *et al* (2003), which is included in the Annex[1].

The provenance means for leaf and wood biomass production, IVDMD and the four compositional variables (crude protein, NDF, extractable CT and bound CT) are shown in Table 9. The same table also shows the percentage of cyanidin in the products of the butanol-HCl reaction. The HPLC showed that the anthocyanidins produced from calliandra tannins by the butanol-HCl reaction consist almost exclusively of cyanidin and delphinidin, possibly with traces of pelargonidin. The percentage of prodelphinidin subunits can therefore be expressed as (100 - % procyanidin).

The values for leaf and wood biomass production show total production over the 48-week period of the experiment under the two cutting regimes, because the trait of interest is cumulative biomass production over consecutive harvests. For the quality traits, however, the values shown are means, also across the whole period of the experiment.

The effects of provenance, cutting frequency, and the interaction between them, are shown for each trait in Table 10. There was a significant difference between provenances in every trait estimated. While San Ramón provenance gave the highest leaf biomass production, Embu and Patulul provenances were superior in terms of the leaf quality traits crude protein (higher), NDF (lower) and IVDMD (higher). Surprisingly, given that high tannin content generally tends to reduce dry matter digestibility, CT content (both extractable and bound) was lowest in San Ramón provenance. There is also a major structural difference in the CTs from San Ramón compared to those from Patulul and Embu, with those from San Ramón provenance comprising mainly prodelphinidin tannins, and the other two provenances mainly procyanidin tannins.

Over the year during which biomass was harvested, frequent (6-weekly) harvesting generally gave higher total leaf production than 12-weekly cutting, although the opposite was true for the first pair of harvests (data not shown), and differences between these two treatments was small (Table 9). Wood biomass production, however, was greatly reduced by frequent cutting, with the 12-week cycle producing almost four times as much wood as the 6-week cycle in the course of the year (Table 9), and the latter producing little or no wood at several harvests. In contrast, the quality traits showed little consistent variation with harvesting regime. The effect of cutting frequency was only (barely) significant for NDF (P=0.022, Table 10). As might be expected, younger leaves (6-weekly harvest) were generally lower in fibre.

For most traits, provenance effects were unaffected by cutting frequency. The only exception was woody biomass, for which this interaction was highly significant (P<0.001): over the first two cutting cycles, San Ramón produced much more wood than the other provenances under the 12-week cutting regime, while all three provenances produced similar amounts under 6-weekly cutting.

All the traits measured, except extractable CT, showed significant variation over the course of the year in the analysis of pairs of harvests ("time" in Table 10). However, there was no consistent pattern of variation among the different traits.

[1] R6549-FTR-Phase 1-Tuwei et al 2003

Table 9: Cumulative biomass production and mean values for fodder quality traits over 48 weeks. Standard errors in brackets to compare means for different cut frequencies.

Trait	Units	Cutting frequency	Provenance			Means (across provenance)	S.E.s (12 D.F.) to compare provenance means for the same cut frequency
			Embu	Patulul	San Ramón		
Leaf biomass production	kg DM/ha	6 week	13486 (463.3)	13906 (463.3)	14744 (463.3)	14045 (189.4)	517.8
		12 week	11291 (463.3)	12302 (463.3)	14102 (463.3)	12565 (189.4)	517.8
		Means	12388 (366.1)	13104 (366.1)	14423 (366.1)	13305	
Wood biomass Production	kg DM/ha	6 week	1285 (237.2)	1248 (237.2)	942 (237.2)	1158 (215.5)	121.4
		12 week	3448 (237.2)	4438 (237.2)	4838 (237.^{2})	4241 (215.5)	121.4
		Means	2366 (85.9)	2843 (85.9)	2890 (85.9)	2700	
Crude protein	g/kg	6 week	224 (4.5)	223 (4.5)	203 (4.5)	217 (2.8)	4.2
		12 week	216 (4.5)	217 (4.5)	197 (4.5)	210 (2.8)	4.2
		Means	220 (3.0)	220 (3.0)	200 (3.0)	213	
NDF	g/kg	6 week	389 (13.7)	377 (13.7)	406 (13.7)	391 (8.4)	13.2
		12 week	426 (13.7)	424 (13.7)	478 (13.7)	442 (8.4)	13.2
		Means	407 (9.3)	400 (9.3)	442 (9.3)	416	
IVDMD	%	6 week	38.9 (0.93)	35.7 (0.93)	30.0 (0.93)	34.9 (0.36)	1.05
		12 week	36.5 (0.93)	34.5 (0.93)	30.5 (0.93)	33.8 (0.36)	1.05
		Means	37.7 (0.74)	35.1 (0.74)	30.3 (0.74)	34.4	
Extractable CT	g/kg	6 week	262 (13.6)	307 (13.6)	240 (13.6)	270 (5.0)	15.4
		12 week	280 (13.6)	290 (13.6)	231 (13.6)	267 (5.0)	15.4
		Means	271 (10.9)	299 (10.9)	235 (10.9)	268	
Bound CT	g/kg	6 week	66 (2.0)	61 (2.0)	51 (2.0)	59 (1.4)	1.7
		12 week	66 (2.0)	60 (2.0)	52 (2.0)	59 (1.4)	1.7
		Means	66 (1.2)	60 (1.2)	51 (1.2)	59	
Proportion of procyanidin in extractable CT	%	6 week	86.1 (0.97)	87.1 (0.97)	29.6 (0.97)	67.6 (0.70)	0.82
		12 week	83.8 (0.97)	85.8 (0.97)	30.5 (0.97)	66.7 (0.70)	0.82
		Means	84.9 (0.58)	86.5 (0.58)	30.1 (0.58)	67.1	

Table 10: Significance (P) of effects of provenance, cutting frequency and their interaction on all traits measured in the agronomic trial.

	Leaf biomass	Wood biomass	IVDMD	CP	NDF	Extractable CT	Bound CT	%PC
Cutting frequency	0.012	0.002	0.14	0.18	0.022	0.71	0.93	0.42
Provenance	0.006	0.002	<0.001	<0.001	0.018	0.005	<0.001	<0.001
Provenance × cutting frequency	0.35	<0.001	0.39	0.97	0.42	0.48	0.81	0.19
Time	<0.001	<0.001	0.04	0.01	<0.001	0.10	0.002	<0.001
Time × provenance	0.29	0.10	0.84	0.70	0.42	0.50	0.65	<0.001
Time × cutting frequency	<0.001	<0.001	0.36	0.45	0.003	0.003	0.19	0.10

OUTPUT 2: EFFECTS OF DRYING *CALLIANDRA* LEAVES ON DEGRADABILITY, AND THE ROLE OF TANNINS IN THESE EFFECTS, INVESTIGATED.

N.B. The results summarised here are discussed in more detail in Stewart *et al* (2000), which is included in the Annex[1].

The results of the analyses carried out at the University of Reading for the greenhouse experiment are summarised in Tables 11 and 12. Table 11 shows treatment means and significance levels for the newly-prepared samples, and Table 12 gives the results after 12 months of storage. For the newly-prepared material the study showed significant provenance variation in all the traits measured except protein-bound and fibre-bound CT. Patulul was superior to San Ramón in terms of crude protein (higher), IVDMD (higher) and fibre (lower), although its extractable CT content was also higher, which might be expected to depress digestibility. These results are in agreement with the analyses carried out under Output 1b, again suggesting that the difference between the provenances in fibre content may have more effect on their relative digestibilities than CT content as estimated by the butanol-HCl assay.

The procyanidin:prodelphinidin ratios (Table 12: P<0.001) again revealed the striking difference between the two provenances in tannin structure, which was also detected in the analysis under Output 1b. The CT in the Patulul samples comprised mainly procyanidin subunits, whereas that in the San Ramón samples was composed largely of prodelphinidin subunits. The fact that CT structures can be so diverse, even within a species, highlights the need for future tannin research to concentrate on investigating the extent to which differences in structure affect important nutritional traits such as digestibility.

[1] R6549-FTR-Phase 1-Stewart et al 2000

Table 11: Effect of provenance and drying treatment[1] on in vitro digestibility, protein precipitation capacity, crude protein, fibre (ADF, NDF), and condensed tannin level in recently-harvested calliandra leaf: treatment means, expressed on dry matter basis (standard deviations in brackets).

Provenance	Drying treatment	*In vitro* DOMD (%)	Crude protein (g kg^{-1})	ADF (g kg^{-1})	NDF (g kg^{-1})	Astringency (g protein g^{-1} CT)	CT (g kg^{-1}) (butanol-HCl assay)			
							Extractable	Protein-bound	Fibre-bound	Total CT[2]
Patulul	Air-dried	62.4^{b} (1.67)	24.0 (1.62)	16.4 (3.02)	30.2 (3.89)	0.532 (0.072)	132.8^{b} (21.8)	26.4^{a} (7.35)	6.45^{a} (0.36)	152.1^{a} (18.1)
	Freeze-dried	61.8^{b} (2.62)	24.3 (1.55)	16.5 (2.93)	30.8 (1.47)	0.574 (0.084)	145.0^{ab} (16.0)	21.7^{a} (5.05)	4.76^{b} (0.43)	175.8^{a} (15.0)
	Fresh	53.0^{a} (1.79)	-	-	-	-	159.9^{a} (19.8)	13.2^{b} (4.20)	7.81^{a} (1.33)	178.3^{a} (17.4)
San Ramón	Air-dried	48.7^{a} (1.12)	21.5 (2.14)	22.8 (3.51)	40.6 (4.80)	0.656 (0.098)	105.3^{b} (14.6)	25.6^{a} (2.32)	6.22^{a} (1.23)	134.2^{a} (15.6)
	Freeze-dried	47.6^{a} (0.61)	20.6 (1.62)	20.4 (4.45)	37.9 (2.18)	0.660 (0.102)	136.7^{a} (20.8)	20.6^{b} (1.50)	4.96^{a} (1.76)	165.7^{a} (25.1)
	Fresh	45.7^{a} (3.29)	-	-	-	-	134.8^{a} (17.0)	19.8^{b} (1.93)	5.99^{a} (1.95)	155.0^{a} (16.8)
Significance (p) of effects of:										
provenance		<0.001	0.007	0.013	<0.001	0.001	<0.001	0.204	0.265	0.034
drying treatment		<0.001	0.763	0.518	0.548	0.425	<0.001	<0.001	0.018	0.016
provenance x drying treatment		0.006	0.533	0.501	0.341	0.517	0.288	0.022	0.300	0.773

[1]Within each provenance, values in the same column having the same suffix do not differ significantly (Tukey=s *w* procedure, = 0.05).

[2]Values not identical to sum of means of each fraction, because numbers of observations vary among fractions.

Table 12: Effect of provenance and storage treatment[1] on *in vitro* digestibility, condensed tannin level and procyanidin:prodelphinidin (PC:PD) ratio in calliandra leaf after 12 months storage: treatment means, expressed on dry matter basis (standard deviations in brackets).

Provenance	Storage treatment	*In vitro* DOMD (%)	Condensed tannins (g kg^{-1})				PC:PD ratio
			Extractable	Protein-bound	Fibre-bound	Total CT[2]	
Patulul	Air-dried	38.4^{b} (1.46)	142.0^{b} (10.0)	38.5^{a} (3.54)	9.81^{a} (1.33)	192.9^{b} (12.8)	5.67^{a} (0.401)
	Freeze-dried	47.4^{a} (1.25)	166.2^{a} (9.01)	37.1^{a} (9.01)	8.17^{ab} (0.44)	217.9^{a} (5.76)	5.19^{a} (0.110)
	Fresh-frozen	45.3^{a} (2.91)	71.3^{c} (8.63)	36.7^{a} (3.88)	7.50^{b} (0.70)	118.3^{c} (5.95)	7.31^{b} (0.195)
San Ramón	Air-dried	28.2^{a} (1.77)	91.3^{b} (5.14)	36.2^{a} (7.68)	11.2^{a} (1.11)	137.2^{b} (2.59)	0.665^{a} (0.015)
	Freeze-dried	30.0^{a} (2.42)	134.7^{a} (10.1)	32.2^{a} (5.61)	7.37^{b} (0.34)	179.6^{a} (8.86)	0.659^{a} (0.004)
	Fresh-frozen	30.9^{a} (5.52)	78.8^{b} (10.4)	34.3^{a} (5.95)	9.49^{a} (0.74)	121.3^{b} (14.7)	0.415^{b} (0.042)
Significance (p) of effects of:							
provenance		<0.001	<0.001	0.229	0.057	<0.001	<0.001
drying treatment		<0.001	<0.001	0.682	<0.001	<0.001	0.001
provenance x drying treatment		0.005	<0.001	0.897	0.036	0.001	<0.001

[1]Within each provenance, values in the same column having the same suffix do not differ significantly (Tukey=s *w* procedure, = 0.05).
[2]Values not identical to sum of means of each fraction, because numbers of observations vary among fractions.

Drying was not found to reduce *in vitro* digestibility of calliandra leaf, and in Patulul provenance both air-drying and freeze-drying appeared significantly to increase DOMD. This is contrary to the results of previous studies[1]. Air-drying reduced extractable CT and increased bound CT, relative to fresh leaf, but there was no significant effect of drying on total CT in either provenance. There is therefore no evidence from this study that air-dried leaf is inferior to fresh leaf in nutritive value.

CT values for freeze-dried leaf were closer to the values for fresh leaf than were those for air-dried samples. The study thus confirms that freeze-dried rather than air-dried samples should be used in tannin studies where possible.

Freezing of fresh leaf was found to be an unsuitable storage method for tannin studies, owing to major losses of extractable CT. Digestibility of both dried and frozen samples was reduced significantly by storage.

OUTPUT 3: RELATIONSHIP BETWEEN TANNIN STRUCTURE AND FUNCTION INVESTIGATED.

There are essentially two approaches to the quantification of tannins in feeds. First, there is a variety of methods for the estimation of tannin concentration in plant tissue, using tannin extracts (preferably from the same plant material, though this is not always the case) as standards. The butanol-HCl spectrophotometric assay is one such method, and we used it in the analyses at both CIAT and Reading. The second approach is to estimate biological activity of the tannins by an assay in which the tannin binds to, and precipitates, protein, such as the radial diffusion assay. This is known as the *astringency* of the tannin, and relates more closely to its function in nutrition. Where similar concentrations of two different tannins show differing protein precipitation activity, this is due to differences in their chemical structure.

Condensed tannins, also known as *proanthocyanodins*, are made up of sub-units, mainly *procyanidin* and *prodelphinidin*, which are converted to *cyanidin* and *delphinidin* when the tannin undergoes acid hydrolysis. These are the dark red reaction products in the butanol-HCl reaction. These products can be examined using HPLC, and the relative proportions of cyanidin and dephinidin determined.

In our analyses we converted the spectrophotometric absorbance readings from the butanol-HCl assay to tannin concentrations using semi-purified tannins which were isolated separately from the two provenances. San Ramón leaf extracts consistently gave higher absorbance values, but so did the San Ramón standard, and when the standards were used to convert the absorbances to concentrations, the tannin concentration in San Ramón leaves was actually lower than in Patulul. This underlines the importance of preparing separate standards, even for different accessions within a species. Most studies use, at best, one standard per species; but if we had taken this approach in the calliandra work we would have come to the incorrect conclusion that San Ramón contains higher levels of tannin than Patulul.

Analysis of the tannins using the radial diffusion assay showed higher astringency for San Ramón than for Patulul (see Table 8 and Table 11). The greater protein-binding capacity of the San Ramón tannin could contribute to the lower digestibility of this provenance, despite its lower concentration. The difference in astringency suggests a difference in chemical structure, and this was confirmed using HPLC which, as explained above, revealed that the tannin from Patulul was mainly composed of procyanidin subunits, whereas the tannin from San Ramón consists almost entirely of prodelphinidin. This could explain the greater astringency of the San Ramón tannin: delphinidin has one more phenolic group than cyanidin, which could result in greater binding capacity. It could also explain the generally poorer performance of animals fed San Ramón provenance in the feeding trials.

[1] Palmer, B. & Schlink, A.C. (1992). The effect of drying on the intake and rate of digestion of the shrub legume *Calliandra calothyrsus*. Tropical Grasslands **26**, 89-93.; Mahyuddin P., Little, D.A. and Lowry, J.B. (1998). Drying treatment drastically affects feed evaluation and feed quality with certain tropical forage species. Tropical Grasslands **22**, 69-78.

OUTPUT 4: RESULTS FROM OUTPUTS 1-3 USED TO FORMULATE IMPROVED UTILISATION STRATEGIES, AND DISSEMINATED THROUGH REGIONAL WORKSHOPS AND APPROPRIATE EXTENSION MEDIA.

Project maturity workshop in Costa Rica

The main points arising from the workshop discussions are summarised here. Calliandra is a much less well-known fodder species in Central America (despite being native to the region) than in East Africa, and this is reflected in the caution expressed by the participants at this workshop about widespread promotion of the technology.

Use of trees for fodder
Several important points emerged during discussions on the first day of the workshop. First and foremost was the current very low level of utilisation of calliandra, or indeed any woody legume, as fodder in Central America, despite past and present activities in this area by a range of institutions and projects. CATIE, for example, has working with fodder trees for many years, but because of low uptake no longer sees this as a priority area. However the participants felt that it was important to distinguish between humid and seasonally dry areas. CATIE's efforts in Costa Rica have been largely limited to the humid (Atlantic) zone, where human and animal population densities are relatively low, systems are extensive, and fodder shortage is not widely perceived as a problem. Tropileche works specifically in the dry (Pacific) zone, and sees the use of woody legumes as a strategy specifically to alleviate perceived dry season fodder shortages.

Dry season tolerance
Given the consensus that the potential for woody legumes in forage production lies mainly in the drier parts of Central America, the next issue of concern was the drought tolerance of calliandra. Most natural populations occur in areas with only four months (or less) dry season, and moreover many populations are riverine, so probably have access to a high water table. The areas where woody legumes are thought to have most potential as fodder are those with a harsh dry season of up to 5-6 months. It is likely that most calliandra provenances would not tolerate this level of drought, or at least would not maintain useful levels of production under these conditions. Only one accession of *Calliandra calothyrsus*, of unknown provenance, has been tested in the CIAT forage germplasm plots at ECAG (where the dry season lasts 5-6 months), and this died out after two years (although it showed good early dry season production compared to *C. houstoniana* and *C. grandiflora*, which have shown good survival on the same site for ten years). In view of this potential difficulty, there is a need to revisit the OFI provenance trial network data and look for evidence of drought tolerance in trials. There was also interest in further testing of *C. houstoniana* and *C. grandiflora*.

