Australian Government

Australian Centre for International Agricultural Research

Final report

project	Improving smallholder cattle fattening systems based on forage tree legume diets in eastern Indonesia and northern Australia
project number	LPS/2008/054
date published	1/06/2019
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approved by	Werner Stur
final report number	Fr2019-26
ISBN	978-1-925747-02-7
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

All members of the Project Team (see below) are acknowledged for their enormous contributions to this very successful project. BPTP Indonesia, the University of Mataram, The University of Queensland and CSIRO are thanked for their support of the project. ACIAR is especially acknowledged for providing the funding that led to the excellent outcomes reported here.

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2 Executive summary

Indonesia has a strong unmet demand for beef. Smallholder farmers in the provinces of West Nusa Tenggara (NTB) and East Nusa Tenggara (NTT) have traditionally been producers of cattle but productivity was low because of poor nutrition, particularly during the prolonged dry season common in eastern Indonesia. Fodder tree legumes (FTL) can provide large amounts of high protein feed and some, such as Leucaena (*Leucaena leucocephala*), are able to access residual soil moisture deep in the soil profile and so produce feed even during long periods of drought. There are excellent examples of successful feeding of Sesbania (*Sesbania grandiflora*) in NTB, and Leucaena in NTT and in Queensland (>200,000 ha).

This project was developed to answer the following three research questions: (1) Why have FTL feeding practices, already successfully used in specific regions of Indonesia and Australia, not been adopted in adjacent regions with similar socio-economic and biophysical parameters? (2) How can specific technical constraints that might limit adoption be overcome in Indonesia and Australia? (3) What are the mechanisms required to remove the barriers to adoption of the FTL feeding practices by farmers with diverse cattle management profiles?

The overall aim of the project was *to lift rural income by increasing the rate of turn-off and sales from cattle fattening enterprises through increased use of high quality FTL in cattle diets in Indonesia and Australia*. Specific objectives were to (1) Identify the barriers to widespread application of FTL feeding practices in diverse cattle fattening systems/regions/hamlets in NTT and NTB; (2) Resolve specific technical constraints that hamper adoption of the FTL feeding practices; and (3) Determine the key factors and mechanisms required to achieve widespread adoption of FTL feeding practices in Indonesia and Australia. The focus was on the use of FTL for growing and fattening cattle in pens. Three associated Small Research Activities focussed on adoption processes (managed by Assoc. Prof Elske van de Fliert) and economic analysis of cattle fattening (managed by Dr Scott Waldron) contributed to the outcomes of this project.

The project identified critical barriers and opportunities for adoption of FTL in eastern Indonesia, and developed a large range of extension material including 12 promotional videos that can be used with farmers, extension workers, and policy makers to encourage and support the adoption of FTL-based fattening systems. Building capacity of junior scientists and Government extension staff was a high priority for the project. It worked directly with about 2,000 farmers to provide support for FTL establishment and setting up of cattle fattening and supported the Government Livestock Service to expand FTL-based fattening systems to areas beyond the project's reach. As successful sites emerged these were used for demonstration and training of other interested farmers and farmer groups. Initially seed of leucaena (cv. Tarramba) was imported from Australia. Quickly, Tarramba was recognised as having superior value when compared to other leucaena varieties in Indonesia. The project fostered local production of Tarramba seed to ensure local availability and more than 2000 kg of Tarramba seed have already been sold and distributed. Seed of sesbania is also produced locally and the project developed options for rapid establishment of FTL. By the end of the project more that 1 million FTL seedlings had been planted to support cattle fattening, and more that 2,300 bulls had been fattened by farmers at project sites. Monitoring of liveweight gain has helped farmers improve their feeding system and improved their negotiation power when selling animals to traders. In Indonesia, research on leucaena toxicity has shown that, provided leucaena is introduced gradually, cattle can detoxify the mimosine compound in the leaves through a process of conjugation. If confirmed, there is no need for inoculation of cattle with the bacterium *Synergistes jonesii* that was thought to be the primary pathway in the breakdown of the leucaena toxin mimosine.

By the end of the project more than 2000 farmers had planted FTL and reported that they were turning off fattened bulls at about three times the previous rate as a result of faster growth and more consistent supply of feed from FTL with reduced labour required collecting feed. Economic analysis showed that under all measures of profitability, cattle fattening using FTLs was profitable in wet season (lower in the dry season) and economic returns were far higher than fattening systems without leucaena/sesbania (based on cut grass, residues and purchased feeds). Over 30 publications, including peer-reviewed journal article were produced by the project.

Project outcomes demonstrate that it is possible to double productivity of small holder cattle fatteners in eastern Indonesia; and to improve the livelihoods of farming families by improving the nutrition of cattle based on feeding leucaena and sesbania. The results of this project present a huge opportunity for ACIAR/DFAT to enhance other projects in Indonesia and other tropical developing countries where future cattle improvement projects are planned.

Recommendations for future activities and support:

1. The concept of a Sumbawa Beef project should be promoted and strongly supported by ACIAR and other agencies interested in cattle production in eastern Indonesia.
2. Practical manuals should be prepared describing best practices for the establishment, management and feeding of leucaena and sesbania.
3. GIS maps showing the biophysical suitability of the various agro-ecological zones in Eastern Indonesia for growing *Leucaena leucocephala* and *Sesbania grandiflora* are needed to identify and promote the areas of greatest opportunity for expansion of FTLs.
4. Owing to the continuing strong demand for seed of the Tarramba variety of leucaena, a private investor or investors should be encouraged to invest in the seed business to ensure a sustainable market supply as demand increases.
5. Continuing priorities for new research activities include work on leucaena toxicity as such work has far-reaching implications for all tropical countries. Confirming the ability of cattle on high leucaena diets to neutralise DHP toxicity by a process of conjugation is of utmost importance, as is the management of pregnant females when introduced to leucaena in diet.
6. Other research priorities include study of (a) the anthelmintic properties of leucaena, and (b) the introduction and evaluation of the new psyllid resistant leucaena cultivar ‘Redlands’. This will latter activity will require negotiations with the owner of the PBR rights (MLA/Uniquest).

3 Extended summary

2.1 Background

The Indonesian provinces of West Nusa Tenggara (NTB) and East Nusa Tenggara (NTT) were identified as areas with high potential for expansion of smallholder beef production.

Lifting the productivity of fattened cattle to meet the increasing demands of the Indonesian population has been nominated by provincial agencies as one of the most important ways to improve the incomes of the rural poor.

Currently, smallholder fattening systems are characterised by irregular, slow turn-off and poor carcass quality, largely resulting from very poor protein nutrition of cattle fattened under traditional feeding systems.

Expanded utilization of forage tree legumes (FTL) offers the best chance of providing high quality protein supplement to ruminants on poor quality diets, especially in the dry season. Their value has been demonstrated repeatedly throughout the tropical world.

In Indonesia, there are two significant examples where farmers have been able to enhance the protein nutrition of ruminants by feeding leaf of FTL. These are sesbania (*Sesbania grandiflora*) in NTB and leucaena (*Leucaena leucocephala*) in both NTB and NTT.

In Australia, >200,000 ha of leucaena pastures have been planted in Queensland to meet graziers' needs for a highly productive and profitable system producing "grass-fed" beef of superior quality. This experience was used to promote uptake of tree legumes in Indonesia.

2.2 Objectives

Project LPS/2008/054 was developed on the hypothesis that: "FTL feeding practices can be successfully transferred to neighbouring districts provided the implications for diverse groups of farmers are identified and effectively tackled through participatory adaptive research and 'Roll-Out' efforts, and provided specific technical issues that might limit their use are resolved."

This hypothesis resulted in three clear research questions, namely:

a. Why have FTL feeding practices, already successfully used in specific regions of Indonesia and Australia, not been adopted in adjacent regions with similar socio-economic and biophysical parameters?
b. How can specific technical constraints that might limit adoption be overcome in Indonesia and Australia?
c. What are the mechanisms required to remove the barriers to adoption of the FTL feeding practices by farmers with diverse cattle management profiles?

The general aim was to lift rural income by increasing the rate of turn-off and sales from cattle fattening enterprises through increased use of high quality FTL in cattle diets in Indonesia and Australia.

Specific objectives were to:

1. Identify the barriers to widespread application of FTL feeding practices in diverse cattle fattening systems/regions/hamlets in NTT and NTB
2. Resolve specific technical constraints that hamper adoption of the FTL feeding practices.
    a. Constraint 1. Subclinical toxicity experienced by cattle consuming leucaena in Indonesia and Australia is limiting intake of animals and therefore their ability to respond to the higher protein diet

   b. Constraint 2. Lack of understanding and information on the bio-physical parameters of sesbania feeding systems in Lombok is limiting ability to roll-out the system to other regions.

3. Determine the key factors and mechanisms required to achieve widespread adoption of FTL feeding practices in regions of Indonesia and Australia adjacent to those where successful adoption has already taken place and that have similar socio-economic and biophysical parameters.

A variation in the project was proposed and approved to enhance the assessment of barriers to adoption. Three Small Research Activities (SRAs) were designed to focus on the adoption processes for FTLs and on economic analyses of FTL-based cattle fattening systems. These were managed independently by Assoc. Prof. Elske van de Fliert and Dr Scott Waldron.

The outcomes of LPS/2008/054 and the related projects were expected to advance the understanding and management of FTL, both in Australia and Indonesia, and have direct impact on farmers in NTT and NTB through roll-out activities of the project.

Project LPS/2008/054 was designed with an important proof of concept focus to show that leucaena and sesbania are safe and productive for use, at high rates, in diets to fatten cattle and that they can be established and managed effectively by farmers.

The activities were also designed to provide clear recommendations for next users on how to best target and support scale out of FTL systems in NTT and NTB, in other parts of Indonesia, and in tropical locations generally.

2.3 Methodology

Start up, selection and training of field research team. A Workshop was conducted in December 2010 to plan detailed activities for the first years of the project and to initiate key partnerships with important stakeholders e.g. with Dinas and NGOs.

A field research (FR) team comprising nine young recent graduates was recruited to be responsible for smallholder development and extension activities working under the supervision of project leaders. The FRs were trained in using FTL to fatten cattle, and in methodological topics and group dynamics associated with working with farmers. We understood that the success of their future work in villages rested strongly on their social and technical competence, and that this would influence how well they were regarded / respected by farmers.

Mentoring Contracts were established for the senior Indonesian project staff to mentor the Field Researchers with the aim of improving their skills and technical competence in livestock R&D, methodological confidence in adaptive research, and commitment to research data collection.

Selection of project sites. In Indonesia, the target unit for the project was initially the farmer group physically located at the hamlet level. In each of the two provinces, we chose 1-2 locations where FTLs feeding systems already existed (but could be improved) and 2-3 locations where there was no history of intensive feeding with FTL. Initial selection of potential sub-districts occurred during the Start-up Workshop in December 2010.