Quality issues
The quality (nutritive value) of calliandra leaves as fodder remains a controversial issue, with opinion divided among researchers regarding the nutritional benefit of including calliandra in ruminant diets. Low and variable values have been reported for *in vitro* dry matter digestibility (IVDMD), as well as problems with nitrogen utilisation, probably due to very high levels of condensed tannin. Important findings from Outputs 1-3 include (i) consistently higher IVDMD for Patulul than for San Ramón, reflected in higher intake and (in Embu) better animal production with this provenance; (ii) increase in IVDMD and apparent N digestibility *in vivo* on drying. However the highest values we have recorded (with dried material of Patulul provenance) are around 45-50% for IVDMD and 70% for N digestibility *in vivo.* These rather low nutritional values should be weighed up against some of the clear advantages of calliandra, such as its high tolerance of acid, high aluminium soils (San Ramón performs better than Patulul on poor soils) and its multiple uses.

A separate evaluation was described at the workshop, of a wider range of OFI provenances in a CIAT trial on acid soils[1]. Extremely low *in vitro* digestibility values (<20%) were measured in most of the provenances (including Patulul and San Ramón), but one provenance, La Ceiba,

[1] M. Peters, CIAT, Colombia

had significantly higher IVDMD. CIAT is therefore interested in testing La Ceiba on-farm alongside Patulul and San Ramón.

Towards a strategy for calliandra utilisation
The discussion of these issues led to a consensus that the most appropriate strategy for calliandra utilisation as fodder would be at moderate levels (around 25-30% of the diet), and as one of a range of species in a system, rather than as the only supplement. Fed as one component of a mixture, its high tannin levels could even improve the utilisation of other species (e.g. *Cratylia argentea*, whose N may be too rapidly degraded in the rumen).

In view of the very limited utilisation of tree fodder in general in Central America, other uses of calliandra should also be considered as part of a promotion strategy. In Costa Rica, for instance, there is currently much interest in agroforestry interventions for soil improvement and rehabilitation of degraded lands, and calliandra has been identified as a valuable mulch/soil improvement species because of the slow rate of nutrient release from the leaves (due again to their high tannin content). The research on differences between Patulul and San Ramón provenances has relevance to this: San Ramón leaf has been shown by (non-FRP) research at CIAT to have a slower rate of decomposition than Patulul, and therefore to be preferable for this use, whereas Patulul is superior for fodder. It was felt that these provenances should be tested in parallel for soil amelioration and fodder respectively.

Plans for future action
There was a unanimous view that it would be premature to promote the use of calliandra in Central America, for example through the preparation of extension materials, at this stage. Given its current non-utilisation within the region, there needs first to be a process of on-farm testing, to identify suitable niches for calliandra within the wider picture of tree fodder use. For this reason, the working groups on the third day of the workshop considered options for on-farm testing rather than dissemination pathways as had originally been planned. For each of the countries represented, participants were asked to consider:

1. Areas within each country with conditions appropriate for calliandra
2. Predominant production systems in these areas
3. Opportunities (“niches”) for utilisation of calliandra
4. Research activities needed to realise benefits from calliandra
5. Institutional commitments necessary to carry out the research (including staff and time)
6. Other inputs necessary for the research

Their recommendations could provide a basis for developing future research proposals for calliandra and other fodder trees. It was agreed that Pedro Argel (CIAT staff, based in Costa Rica) would coordinate an informal network for exchange of information on calliandra and other fodder tree initiatives in Central America.

Project maturity workshop in Kenya

One of the stated objectives of the workshop in Kenya was to develop concept notes for further funding, particularly to increase the impact of the research done under Phase 1 by supporting and facilitating dissemination. The working group exercise to develop a concept note was very productive and resulted in the outline from which Phase 2 was subsequently developed.

During discussion between presentations on the first day, topics perceived by participants to need further funding (either for research or dissemination) had already started to emerge. The group activities on days 2 and 3 were intended to articulate these ideas more clearly, and then to prioritise them and form them into coherent outline project proposals. This process worked remarkably well, and resulted in a clear outline of a single project to increase the utility and impact of the research on calliandra to date.

First, individuals wrote down on cards up to five research and/or dissemination topics relating to calliandra and other fodder trees, in which they felt that more work was urgently needed. The topics thus identified were grouped into four broad categories: feeding issues; species/ provenance testing; dissemination; and monitoring and evaluation. Working groups were then

formed to distil the suggested topics in each category into a coherent list of issues. Many people also mentioned seed supply as a very important issue, but it was agreed that this topic would be fully addressed by a workshop at ICRAF later in 2000, so it was omitted from this workshop's outputs.

The following day, a plenary session reconsidered the groups of topics, and reached a consensus as to which topics were of highest priority and could form coherent project objectives. Several objectives were thus defined, and because they were closely inter-related it was agreed that they should form the basis of a single concept note. Working groups were formed to address each of the objectives and to define activities and indicators related to them.

Project maturity workshop in Indonesia

As described in the *Activities* section, the workshop in Indonesia comprised discussions in working groups made up of researchers and NGO representatives from different parts of the country. The discussions from the session relevant to the findings of R6549 are presented here.

Calliandra utilisation in Indonesia and the identification of knowledge gaps/constraints

There were four working groups for this session, one composed of researchers, and three with NGO representatives.

Researchers
The research group discussed the difference in the results of fodder quality experiments conducted under R6549 and by Budi Tangendjaja (Research Institute for Animal Production, Bogor), and what recommendations should be made to NGOs and farmers. Research under R6549 found that drying calliandra leaves had no adverse effect on the intake of fodder or animal production, however, Budi's group in Bogor found that drying did adversely affect the digestibility of calliandra and animal production. These apparently conflicting results were thought to give a confused message to NGOs and their farmers, so the group discussed why the results of the two experiments may have differed. Two reasons could be found:

- The R6549 experiments on digestibility involved air-drying at 30ºC, whereas Budi's involved oven-drying at much higher temperatures.
- The animals used under R6549 (in Embu) were not used to calliandra as a fodder (fed either fresh or dry), but Budi's animals had been regularly fed on fresh calliandra, which would tend to give them a preference for this.

The group therefore made the following recommendations:

- Do not allow calliandra fodder to wilt for longer than 24 hours, as the quality may reduce after this time.
- Preferably feed calliandra fodder on the same day as it is cut.
- Do not feed calliandra in a dry pellet form.

NGOs from Sumatera
This group felt that although calliandra was fairly common in Sumatra, the species was under-utilised. Their combined knowledge of calliandra was poor and they were only familiar with it as a source of fuelwood and for honey production. They commented that it was difficult to get seed, despite the tree flowering well. This group was therefore keen for a lot more information on calliandra especially as a source of fodder. They identified, in particular, a need for simple demonstrations of the benefits of feeding calliandra, as well as information on how much calliandra is needed per animal, and how this relates to land requirements. Landholdings in Sumatera tend to be larger than in Java, potentially giving more scope for on-farm planting. In Java it is usually only possible to plant on boundaries and field corners; most calliandra is collected from nearby forest areas, where it is naturalised.

NGOs from south Sumatra to Flores

Calliandra was known to this group as a source of fodder, fuelwood and green manure, as a nurse crop for other tree species, and as a means of generating income through the sale of seed (to a Belgian development project). This group felt that farmers were constrained by a lack of information and planting material, and that research needed to be put into a language that extension workers could understand. The group felt that there should be more research with farmers, economic analyses of systems involving calliandra to facilitate adoption and more information about how to cultivate and manage calliandra, particularly for wetlands and coastal areas. A problem of seed predation by caterpillars was noted, as well as a local belief that handling calliandra could induce 'flu-like' (allergic?) symptoms in humans.

NGOs from NTT (West Timor)

Calliandra was known to this group as a source of fuelwood, fodder and green manure, as a means of preventing soil erosion, and for income generation through the sale of seed to NGOs. Calliandra is normally found inter-cropped with food or cash crops and in hedgerows, often on very steep slopes (contour hedge spacing 1m-2m on slopes steeper than 45°, 6m-10m on less steep slopes). Farmers generally harvest calliandra once a year for wood, leaf and seed (it starts seeding after one year). Seed is produced in small seed orchards coordinated by local NGOs. When fed as a fodder it is allowed to wilt briefly (1-2 hours) as otherwise it is believed to cause bloat in goats. Up to 1.5 kg of seed can be collected per tree per year, which can be sold at 6000 Rupiah per kg (US$ 0.75), although the price varies from region to region. 1 kg of seed is considered to be enough for 1.5 km of hedgerow.

Contribution of Outputs: Phase 1 (1996-2001)

The findings from Phase 1 have several important implications for the planting and management of calliandra and other fodder shrubs, which are summarised below for both the African and the Latin American contexts. However findings such as these will only translate into real developmental benefits if they are effectively disseminated to the potential beneficiaries. This aspect of R6549 was the main focus of Phase 2, and it is only through the activities under Phase 2 that the findings from Phase 1 have been able to make a tangible contribution in terms of impacts on the livelihoods of smallholder farmers. These are discussed further under the corresponding section of this report for Phase 2. Here we summarise the main practical recommendations arising from the bio-physical research component of the project, which informed our dissemination activities under Phase 2.

The utility of calliandra as fodder for ruminants has sometimes been questioned, both in the literature and in practice, owing mainly to its very high content of condensed tannins which results in relatively low digestibility as well as complex metabolic effects on the animal and on the ecology of the rumen. Nonetheless, the initial experiences of farmers using calliandra in East Africa during the 1990s were mostly very positive, and there was already clear potential for further expansion in its adoption. However, before scaling up the promotion of calliandra in the region, it was essential to look in more detail at its nutritive value to allay any concerns about its quality.

In the native range of calliandra in Central America, in contrast, there is very little use of tree fodder, and therefore little or no indigenous knowledge regarding its utilisation. Participants at the workshop held in Costa Rica felt that it was too soon to promote fodder shrubs such as calliandra on a large scale. The project findings will therefore not translate into substantial developmental benefit in Latin America, at least in the short term. However, this is not to say that the part of the project carried out in Colombia will not be useful. CIAT was chosen as the location for the detailed metabolic trials because of their particular expertise in forage evaluation, and their findings apply equally to calliandra used in East Africa.

The first important finding from Phase 1 (in both Kenya and Colombia) is that there is significant variation in nutritive value between **provenances** of calliandra. The nutritive value of Patulul provenance was found to be significantly higher than that of San Ramón in both lab analyses and feeding trials. However Patulul provenance and the Embu land race were very similar in all the traits measured. Patulul and San Ramón differed much more profoundly than expected in tannin structure, although structure/function relationships in condensed tannins are not well enough understood to enable detailed prediction of the nutritional effects of these differences. However this is the first evidence of major differences in tannin chemistry within a species, so scientifically it is a most interesting result.

The practical implication of these results for farmers in East Africa is that the land race material which they are already using is of good nutritive value (better than the high-yielding San Ramón provenance). There is therefore no need for investment in production and dissemination of new genetic material. In fact, as a result of the project, ICRAF has stopped producing seed of San Ramón for distribution to farmers.

Our research on the effect of **site** showed consistently higher quality of material from the more fertile site (in Colombia). **Cutting frequency** (6- or 12-weekly) had little effect on quality traits but the more frequent cutting gave higher leaf biomass production. Seasonal variation was substantial for some traits but followed no clear pattern.

The metabolic feeding trials in Colombia and the production (growth) trials in Kenya both showed **drying** of the leaves to have a positive effect on voluntary intake. This contradicts early research on calliandra which showed that drying reduced intake, leading to a widespread recommendation that calliandra must always be fed immediately after harvesting. However, in this earlier work calliandra was fed as a sole feed; when fed as a supplement no depression of intake on drying is observed.

The metabolic studies at CIAT (Colombia) showed small but important differences in nitrogen (N) metabolism between fresh and dried material. In terms of apparent N digestibility (i.e. (N intake – faecal N)/N intake), dried leaves appear superior to fresh; but there is also a small but significant increase in N absorption in the hind gut (arguably a more refined measure of N utilisation) with

fresh leaves, owing to higher levels of microbial N production in the rumen. The overall conclusion from the metabolic studies is that the differences observed between fresh and dried leaves are unlikely to be large enough to affect animal production significantly. In Kenya, better growth was observed in lambs fed dried calliandra, as a supplement to maize stover, although these data were from only one provenance (Patulul). Conversely, with calliandra supplementing Napier grass, intake was higher for dried calliandra, but live weight gain was not, suggesting in this case that the fresh material may have been of higher nutritive value.

The overall conclusion from all these studies is that the effects of drying on animal production may be positive or negative but are in any case much smaller than previously thought. Intake was never found to be reduced by drying, and in the trials with sheep it was significantly increased. These findings have important practical implications for farmers. They greatly increase the flexibility in the way calliandra can be used, including the possibility of conserving and storing it as leaf meal, or selling surpluses to other farmers. They also make it possible for farmers who are too poor to keep animals of their own to generate income by growing fodder for sale.

Research Activities: Phase 2 (2001-2006)

Phase 2 of R6549 comprised nine discrete outputs, five of which were developed at the start of this phase, and four more which were added through contract amendments during the course of the project. The activities associated with each of these are described briefly here, and in more detail in the associated Annex.

An important point with regard to all the Phase 2 activities and outputs is that the original intention was to focus specifically on *Calliandra calothyrsus* ('calliandra'), as this species had been the subject of all the research conducted under Phase 1. However, as Phase 2 progressed it became increasingly clear that it would be more appropriate to include information on the other fodder shrub species currently being promoted in the region, whilst still maintaining the primary focus on calliandra.

OUTPUT 1: FARMERS' EXPERIENCES IN CALLIANDRA MANAGEMENT AND UTILISATION

The aim of Output 1 was to help us to target our promotion activities as accurately as possible, by increasing our understanding of farmers' perceptions regarding previously disseminated research results, including: the extent to which farmers are aware of the results of research on calliandra; whether research findings concur with farmers' own experiences; farmers' innovations in growing and feeding calliandra; and ways in which research outputs have been adapted and tailored to farmers' own needs. Understanding these issues is important in facilitating the development and introduction of technologies that meet farmers' aspirations and are thus likely to be adopted by them.

There were two studies associated with Output 1:

1. Informal survey of calliandra utilisation, Moshi Rural District, Tanzania

M. Kingamkono & C. Lyamchai, SARI[1], Arusha, Tanzania

Shortages of high quality animal feed are becoming more acute on the slopes of Mount Kilimanjaro, reducing livestock productivity. Dissemination of high quality fodder such as calliandra was started in 1999 by SARI, under the AFRENA-ECA[2] programme, but unfortunately these activities stopped within a year of their inception due to lack of funding. However subsequent visits showed that farmers had continued to grow and utilise the fodder shrubs, and some were also sharing seeds with neighbouring farmers. The promotion of fodder shrubs started again in early 2003 under Output 4. The study aimed to provide baseline information about the current state of knowledge among farmers, as a basis from which to re-start the fodder promotion activities.

An informal survey was conducted in Kilema, Marangu and Mamba wards in May 2003, in which 44 farmers were interviewed to capture their experiences and opinions about calliandra and other fodder shrubs, particularly during the period when outside support to the dissemination process had been interrupted. The survey also recorded farmers' experiences of management practices and biomass production. Three agro-ecological zones on the slopes of Mt Kilimanjaro were sampled: the Upland, Intermediate and Lowland Zones. The study methodology is described in detail in the unpublished report which is included in the Annex[3].

2. Farmers' experiences in the management and utilisation of calliandra in Uganda

P. Nyeko, Makerere University, Kampala, Uganda

The study in Uganda under Output 1 documented farmers' knowledge, perceptions and practices in the cultivation and utilisation of calliandra, and specifically their experiences with regard to pest and

[1] Selian Agricultural Research Institute
[2] Agroforestry Research Network for Africa – East and Central Africa
[3] R6549-FTR-Phase 2 Output 1-Kingkamkono & Lyamchai 2003

disease attack. There was a specific emphasis on pest and diseases because problems have been noted on calliandra in Uganda which have not yet spread to the rest of the region, notably a scale insect and a disease causing sudden die-back and death in young calliandra trees.

A survey of 30 farmers was conducted using a pre-tested questionnaire in each of three agroecological zones: the Lake Victoria Crescent, in the Kampala/Entebbe area (LVC), the Southern Drylands (SDL) and the Southern Highlands (SHL). These are all areas where farmers have substantial experience of growing and managing calliandra. LVC and SDL correspond to the two areas in Uganda where R6549 has had active fodder shrub promotion activities ('Lakeshore' and 'SW Uganda': see Output 4); and SHL is a hilly area close to the Rwanda border, centred on Kabale, where ICRAF has been working with fodder shrubs for several years. All the farmers included in the study had at least two years' experience of growing fodder shrubs.

The study methodology is described in more detail in the unpublished report, and in the published paper (AgREN report), both of which are included in the Annex[1].

OUTPUT 2: CALLIANDRA ADOPTION STUDIES

Two studies were commissioned to investigate different aspects of fodder shrub adoption in the region. The first was conducted in central Kenya, in an area where there had been intensive promotion of calliandra through farmer groups under a previous project at ICRAF. The specific objective of this study was to find out the degree to which farmer groups and their members in central Kenya disseminate fodder shrubs, what types of planting material they disseminate (seed, seedlings, and wildlings) and to whom. With formal extension systems in decline throughout Africa, such information can help policy makers understand the degree to which farmer-to-farmer dissemination can substitute for or complement formal extension services, and how to promote it.

The other study was carried out in Rwanda, because although calliandra has been promoted in Rwanda since the late 1980s, no study has previously been conducted on its adoption by farmers. The ICRAF/ISAR[2] project has been promoting calliandra for fodder, soil conservation, and stakes since 1994. The objective of this study was to assess factors affecting adoption in contrasting sites which had received support from that project.

1. Farmer to farmer dissemination of fodder shrubs in central Kenya

Steven Franzel, Charles Rufuata, Tutui Nanok, and Charles Wambugu, ICRAF

During 1999-2001, ICRAF assisted 48 farmer groups in Central Kenya, comprising about 2,000 farmers, to plant fodder shrubs. Most of the groups were pre-existing; their main activities included dairy goat production, soil conservation, water tanks, and credit. ICRAF staff provided the groups with planting material and technical assistance. In 2002, three years after planting, we identified a random sample of 14 farmer groups in Nyeri, Embu, Kirinyaga, and Maragua Districts. Group leaders were interviewed about the dissemination activities of their groups. Ninety-four members (seven per group) were selected randomly from group lists and interviewed about their dissemination activities. Finally, from the interviews with these "first-generation farmers" (farmers who received planting material and information from ICRAF), we drew up a list of "second-generation farmers" (farmers who received planting material from the first-generation farmers). From this list, we randomly selected and interviewed 55 farmers.