Criteria used to analyse and compare villages and hamlets included land and cattle ownership, predominance of cattle enterprise, availability of suitable land to plant FTLs, existing use of FTLs as cattle feed, village location and accessibility, and group functionality. The selection process involved the following steps in each sub-district:

Twenty-four farmer groups were selected in November 2011 in 8 sub-districts representing the variable conditions and cattle fattening systems based on comprehensive

information gathered. As the project progressed and our understanding improved, there were changes to the locations of activities more appropriate to changing circumstances.

Communication was conducted via smartphones, a Facebook Site (TIM PLP, emails and messaging apps such as: Whatsapp, BBM, Facebook, Messenger, and Viber. We also encouraged regular visits to project sites within Indonesia and in Australia. Annual site visits and annual meetings were held to discuss and evaluate progress, and to plan the next year's activities.

Research methods for Objectives 1 and 3. In order to achieve the first project objective to 'identify the barriers to widespread application of FTL feeding practices in diverse cattle fattening systems in Eastern Indonesia', a situation analysis was designed to investigate technical, economic and socio-cultural aspects of cattle farming in the target areas. The main barriers and opportunities were extracted and categorised, and a framework for an Extension Strategy was drafted.

The framework for the FTL Extension Strategy was further developed in collaboration with representatives from all important stakeholder groups including:- heads of the hamlet and/or village of the project sites and farmers; representatives from the district extension or extension coordinators at sub-district level and agricultural extension officers; representatives from district livestock departments; and Project Leaders and Field Researchers.

To implement the Pilot Roll Out (PRO), a participatory needs and opportunity assessment was conducted in regions adjacent to successful adoption areas of FTL feeding practices through community based focus group discussions and interviews with farmers, extension officers and community leaders.

- In Phase 1, a small scale pilot of FTL Extension practices (2 groups per province with10-20 farmers/group) was implemented and evaluated, followed by revision of the Extension Strategy, and development of communication materials and media.
- In Phase 2, a medium scale pilot of FTL practices was implemented. Initially the plan was for 10 groups per province with 20 farmers/group, but in reality, due to ever-increasing requests to become involved by Government and NGO agencies, farmer groups, and individuals, participating could not be neatly categorised as there were so many.

Training of trainers was conducted for extension officers and/or farmer facilitators. Forty to sixty facilitators were trained in expanding FTL practices to target communities. This activity continues post-project. Materials and media for expansion of FTL systems were produced for training purposes.

In Australia, information on the management and establishment of leucaena, was imparted to Australian farmers via UQ training activities/field days, DAF extension services and The Leucaena Network website. Since 2004, more than 500 farmers have participated in education and training activities at various locations around Queensland conducted by the UQ group.

Research methods for Objective 2. Methodology for the principal research projects undertaken is summarised for each of the major investigations. All investigations have been published as indicated in the outputs/achievements.

Agronomy and feeding of leucaena and sesbania. The growth of Bali bulls fattened with *Leucaena leucocephala* in Sumbawa, Indonesia was studied from April 2012 to March 2013 in the hamlet of Jati Sari in Sumbawa district (Panjaitan *et al.* 2013). Parameters monitored included bull average daily gain (ADG), feed offered including amount of leucaena in diet, and sale weight.

Bali bull fattening practices in Central Lombok, Eastern Indonesia, based on feeding of *Sesbania grandiflora*, were monitored from January to December 2013 in the hamlet of Nyerot (8º40´S 116º13´E) in the subdistrict of Jonggat.

In the hamlet, 34 farmers were independently fattening 1-2 bulls each but operated as a group in a shared cattle barn (kandang) for security reasons. Parameters measured in the longitudinal survey were: climatic conditions; area of land for rice and length of rice bunds planted to sesbania; agronomy and management of sesbania trees; monthly bull live weights following overnight fasting; purchase and sale weights from February to October 2013.

Leucaena toxicity. The prevalence of DHP toxicity and *Synergistes jonesii* in ruminants consuming *Leucaena leucocephala* was investigated in cattle production areas of eastern Indonesia and in Queensland, in the major goat-producing regions of Thailand, and in ruminants in the Yucatan peninsula of Mexico. Urine samples were collected, preserved and analysed by HPLC for DHP. Where possible, rumen fluid was collected for PCR detection of *S. jonesii* at CSIRO Animal, Food & Health Sciences lab in Brisbane.

The effectiveness of inoculation with rumen fluid containing *Synergistes jonesii* to control DHP toxicity in ruminants was studied in eastern Indonesia. Rumen fluid from donor animals, identified as being protected by *S. jonesii*, was used to inoculate recipient animals from areas known to be prone to DHP toxicity. The success of inoculation was gauged by measuring the extent of urinary DHP excretion in the recipient animals. The efficacy of a cultured *Synergistes jonesii* inoculum in degrading the *Leucaena leucocephala* toxins was also studied in southeast Queensland.

The genetic diversity in the ‘leucaena bug’ *Synergistes jonesii* was investigated in rumen fluid or faeces collected from Australian cattle in Queensland, and from cattle, sheep, goats, buffalos, native cattle from Indonesia, Thailand, Vietnam, China (including yak) and Brazil, mainly from local farmers. Microbial DNA was extracted from these samples and amplified with a set of 16S rDNA nested PCR primers specific for *S. jonesii*. PCR products positive for *S. jonesii* were then aligned against full-length *S. jonesii* 16S rDNA sequence for identification of SNPs.

2.4 Achievement against activities and outputs/milestones

Barriers and Opportunities for adoption of FTL

The barriers and opportunities to adoption of FTL in Indonesia are now well understood. Our findings were first presented in the paper by Kana Hou *et al*. (2013) then an updated list of barriers and opportunities for adoption was completed in year 5 (Table 6.1). This more detailed list of the barriers and opportunities for adoption of FTL is described under the principal categories:

1. Nature of the innovation
2. Technical constraints
3. Project leadership and staffing
4. Engagement with farmers
5. Socio-economic and agribusiness issues
6. Government policy and involvement

Implementation of the Pilot Roll Out (PRO)

Range of extension materials. Twelve promotional videos were produced Both still photographs and videos are being used for the promotion of the general principles of fattening with FTLs. The videos were used to promote the use of FTL to more than 60 government extension staff and more than 100 farmer leaders, as well as to educational institutions in eastern Indonesia and across the country.

These videos are also available online on YouTube at:
https://www.youtube.com/channel/UCzJ2nYUlS5No28HaI_2SdnA

Working with farmers. During the establishment of the demonstration sites and the two phases of roll-out, the project has worked with about 2,000 farmers in NTT (Timor and Sumba) and NTB (Lombok and Sumbawa) (Table 6.2). The direct contact with farmers and farmer groups has been largely handled by the Field Researchers under the supervision and mentorship of the Indonesian project leaders.

Case studies. Seven active successful demonstration sites have become case study sites and are being used for demonstration and training. They are: - a village group in Oebola on Timor; a village group in Setetes Madu on Timor; several farms in the village of Labangka on Sumbawa; Balinese farmers in village of Jati Sari on Sumbawa; the individual farms of Mr Samsidar and Mr Muin on Sumbawa; and the village group in Nyerot on Lombok.

The case studies were developed and described in collaboration with SRAs lead by Dr Elske van de Fliert (sociologist) and Dr Scott Waldron (economist). The SRAs have enhanced our understanding of the FTL systems and provide better social and economic documentation for use in promotion of FTLs to farmers, extension workers, and policy makers.

Level of adoption. Significant adoption has already occurred during the project, well in excess of planned goals. The level of adoption during the life of the project can be measured in several ways e.g. number of FTL seedlings planted, number of bulls fattened, number of farmers involved. For instance, >2000 kg of Tarramba leucaena seed was distributed throughout every province in Indonesia. Dinas Peternakan was the largest purchaser of seed, but there have been multiple smaller purchases from many organisations, NGOs, private farmers, as well as farmer to farmer sales. More than >1,000,000 FTL trees have been planted to fatten bulls.

Dinas Peternakan programs are now supplying feeder cattle to allow farmers to get started with fattening provided they have already planted Tarramba leucaena. This has created a significant incentive to plant FTL.

Engagement with Government and NGO stakeholders. We have developed strong links with Government and non-government agencies. In NTT, we have been especially successful in linking with and gaining support for project activities from agencies at Provincial and Kabupaten Levels. In NTB, memorandums of understanding (MOUs) were prepared and signed to formalise linkages with Bupati of West Sumbawa; the Head of Dinas in Sumbawa District, and the Head of Dinas in Central Lombok.

The value of Tarramba leucaena and supply of seed. The leucaena cultivar Tarramba was first introduced to Indonesia as a component of ACIAR Project AS2/2000/157 Leucaena management in West Timor and Cape York (1 January 2001 to 31 December 2003). There is now widespread recognition of the superior value of the cultivar which was found to be preferred by cattle, less affected by psyllids, leafier, lasted longer into dry season, and yielded better poles. It is widely accepted as vastly superior to local or Cunningham varieties. The development and use of Tarramba have been highly supported by Provincial Bappeda and Livestock Dinas, District Livestock Dinas, etc. There is now strong demand for seed.

LPS/2008/054 has worked with smallholders and Government agencies - BPTP and Dinas Peternakan – to establish seed orchards of this cultivar. BPTP-NTT is now the major supplier of Tarramba for Indonesia, organised by Ms. Debbie Kana Hau. During the life of the project, >2,000 kg seed has been distributed to various locations within and outside NTT and NTB.

Scientific outcomes from technical research. There were very substantial advances made in addressing technical constraints. The findings were major highlights of the project

and will have major impacts on the livelihoods of smallholder farmers in NTB and NTT, as well as in other regions of Indonesia and Australia, and beyond.

Productivity of Cattle fattening with FTLs. As part of the on-farm research and demonstration of FTL systems (Objective 2), there were extensive feeding and demonstration trials of cattle fattening with leucaena and sesbania. These multi-site trials and demonstrations have demonstrated the high value of leucaena and sesbania for cattle fattening, especially compared to the standard animal diets based on a wide range of feeds, which were mostly of quite low quality. Monitoring of live weight gains has led to a better understanding by farmers of the benefits of improved diets based on FTLs, and has prepared the farmers for negotiating with traders with respect to estimated live weight of purchased and sale cattle.

We now have a thorough knowledge of methods for FTL establishment, improved management, cattle productivity, housing and hygiene of the bulls, and an understanding of the barriers to adoption. All of this work was documented and published (Panjaitan *et al*. 2014; Dahlanuddin *et al*. 2014).

There was also some preliminary work on the impact of leucaena and sesbania on controlling gastrointestinal parasites in NTB (Luh Gde Astiti *et al*. 2013). These results suggested that the higher tannin content of leucaena may make it effective for control of parasites, enhanced by the harvest of forage well above ground-level.

There was some evaluation of different varieties and accessions of sesbania.

One obvious difference between leucaena and sesbania is that leucaena can be maintained for many more years, while sesbania needs to be re-established more regularly but grows more quickly. Thus, there is the option of starting production and feeding based on sesbania and then moving increasingly to leucaena as the leucaena becomes established among the sesbania trees.