2. Socioeconomic factors affecting the adoption of calliandra in Rwanda

L. Dusengemungu, ISAR, Butare, Rwanda and the late C. Zaongo, ICRAF.

Three sites were selected in Rwanda on the basis of contrasting environmental characteristics (Table 13). In Butare, during 1997/98, the project had distributed seedlings to farmers who had volunteered at village meetings to plant them. For the survey, we selected 17 farmers who had planted and 17 who had not planted. In Gikongoro, we selected four farmers near an ICRAF/ISAR demonstration plot who had planted some shrubs that had been left over when establishing the

[1] R6549-FTR-Phase 2 Output 1-Nyeko 2003; R6549-FTR-Phase 2 Output 1-Nyeko 2004
[2] Institut des Sciences Agronomiques du Rwanda (Rwanda Agricultural Research Institute)

site. We also selected 26 other farmers in the village who had not planted. In Umutara, farmers were selected around a village nursery which had been set up to distribute seedlings to farmers. Eighteen farmers who planted and 12 who did not were selected. The overall sample thus included 124 farmers, of whom 56 had planted calliandra and 68 had not. The farmers were interviewed in 2002. Survey results were shared with farmers, which enriched the quality of the findings.

Table 13: Site characteristics (Rwanda)

District	Province	Ecozone
Save and Nyakizu	Butare	Plateau, 1400-2100 m
Mudawomwa	Gikongoro	Highlands, 1800-2800 m
Muvumba and Kahi	Umutara	Savannah, 1200-1600 m

The study methodology is described in detail in the unpublished thesis (in French) which is included in the Annex[1].

OUTPUT 3: ASSESSMENT OF THE IMPACT OF CALLIANDRA

Two studies were carried out to estimate the profitability of using calliandra as a fodder. The first of these was conducted in Uganda; the second, in central Kenya, also compared the economic impact of calliandra with that of desmodium. Both studies were written up as M.Sc. theses. The methodology of each is described in detail in the unpublished theses, which are included in the Annex[2].

1. Socio-economic and farmers' perceived environmental impacts of calliandra in Uganda: a case study in Mukono and Kabale Districts

F. Mawanda, Makerere University, Kampala, Uganda

Calliandra has been promoted in Uganda since 1987 by research organisations and NGOs, mainly for soil conservation and firewood. The overall objective of the study was to determine the potential and current socio-economic impacts of calliandra at the plot, household and community levels, as well as the environmental impacts perceived by farmers. The specific objectives were to determine the primary reasons for planting and the primary benefits derived from calliandra; to assess the cost of calliandra seedling production and assess the costs, returns, and economic impact of Calliandra use as fodder; and to establish farmers' own perceptions of both economic and environmental impacts of calliandra.

A questionnaire was administered to 93 households to determine the reasons for planting and the benefits from calliandra. The economic profitability of planting calliandra was assessed, and the incremental cost and benefits in milk production estimated. Data were collected from nine calliandra nurseries. Data on labour were collected using recall and observation methods. Three farmers' workshops were held in Mukono District, and three in Kabale District, to determine farmers' perceptions of the environmental impacts of calliandra. A total of 59 farmers, of whom 47 were adopters, attended the workshop in Mukono, while 52 farmers, of whom 27 were adopters, attended in Kabale.

2. Socio-economic analysis of fodder legumes: the case of calliandra and desmodium in smallholder dairy farms of Embu district, Kenya

S. Koech, Egerton University, Njoro, Kenya

Previous research in central Kenya has shown that desmodium and calliandra can be integrated into existing farming systems, resulting in substantial benefits. The purpose of this study, conducted in Embu District, was to examine the economic benefits of these legumes when they are used as a

[1] R6549-FTR-Phase 2 Output 2-Dusengemungu 2002
[2] R6549-FTR-Phase 2 Output 3-Mawanda 2004; R6549-FTR-Phase 2 Output 3-Koech 2004

supplement to increase milk production, particularly with reference to differing access to markets, to different cattle management levels, and to gender. Current uses of the fodder legumes, as well as farmer innovations based on farmers' experience with the technology, were also assessed. Factors affecting farmer innovation were analysed using the logit model.

Data was collected from a randomly selected sample of farmers. It comprised 56 calliandra and 24 desmodium farmers; 20 of the 24 desmodium farmers also had calliandra. Formal personal interviews with structured questionnaires were used to collect primary data from farmers who had adopted calliandra and desmodium, so as to develop an understanding of the performance of these fodder legumes from the farmers' perspective. Information on farm and household characteristics was also collected using the structured questionnaire. The formal interviews were supplemented with field visits and farm observations to determine the farmers' innovations and current uses of fodder shrubs.

The 20 farmers with the highest number of calliandra trees were selected for determination of net benefits of calliandra. We chose farmers with many trees because farmers with low numbers were not likely to discern impact on milk production. Ten farmers or groups with fodder shrub nurseries were identified, and all of them were interviewed to determine the costs associated with establishment of calliandra seedlings.

Partial budgets were used to analyse data to determine the net benefits when fodder legumes were used as a supplement under different scenarios. Gross margins for major enterprises (maize and coffee) were evaluated using secondary data. The sets of data were then combined in a linear programming model in order to determine the maximum yearly net return of fodder legumes. Descriptive statistics were also used.

OUTPUT 4: DISSEMINATION AND PROMOTION OF FODDER SHRUBS

C. Wambugu, H. Arimi, J. Kugonza, B.D. Sande, C. Lyamchai, M. Kingamkono, the late C. Zaongo, and S. Franzel

Output 4 was concerned principally with scaling up the uptake, adoption and application of fodder shrub technologies in the East African region, rather than with formal experimentation. The project's promotion activities were focused on six sites in the four countries, as follows:

- Kenya: Central Province
- Kenya: Western Province
- Uganda: Lakeshore (Kampala peri-urban), Mukono & Wakiso Districts
- SW Uganda: Isingoro South, Mbarara District
- Tanzania: Kilimanjaro
- Rwanda: Kigali-Ngali (peri-urban), Byumba, Gisenyi

In order to maximise our impact, we provided training and technical backstopping to a range of extension providers, rather than training farmers directly. For this reason our staff were called "dissemination facilitators" rather than extension specialists. Staff were employed specifically by the project to take responsibility for our activities in central Kenya (Charles Wambugu, who also had overall responsibility for all the project's field extension activities), western Kenya (Hellen Arimi) and Uganda Lakeshore (Jane Kugonza). Activities in Tanzania and SW Uganda were led by staff of partner organisations: Charles Lyamchai and Margaret Kingamkono from SARI in northern Tanzania, and Sande Dickens and Peter Alele from FORRI[1] in Uganda. However in both these areas the project also directly supported village level extension staff (Dickson Beinomugisha in SW Uganda, Dauson Lyimo in Tanzania), because the team leaders had a range of other responsibilities in addition to the fodder project. In Rwanda, the project was managed by the late Christophe Zaongo, the ICRAF team leader in Rwanda, until his tragic and untimely death in early 2004; since then the work in Rwanda has been continued by David Kagoro, as part of a larger fodder initiative funded by the World Bank, but without further funding from DFID/FRP. Several ISAR staff have also supported our work in Rwanda, particularly Télesphore Ndabamenye, Gilbert Ndizeye and Thomas Gakwavu.

[1] Forestry Resources Research Institute, Uganda

There are many socio-economic and cultural differences between the six sites, as well as the extent of previous experience with calliandra and other fodder trees. This has meant that, although we were not formally testing different extension approaches under Output 4, our experiences in a range of different situations have enabled us to identify key elements for successful scaling up of fodder technologies. Some of these are general in application, others more site- or situation-specific.

Our activities have focused mainly on training and the provision of seed; though we see the latter as a temporary intervention, giving farmers initial materials with which to start, but with the expectation that in future they will either buy seed or collect it from their own trees. Our training activities are discussed in more detail below. Another approach which we have found to be highly effective is farmer exchange visits. A visit by farmers from the Kilimanjaro area of Tanzania to Embu, Kenya in 1999 had a clear motivating effect on the participating farmers, even four years later. Such international exchange trips are expensive, and visits under the present project have been much more local (e.g. within SW Uganda and western Kenya, respectively), but nonetheless highly appreciated by farmers, to the extent that in Uganda they were prepared to cover their own transport costs. In central Kenya farmers in new sites have gone even further: they have covered the full costs of field tours to sites where adoption is high, and have even invited the extension staff to accompany them as a way of ensuring that future follow-up occurs during the implementation phase.

A central element of our approach, at all sites, has been to work as far as possible with partner organisations. The partners include governmental extension services, international and national NGOs, and small community-based organisations (CBOs), who are either already specifically interested in promoting fodder, or who work in related areas of agricultural or livestock development to which they can add value by including fodder in the package they offer to farmers. The collaboration has been most fruitful when the partner has a clear vision of this value addition: for instance several international NGOs, including Heifer International, Farm Africa and Africa Now, provide improved dairy cows or goats to farmers, but with the condition that they must first plant enough fodder to support the animal, so there is a ready-made demand which means that the NGO is likely to welcome collaboration.

Our experience of working through partners has been more positive at some sites than at others. In some areas, particularly in Kenya, there is a proliferation of small local NGOs and CBOs concerned with livelihoods issues, who can readily incorporate fodder into the package they are offering to smallholders, without needing to divert resources from other activities. However in other cases, where the partner has a wide-reaching mandate, the staff may have many other responsibilities and so be unable to give a sufficient priority to fodder-related activities.

Where suitable partners exist, we have found it highly cost-effective to focus our training on partners' extension staff, because each extensionist we train can then pass the knowledge on to a large number of farmers, giving a multiplier effect. This has been the main dissemination approach used by the project. We have organised training sessions for extension staff from partner institutions and farmer leaders, focusing on technical aspects related to fodder shrub production, management and utilisation. Many agricultural extension providers have had little previous exposure to fodder technologies. Training materials such as pamphlets, posters and leaflets were also provided for the trainees. Fodder shrub articles have also been submitted by project staff to magazines that focus on farmers and this have been useful in creating awareness to a wider audience. In Rwanda, the project targeted the primary school children through messages that were put on the covers of exercise books.

In most areas, notably central and western Kenya, Uganda-Lakeshore, and Rwanda, it was possible to develop a strong network of partners; but in SW Uganda and northern Tanzania there were fewer potential partners so we focused more on working directly with farmers. This is reflected in the lower numbers of farmers reached, as we could not benefit from the multiplier effect of training trainers.

When working directly with farmers, we have maximised the impact of our training activities by working mainly with groups rather than with individual farmers. We have usually found group nurseries to be the most effective way to raise seedlings initially, though later, once the group

members are conversant with the technology, many prefer to set up small individual nurseries. Wherever possible we have worked with pre-existing groups (often set up previously by our partners), though we have also formed groups specifically for training purposes in some areas. In SW Uganda, for instance, these groups were formed at the parish level by coordinators who were voted for by the community.

Project impact: numbers of farmers planting

We have attempted to quantify the effectiveness of our approach by monitoring and recording the numbers of farmers receiving training, and subsequently planting (though within the three-year time scale of the project it is not possible to estimate longer-term adoption or economic impact). To put this is the context of the overall scale of adoption of fodder technologies, we have also tried to estimate the total numbers of farmers adopting the technology at a national level, in Kenya and Uganda. The methods we used included farmer surveys (e.g., farmer to farmer dissemination of fodder shrubs: see Output 2), secondary information, and surveys of partners. This was an additional activity which does not correspond directly to a project output, but a short report of it was published in the ICRAF *Prunus* newsletter, and this is included in the Annex[1].

Project maturity workshop

An important dissemination activity within the project was the project maturity workshop held at ICRAF, Nairobi in June 2004. This is described in detail in a report by Josina Kimotho, ICRAF, which is included in the Annex[2].

OUTPUT 5: SUSTAINABLE SEED DISTRIBUTION AND MARKETING SYSTEMS FOR CALLIANDRA

TechnoServe, Nairobi, Kenya

The full report of this study is included in the Annex[3].

Adequate and sustained supply of planting materials is a problem wherever calliandra planting is expanding. There seems to be little spontaneous development of market-driven seed or seedling production. This study, carried out by TechnoServe/Kenya in collaboration with ICRAF staff in Kenya, explored the current distribution and marketing systems for calliandra planting material, identifying constraints and suggesting options for the development of more sustainable systems.

The key objectives of the study were:

I. To analyse the status of the existing calliandra planting material (seed & seedling) production, distribution and marketing scenarios in Kenya.

II. To define key factors for sustainable calliandra seed/seedling production, distribution and marketing in Kenya. The following issues were explored:

   a. Farmer's motivation to produce planting materials for calliandra.
   b. Why a sustainable private sector seed-marketing system has not developed.
   c. The circumstances where, and extent to which, calliandra seeds/seedlings can be promoted through the private sector; and when other subsidised channels need to be used.
   d. Steps that ICRAF and Technoserve can take to facilitate a sustainable seed/seedling supply system.

The study was conducted in central and western Kenya in areas where ICRAF and partners have facilitated calliandra seed production and tree planting.

A stratified purposive sample was taken, to cover the range of existing scenarios for calliandra production, distribution and marketing along the whole market chain. Owing to resource constraints, a very limited sample was taken from each of the following categories:

[1] R6549-FTR-Phase 2 Output 4-Franzel et al 2005
[2] R6549-FTR-Phase 2 Output 4-Kimotho 2005
[3] R6549-FTR-Phase 2 Output 5-Technoserve 2003

1. Individual dairy farmers who grow and use calliandra in the central highlands of Kenya
2. Key informants from institutions involved in agroforestry development such as MoARD, KARI, churches, development departments, NGOs and CBOs
3. Commercial seed farmers/vendors in Western Kenya
4. Farmer group nurseries and private nurseries (seed/seedling sellers)
5. Farmer groups involved in agroforestry activities
    a. Successful groups
    b. Unsuccessful groups

A total of 44 interviews were conducted, as follows:

Category	**Central**	**Western**	**Total**
Individual calliandra farmers	10	-	**10**
Institutional key informants	10	3	**13**
Commercial seed farmers/Vendors	-	7	**7**
Seed/seedling sellers	6	2	**8**
Farmer groups	4	2	**6**
Total	**30**	**14**	**44**

OUTPUT 6: DECISION SUPPORT TOOL AND EXTENSION MANUAL DEVELOPED AND DISSEMINATED.

In Output 6 we aimed to capture our experiences on the project and the key findings of our research in a document that would be of day-to-day use to field extensionists working directly with farmers. Initially two separate documents were drafted: a decision support tool intended for extension managers, and an extension manual for front-line field staff. These documents were reviewed by invited extensionists at a workshop in Nairobi in July 2005. The reviewers felt that in many organisations the distinction between managers and field workers was too blurred to be useful, and that the two documents should be combined into one. There was also the feeling that the language was too complex in places. The full workshop report is included in the Annex[1].

The reviewers' comments were addressed through a substantial re-write to combine the documents and simplify the language. Because of this the production of the manual was considerably delayed. It is now in press, but at the time of writing printed copies are not yet available. However the final draft is included in the Annex[2].

OUTPUT 7: DETERMINANTS OF EFFECTIVE FARMER-TO-FARMER DISSEMINATION IN CENTRAL KENYA IDENTIFIED.

(A) THE IMPORTANCE OF EXPERTISE AND INNOVATION, AS DETERMINANTS OF THE EFFECTIVENESS OF FARMERS AS DISSEMINATORS, ASSESSED.

(B) EXPERTS, INNOVATORS AND DISSEMINATORS OF TREE TECHNOLOGIES CHARACTERISED.

Farmer-to-farmer extension is a way of accelerating the diffusion of new technologies and innovations, particularly in countries such as Kenya where the delivery of extension services by both governmental and non-governmental extension providers has been declining over the years. However, it is not well understood why some farmers are good at disseminating new technologies while others are not. One possibility is that the farmer's personal characteristics (such as gender, age or wealth status) could influence his or her effectiveness as a disseminator; another is that personality traits could be important. Previous research has indicated that farmer trainers (disseminators), who are themselves innovative, are more successful in farmer-to-farmer extension. Research in the United States, on the other hand, has shown that experts and disseminators of a technology have different personality characteristics which are rarely combined in a single person.

[1] R6549-FTR-Phase 2 Output 6-Cordero 2005
[2] R6549-FTR-Phase 2 Output 6-Wambugu et al 2006

Output 7 comprised two closely linked studies (corresponding to Outputs 7a and 7b above) to investigate how different personal attributes and personality traits in farmers influence their effectiveness in farmer-to-farmer dissemination of fodder shrub technologies in the East African context. The two studies are summarised here, and the full reports are included in the Annex[1].

(a) Factors influencing the effectiveness of farmers as disseminators of fodder shrubs in the Central Kenya Highlands

C. Wambugu, World Agroforestry Centre, Nairobi, Kenya

The purpose of Output 7a was to identify some of the factors that influence farmer-to-farmer dissemination of fodder shrubs among the smallholder farmers in four districts in the central highlands of Kenya, particularly with regard to farmers' personal characteristics and extension institutional factors. We also assessed whether expertise, innovation, and dissemination are characteristics which are associated in a single individual. To do this, we needed to score individuals on these characteristics and then assess whether the scores are correlated among the three categories.

The specific objectives were to:

1. Identify and assess farmer's personal characteristics that influence farmer-to-farmer dissemination of fodder shrubs among the smallholder farmers in the central highlands of Kenya.
2. Investigate if farmers who are knowledgeable, skilled, innovative and experienced (farmer experts) on fodder shrubs are also good at disseminating the shrubs to other farmers in the study area.
3. Investigate from the farmers' perspective the extension institutional factors that influence farmer-to-farmer extension in the study area.
4. Estimate the extent of diffusion (spread) of fodder shrubs through farmer-to-farmer extension in the study area.

The study centred on a questionnaire survey of 113 randomly selected farmers who had adopted fodder shrubs (an adopter was defined as a farmer who had planted at least 100 shrubs). The questionnaire gathered both qualitative and quantitative information relating to the extent and effectiveness of farmer-to-farmer dissemination, and the factors affecting this (for Objectives 1 and 3); and to the indices of expertise, innovation and dissemination which form the basis of Objective 2. These indices were designed to test the hypothesis that expertise, innovation, and dissemination are characteristics which are associated in a single individual. We defined criteria which could be used as indicators for each of these traits, and weighted them according to their relative importance. We scored each farmer according to the weighted criteria, and then assessed whether the scores were correlated among the three traits.

The statistical analyses relating to Objective 1 explored the association between the farmers' personal characteristics and the extent to which they disseminated planting material and information to other farmers. The personal attributes which were tested for their effect on farmer-to-farmer dissemination were: gender, age, education level, main occupation, leadership position, and wealth status. The extent to which a respondent had disseminated to others was measured by (a) the number of farmers to whom (s)he had given planting material, and (b) the number to whom s(he) had given both planting material and information.