Much can and should be done to promote FTL production and feeding systems in other parts of NTB and NTT, and the rest of Indonesia as well as throughout Southeast Asia.

Leucaena toxicity. The scientific and practical outputs on leucaena toxicity are very exciting and the potential for impact elsewhere cannot be underestimated. There are some very interesting findings on the presence and nature of the bacterium *Synergistes jonesii* that was thought to be the primary pathway in the breakdown of the leucaena toxin mimosine and DHP to non-toxic products. Our findings suggest a new toxin degradation paradigm and can be summarised:

- *S. jonesii* is ubiquitous in ruminants worldwide, but not degrading all of the DHP in animals on high leucaena diets. Animals appear to cope with high levels of DHP in blood by a process of conjugation in the liver which neutralizes its toxicity.
- These findings if confirmed, will lead to a dramatic change to our understanding of how animals consuming leucaena world-wide should be managed: e.g. Indonesian Bali bulls do not require inoculation, but do need gradual introduction to leucaena to adapt to mimosine, and to induce conjugation pathways to neutralize DHP.
- We now hypothesize that: through a gradual introduction of leucaena into the diet, and without the need for an inoculation with *S. jonesii*, animals can be healthy and have high LWGs on a diet with a high proportion of leucaena. These findings if accepted mean that there is no longer a need to focus on inoculation with *S. jonesii* as the primary detoxification pathway, as was proposed in the original project document.

Further work is required to confirm the significance of this detoxification pathway in Australian cattle consuming leucaena, where we know that conjugation occurs, but the extent is unknown.

Full details of this work are given in the published papers (e.g. Halliday *et al.* 2013).

Communication and dissemination. There have been extensive communication and dissemination activities to maximise social and technical contact among team members, and with other stakeholders. Communication was conducted in several ways and was important in maintaining team spirit. For day to day communication, we used Smartphones and a Facebook Site (TIM PLP). This site is still being utilized post-project and enables continuing communication at project technical and personal levels.

We also held regular meetings, discussions with many farmer groups and individuals as well as with Government and non-government agencies. There were also regular field visits involving a large number and diversity of people including visiting Australian scientists, graziers, as well as many Indonesian Government personnel. Annual site visits and meetings were used by Indonesian and Australian project leaders to reflect on the year's activities and plan for the new year. They also were useful in building team morale and a sense of team unity.

Training. Training of the young Field Researchers was a continuing on-going priority. Most responded well and demonstrated greatly improved capacity.

During the latter period of the project, training courses were prepared and delivered for extension staff from Livestock and Extension Departments. These courses were supplemented with course materials including 12 training videos that highlighted various aspects of cattle fattening with FTL.

In Australia, two short courses (Leucaena for profit and Sustainability) were given to graziers and Santos staff at Roma and Wallumbilla in 2012. The course provided information on all aspects of planting, management and feeding leucaena. Australian staff also presented talks to The Leucaena Network Meetings (Australian graziers) in 2012, 2013, 2014, and 2016.

Research outputs and publications. The Project has had a prodigious publication output. There were:

- 14 published papers in journals
- 19 conference presentations and papers
- Article in Partners Mag.; in local Indonesia magazines
- Indonesian radio ads
- The Leucaena Network Newsletter and several AGM meetings
- Article of "Update on leucaena toxicity"
- Article in School of Agriculture and Food Science newsletter
- Extra activities of by Indonesian staff
- Indonesian presentations to groups, agencies, IAARD, etc

There was a major focus on participation in conferences including a major presence at the International Grasslands Congress (IGC) in 2013, and participation in a number of other international and national meetings in Australia, Indonesia, and elsewhere.

2.5 Key results and discussion

Management, collaboration and cooperation. Lefroy and Ibrahim (2016) reported that the project leaders in Australia and Indonesia led the project competently and enthusiastically, supported by an excellent team in NTT, NTB, and in Australia. An important factor was the establishment of strong communications including establishing a team Facebook page, provision of smartphones to the Field Researchers, and the widespread use of emails, direct messaging, and other support apps.

There were regular team building events including regular annual meetings, and a group trip to Australia. The specific role of Mic Halliday in initiating and supporting many of the communications and his time spent in the field, was acknowledged, along with strong leadership from Dr. Tanda Panjaitan and Assoc. Prof. Max Shelton.

Situation analysis. While the situation analysis under Objective 1 sought a systematic analysis of the livestock feeding systems, it consumed too much time, involved all staff at each site, and much of the output was unusable. There was insufficient attention paid to the resources of the farmers.

The initial implementation focused on working with whole groups of farmers, whereas in quite a number of cases it was better to work with individuals within groups or very small groups. It was better to focus on people willing and able to try the FTL systems.

However, the project effectively addressed constraints leading to effective roll-out of the FTL innovations. The establishment of demonstration sites was a critical component of this work and were used for important cross-visits to promote good management practices.

The project developed a basic model of a fattening shed (kandang) which could be easily replicated by farmers or farmer groups, in single or multiple units, either exactly as recommended or modified for local construction materials.

Understanding animal nutrition. Fundamental to successful fattening of cattle was improving farmer understanding of the importance of nutrition of cattle and the vital role for FTLs in providing high nutritive value forage that can be safely fed to cattle. One reason for not adopting FTLs was legitimate concern about the safety and nutritive value of leucaena. This project has demonstrated that leucaena toxicity is not as severe as first thought.

Where can FTLs be grown? There is a strong argument to use agro-ecological zoning (AEZ) as a tool to document the biophysical suitability of different regions information for FTL production in terms of soils, climate, altitude, etc., based on expert knowledge from the project and elsewhere. This had already been done for NTT in Project AS2/2000/157. The GIS mapping indicated that most of East Nusa Tenggara Province, with its tropical climate and soils of neutral to alkaline in pH, is suitable for growing *Leucaena* spp.. There is a need to digitize soil and socio-economic data to refine/increase the precision of mapping. GIS suitability maps have not yet been prepared for East Nusa Barat Province.

Lessons learned and reasons for success. Both the reviewers and the project team leaders made a number of valuable points regarding lessons learned and reasons for success. Lefroy and Ibrahim (2016) noted that the "*project demonstrated some of the best aspects of the ACIAR model for project implementation. There was a very strong and capable project team, with excellent complementary skills in several scientific fields, in Australia and Indonesia, in field work, and in the interest and ability to engage with policy makers".*

Some reasons for success are listed:

1. The project was well led, and the team worked effectively together, with excellent communications at all levels across island and countries. The Field Researchers were a critical part of the project team.
2. The goals and objectives of the project were clearly defined and executed, both socio-economic and technical. Technical issues were answered quite categorically, with strong scientific findings.
3. There was good complementarity of interests between Australia and Indonesia, strong links with government agencies due to alignment of policy objectives at Provincial and National levels, and relevant Australian expertise.
4. While a cattle fattening project, our initial emphasis was on establishing forage (not cattle), then cattle were introduced once feed supply was assured.
5. Changing historical circumstances had lifted farmer interest in planted forages from the mid to late 90s due to increasing value and demand for high quality cattle, less

land available for free grazing, and increasing labour requirement to herd free range animals.

6. Despite historical adoption of improved grasses - mostly elephant grass - productivity of cattle remained quite low as grasses did not satisfy dry season need for high quantity and high quality forage. Similarly, herbaceous legumes do not have the longevity or capacity to provide forage into the dry season afforded by deep-rooted FTLs. FTLs also provide other benefits such as timber, fuelwood, and weed control, as well as grazing animal control (once established) and improved gastro-intestinal parasite control.
7. We introduced legumes (leucaena and sesbania) that were not new as many farmers were already using them, and the project concept was uncomplicated, culturally and work load appropriate.
8. The success of the variety – cultivar Tarramba – was paramount. This variety now has a huge reputation among Government officials and farmers alike as it is preferred by cattle, less affected by psyllids, leafier, lasts longer into the dry season, yields better poles. This was a major achievement of ACIAR Project AS2/2000/157

2.6 Project impacts

There have been many positive impacts within the life of the project and this is expected to continue on completion of the project in 2016. They are now summarised.

Adoption. In Phase 2, the medium scale pilot-roll-out of FTL practices planned to reach 10 groups per province at 20 farmers/group. In reality due to ever-increasing requests to become involved by Government and NGO agencies, farmer groups, and individuals, participating farmers could not be neatly categorised and there were many more adopters than originally planned (see Table 6.2).

We used the ‘Adopt’ program sponsored by ACIAR, UWA, DAFWA, CSIRO, GRDC, DPI Victoria, Future Farm Industries CRC, Charles Sturt University. The output summarised in Table 8.1 indicated 11.8 years to peak adoption.

Economic impacts. Dr Scott Waldron conducted an analysis of our key FTL sites and reported that: “Under all measures of profitability, representative (cattle fattening) households at all sites were profitable in wet season. As could be expected, “return to person days” in the dry season were lower than average off-farm wages. These returns were far higher than fattening systems without leucaena/sesbania (based on cut grass, residues and purchased feeds) which were not viable by any measure of profitability. In general, returns were (in order of importance) sensitive to weight gains, input-output price alignments, capacity utilisation and capital costs”.

The economic impacts documented by Lefroy and Ibrahim (2016) showed that farmers working with the project sold more than 2,300 bulls at an average weight of 250kg and an average price of IDR25,000 per kg live weight, with a gross sale value of approximately AUD1.5 million equivalent to about 85% of the value of the project.

Farmers said that they were turning off fattened bulls at about three times the previous rate as a result of faster growth and more consistent supply of feed from FTL with reduced labour required collecting feed. Many farmers said that cattle fattening had become more of a business for them, and that they had shifted from being keepers of cattle selling poorer quality animals when cash is required or when feed is limited, to producers of cattle who keep and sell animals more regularly, in better condition, and at higher body weights.

The demand for Tarramba seed continues to increase and is indicative of the interest in expanding FTL production; sale of seed in the first year after planting provides an attractive lucrative additional source of income for farmers or farmer groups.

Social impacts. Lefroy and Ibrahim (2016) reported that “Social benefits flow from the economic benefits from sale of greater numbers and higher value cattle. There have been clear improvements in living conditions of households as profits from cattle fattening have been put into improvements in housing and other essential family needs. The purchase of assets such as motorbikes is another benefit, as well as satisfying other essential asset needs for the family. Improvements in education, health and labour productivity are likely consequences of increased cash income, especially on a more regular basis, and particularly through the dry season”.

The adoption of biogas systems by farmers involved in cattle fattening has social and economic impacts through the provision of light and heating. The trees can also provide both firewood and poles for building.

Environmental impacts. Environmental benefits from the adoption and expansion of FTL based cattle fattening systems can be realized at the farm, catchment and global levels. Farm level benefits occur as FTL can buffer extended dry periods, improve water use efficiency, enhance soil fertility and control weed ingress.