Objective 3 similarly explored the effect of extension institutional factors on the extent of dissemination by the respondent. In this case the amount and effectiveness of extension provision was estimated by (a) the number of contacts per year that the respondent had had with extension providers, and (b) the number of different sources of extension information that s(he) had accessed. The extent of the respondent's dissemination activity was estimated in the same way as for Objective 1.

[1] R6549-FTR-Phase 2 Output 7a-Wambugu 2006; R6549-FTR-Phase 2 Output 7b-Nanok 2006

For both Objective 1 and Objective 3, the statistical analysis used included correlations (Pearson Product-Moment correlation, r), t-test and analysis of variance (ANOVA).

To assess the association between the three traits (expert, innovator and disseminator) under Objective 2, data on each farmer's index scores were subjected to a loglinear analysis of a three-way contingency table. This is a multi-way generalisation of the chi-squared analysis which would have been appropriate if there were only two variables.

(b) Characterisation of experts, innovators, and disseminators of fodder shrub technologies in small holder dairy farming communities in central Kenya

T. Nanok, World Agroforestry Centre, Nairobi, Kenya

The purpose of Output 7b was to characterise experts, innovators, and disseminators in more detail, by describing them in terms of personal, farm, and household characteristics. The specific objectives were to:

a. Assess whether members of farmer groups are accurate sources of information for identifying experts, innovators, and disseminators of fodder shrubs technologies.
b. Describe experts, innovators, and disseminators in terms of personalities, farm, and household characteristics
c. Identify and asses the factors that motivate farmers to be experts, innovators, and disseminators, from these farmers' own perspectives.
d. Assess the views of experts, innovators, and disseminators and those of farmer groups on how researchers and extension staff can support experts, innovators, and disseminators in implementing farmer-based research and extension programs.
e. Describe the innovations/experiments farmers make how they test them and the decisions they make as a result.

As in Output 7a, most of the information was gathered through a formal questionnaire survey. Participant observation was also used, to assess innovation by farmers as well as evidence of expertise in the use of fodder shrubs. The study required a minimum sample size of 45 for each of the three categories (expert, innovator, disseminator), and this would probably not have been achieved through the random sampling approach used in Output 7a. We therefore decided on a purposive sampling strategy for Output 7b, asking representatives of farmer groups to name experts, innovators, and disseminators to be interviewed.

The original plan had thus been that the two studies would use different (but possibly overlapping) samples. In practice, however, we found that farmers were unable to distinguish clearly among the three categories (in other words, the answer to the question implicit in Objective a was "No"), so we ended up using almost the same sample of farmers as in Output 7a. Because the number of expert farmers in that sample was insufficient, however, we added 13 additional expert farmers to the sample in order to get the required number.

Each respondent was given an index score for each of the three traits, as described above for Output 7a. The highest scoring group for each trait (around 45 farmers in each case) were defined as experts, innovators and disseminators respectively. These groups were compared with the lower-scoring respondents, to identify defining characteristics for each trait (Objective b). The respondents were also asked to identify factors motivating them to the experts, innovators and disseminators respectively (Objective c). Objective d was addressed through a series of case studies, and Objective e through survey questions addressed to the innovator group.

OUTPUT 8: PROCESSING & MARKETING OF LEAF MEAL FROM FODDER SHRUBS PROMOTED.
Franzel, S., Wambugu, C., Nanok, T., Kavana P., Njau T., Aithal, A., Muriuki, J., and Kitalyi, A., World Agroforestry Centre, Nairobi, Kenya.
The full report of this study is included in the Annex[1].

The marketing and processing of raw materials is an important means for increasing smallholder incomes and generating employment. In East Africa, the production and use of fodder shrubs has rapidly increased over the last 15 years but processing and marketing are relatively minor, with one exception, around Tanga, Tanzania. There, in north-eastern Tanzania (Tanga, Pangani and Muheza districts), near the Indian Ocean, leaf meal is widely processed and marketed.

The overall objective of the study was to promote the processing and marketing of leaf meal for improved livestock production. Specifically we:

1. assessed the market chain for leaf meal in Tanzania from production through to final use, including the costs and returns at each stage of the chain, the number of men and women employed in the system, the income generated, and the wealth rank of these persons.
2. identified the constraints and opportunities faced by different market participants (collectors, processors, transporters, stockists, and livestock farmers).
3. assessed the feasibility of using leaf meal in commercial feed manufacturing as a substitute for imported protein sources.
4. sensitised and trained selected participants (farmers, farm input stockists and extension staff) from central Kenya on the mechanisms involved in production, collection, processing, transportation and marketing of fodder shrub leaf meal for livestock farmers.

Market chain and sub-sector analysis were used to characterise the fodder shrub industry. The study began with a rapid reconnaissance survey conducted by a multi-disciplinary team. The team returned to the study area for a second survey and to organise the formal questionnaire survey. Team members designed three different questionnaires for each of the main actors in the sub-sector: collectors, traders, and consumers. Sample frames were unavailable for the three groups, rather quota sampling was used to interview 28 consumers, 11 traders, ten collectors and five stockists. Extension staff and interviewees themselves assisted in identifying other persons to be interviewed.

OUTPUT 9: STUDY TO ASSESS THE IMPACT OF FODDER SHRUB EXTENSION IN EAST AFRICA PLANNED AND PREPARED.
S. Franzel, World Agroforestry Centre, Nairobi, Kenya
The full report of this output is included in the Annex[2].

Over the last decade, many organisations have been involved in promoting fodder shrubs to farmers in East Africa. These organisations use a range of different extension approaches and have quite varied objectives, staff and physical resources, knowledge and skills. Similarly, the farmers they work with vary in many different ways: biophysical and socio-economic environment, the types of assets and resources that they have access to, and their proximity to markets. Researchers, extension managers and policy makers often discuss key factors contributing to successful extension programmes, but there is little empirical evidence, especially with regard to agroforestry. The factors influencing success are likely to be different from those for other agricultural practices, because agroforestry is more complex, long-term, and knowledge-intensive than most types of agriculture.

[1] R6549-FTR-Phase 2 Output 8-Franzel et al 2006
[2] R6549-FTR-Phase 2 Output 9-Franzel 2006

The overall objective was to complete a survey of extension providers and plan a study assessing the impact of fodder shrub extension across four countries of Eastern Africa. Specific objectives were to:

1. assemble an inventory of organisations and government agencies promoting fodder shrubs in each country.
2. assess organisation-level factors affecting the quantifiable impact of fodder shrub extension (number of farmers trained, numbers of farmers planting, and numbers of trees per farmer).
3. assess organisations' perception and record of their impact in fodder shrub extension, including data they collect on numbers of farmers trained, planting, and using fodder shrubs, and economic impact.
4. determine organisations' views on the key factors that contributed to success or lack of success in achieving impact, including meeting the needs of farmers, building relevant partnerships, understanding the socio-economic context and skills of farmers, participatory involvement with rural communities, and long-term involvement of champions.
5. plan a second phase for this research: a survey of farmers reached by the above organisations, to assess the impact of fodder shrubs on their farms and their perceptions of the key factors contributing to their achievements.

In Kenya, Uganda, and Rwanda, researchers assembled lists of organisations promoting fodder shrubs, based on lists of buyers of fodder shrub seed which they obtained from the national seed service and other seed sellers. Key informants also supplied names of organisations, especially government extension services, which promote fodder shrubs without buying seed. In Tanzania, only key informants were used as lists from the government seed service were not available.

A team of researchers and extension providers from the four countries identified the impact indicators and organisation-level factors thought to influence impact.

From the sample frame, 70 organisations were selected for the survey of organisations, across four countries. The main objective of the organisation-level survey was to pre-test a questionnaire for identifying impact indicators, measuring impact, and assessing organisation-level factors affecting impact. The survey was also useful for assessing the sample organisations' perception and record of their impact, and their views on key factors that contributed to impact. It was also the basis for preparing for the next phase of the study.

Outputs: Phase 2 (2001-2006)

OUTPUT 1: FARMERS' EXPERIENCES IN CALLIANDRA MANAGEMENT AND UTILISATION

1. Informal survey of calliandra utilisation, Moshi Rural District, Tanzania

M. Kingamkono & C. Lyamchai, SARI[1], Arusha, Tanzania

The survey showed that, in general, farmers are well aware of the good qualities of calliandra and are eager to grow more. Of the three altitudinal bands into which the slopes of Mt Kilimanjaro are divided, the survey found that calliandra grew well in the Upland zone owing to high rainfall, whilst in the Intermediate zone supplementary irrigation was needed to optimise its performance. It largely failed in the Lowland zone, however, owing to low rainfall and a free-grazing system. Those farmers with more than 100 calliandra trees who had started feeding their dairy animals reported an increment of up to one litre per milking. They also reported that calliandra is very palatable to livestock, reduces the amount spent on commercial concentrates by 50%, and saves time otherwise spent looking for fodder. However, despite the fact that calliandra is seen as a useful fodder plant in the surveyed villages, the majority of farmers do not have the enough plants to realise its full potential. Unavailability of seeds and seedlings is a major limitation to expansion of calliandra growing; another is pests and diseases, especially in the Intermediate zone. Continuing joint efforts by different partners are therefore needed to train farmers in pest and disease management, seed harvesting and processing, and nursery establishment. The majority of farmers in the area have diversified the species they use for fodder, mainly by planting *Morus alba*, *Leucaena trichandra* and desmodium.

The survey findings are described in more detail in the unpublished report which is included in the Annex[2].

2. Farmers' experiences in the management and utilisation of calliandra in Uganda

P. Nyeko, Makerere University, Kampala, Uganda

The study found that farmers established calliandra using nursery-raised seedlings, direct seed sowing in the field, or through maintenance of wildlings. Whereas farmers' decisions on the use of nursery seedlings and direct sowing seemed largely dependent on advice from organisations promoting calliandra, the use of wildlings was mainly attributed to farmers' own innovations. The farmers participating in the survey had, on average, 924, 626 and 362 calliandra trees per household in the Southern Drylands (SDL), Southern Highlands (SHL) and Lake Victoria Crescent (LVC) respectively. The most preferred planting niche was field boundaries, mainly for soil conservation. A few farmers planted calliandra around apiaries and fishponds, which are relatively new niches for calliandra in Uganda. Farmers performed several tending operations including weeding, replacement planting, crown and root pruning, and manure application for their calliandra, using a wide range of hand tools. Most farmers had received relevant advice from organisations and/or individuals on how to do the different tending operations, except weeding which was largely based on their experience with crops.

Findings of this study indicate that farmers were aware and concerned about some pest problems on calliandra, but they lacked advice on pests and diseases that attacked the species. The most damaging health problem on calliandra was a dieback disease. Insect pests that may become important on calliandra, and thus require regular monitoring and control, include a scale insect, *Pulvinarisca jacksoni* (Newstead), and a termite species, *Marcrotermes subhyalinus* (Rambur). Other damaging agents reported by farmers included livestock, humans, birds and wild mammals. Farmers who attempted to control pest problems on calliandra relied on their own indigenous knowledge and experience. As technologies associated with calliandra are developed and promoted, there is a need to incorporate information on the diagnosis and management of pests and diseases of the shrub in dissemination packages.

[1] Selian Agricultural Research Institute
[2] R6549-FTR-Phase 2 Output 1-Kingkamkono & Lyamchai 2003

Farmers cultivated calliandra for various products and services, the most important being fodder, which they fed to cattle, goats, sheep, rabbits, pigs, poultry and fish. Very few farmers fed cows on dairy meal concentrates, mainly because of the high cost of the concentrates compared to low financial returns from milk. This indicates a high potential for using cheap protein-rich tree fodders such as calliandra in small-scale dairy enterprises. There is a need for deliberate government policies to improve the processing and marketing of milk in order to maximise the profitability of such innovations.

The survey findings are described in more detail in the published AgREN paper and the unpublished report, both of which are included in the Annex[1].

OUTPUT 2: CALLIANDRA ADOPTION STUDIES

1. Farmer to farmer dissemination of fodder shrubs in central Kenya

Steven Franzel, Charles Rufuata, Tutui Nanok, and Charles Wambugu, ICRAF

Farmer groups and members who disseminate. Group size averaged 18 (10 males and 8 females). All 14 groups reported that they reached out to non-members with messages on fodder shrubs. Ten groups invited outsiders to group functions, five invited others to visit their farms and nurseries, two held field days, and two visited schools to educate teachers and school children. Ten of the fourteen groups distributed or sold seedlings. Four of the groups also gave out or sold seed to non-members. Overall, the groups gave out or sold seed and seedlings, on average, to 18 farmers. Two-thirds of recipients were male farmers and three-quarters were in the village where the group was based.

In the group member survey, 57% of respondents were male and 43% female. Respondents on average were 53 years old, had seven years of education, and 2.4 ha of land. Seventy-six percent had a dairy cow, 37% had a dairy goat. Farmers had an average of 352 fodder shrubs. Male farmers had significantly more shrubs than females: 454 for males as compared to 212 for females (t-test, $p<0.01$). Men also tended to have their own nurseries more often than women (39% vs. 18%), which may explain why they had more shrubs.

Over half (55%) of the group members gave out calliandra planting material to non-members. A slightly higher proportion of men gave out planting material than women and each tended to give out different types of planting material. Female members tended to give out more seedlings that they had received from group nurseries than males. Male members gave out more seedlings from their own nurseries than females (all farmers received seedlings from group nurseries whereas men had more private nurseries than women). Both men and women gave out seed from their shrubs in roughly equal proportions. Most groups gave out seedlings from their nurseries, some also gave out seed (Table 14).

On average, each group member gave out calliandra planting material to 6.3 farmers outside their group. Of this total, individual members distributed material to 5.3 farmers while groups distributed to 1.0 farmer per group member. The most common types of planting material that farmers gave out were seed from their shrubs, seedlings from their own nurseries, and seedlings that they had received from group nurseries (Table 14).

Dissemination of planting material was highly concentrated: five farmers (5% of the total) accounted for 66% of all dissemination. The eight who disseminated to 12 or more other farmers were a varied group. Five were male while three were female. Four were officials of their group while three were ordinary members. Their median age, farm size, and number of years of education were about the same as for the entire sample. The proportion that had been visited by researchers and extensionists was higher than for the sample, five out of eight as compared to one-third, respectively. The strong disseminators had more trees (454) than the sample mean (352).

[1] R6549-FTR-Phase 2 Output 1-Nyeko 2003; R6549-FTR-Phase 2 Output 1-Nyeko 2004.

Second-generation farmers. Recipients of calliandra planting material were overwhelmingly male; women accounted for 37% of farmers disseminating but only 25% of the farmers receiving planting material (Table 15). Apparently, even if a woman brings seed or seedlings onto the farm, men often give out planting material to others, and they tend to give to other men. Recipients of seedlings received on average 38-49 seedlings if the source was a nursery and eight seedlings if the source was wildlings. Farmers tended to give out seedlings from group nurseries to relatives, whereas other types of planting material such as seedlings from own nurseries, wildlings, and seed from own shrubs were given mostly to friends. Other people (neither friends nor relatives) accounted for between 5% and 40% of recipients, depending on the type of planting material.

Table 14: Farmer-to-farmer dissemination: proportions of group members and groups giving out planting material and mean numbers of farmers receiving different kinds of planting material

	% of group members and groups giving out planting material to non-members			Mean no. of farmers receiving planting material		
Source of planting material	% of men members	% of women members	Total % of members	Men farmers	Women farmers	Total no. of farmers
Individual group members						
-Seedlings farmers received from group nursery	28	38	32	0.6	1.8	1.1
-Seedlings from farmers own nurseries	17	10	14	2.6	0.3	1.6
-Seed from farmers own shrubs	22	20	21	3.1	0.7	2.0
-Wildlings	15	5	11	0.3	0.1	0.2
-Seed from farmers who got seed from group	9	8	9	0.6	0.2	0.4
Groups						
Seedlings from group nurseries	-	-	71	0.6	0	0.5
Seed from group	-	-	28	0.7	0	0.5
Total	**61**	**48**	**55**	**8.5**	**3.1**	**6.3**

Table 15: Recipients of planting material by gender

	Recipients of planting material		
Source of planting material	No. of men	No. of women	Total no. and % of recipients
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)
-Wildlings	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)**

Seedlings obtained from group nurseries were in almost every case given away for free. Private nurseries emerged somewhat later and 15% of second generation farmers receiving seedlings from private nurseries paid for their seedlings. Seed became available from farmers' own shrubs 1-2 years after the nurseries were started and 40% of those receiving tree seed from farmers' own shrubs paid for the seed. This increasing trend in commercialisation of planting material over time probably reflects the perceived increased value of fodder shrub planting material.

Fifty-one of the 55 second-generation farmers interviewed had fodder shrubs and one-quarter had over 100 shrubs, indicating their success in planting. Their high success rate may be due in part to sampling bias, because first-generation farmers were probably hesitant to give us the names of those who failed in planting shrubs. Most second generation farmers were unable to get as much planting material as they needed; 42% had fewer than 20 shrubs. The low numbers may also have reflected farmers' wishes to experiment with the shrubs before planting a lot of them.

Factors affecting dissemination. A series of farm and household characteristics were assessed to see if they were associated with farmer-to-farmer dissemination (Table 16). Three variables had significant associations: farmers with larger numbers of fodder shrubs, those who were visited by extension staff, and those visited by researchers tended to disseminate more than others. On the other hand, most household characteristics, such as gender, wealth, education, and age did not affect whether farmers disseminated or not. Surprisingly, farmers who had had nurseries did not disseminate more than those who had never had them.

Conclusion. The study demonstrated the importance of farmer-to-farmer dissemination in spreading the adoption of fodder shrubs in central Kenya. Whereas men and women are both active in disseminating, most of the planting material tends to go to males. Groups play an important role in dissemination but group members, acting as individuals, do far more in distributing information and planting material than do the groups themselves. Contact with research and extension is an important motivating force in farmer-to-farmer dissemination. More information is needed on which farmers account for most of the dissemination and how to motivate the groups and their members to disseminate more actively. Extension staff should not assume that only farmers with nurseries are active disseminators: farmers without nurseries do just as much dissemination as those with nurseries. This finding also supports the hypothesis that experts in practicing a technology, such as farmers with nurseries, are not necessarily the most active disseminators. Dissemination may not be best promoted by identifying 'contact farmers', farmers who are both experts and effective disseminators but by (a) identifying experts and effective disseminators separately, or by (b) working with farmer groups, which are likely to have both types of farmers. These ideas were explored further under Output 7.

Table 16: Factors associated with the giving out planting material to others

Significant association (p<0.05 for a chi square or t-test):
Number of fodder shrubs planted
Visited by extension staff
Degree of contact with ICRAF staff
Marginally significant association (0.05<p<0.10)
No variables
No significant association (p > 0.10)
Gender
Age
Years of education
Farm size
Wealth level
Ranking of dairy enterprise
Number of seed producing shrubs
Ever had own nursery
Ever hosted nursery for group
Membership in other groups
Whether or not holds office in group

2. Socioeconomic factors affecting the adoption of calliandra in Rwanda

L. Dusengemungu, ISAR, Butare, Rwanda and the late C. Zaongo, ICRAF.

In the adoption study in Rwanda, female-headed households made up 42% of the total sample. Women had significantly smaller farm size than men and were also significantly poorer. Eighteen of the 56 farmers planting calliandra had received between 101 and 500 seedlings, eight had received 51-100, and 27 had received between one and 50 seedlings. Farmers planted the seedlings mainly in fodder banks (pure plots). Uses of calliandra varied among sites: farmers in Butare used the shrubs primarily for stakes and fodder, while in Umutara the main uses were fodder and fuelwood.

The factors significantly associated with planting calliandra included:

1. *Family size*. Planters' family size averaged 5.6 as compared to 4.6 for non-planters.
2. *Age*. Planters' average age was 46 years, compared to 40 years for non-planters.
3. *Visits by extension staff*. Planters tended to be visited more than non-planters but these visits may have been more a result of planting than a cause.

For several other factors the association with planting was non-significant:

1. *Farm size*. Planters had only slightly larger farm sizes.
2. *Gender*. About 49% of planters were male, while only 40% of non-planters were male.
3. *Education*. About 75% of planters had attended school compared to 63% of non-planters.
4. *Wealth level*. Farmers identified four wealth levels in their communities: rich, medium, poor, and very poor. There were no significant differences in the wealth status of planters and non-planters. Of the rich and medium-income farmers in the sample, 51% had planted calliandra, compared to 40% of the poor and very poor. Of the 16 very poor farmers in the sample, eight had planted.

Farmers who had not planted stated that the main cause of non-adoption was lack of plants (62%), lack of land (23%), and lack of knowledge (12%). There were no significant differences between men and women respondents.

Conclusion. The planting of fodder shrubs at all three sites was based on the distribution of free seedlings to farmers. Farmers are empowered by learning how to establish nurseries, so that they can increase their plantings and not be dependent on outside organisations. Neither wealth status nor gender was associated with planting; this is a very positive finding suggesting that the poor and women can benefit from the practice as much as high-income groups and men. Similarly, farmers with small farms and no education appear to benefit as much as those with bigger farms and education.

The results are described in more detail in the unpublished report which is included in the Annex[1].

OUTPUT 3: ASSESSMENT OF THE IMPACT OF CALLIANDRA

1. Socio-economic and farmers' perceived environmental impacts of calliandra in Uganda: a case study in Mukono and Kabale Districts

F. Mawanda, Makerere University, Kampala, Uganda

The full report of this study is included in the Annex[2].

The purposes for which calliandra had been promoted, and therefore the farmers' main reasons for planting, were not necessarily the same as the primary benefits now perceived by the farmers. In Kabale, calliandra was promoted mainly for soil fertility improvement and as protection against erosion, whereas the benefit now cited by the most farmers was fodder production.

Supplementation of basal feed with calliandra and substitution of dairy meal with calliandra was found to be a profitable venture. Partial budgets economic analysis showed that in the case of supplementation a net present value (NPV) of US $ 132.80 to 172.85 and a net benefit per cow per

[1] R6549-FTR-Phase 2 Output 2-Dusengemungu 2002
[2] R6549-FTR-Phase 2 Output 3-Mawanda 2004

year after the first year of US $ 62.41 to 81.19 were realised. The annualised net benefit, considering the establishment cost as depreciation, is US $ 56.91 to 74.33. For the substitution scenario, a higher NPV of US $ 194.75 to 209.39, and a net benefit per cow per year after the first year of US $ 96.64 to 104, were realised. The annualised net benefit in this case, again considering the establishment cost as depreciation, was US $ 91.13 to 98.13. Sensitivity analysis showed that net present values and net benefits were positive even under a range of possible changes in key parameters such as lower milk prices, lower milk responses, or a reduction in dairy meal prices.

Most farmers in both districts have experienced positive economic, social and environmental benefits from calliandra, but a few farmers had negative experiences, notably competition with other crops. Calliandra was said also to harbour birds, which may destroy other crops.

The study concluded that calliandra is a useful multipurpose shrub in Uganda whose promotion should be encouraged in order to realise its full benefits in rural livelihoods. However, the quantification of all the impacts of calliandra would require use of a multidisciplinary approach to impact assessment.

2. Socio-economic analysis of fodder legumes: the case of calliandra and desmodium in smallholder dairy farms of Embu district, Kenya

S. Koech, Egerton University, Njoro, Kenya

The full report of this study is included in the Annex[1].

The study showed that calliandra farmers were getting higher net benefits compared to desmodium farmers; the differences were significant at p = 0.01 (t-test). Net benefits from using calliandra as a supplement averaged $43.67 per cow per year as compared to desmodium at $22.23/cow/year, using the actual quantities fed. However, the two legumes can be used as complements in production and not substitutes. Alternative enterprises, which were also considered, were maize and coffee. The results suggest a promising future for a combined production of agricultural and fodder legumes by smallholder dairy farmers.

Production costs per calliandra seedling ranged from $0.005 for bare-root seedling to $0.019 for potted seedlings. The median milk increase per 6 kg of fresh calliandra (the recommended daily feeding rate) was 1.35 kg, or 0.67 kg milk per 1 kg of dry calliandra. Farmers using calliandra as a supplement earned $65.50 per cow per year, when feeding 6 kg fresh calliandra per day.

In addition to being used as a fodder, the most important benefits of the legumes were improvement of soil fertility, utilisation as firewood and improved animal health. Other benefits included control of soil erosion, and revenue from the sale of either fodder or planting materials (seeds/seedlings). Farmers also modified extension recommendations or did some experiments on their own. Most experiments were done on calliandra, mainly on its uses. Innovations mentioned by farmers included drying calliandra and mixing it with bran for use as cattle or poultry feed; drying and mixing with indigenous fodder (*Muthatha* or *Mumbembu*) to feed goats; using the legume as compost when there is excess, especially during the rainy season; and intercropping calliandra and desmodium. Data from the farmer survey were analysed to assess the factors associated with farmer innovation. The results indicated education as the main socio-economic factor that significantly influenced the decision to innovate in the case of calliandra. The relationship was negative, that is more education was associated with a decline in innovation.

Calculating the profitability of using fodder shrubs to feed dairy cows

Koech, S., Egerton University, Njoro, Kenya; Mawanda, F., Makerere University, Kampala, Uganda; Franzel S., World Agroforestry Centre, Kenya

The results from the two impact studies have also been combined into an overall economic analysis of the profitability of calliandra. This provides a simple tool enabling extensionists and others to calculate the potential profitability of calliandra in any given situation, using coefficients and prices appropriate for their own area. We also compare two scenarios: (1) where calliandra is used as a substitute for commercial concentrate (dairy meal), and (2) where it is used as an additional supplement to the basal diet.

[1] R6549-FTR-Phase 2 Output 3-Koech 2004

First, two different scenarios are presented that can be used to calculate the profitability of calliandra for increasing milk production. Next, other unquantified costs and benefits are discussed. Finally, we present the profitability of calliandra under different scenarios and at different locations.

Scenario 1: calliandra used as a substitute for dairy meal

Some farmers use calliandra instead of dairy meal; they thus perceive the benefits of calliandra to be the money they save from not having to buy dairy meal. In the economic analysis, the costs and benefits of feeding a cow 6 kg of fresh calliandra a day are compared with the costs and benefits of feeding 2 kg of dairy meal, which is assumed here to have about the same quantity of digestible protein and gives roughly the same milk output. Assuming this substitution rate, we compare:

- the benefits of using calliandra, that is, the money saved by not purchasing and transporting the equivalent quantity of dairy meal for protein, with:

- the cost of using calliandra, that is, planting, cutting and feeding it. Planting costs (including the costs of raising bare-root seedlings) are modest-about $US 6 to $US 8 per 500 shrubs.

Beginning in the second year after planting 500 calliandra shrubs, a farmer's net income increases by about $US 101 to $US 122 a year by using calliandra as a substitute for dairy meal. The increases in income vary by site because of differences in prices and coefficients (Tables 17-18).

Scenario 2: calliandra used as a supplement to 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, rather it is viewed as a supplement. We compare:

- the benefits of using calliandra, that is, the value of the extra milk produced, with:

- the costs of planting, cutting and feeding calliandra.

Beginning in the 2nd year after planting 500 calliandra shrubs, a farmer's net income increases by about $US 62 to $US 115 a year by using calliandra as a supplement (Tables 17-18).

Other benefits and costs

The above analysis does not take into account several other benefits of calliandra:

- It increases the butterfat content of milk and therefore its 'creaminess'

- If used as a supplement, it may improve the cow's health and shorten the calving interval

- It provides firewood, fencing, boundary marking, and erosion control. Many also appreciate calliandra for its beauty!

The analysis also does not include the slightly negative impact that a calliandra hedge has on adjacent crops by shading them or interfering with their roots. It is also important to realise that calliandra may sometimes need to be fed at a higher level to substitute for the same amount of dairy meal, and this will reduce its profitability.

Table 17: Selected coefficients and prices used in the economic analysis

Items	Values
Coefficients	
Calliandra quantity fed per cow per day (equiv. to 2 kg dry)	6 kg fresh
Dairy meal quantity fed per cow per day	2 kg
Milk output per day from 1 kg dry calliandra	0.6-0.8 litre
Calliandra leafy biomass yield per tree in year 1	None
Calliandra tree biomass yield per tree per year, year 2–5	1.5 kg (dry)
Shrubs required to feed 1 cow per year	500
Labour in planting calliandra	20-28 shrubs per hour
Labour in cutting and feeding calliandra	30-40 minutes per day
Prices ($ US)	
Dairy meal	$ 0.16-0.17/kg
Seedling cost of production (bare-rooted)	$ 0.50-0.96/100 shrubs
Labour wage rate	$ 0.51-0.79/ day
Milk price (farm gate)	$ 0.13-0.33/litre

Because coefficients and prices often vary by site, values are presented as ranges rather than specific values.
2003 Exchange rates: 1 $ US = 1881 Uganda Shillings ; 1 $ US = 76 Kenya Shillings

Table 18: Net returns per year earned by fodder shrub farmers at different locations, using different strategies.

Location	Strategy	Net returns ($US per year) for full adopter (farmer with 500 shrubs)[1]	Mean no. of shrubs/farmer[2]	Net returns ($US per year) for farmer with mean no. of shrubs
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

Notes:
[1] Net returns per year are returns earned beginning in the second year after planting, when farmers start feeding fodder shrubs to their dairy cows.
[2] The samples of farmers were not random in the case of Embu, Makono, and Kabale. Rather, farmers with large numbers of trees were selected as farmers with small numbers of trees would not be able to give accurate data on key parameters, such as milk response to feeding calliandra. Data for Kisumu used milk response and labour data from Embu and data on prices from Kisumu.

Conclusion

The analysis thus shows that farmers with 500 calliandra shrubs increase their net income by between $US 62 to $US 122 depending on whether they use it as a substitute or a supplement and depending on where they are located (Table 18). Among the four areas studied, the Kisumu area had the highest profitability, largely because of high milk prices. Returns were lowest in the Embu area, primarily because of low milk prices. The study also assessed the profitability of calliandra according to the actual number of shrubs farmers had. Mean numbers of shrubs were highest in the Kabale sample and lowest in the Kisumu sample. Actual profitability followed the same pattern, highest in Kabale and lowest in Kisumu. The low numbers of shrubs per farmer in the Kisumu area is because fodder shrubs were introduced there only recently, relative to the other three sites. Tree numbers there are likely to increase significantly, owing to their high profitability.

OUTPUT 4: DISSEMINATION AND PROMOTION OF FODDER SHRUBS

Comparison of the data from our project activities at different sites shows large differences in the extent of scaling up that we have been able to achieve. In western Kenya the group approach has been highly effective, and we have trained a total of 2311 farmers in 68 groups. Of these, 1802 subsequently planted fodder on their farms: a total of over 183800 plants, with an average of 102 plants per household, and most farmers planting between 50 and 300 plants. This is not enough to provide full year-round supplementation for a dairy cow (which requires about 500 shrubs) but it is enough to make a major contribution to the animal's nutrition. Women accounted for 54% of the farmers who planted.

In central Kenya our most effective collaboration has been with the government extension services, and we have trained 98 Ministry of Agriculture extensionists on fodder technologies. At this site we have also developed links with private sector extensionists. Over 700 farmers have also been trained, and we estimate that about 2100 have been reached indirectly. Additional farmers may also have been reached by private seed dealers who are active in seed distribution.

There are several aspects of the situation at the two sites in Kenya that have particularly contributed to our success there:

- Active government extension services, also willing to form partnerships with the project. They have also been working with groups in a 'focal area' approach.
- A very active NGO community, already working with farmer groups and providing numerous potential partners, particularly in western Kenya.
- Agro-ecological conditions well suited to calliandra and the leucaena species that we have been promoting (trichandra, diversifolia, pallida).
- Good local markets for milk (Nairobi, Kisumu).

At both the Uganda-Lakeshore site and in northern Tanzania there was a more limited range of possible partners. The most active partnership in Uganda has been with existing groups established earlier by the NGO Heifer International, and at both sites we have also worked with several local NGOs. In addition, parish-level groups have been formed in Uganda specifically for fodder promotion by government extension staff at the sub-county level. Through the project at the Lakeshore site we have trained 69 partners' extension staff and a total of 1558 farmers (610 men, 948 women). An even larger number went on to plant seedlings from group nurseries established by the project: a total of 1858 farmers (772 men, 1086 women). In Tanzania, 553 farmers now have almost 64,000 well-established calliandra plants as a result of the project's activities. Although this is fewer than at the other sites, it is still an impressive achievement given the much lower previous exposure to fodder shrub technologies at this site.

In SW Uganda there proved to be very limited scope for partnerships, as few NGOs or other groups were active in Isingoro South, and new groups had to be formed at parish level by project staff working with local community leaders and a supportive local government administration at the sub-county level. A total of 24 groups have been formed in this way, with a total of 585 members (ranging from 4 to 69 per group). The members have planted a total of 185,629 fodder shrubs, broken down by species as follows: calliandra 56,422; trichandra 55,639; pallida 57,501; gliricidia

16,067. It should be noted, however, that survival has been lower here than at the other sites, for several reasons:

- Isingoro South is drier than any of our other sites, so not only is it more prone to droughts, but also water is limiting for nursery establishment, and emergency watering during droughts is not generally possible.
- There was little or no previous experience with fodder shrubs.
- Population density is relatively low and many animals are still free-ranging (compared to the other sites, where zero grazing is more widely practised).

Despite these limitations, the impact of the project's activities at this site has been impressive, particularly the facilitation of group activities in an area without a strong culture of collective action. Farmers have been less willing than at other sites to establish their own on-farm nurseries, largely because of the water problem, and have tended to rely on central nurseries operated by the sub-counties.

Rwanda is the smallest of the four project countries and the density of dairy cows is much lower. Our efforts have focused on two of the largest partners promoting dairy production in the country: the international NGOs Heifer International and Send-a-Cow. Working closely with ISAR staff, ICRAF dissemination facilitators have trained extension staff from these organisations. The Heifer International staff helped farmers in six districts of Byumba Province to plant fodder shrubs across the contour of their farms: they trained 300 farmers who established 244 nurseries, and planted an average of 301 trees per farm. Through Send-a-Cow, the project also helped 189 farmers in Kigali-Ngali Province to plant fodder shrubs. In addition, we have helped 40 farmers in six provinces (Gisenyi, Gikongoro, Butare, Gitarama, Umutara, and Kigali-Ngali) to plant fodder shrubs to feed their cross-bred dairy cows, which were recently donated to them by a World Bank project.

Extension materials

During Phase 2 of the project we have produced several extension materials, copies of which are included in the Annex. Two booklets[1] were produced in 2001-2002, incorporating recommendations arising from the Phase 1 research. At the same time *Calliandra for Livestock*, the main extension booklet used by ICRAF for promotion of calliandra as fodder[2], was revised and updated to include our recommendations. The two booklets were translated into Luganda[3] (for southern Uganda, and the one on utilisation was also translated into Swahili[4] (for Tanzania). In addition, leaflets, posters and banners[5] promoting fodder shrubs were produced jointly with ILRI[6].

The most comprehensive extension document arising from R6549 is the decision support tool and extension manual which comprises Output 6.

Other dissemination media

In addition to our promotion and dissemination activities in the East African region, we have also taken advantage of several opportunities to present the project to a wider audience. In December 2004 Janet Stewart (OFI) participated in an 'Environmental Showcase' event at the Begbroke Science Park of Oxford University, where a poster about the project was presented; a copy in included in the Annex[7]. In June 2005 we presented another poster at the 20th International Grasslands Congress in Dublin; this is also included in the Annex[8].

[1] *Calliandra calothyrsus*: *Nursery Establishment and management* (R6549-FTR-Phase 2 Output 4-Wambugu 2001) and *Calliandra calothyrsus*: *Tree management and utilization* R6549-FTR-Phase 2 Output 4-Wambugu 2002).
[2] *Calliandra for Livestock* (R6549-FTR-Phase 2 Output 4-Roothaert et al 2002).
[3] R6549-FTR-Phase 2 Output 4-Wambugu 2005a; R6549-FTR-Phase 2 Output 4-Wambugu 2005b
[4] R6549-FTR-Phase 2 Output 4-Lyamchai et al 2005
[5] *Plant fodder trees for more milk and cash* (R6549-FTR-Phase 2 Output 4-Wambugu & Karanja 2004)
[6] International Livestock Research Institute
[7] R6549-FTR-Phase 2 Output 4-Stewart 2004
[8] R6549-FTR-Phase 2 Output 4-Stewart & Franzel 2005

OUTPUT 5: SUSTAINABLE SEED DISTRIBUTION AND MARKETING SYSTEMS FOR CALLIANDRA

TechnoServe, Nairobi, Kenya

More details about the findings of this study may be found in the report by Technoserve which is included in the Annex[1].

The study of the calliandra seed market in Kenya found that the private sector in western Kenya was effective in providing seed for sale to institutional buyers (projects, NGOs etc.), but not to farmers (Figure 1). In central Kenya these institutional buyers supplied farmer groups with free seed. The groups then established group nurseries to supply seedlings for their members. Farmers were encouraged to leave some trees uncut for seed production in their farms; this practice may ensure that, following adoption, areas with calliandra could be self-sustaining in seeds. This approach can work well if farmers can be encouraged to collect seed from a sufficient number of trees to ensure maintenance of genetic diversity.