Catchment level benefits accrue from improved hydrological balance, while global level benefits accrue improved greenhouse gas balance due to C sequestration and methane reductions.

Capacity-building impacts. The project has improved capacity at several levels, namely the skills of our senior project leaders and our junior field researchers (FRs), as well as other stakeholders such as Provincial Livestock Department and Extension personnel.

Scientific impacts. The scientific outputs of the project are broad ranging covering plant and animal research, molecular research, through to field research aimed at development impacts. Over 30 publications, including peer reviewed journal articles, conference papers and several other forms of written and oral communication, were completed. There were 9 journal papers on leucaena toxicity issues and 5 on the agronomy of FTLs, the feeding of FTLs to cattle, and the adoption of FTL systems. There has been a major focus on participation in conferences with at least 19 presentations or posters.

2.7 Conclusions and recommendations

Conclusions. Project outcomes demonstrate that it is possible to double productivity of small holder cattle fatteners in Indonesia; and to improve the livelihoods of farming families by improving the nutrition of cattle based on feeding leucaena and sesbania. The results of this project present a huge opportunity for ACIAR/DFAT to enhance other projects in Indonesia and other tropical developing countries where future cattle improvement projects are planned.

The project has also demonstrated that a sustainable supply of either leucaena or sesbania can be established, maintained, and managed for feeding and fattening cattle.

The project has produced extension materials that can be used to promote the innovations with policy makers. There was also a prodigious level of significant scientific output ranging from in-depth scientific knowledge to applied research on practical aspects of cattle fattening systems.

Our reviewer commented that “With no further effort, the impacts of the project are impressive, but with well-coordinated follow-up the impacts can be very large”.

Recommendations for future activities and support. It is recommended that:

7. The concept of a Sumbawa Beef project should be promoted and strongly supported by ACIAR and other agencies interested in cattle production in eastern Indonesia.
8. Practical manuals should be prepared describing best practices for the establishment, management and feeding of leucaena and sesbania.

9. GIS maps showing the biophysical suitability of the various agro-ecological zones in Eastern Indonesia for growing *Leucaena leucocephala* and *Sesbania grandiflora* are needed to identify and promote the areas of greatest opportunity for expansion of FTLs.
10. Owing to the continuing strong demand for seed of the Tarramba variety of leucaena, a private investor or investors should be encouraged to invest in the seed business to ensure a sustainable market supply as demand increases.
11. Continuing priorities for new research activities include work on leucaena toxicity as such work has far-reaching implications for all tropical countries. Confirming the ability of cattle on high leucaena diets to neutralise DHP toxicity by a process of conjugation is of utmost importance, as is the management of pregnant females when introduced to leucaena in diet.
12. Other research priorities include study of (a) the anthelmintic properties of leucaena, and (b) the introduction and evaluation of the new psyllid resistant leucaena cultivar ‘Redlands’. This will latter activity will require negotiations with the owner of the PBR rights (MLA/Uniquest).

4 Background

3.1 Beef production and consumption in Indonesia

Average incomes in Indonesia are increasing as the population and economy grows; in 2000, the population was 211 million increasing to 257 million in 2015. With shifts in income and movement of rural population to urban areas there has been increased consumption of meat (chicken and beef). Similar trends have occurred in other Southeast Asian countries.

This increasing demand for beef in Indonesia has resulted in high prices for animals bred and fattened in Indonesia, as well as for imported beef and live cattle imports, especially from Australia. By global and regional standards, Indonesia does not have a high per capita beef consumption, with the average consumption estimated at only 1.5 kg/capita/yr in 2000 increasing to about 2.5 kg/capita/yr in 2015 (Figure 1). This tight supply and demand relationship is reflected in the retail price of beef, which has quadrupled from 2000 to 2015 (Lefroy and Ibrahim 2016).

A projection by ABARES suggested that the value of national beef consumption in Indonesia will increase 13-fold from 2009 to 2050 (Gunning-Trant *et al*. 2015).