It will be much more difficult for the private sector to provide seed to new areas, where calliandra is not found and is not known. For example, seed vendors in western Kenya have been unable to sell all of their seed, and yet there is a lack of seed in many areas of central Kenya. Currently, there is little private sector involvement in producing and marketing tree seeds in central Kenya, where most of the demand is. There appear to be insufficient incentives for the private sector to undertake calliandra seed distribution, especially given that so much seed is given away free. In some areas, the poor performance of the milk marketing system discourages farmers from testing new technologies.

Demand for calliandra seed needs to be developed by raising awareness and training of farmers on calliandra management and use. A subsidised seed distribution and marketing system is still necessary, and the following marketing options are being explored (Figure 1):

- Link seed marketing to other economically attractive activities such as milk collection, crop seed companies, and stockists. Thus far, we have been unsuccessful in attracting dairy and seed companies to sell calliandra seed. We believe there are two main reasons that seed companies do not get involved: calliandra seed is too low in value relative to crop seeds and, unlike most crop seed, a farmer does not need to buy calliandra seed every year.
- Develop and/or strengthen partnerships with organisations and institutions in dairy development to help publicise fodder shrubs and promote seed demand. One private company has planted fodder shrubs with the intention of exploring the profitability of seed marketing. Dairy development organisations with whom we have built partnerships include Land O' Lakes in Kenya and Uganda, Heifer International in Kenya, Uganda and Rwanda, and Send a Cow in Kenya and Rwanda.
- Explore and initiate pilot private sector seed distribution systems in areas where calliandra planting is expanding. ICRAF and KARI are currently assisting private nurseries and seed vendors in central Kenya, where demand is rapidly expanding, to link with small-scale farmers and institutions interested in buying seed. Our main task is simply providing contact information to buyers and sellers about each other. We have records of private seed dealers selling 70 kg of seed from western Kenya to farmers and organisations in central Kenya during 2004. An NGO is making calliandra seed available in small packets to agricultural extension agents in Kiambu District, who in turn sell the seed, and provide information on fodder trees to farmers.

Areas for future development include:

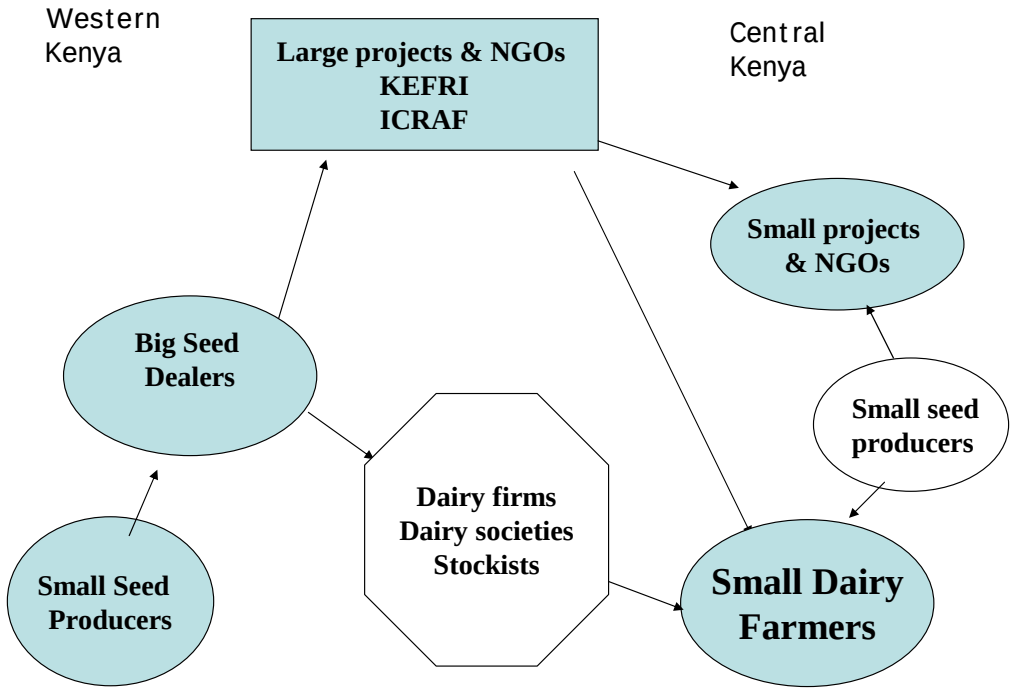
- Helping seed dealers to form an association. The objectives may be to share information, to improve access to seed, and to lobby policy makers.
- Providing training in entrepreneurship and business skills to seed producers and dealers.
- Persuading policy makers to allow calliandra seed dealers to be exempted from the high licensing fees charged to crop seed dealers.

An important lesson learned is that the biggest reason behind the lack of available seed is a lack of information about calliandra, both the potential of the shrub as a livestock feed as well as

[1] R6549-FTR-Phase 2 Output 5-Technoserve 2003

how to harvest, store, and market seed and seedlings to farmers who want to buy it. It is clear from the study that a key to success is promoting the role of the private sector in producing and marketing seed.

Figure 1



The market chain for calliandra seed in Kenya
(Light-coloured shapes show current status; unshaded shapes show interventions which need supporting)

We have prepared a policy brief, summarising our main findings for policy makers and organisations involved in facilitating the access of farmers to seed of fodder shrubs. This is also included in the Annex[1].

OUTPUT 6: DECISION SUPPORT TOOL AND EXTENSION MANUAL DEVELOPED AND DISSEMINATED.

A printout of the decision support tool/extension manual is included in the Annex[2]. The document is in press at the time of writing, so printed, full-colour copies are unfortunately not yet available.

When two separate documents were envisaged, we had planned to produce 1000 copies of the decision support tool (for extension managers), and 10000 copies of the extension manual (for field extensionists). Once the two documents were combined, we were still able to produce 10000 copies, thanks to a contribution of additional funding from the Dutch Government, through the ICRAF Training Unit.

[1] R6549-FTR-Phase 2 Output 5-policy brief 2006
[2] R6549-FTR-Phase 2 Output 6-Wambugu et al 2006

OUTPUT 7: DETERMINANTS OF EFFECTIVE FARMER-TO-FARMER DISSEMINATION IN CENTRAL KENYA IDENTIFIED.
(A) THE IMPORTANCE OF EXPERTISE AND INNOVATION, AS DETERMINANTS OF THE EFFECTIVENESS OF FARMERS AS DISSEMINATORS, ASSESSED.
(B) EXPERTS, INNOVATORS AND DISSEMINATORS OF TREE TECHNOLOGIES CHARACTERISED.

(a) Factors influencing the effectiveness of farmers as disseminators of fodder shrubs in the Central Kenya Highlands

C. Wambugu, World Agroforestry Centre, Nairobi, Kenya

The results of this study are described in more detail in the unpublished report which is included in the Annex[1].

Objective 1: Effects of farmers' personal characteristics on farmer-to-farmer dissemination

None of the traits examined (gender, age, education level, main occupation, leadership position, group membership, and wealth status) showed a significant association with the extent of dissemination. This suggests that many different types of persons disseminate information and planting material. These results are in contrast of those from two previous studies: research in western Kenya[2] indicated that age, gender and level of education all influenced the diffusion of a new technology, and a study in Meru District of central Kenya[3] showed a positive correlation between dissemination and participation of a farmer in group activities.

Objective 2: Associations between expertise, innovation and dissemination

Using the indices described in the *Research Activities* section, each farmer was assessed to see if s(he) was an expert, an innovator, or a disseminator. A farmer could be all three or none at all, depending on how s(he) scored on each index. We found that farmers who were disseminators were often also innovators, whether or not they were experts. Farmers who were not disseminators were usually not innovators, whether or not they were experts. The data thus showed that there was little association between innovation and expertise, even thought there was considerable association between dissemination and expertise and between dissemination and innovation. We used a loglinear model to test the association between the three categories,. Regression analysis revealed that expertise and dissemination were positively associated, as were innovation and dissemination, but that there was no association between expertise and innovation.

The implication is that it should be very possible to identify "contact farmers" who are both experts in use of a practice and skilled in dissemination. Similarly, farmers who innovate a lot are likely to disseminate a lot and vice versa. But farmers who are experts in use of a practice are not likely to innovate much, nor can innovators be assumed to be experts in using a technology.

Objective 3: Effects of exposure to formal extension on farmer-to-farmer dissemination

The number of contacts that a farmer had with extension providers (either extension staff visiting farmers, or farmers visiting extension staff) was significantly correlated with the extent of his/her dissemination of planting material and information (although when planting material alone was considered, the association was no longer significant). Contact with extension therefore appears to be an important variable associated with dissemination. In contrast, the

[1] R6549-FTR-Phase 2 Output 7a-Wambugu 2006

[2] Chitere, O.P. (1998). Diffusion and adoption of farm technologies among resource-limited farmers: experiences from the ICIPE/UNECA Integrated Pest Management Project in Western Kenya, *International Journal of Pest Management, 1998, 44(2) 49-52.*

[3] Davis, K., Franzel, F., Hildebrand, P., Irani, T. and Place, N. (2004). Extending technologies among small-scale farmers in Meru, Kenya: Ingredients for success in farmer groups.

number of different sources of extension information which a farmer accessed was not correlated with his/her activity as a disseminator.

Objective 4: Diffusion of fodder shrubs through farmer-to-farmer dissemination

We calculated the total number of farmers given fodder shrub planting materials or information by the farmer disseminators, although we lacked the necessary information to extrapolate our findings to the whole population in the study area. 2422 farmers were given planting material and/or information within the study area. However it should be noted that this total is derived by adding together the number receiving information (1137) and the number receiving planting material (1285). The total may be an overestimate as it is possible that some recipients were counted twice.

There was a large range of dissemination activity within the sample. Sixty-six respondents had disseminated no information, but at the other end of the scale, the three most active disseminators for passed on information about fodder shrubs to 100, 240 and 300 other farmers respectively. The mean number of farmers receiving information was 10.1. Dissemination of planting material was a more widespread activity in our sample: only 17 respondents had not given out any planting material; the two most active had given material to 100 and 200 farmers respectively. However the mean number of recipients was similar (11.4). The data shows that in our study area, farmer to farmer dissemination is an important element of the scaling up process.

Conclusions

Among the farmers' personal attributes, only knowledge about fodder shrubs, and the number of groups that the household belonged to, had a significant association with dissemination. Other personal attributes (gender, age, level of education, type of occupation, wealth status and leadership position) had no significant influence on dissemination. The findings are important as they show that none of these features prevents people from disseminating fodder shrubs. Rich and poor, educated and uneducated, young and old: all appear to be involved in disseminating. It is reassuring that those disseminating are knowledgeable, and this probably contributes to the effectiveness of farmer-to-farmer dissemination. The fact that disseminators belong to more groups than non-disseminators suggests that they may use the groups as a means of dissemination. The study also assessed the characteristics and the nature of fodder shrub technologies, and it was clear that it was easy for the farmers to adopt and disseminate fodder shrubs.

For the factors associated with extension institutional factors, contact with extension services, but not the number of extension sources, was significantly associated with dissemination of information. Analysis of the factors affecting dissemination of planting material revealed different results: in this case the number of extension sources was significant but not the number of contacts. The results imply that conventional extension services play a crucial role in making farmer-to-farmer dissemination effective: they link farmers to sources of new knowledge and skills and also provide them with training, thus building their technical capacity. In most cases extension is done though groups as a means of using resources more efficiently. The existence of effective farmer groups and the presence of an effective extension system are thus prerequisites for a vibrant farmer-to-farmer extension system.

The study found a high degree of association between experts and disseminators; experts tend to disseminate widely while disseminators have considerable knowledge about the technology. Many extension programmes work with contact farmers who are expected to be both experts in a practice and effective disseminators. Our findings imply that among Kenyan dairy farmers this is a reasonable expectation.

The study also found a high degree of association between disseminators and innovators but surprisingly, there was little association between experts and innovators. This latter finding has important implications for researchers working with farmers in on-farm trials. If researchers are interested in having farmers follow instructions carefully, they will be better off working with experts. If they are interested in monitoring how farmers modify practices to meet their needs,

they will be better off working with innovators. Researchers are not likely to find many farmers who can do both, that is, are both experts in a practice and innovators. The finding that experts are not innovators also lends support to the hypothesis that the process whereby farmers work closely with extension staff can lead to a stifling of their ability to innovate. For example, the extension staff may tell the farmer that there is only one way to use the practice and advise them not to modify it.

Transfer of knowledge and skills among farmers takes place within their social structures and networks. Group meetings provide an avenue for exchange and sharing of information and planting materials. It is therefore necessary to understand the social structures and networks and exploit them to enhance the diffusion of innovations in a community. Since farmers interact easily among themselves, they can greatly enhance the scaling up process if their extension methods are well organised, for instance by identifying effective disseminators and building their technical and public mobilisation capacity.

There is now a need to identify policies which enhance or inhibit farmer-to-farmer dissemination. Moreover, different factors may be important for different technologies. Comparative studies of alternative practices could identify those which facilitate farmer-to-farmer dissemination. For example, it is likely to be easier for a farmer to disseminate shrubs which can be vegetatively propagated than those which require seed to be planted in nurseries. Such studies should be repeated in different cultural contexts, as the results obtained, for example concerning the association of disseminators, experts, and innovators, may be to some extent culturally determined.

(b) Characterisation of experts, innovators, and disseminators of fodder shrub technologies in small holder dairy farming communities in central Kenya

T. Nanok, World Agroforestry Centre, Nairobi, Kenya

The results of this study are described in more detail in the unpublished report which is included in the Annex[1].

Objective a: Identification of experts, innovators and disseminators by farmer groups

Our original plan was to ask group members to identify experts, innovators and disseminators of fodder shrub technologies. We quickly found out, however, that group members were not reliable sources of this information. In practice, the members were generally unable to distinguish between the three categories, and kept referring to them as one and the same thing. The individuals they nominated to be interviewed for each category were therefore the same in most of the cases.

Objective b: Characterisation of experts, innovators, and disseminators in terms of personality, farm, and household characteristics

The criteria for the indices (see Research Activities section) were developed before the start of the study, and modified during the informal survey. The indices proved useful for characterising the experts, innovators and disseminators based on their farm and household characteristics. However, we were unable to capture personality characteristics in the indices, as asking about these proved unproductive. During the informal survey, we realised that questions about these (e.g. how extroverted a person was) were not culturally appropriate.

Forty-eight farmers were designated as experts. They tended to be wealthier than the 'non-expert' group, with slightly larger land holdings, more leadership positions, and more off-farm employment. We found no significant association between expertise and gender, age, or education, suggesting that men and women, old and young, educated and uneducated can all become experts in the use of fodder shrubs.

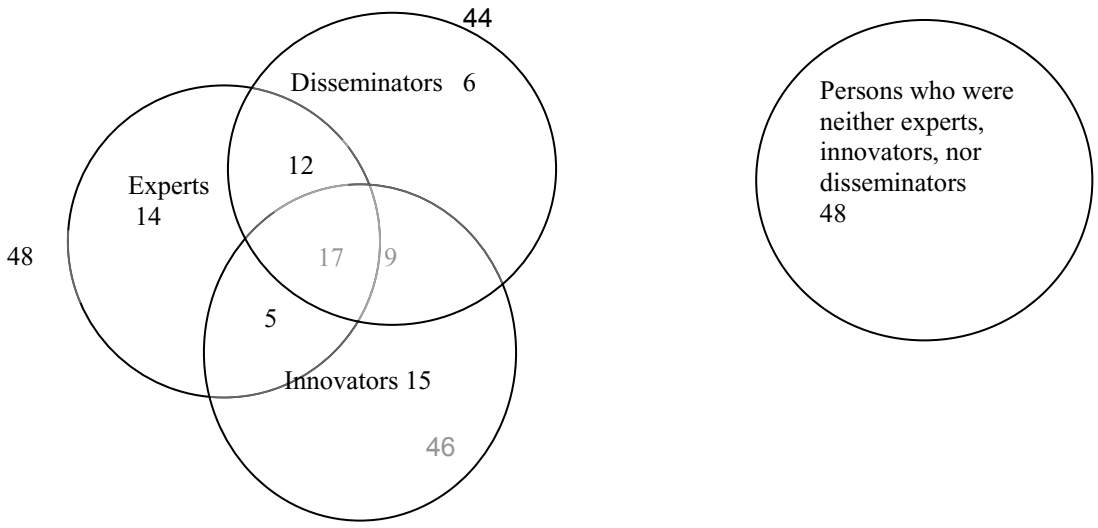
[1] R6549-FTR-Phase 2 Output 7b-Nanok 2006

There were 46 innovators in the sample. Innovators did not differ significantly in age, gender balance, wealth status, or education level from 'non-innovators'. In contrast with experts, innovators tended to have smaller farms than non-innovators. Innovators had more off-farm employment, which may have given them more exposure to innovation in other areas. They were also more frequently in leadership positions.

Forty-four farmers were designated as disseminators. Disseminators and non-disseminators had similar average ages, a similar gender balance, and similar levels of wealth and education. However, the disseminators had more off-farm employment, smaller farms, and held more leadership positions than non-disseminators.

There was some overlap among the three categories, experts, innovators, and disseminators (Figure 2). Seventeen (13%) of the interviewed farmers were experts, innovators, and disseminators. Disseminators and experts were 29, disseminators and innovators were 26, and experts and innovators, 22. The farmers who were only experts, innovators, or disseminators were 14, 15, and 6 respectively. A further 48 (38%) were neither experts, innovators, nor disseminators.

Figure 2: Overlap between experts, innovators, and disseminators



Objective c: Factors motivating farmers to become experts, innovators or disseminators

The main factors mentioned by the survey respondents as motivating farmers to become disseminators were the desire to make others benefit, and the wish to avoid jealousy from others. Other factors mentioned by the respondents (in decreasing order of importance) included social benefits (gaining respect and authority in the community); monetary benefit (through the sale of planting material); and response to enquiries from other farmers.

Whereas farmers were able to discuss their motivations for disseminating, they had more trouble defining the reasons why they innovate, and most were unable to give any reasons. Eight mentioned their interest in experimenting, not only on fodder shrubs but on agricultural practices in general. Several were motivated by specific problems they encountered, such as lack of sufficient feed during dry season or lack of labour for managing a nursery. Trying to reduce production costs was another major reason for innovating.

Objective d: How researchers and extension staff can support experts, innovators, and disseminators in implementing farmer-based research and extension programs.

This objective was addressed using the informal survey and case studies, to capture the views of experts, innovators, and disseminators on how researchers and extension staff can support them in implementing farmer-based research and extension programs. There were five case studies, one each for experts and disseminators, two for innovators, and one for a farmer who was all three.

The case studies corroborated several of the findings under Objectives b and c. Objective b found that experts, innovators, and disseminators are each diverse groups made up of persons with different socio-economic characteristics: different genders, education and wealth levels, and ages. The case studies were also very diverse. Second, all the farmers in the case studies had had strong and proactive contact with research and extension providers, and had learned about fodder shrub technologies through visiting and consulting them. Third, altruism was a major motivating factor in dissemination.

From the case studies, personality characteristics appear to be the most important factor distinguishing innovators and disseminators from other farmers. Innovators are people who are curious, while disseminators are extroverts: they have many social contacts and use these relationships to disseminate practices. Their interest in helping others is also an important motivating factor.

Farmers also mentioned that tour/visits exposures and training of farmers to train others during meetings by research and extension services could support development of farmer expertise, innovations, and dissemination.

Objective e: Farmers' innovations and experiments

Forty-six respondents were able to identify innovations and experiments testing innovations they had conducted on fodder shrubs. The farmers identified a total of 30 innovations. The most common innovations involved feed conservation, plant propagation, and spacing/planting configurations. The two most common reasons given for experimenting and innovating were to increase plant productivity (e.g. by improving germination rates or biomass production), and to improve feed utilisation, for instance by drying the fodder or mixing it with other feeds.

Conclusions

The study revealed many interesting differences between experts, innovators and disseminators in terms of their personal, farm and household characteristics. We found, however, that it was not possible to identify farmers in each of these categories by asking members of farmer groups to name them. The hypothesis that members of farmer groups would be able to differentiate experts, innovators, and disseminators of fodder shrubs technologies (Objective a) was found not to be true. The individuals they nominated to be interviewed for each category were the same farmers in most cases.

The characterisation of expert farmers revealed them to be generally of higher wealth status than non-experts ($p=0.04$), though there were no significant differences between experts and non-experts with respect to gender, age, and education. This shows that there are few barriers to becoming an expert − men and women, old and young, educated or uneducated can all become experts in the use of fodder shrubs.

Innovators were found to have about the same age, gender balance, wealth status, and education level as non-innovators. They had more off-farm employment, however ($p=0.02$), which may have given them more exposure to innovation in other areas. As with experts, there are no important socio-economic barriers to becoming an innovator. Farmers develop innovations mainly by experimenting and by observing other farmers. Although they were able to discuss their motivations for disseminating, respondents had more trouble describing the reasons they innovate. The reasons mentioned included interest in experimenting; addressing

specific problems such as lack of sufficient feed during the dry season or lack of labour for managing a nursery; and reducing production costs.

Disseminators and non-disseminators were found to have similar average ages, similar gender balances, and similar levels of wealth and education. The disseminators had more off-farm employment but the difference between disseminators and non-disseminators was only marginally significant. The factors that motivated farmers to be disseminators were desire to make other farmers benefit, social benefits, monetary benefits and interest or enquiry by other farmers.

There was some overlap among the three categories: of the 78 farmers (out of the sample of 126) who were found to belong to at least one of the categories, 17 belonged to all three (i.e. were experts, innovators *and* disseminators), and a further 26 fell into two of the three categories. For all three categories of farmer, there appeared to be no important socioeconomic barriers to becoming an expert, innovator, or disseminator.

Objective d addressed the question of support to experts, innovators, and disseminators from research agencies and extension providers. Farmers believe that organising farmer tours and visits will help them to be better experts, innovators, and disseminators. Tours and visits will also expose them to various agricultural technologies. Training farmers to train others during open days could also support development of farmer expertise, innovations, and dissemination.

The case studies showed that farmer experts had strong contacts with extension providers whereas farmer innovators did not. These findings are consistent with the theory that extension staff tend to discount innovations, preferring to promote fixed technology packages.

In summary, the study showed that more than half the sampled farmers could be defined as experts, innovators and disseminators, and that there was no social or economic barrier to becoming any of these. By recognising and supporting the development of these skills within the farming community, extension services could facilitate and strengthen the farmer-to-farmer dissemination process, not only with regard to fodder technologies but in many areas of agricultural extension.

OUTPUT 8: PROCESSING & MARKETING OF LEAF MEAL FROM FODDER SHRUBS PROMOTED.

Franzel, S., Wambugu, C., Nanok, T., Kavana P., Njau T., Aithal, A., Muriuki, J., and Kitalyi, A., World Agroforestry Centre, Nairobi, Kenya.

A summary of the results for each of the study's objectives is presented here. More details are given is the full report which is included in the Annex[1].

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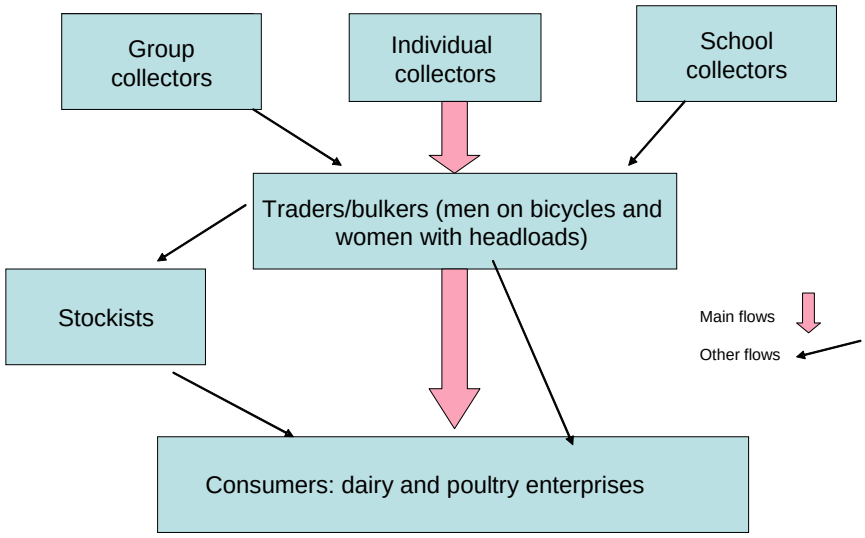
1. Assess the market chain for leaf meal in Tanzania from production through to final use

The main components of the chain (Figure 3) were:

(a) collectors, who collect leucaena branches from the wild and dry and crush the leaves into leaf meal,
(b) traders, who transport the leaf meal to the towns of Tanga and Muheza, and
(c) owners of dairy and poultry enterprises who buy leaf meal to feed their livestock.

[1] R6549-FTR-Phase 2 Output 8-Franzel et al 2006

Figure 3: Market chain for leucaena leaf meal, Tanga, Tanzania.



Several other actors also participated in the chain. In addition to individual collectors, some farmer groups and schools also collect and process leaf meal. Where distances between sources and consumers are not great, women vendors transport leaf meal by the headload. Six agro-vet stockists in Tanga also sell leaf meal in their shops.

Among the 5400 dairy farmers in Tanga, Muheza and Pangani Districts, about 61%, 3,290, use leucaena leaf meal. About half of these farmers are in the towns of Tanga and Muheza and buy leaf meal to meet their feed needs. Most of the remainder are in rural areas and collect leucaena themselves. Numbers of traders and collectors are more difficult to estimate but traders probably number over 100 and collectors, over 1,000. Nine of eleven traders were men, while eleven of seventeen collectors were women. Collectors and traders benefit considerably from leaf meal during the dry season, when there are few alternative income-earning opportunities. Households purchasing leaf meal tended to be male-headed, but females tend to have more responsibilities in feeding cows than men. Consumers appreciate leaf meal as being a cheap source of protein and other nutrients for their cows. Poultry keepers like leaf meal because it is nutritious and because it darkens egg yolks, making eggs more marketable.

Extension services recommend maize bran, cottonseed cake, and leucaena leaf meal for feeding dairy cows in a 3-2-1 or 3-2-2 ratio. Collector and trader profit margins tended to be low, reflecting the ease of entry into the leaf meal business and the high competition among collectors and traders. Collectors earn slightly higher returns per day than day labourers. Traders earn somewhat more, reflecting the risk involved and the capital needed to buy and sell leaf meal. Whereas traders are often considered to be well off, leucaena traders are not; 8 of 10 were categorised as poor. Similarly, 11 of 13 collectors were poor. In contrast, 12 of 26 consumers were well-off; only 2 could be considered poor.

2. *Identify the constraints and opportunities faced by different market participants*

Collectors' returns are limited by the small amount of leaves or leaf meal they can carry from the wild to their farms. Collecting is very tedious, often involving long hours in the bush. Several thought that collective action could be useful for improving their terms of trade.

Traders are limited by the small amounts they can carry on their bicycles and their lack of capital for expanding their businesses. The bulkiness of leaf meal makes it costly to transport, relative to other feeds. Traders' main opportunities for improvement are to (1) dry and store leaf

meal for the rainy season, (2) find ways to increase the bulk density of leaf meal to make it cheaper to transport, and (3) hire others to buy, transport, and sell.

Producing leaf meal on farm is not common, but a benefit-cost analysis shows that it gives higher returns to labour than collection and is more profitable than maize, another important cash crop. An additional problem faced by all participants is the low quality, low profit margins, and high prices of leaf meal during the rainy season. Improved drying practices could increase prices, margins, and the amount of leaf meal marketed during the rainy season.

3. *Assess the feasibility of using leaf meal in commercial feed manufacturing*

Commercial feeds are produced in Arusha and Dar es Salaam and do not include leaf meal as a component. There are good reasons for this, as leaf meal is much more costly to transport, on a per-kg basis, than other protein supplements, such as cottonseed cake. Cottonseed cake and leucaena leaf meal both provide metabolic energy and digestible crude protein at about the same cost, but cottonseed cake's lower transport costs make it more attractive to use in feed manufacturing. The cost of transporting leaf meal could be reduced through finding a way to compress it, making bricks or pellets. There is one producer of mineral supplements in Tanga and they use leaf meal in their product, as a filler and nutrient supplement.

4. *Sensitise and train selected participants from central Kenya on the mechanisms involved in producing and marketing of fodder shrub leaf meal*

Forty-five persons from four districts of Kenya participated in a field tour to Tanga and Muheza districts. The tour's objective was to train farmers in the production and marketing of leaf meal and assess the feasibility of undertaking these activities in central Kenya. Participants included teams of farmers, input stockists, and extension staff. The tour was a collaborative activity between ICRAF, SARI (Tanzania) and the Ministry of Agriculture (Kenya). At the end of the tour, participants developed work plans to test some of the practices they learned, such as producing and marketing leaf meal. We are monitoring uptake of these practices: a good number of farmers are conserving the fodder for dry season feeding using the skills they learnt during their visit to Tanga. Others are using the leaf meal for making feed rations for their animals.

Conclusions and recommendations

The leaf meal industry in the Tanga area provides employment and economic benefits to several thousand collectors, traders, and livestock owners. Traders and collectors are among the poorest residents of rural Tanga and collectors are mostly women, who have no other sources of income during the dry season. Improvements in the leaf meal industry can increase benefits to the poorest members of rural communities as well as improving productivity the dairy industry. The proposals for improvements noted below involve new technologies, institutional innovations, and policies.

Technology development and dissemination

Leucaena plots for producing leaf meal. Extension staff could begin assisting farmers to implement on-farm trials to assess the benefits of leucaena production relative to two alternatives: collecting it from the wild or producing other cash crops such as maize. Leucaena could be grown on a plot in a pure stand or along a field boundary as a live fence, depending on farmers' preferences.

Technologies for compressing leaf meal. Low cost methods are needed to compress leaf meal, so as to reduce transport costs. Two different types of technologies could prove useful. One would be a very low cost tool that traders could use to increase the quantity of leaf meal they could carry to town on their bicycles. The second might be a more sophisticated tool for compressing large quantities of leaf meal so that it could be transported over longer distances, Transportation of leaf meal is currently limited by its bulkiness, which makes per-kilogram transport costs very high.

Improved drying practices. Simple, low cost methods are needed for improved drying of leaf meal, especially during the rainy season. Such practices include the use of plastic sheeting, for both drying leaf meal and keeping it clean, and drying under shade and not in the sun, to maintain nutritive quality.

The Livestock Research Centre, Tanga, could lead research and extension efforts in the above areas, in collaboration with Mlingano Agricultural Research Institute, farmers, collectors, and traders.

Introduction of methods for compressing leaf meal or improved drying needs to be based on the lessons learned from past attempts. The Dutch-financed dairy projects in the 1980s and 1990s developed and disseminated methods for improved drying and compressing but they were not widely adopted. An assessment of past efforts is needed, based on interviews with participating farmers and key informants (e.g. former staff of the dairy projects).

Institutional innovation

Trader associations. Traders could benefit from forming an association, and this could benefit the industry as a whole. Since most traders market their leaf meal in Tanga, it would be fairly easy for them to meet.

Price information system. In order to reduce leaf meal deficits in the rainy season, traders need to offer higher prices to collectors to encourage more production. If collectors could get more information on the prices being offered in Tanga during the rainy season, this would help them to negotiate higher leaf meal prices in their communities. Extension staff could test this hypothesis by informing selected groups of collectors in a particular area to see if they can use the information to negotiate higher prices.

Policies

Providing information to farmers for educated decision making. Farmers need information on the components of rations so that they can modify their rations in response to prices or other circumstances, such as the non-availability of particular feeds. Second, farmers do not just need blanket recommendations; they need to learn about the processes whereby improved feeds generate increased milk production. Such information can help them to experiment with different feeds to find the combinations that give them optimal economic performance.

Assessing the potential of leaf meal in other areas of East Africa. Research is also needed to assess the potential of leaf meal production and marketing in other areas of East Africa. First, assessments should be made in Dar es Salaam and Mombasa, where wild leucaena stands reportedly exist but there is little if any leaf meal production and marketing. Next, the economic potential of leaf meal, and farmers' and other stakeholders' interest in it, could be assessed in other areas of East Africa. Our preliminary view, based on the visits of stakeholders from central Kenya to Tanga, is that leaf meal can be widely used by farmers as a dry season feed. In addition, farmers in peri-urban areas may be able to produce and sell it on a small scale to their neighbors who need protein supplements for their livestock. Leucaena may also be useful for commercial feed manufacturers in Dar es Salaam, if supplies can be identified from areas close by.

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Exchanging information with Asian leaf meal producers. Participants in the leaf meal industry in Tanga, particularly enterprising entrepreneurs, could gain a lot from visiting Asian stakeholders (farmers, entrepreneurs, and policy makers) involved in leaf meal production and marketing to learn about the technologies, institutional innovations, and policies involved in the leaf meal industry.

Finally, the above proposals cannot be implemented without resources and a core group of stakeholders to facilitate implementation. A cross-sectoral alliance of stakeholders including representatives of policy makers, dairy farmers, traders, entrepreneurs, researchers and extensionists is needed, to prepare an action plan, seek resources, and facilitate implementation.

OUTPUT 9: STUDY TO ASSESS THE IMPACT OF FODDER SHRUB EXTENSION IN EAST AFRICA PLANNED AND PREPARED.

S. Franzel, World Agroforestry Centre, Nairobi, Kenya

The full report of this study is included in the Annex[1].

Objective 1. Assemble an inventory of organisations and government agencies promoting fodder shrubs in each country.

Researchers in each country established a data base of organisations in each country promoting fodder shrubs. The sources of information for these lists were government tree seed centres, private seed sellers, and key informants. There are 205 organisations that promote or have promoted fodder shrubs, including community-based organisations, international NGOs, national NGOs, government organisations, and private companies. The numbers were fewest in Tanzania because the researchers only work in the northern part of the country, which has similar ecological conditions to those of the highlands in the other three countries.

Objective 2. Assess organisation-level factors affecting the quantifiable impact of fodder shrubs extension (number of farmers trained, numbers of farmers planting, and numbers of trees per farmer).

Here we developed a regression model and used our survey to test whether organisations would be able to provide the necessary information.

Concerning the dependent variable, an index of impact indicators, we found that 86% of the organisations were able to estimate the survival rate of shrubs on the farm, 56% the number of farmers trained, 54% the number of trees planted and 51% the number of farmers planted, but only 30% were able to estimate all four. Because of the problem of missing values, three recommendations may be made for the follow-up impact survey. First, we need to sample all 205 organisations in order to obtain a large enough sample of households for regression analysis. Second, we could use just one of the impact variables at a time, rather than an index of all four. Third, we could create an index for the 46% of the organisations that can report on any three of the four variables and leave the missing value out of both the numerator and the denominator of the index. For example, if each variable in the index has a weight of 0.25, then an organisation with data on only three variables can have a score divided by 0.75 instead of 1.0.

In contrast to the dependent variables, respondents had few problems answering questions about the 18 potential independent variables. Eight of the eighteen variables had response rates of 100%, and the others were all over 94%.

Objective 3. Assess organisations' perception and record of their impact

Thirty-six of the seventy organisations interviewed were able to estimate the numbers of farmers they had assisted to plant fodder shrubs. There was considerable variation across types of organisations. CBOs and international NGOs ranked the highest in making such estimates; 67% and 65%, respectively, were able to estimate numbers of farmers planting. International NGOs have considerable capacity and are often held accountable for providing such numbers. CBOs have less capacity and accountability but they usually operate in fairly small areas so are able to keep track of the number of farmers they assist. Government offices were less likely to keep such records and national NGOs had the least ability to estimate numbers of farmers assisted. About the same proportions of organisations were able to estimate numbers of farmers trained and numbers of trees planted per farmer as numbers of farmers planting. Over 90% were aware of farmers' views on the impact of fodder shrubs and all of these said that fodder shrubs increased milk production. About 72% knew farmers' views on the impact of fodder shrubs on crops next to the shrubs. About 58% of these respondents reported that farmers felt the shrubs improved crop production while about 11% claimed they competed with crops. The rest saw no effect.

[1] R6549-FTR-Phase 2 Output 9-Franzel 2006

Objective 4. Determine organisations' views on the key factors that contributed to success

Nearly all of the respondents (96%) were able to score the factors that they felt contributed to their organisation's achievements. The most important factor was that fodder shrubs met a need of farmers, with a mean score of 4.1 on a scale of 0 to 5. Other key factors were that the fodder shrubs were profitable, that effective extension approaches were used, and that partnerships with other organisations facilitated success. Less important factors included long-term commitment by key players, farmers' commercial orientation, farmer skill levels, availability of training materials and backstopping from research. That training materials and research support were less important is very telling; the findings suggest that these are not necessary to succeed in helping farmers to plant fodder shrubs.

5. Plans for second phase of this research project.

The findings in this pilot phase have several important implications for the next phase:

- The number of organisations promoting fodder shrubs is sufficient to support a rigorous study of factors affecting performance, but all of the 205 organisations need to be sampled.
- There are fairly large numbers of missing cases (14%-49%) for each of the four proposed impact indicators. There are two solutions to this problem: running separate regression models for each impact indicator, and creating an impact index in which organisation reporting on any three indicators could be included.
- Organisations were able to report on all 18 of the proposed independent variables proposed for the study.

The impact indicators used in the above model, e.g. numbers of farmers planting, are very rough proxies for impact at the household level. The objective for visiting farms and interviewing farmers in the second stage of the study is to develop an indicator at the household level which more closely approximates impact on household livelihoods. This will then be included as a dependent variable and a component of the impact index in the regression model assessing factors influencing the impact of extension providers.

A multi-stage sampling approach is required. The sample will be stratified by two key variables, geographical zone and organisational type. The final sample will include 24 organizations from each zone and, at the same time, 24 from each of four main organisational types.

Next, the geographical areas in which each selected organisation works will be identified. The organisations will prepare lists of farmers they are working with and ten farmers will be selected randomly from each organisation, giving 240 farmers per organisation type and 960 overall.

The household livelihoods framework provides the conceptual basis for assessing impact. The effects of fodder shrubs on human, social, physical, and natural capital will be determined. Assessments will include the views of farmers and extension providers and the role of farmer groups, as well as observations regarding the quality of the fodder shrubs.

Contribution of Outputs: Phase 2 (2001-2006)

The whole of Phase 2 of R6549 was concerned with scaling up the promotion of fodder shrubs so as to increase their impact on rural livelihoods (the benefits that fodder shrubs can provide for smallholder dairy farmers, and so contribute to DFID's developmental goals, are described in the Introduction). Most of the outputs of this phase are research studies into the aspects of the dissemination process; others (Outputs 4 and 6) aim directly to facilitate fodder shrub promotion activities by our extension partners in the region. These activities have also given us an ideal opportunity to disseminate the technical findings from Phase 1 of the project, through our written extension materials (particular the decision support tool/extension manual, Output 6) as well as through training of trainers in the partner organisations.

During the course of Phase 2 we have developed extensive networks of partners including governmental, non-governmental and community-based organisations in all four target countries (Kenya, Uganda, Tanzania and Rwanda). In each of the areas in which we worked directly with such organisations (under Output 4), we started our activities with a stakeholder identification exercise so as to target our efforts as effectively as possible. In the partnerships that we subsequently developed, our most important inputs were in training partner extension workers and ensuring that they gave the farmers accurate and up-to-date information, including the findings and recommendations from Phase 1. In Tanzania and Uganda our studies of farmers' previous experience with calliandra (Output 1) also helped to inform the dissemination strategies that we developed with our partners. We have tried as far as possible to strengthen the capacity of our partners so that they will be able to continue effective scaling up activities with fodder shrubs beyond the lifetime of the project.

Another important aspect of our direct promotion activities under Output 4 has been the production of a range of written extension materials, again with the aim of providing correct information, including results from our own research, to our partners. Early in Phase 2 we distributed booklets on calliandra production and management, and Luganda (for southern Uganda) and Swahili (for Tanzania) versions have also been produced: copies are included in the Annex[1]. We also updated the earlier ICRAF publication *Calliandra for Livestock* to include the recommendations from Phase 1. Our most substantial and comprehensive publication, however, has been the extension manual and decision support tool produced under Output 6. This draws together the findings both from Phase 1 and from several of the research studies under Phase 2 (Outputs 1, 2, 3, 5), and combines them with the accumulated experience of our project staff and partners in a comprehensive account of the issues which need to be addressed when promoting fodder shrubs in the region.

At the policy level, the studies of adoption (Output 2) and of the economic impact of fodder shrubs (Output 3) provide clear evidence of the benefits of fodder shrubs to justify continuing investment in promotion of this technology. The studies of farmer-to-farmer dissemination (Output 7) and of factors affecting the effectiveness of extension (Output 9) will help decision makers in extension organisations to improve the effectiveness of their approaches. The studies of distribution mechanisms for calliandra seed in Kenya (Output 5), and of the market for leucaena leaf meal in Tanzania (Output 8), both provide recommendations for the improved functioning of these markets, which would have clear developmental benefits in both instances. We have prepared a policy brief about the recommendations from Output 5, and ICRAF is planning to prepare similar briefs for other outputs. This is a necessary final step for these outputs to achieve their potential developmental benefit.

[1] R6549-FTR-Phase 2 Output 4-Wambugu 2005a; R6549-FTR-Phase 2 Output 4-Wambugu 2005b; R6549-FTR-Phase 2 Output 4-Lyamchai et al 2005

Appendix 1

R6549: Logical frameworks for Phases 1 & 2

R6549, Phase 1: Investigation of factors affecting the nutritive value of *Calliandra calothyrsus* leaf as fodder for ruminants: logical framework.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal: Performance of livestock in high potential farming systems (crop/livestock or livestock) improved.	By 2005 in two nominated areas where primary demand exists: - Output of animal products increased by 20%. - Productivity index increased by 15%. - Milk production increased by 20%.	- Reports of target institutions. - National production statistics. - Evaluation of livestock production programme. - Research programme reports. - Monitoring against baseline data.	- Climatic conditions remain favourable. - Enabling environment (policies, institutions, markets, incentives) for widespread adoption of new technologies and strategies exists.
Purpose: Strategies to improve seasonal availability of livestock feeds in high potential areas developed and promoted. This purpose will be addressed with specific reference to *Calliandra calothyrsus*, and strategies to optimise its fodder value.	At least two target institutions promoting strategies for improved utilisation of *Calliandra* by 2005.	Annual reports of, and correspondence with, target institutions.	Target institutions invest resources in uptake and application of research results.
Outputs: 1. Effects of environment, management and provenance on nutritive value of *Calliandra* forage determined with respect to: (a) utilisation by ruminants. (b) Crude protein (CP), organic matter (OM), *in vitro* and *in sacco* digestibility. 2. Degradability of greenhouse- and field-grown *Calliandra* leaf samples compared: if comparability good, effects of drying *Calliandra* leaves on degradability, and the role of tannins in these effects, investigated. 3. Relationship between tannin structure and function investigated. 4. Results from outputs 1-3 used to formulate improved utilisation strategies, and disseminated through regional workshops and appropriate extension media.	1(a). Data from *Calliandra* feeding trials collected by collaborators (by July 1999), analysed and papers completed (by March 2000). 1(b). *In vitro* and/or *in sacco* digestibility, and gas production profiles, of *Calliandra* leaves from agronomic trial (K1) and feeding trials (C1, C2, K2, K3) determined (by December 1999), paper completed (by May 2000). 2. *In vitro* digestibility of greenhouse- and field-grown *Calliandra* leaves compared; changes on drying determined, and role of tannins in these changes elucidated (by October 1997); paper completed (by March 1999). 3. Data from structure/function trial (C3) collected (by December 1999), analysed and paper completed (by June 2000). 4. Paper summarising results and recommending	Scientific papers published in international refereed journals and national/regional journals. Collaborators' reports and correspondence. Briefing paper summarising research results. Extension materials.	Scientific papers (particularly from output 4) received and read by target institutions. Target institutions active in promotion of improved strategy for *Calliandra* utilisation.

	improved utilisation strategies completed (by September 2000); two workshops held (by June 2000).		
Activities: 1(a). Feeding trials in Kenya (Embu) & Colombia (CIAT) to investigate effects of provenance, site, season and drying on intake, live weight gain, milk production, tannin content, rumen and whole tract digestion, and N utilisation (trials K2, K3, C1, C2). 1(b). Agronomic trial established in Kenya (trial K1) to test effects of provenance, cutting interval & season. For dried leaf samples from this, from an existing provenance trial in Kenya, and from each of the feeding trials in Kenya and Colombia, *in vitro* and/or *in sacco* digestibility, and gas production profiles, determined; also CP & OM for samples from the existing Kenya provenance trial. 2. For fresh and dried leaf of greenhouse-grown *Calliandra calothyrsus* provenances of known high and low digestibility: (a) *in vitro* and *in sacco* digestibility determined. (b) role of tannins as determinants of digestibility in *Calliandra* investigated. 3.Trial at CIAT to investigate effects of differences in tannin structure on biological function, by feeding the two *Calliandra* provenances to sheep as sole feeds (trial C3). 4(a). Scientific papers written with collaborators. 4(b). Regional workshops held in Africa and Latin America to disseminate results and develop improved utilisation strategies. 4(c). Extension materials commissioned and produced.	**Inputs/Resources:** <u>Summary Budget</u> (£) Staff costs: 112,580 Overheads: 56,290 Capital equipment: 0 Overseas travel & subsistence: 7,560 Miscellaneous: 85,636 **TOTAL: 262,066**	Quarterly and annual progress reports. Project Final Report.	1(a). Key collaborators remain in post. Timely establishment of *Calliandra* plots in Kenya and Colombia. Animals and *Calliandra* fodder blocks remain healthy throughout trial period. 1(b). Samples arrive safely. Laboratory resources available and functional. 2. Greenhouse space, and necessary laboratory resources, available and functional. 3. As 1(a). 4. Scientists at collaborating institutions continue to welcome collaboration in preparation of papers; and are willing to assist with organising workshops.

R6549, Phase 2: Scaling up the promotion of calliandra in East Africa: logical framework

NARRATIVE	INDICATORS	M.O.V.s	ASSUMPTIONS
Goal: New knowledge applied to problems in forest and tree resource management, the resolution of which benefits forest and tree dependent poor people in the Forest/Agriculture Interface.	By 2005, increased financial capital for poor households through: expanded tree-based employment opportunities; increased biological and technological productivity; higher product prices through added value in processing and marketing; reduced production costs through greater efficiency and effectiveness in the application of labour resources; and improved availability of subsistence items in land-use systems involving the management of forests and trees - By 2005, increased sustainable natural capital for poor households through: reduced variability and risk in production; and the development of new tree-based production alternatives - By 2005, increased physical capital for poor households through: improved information pathways and the production equipment and means by which poor people earn their living. - By 2005, increased social capital for poor households through: adequate control of access to relevant forest resources; enhanced institutional capacity; and an enabling policy environment.	National and local adoption rate surveys. National and local socio-economic surveys	Poor people invest benefits to improve choices and options for livelihood strategies.
Purpose: Strategies for improved sustainable livelihoods and income generation for forest and tree dependent poor people in the Forest/Agriculture Interface developed and promoted	By 2005, improved nutritional varieties of selected species and feeding practices for high intensity urban fodder production promoted.	Annual research programme reports. External refereeing.	Resources managers, producers and processors are able to adopt new knowledge. Enabling cultural, economic, social

NARRATIVE	INDICATORS	M.O.V.s	ASSUMPTIONS
		External O/P reviews. Client institutions' reports.	and political environment exists for widespread application of new knowledge and is not contrary to measures that enhance sustainable livelihoods. Capabilities of client institutions radically enhanced.
Outputs: 1. Farmers' experiences in calliandra management and utilisation documented 2. Reasons for adoption and non-adoption of calliandra defined. 3. Economic, environmental, and social impact of calliandra at household and community levels assessed. 4. Calliandra effectively disseminated in new target areas. 5. Performance of different approaches to community-based calliandra seed production and distribution assessed. 6. Decision support tool for extension managers, and extension manual for field extensionists, developed and disseminated. 7. Determinants of effective farmer-to-farmer dissemination in central Kenya identified. (a) The importance of expertise and innovation, as determinants of the effectiveness of farmers as disseminators, assessed. (b) Experts, innovators and disseminators of tree technologies characterised. 8. Processing & marketing of leaf meal from fodder	1. Farmers' experiences with calliandra, including their interpretation and adaptation of previous research outputs, reviewed, synthesised & documented. 2. Determinants of calliandra adoption and farmer-to-farmer spread understood & documented. 3. Economic, environmental, and social impacts of calliandra defined, quantified & documented. 4. 75% of farmers in target areas sensitised by June 2002; 50% of target farmers planted at least 100 calliandra seedlings by June 2004. 5. Seed production & distribution mechanisms compared & documented. 6. Project findings and experiences synthesised to provide a basis for decisions relating to fodder dissemination. 7. (a) Attributes of expert farmers, and of effective farmer-disseminators, identified & documented. (b) Farm, household, and personality characteristics of farmer experts/innovators and disseminators described. 8. Leaf meal production, market chain, and potential for use in commercial feeds	• Collaborators' reports by output (Outputs 1, 2, 3, 5). • Published scientific papers (Outputs 1, 2, 3). • Extension materials (Output 4). • Report on seed supply mechanisms (Output 5). • Decision support tool and extension manual in booklet form (Output 6). • Report & policy brief on farmer-to-farmer dissemination, and on characterising farmer experts and disseminators (Output 7). • Recommendations for farmers, extensionists, policy makers & feed manufacturers on production, marketing & utilisation of leaf meal (Output 8). • Report on organisations promoting fodder shrubs; proposal for follow-up study with farmers	Functional milk market in target areas allows farmers to benefit from improved production due to calliandra. Target institutions use new knowledge from Outputs 1, 2, 3, 5 & 6 to improve effectiveness of calliandra dissemination and enhance future impact.

NARRATIVE	INDICATORS	M.O.V.s	ASSUMPTIONS
shrubs promoted. 9. Study to assess the impact of fodder shrub extension in East Africa planned and prepared.	assessed and documented. 9. Objectives, activities and extension messages of organisations promoting fodder shrubs reviewed and documented; phase II proposal prepared.	(Output 9).	
Activities (numbers refer to outputs; H = *all outputs):* 1.1 Review & synthesise existing information on calliandra management & utilisation at national levels (year 2). 1.2 Conduct surveys & farmer workshops to address knowledge gaps identified in 1.1. (year 2) 1.3 Analyse survey data (year 2). 1.4 Document results of literature review and survey (year 2). 1.5 Conduct stakeholder workshop(s) (years 2 & 3). 2.1 Review & synthesise existing knowledge on calliandra adoption in target countries (year 1). 2.2 Conduct surveys of adoption, both formal (questionnaires) and informal (groups and individual farmers) (year 1). 2.3 Analyse and document survey results (year 1, Rwanda; years 2 & 3, Kenya). 3.1 Review & synthesise secondary data on impacts (economic, environmental, and social) (year 2) 3.2 Conduct farmer workshops to identify their criteria for impact (year 2). 3.3 Conduct PRAs/surveys to assess economic, environment, and social benefits (year 2). 3.4 Conduct stakeholder workshop(s) (year 2, Uganda; year 3, Kenya). 4.1 Sensitisation meetings, field days & exchange visits for farmers (years 1-3).	*Inputs/resources:* Summary budget[1] *Salary:* £31229 *Overheads:* £15617 *Travel & subsistence:* £7645 *Equipment:* £1000 *Miscellaneous:* £252164 *TOTAL:* £307655	Literature reviews (Outputs 1, 2) Survey reports (Outputs 1, 2, 3, 5) Stakeholder workshop reports (all outputs) Training reports (Output 4) Quarterly & annual progress reports Final technical report	Local field extension staff in place, and available to participate in project activities (all outputs). Collaborating institutions provide agreed inputs on time (all outputs). Farmers willing to provide information in surveys, interviews & workshops (Outputs 1, 2, 3, 7) Sufficient seed available for initial activities in new target areas (Output 4) Calliandra grows well in new target areas (Output 4). Calliandra sets seed in target areas (Output 4). Socio-cultural environment in target areas conducive to uptake & adoption of calliandra (Output 4). Seed producers willing to provide information (Output 5). Actors in leaf meal market chain willing to share information

[1] Based on contract amendments of 24 October 2001, 24 February 2003, 12 April 2004 and 2 March 2005. Excludes component of co-funding by ICRAF, and funds relating to R6549 Phase I.

NARRATIVE	INDICATORS	M.O.V.s	ASSUMPTIONS
4.2 Acquisition & distribution of seed (years 1-3). 4.3 Training and technical support for stakeholders (years 1-3). 4.4 Adaptation, translation, production & distribution of extension materials (years 1-3). 4.5 Internal monitoring (years 1-3). 5.1 Review existing information on calliandra seed production systems (year 1). 5.2 Interviews with seed producers (year 1). 5.3 Analyse and document results of interviews (year 1). 6.1 Review findings of Outputs 1, 2, 3, 4 & 5 (year 3). 6.2 Identify key determinants of success in fodder promotion (year 3). 6.3. Synthesise findings into decision support tool (DST) (booklet) and extension manual (EM) (years 3 & 4). 6.4. Conduct stakeholder workshop to review the DST & EM (year 4). 6.5 Distribute booklet to extensionists in GOs & NGOs in Kenya, Uganda, Rwanda & Tanzania (year 4). 7a.1 Selection of 10 farmer groups (year 4). 7a.2 Informal meetings with farmer groups (year 4) 7a.3 Interviews with extension agents (one per group) (year 4). 7a.4 Semi-structured farmer interviews (year 5). 7a.5 Formal questionnaire survey of 12 adopters per group (year 5). 7a.6 Data analysis & report writing (year 5). 7a.7. Farmer feedback meetings (year 5). 7b.1 Informal survey in 2 farmer groups (year 4). 7b.2 Semi-structured interviews of 3 farmers in each of 15 selected groups (year 5). 7b.3 Data analysis & report writing (year 5). 7b.4 Farmer feedback meeting (year 5). 8.1 Study of the market chain (year 5).			(Output 8). NGOs and other organisations promoting fodder shrubs willing to share information on their organisations' extension strategy and impact (Output 9).

NARRATIVE	INDICATORS	M.O.V.s	ASSUMPTIONS
8.2 Feed manufacturing feasibility study (year 5). 8.3 Study tour in Tanzania (year 5). 8.4 Report writing (year 5) 8.5 Farmer feedback meeting (year 5). 9.1 Assessment of extension providers in Kenya (year 4) 9.2 Report writing (Kenya) (year 4). 9.3 Assessment of extension providers in Uganda (year 5) 9.4 Report writing (Uganda) (year 5). 9.5 Assessment of extension providers in Tanzania (year 5) 9.6 Report writing (Tanzania) (year 5). 9.7 Assessment of extension providers in Rwanda (year 5) 9.8 Report writing (Rwanda) (year 5). H Project maturity workshop			

Annex: List of Contents

Phase 1:

☆ **R6549-FTR-Phase 1-Lascano et al 2003:**
Lascano, C., Avila, P. and Stewart, J. (2003). Effect on intake, digestibility and nitrogen utilization by sheep fed with *Calliandra calothyrsus* Meissner with different tannin structure. *Archivos Latinoamericanos de Producción Animal* **11(1)**, 1-7.

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