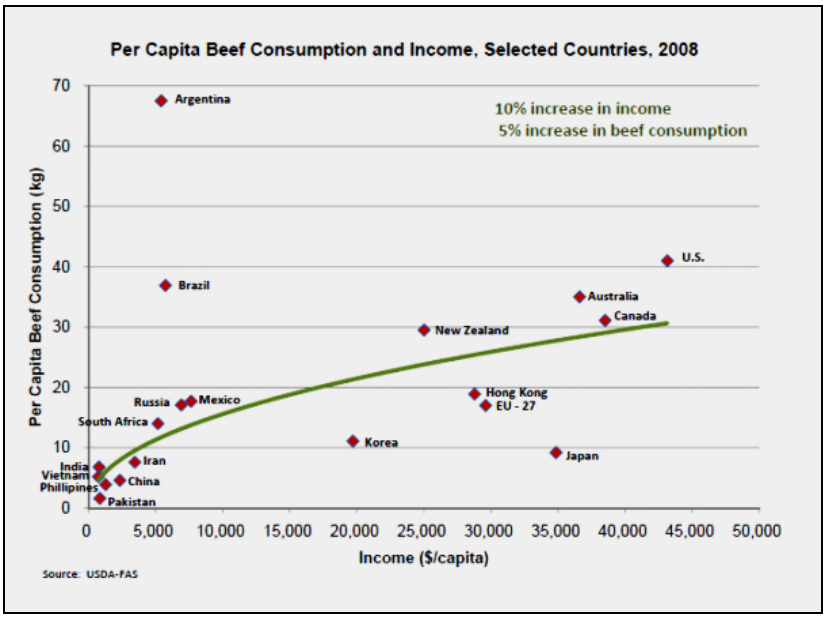


Figure 1. Per capita beef consumption and income, selected countries, 2008

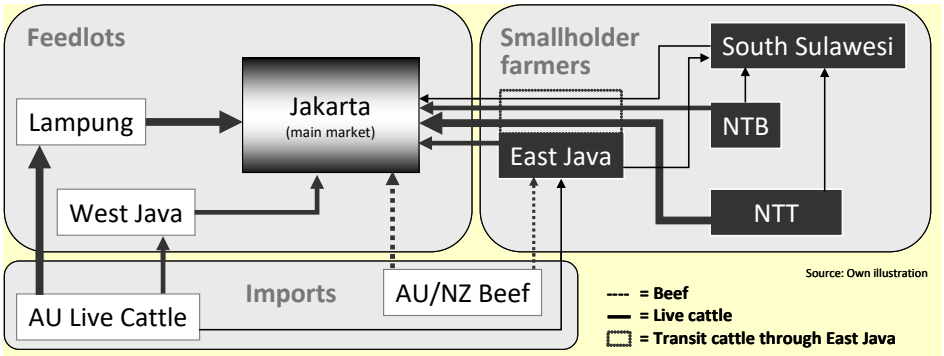


Figure 2. Cattle production sectors and marketing flows in Indonesia (Deblitz and Kristedit, 2011).

The national beef herd beef cattle in Indonesia was estimated at nearly 16 million, with about half in Java, the area of highest population and demand for beef. However, Waldron (2016) reported that "data from an agricultural census conducted in 2013 found herd number was lower at 12.6 million head. Cattle numbers were revised down even more in NTB (by 35% to only 650,000 head in 2013), while the revision was minor in NTT (to 803,000 head in 2013).

In 2010, domestic production approached 414,000 t which satisfied just over 60% of demand. This shortfall in local supply was largely met by import of live cattle from Australia which, between 2005 and 2015, varied between 200,000 and nearly 700,000 head per year (see Figure 2 for diagram of beef production and marketing sectors).

The Indonesian government, with the aim of achieving self-sufficiency, has initiated programs to boost domestic beef production. The majority of cattle in Indonesia are kept by about 6.5 million smallholder farmers, supplemented by a small number of much larger cattle ranches and larger feedlots, especially in Java and Sumatra.

National and Provincial governments have targeted areas with high potential for increased smallholder beef cattle production such as West Nusa Tenggara (Nusa Tenggara Barat, NTB) and East Nusa Tenggara (Nusa Tenggara Timur, NTT). These Provinces currently support more than 10% of the national herd and have a high number of cattle per farmer.

In addition to the objective of increasing the domestic beef supply, assistance to the smallholders was viewed as the best way to improve the livelihoods of the rural poor. This was important as NTB and NTT have low per capita GDP (in 2014, at 41 and 32% of the national average, respectively) and are ranked 30th and 31st out of 34 Provinces in the 2014 provincial Human Development Index (BPS) (Lefroy and Ibrahim 2016).

3.2 Challenges to increasing the domestic supply of beef in Indonesia

Prospects for expansion of the smallholder sector are constrained by both low production efficiency and socio-economic factors, namely:

Production efficiency limitations

a. Very slow growth rates (0.15–0.25 kg/day) including loss of weight in the dry season
b. Low calving rate (±65%), combined with high calf mortality (10-20%) causing very low rates of turn-off necessitating slaughter of underweight and older animals;
c. Low sale weights (averaging 250 kg) causing low carcass weight and low dressing % (45% in Indonesia cf. 54% in northern Australia).;
d. Low genetic potential of local breeds mainly Bali and Ongole breeds;
e. Poor management of the herd structure due to slaughter of productive cows and lack of bull selection; and
f. Poor sanitation, housing, health, management.

The principal production efficiency limitations (a), (b), (c) and (d) are all related to lack of a good quality (high protein) forage supply year-round, especially in the dry season (Figure 3).

Socio-economic limitations

a. Poor understanding of the barriers, opportunities and drivers of improvement of smallholder cattle fattening enterprises;
b. Lack of knowledge, experience and relevant training in forage improvement;

c. Problems with supply of credit, lack of land, poor extension & training;

d. While access to markets and transportation were generally available, there is a lack of market knowledge and high transport costs; and

e. Government policy settings have sometimes unintended negative consequences.

Limited wet season communal grazing (Sumbawa)

Lack of forage in dry season (Sumba)

Lack of forage in dry season (Timor)

Calf mortality is high due to inadequate nutrition (Timor)

Figure 3. Lack of adequate forage severely limits nutrition of beef cattle in eastern Indonesia

The Regional Planning and Development Agency (Badan Perencana Pembangunan Daerah, BAPPEDA) in both Provinces has attempted to address low productivity by increasing the number of extension staff and providing support for breeding, animal husbandry, improving loan schemes, developing market incentives, upgrading transport and slaughter facilities, and by achieving better collaboration between Government agencies, banks, and NGOs. However, it is widely recognised that due to lack of expertise and experience, the central problem of poor feeding was not being adequately addressed.

3.3 Justification for ACIAR project LPS/2008/054

In 2000, ACIAR initiated a series of co-ordinated and collaboratively linked experiments across the eastern islands of Indonesia. The projects linked a wide variety of Institutes, focused on major beef cattle breeding regions and on Bali cattle (Table 1). However, the issue of utilizing high quality forages to fattening cattle efficiently was not addressed. Accordingly, the focus of the current ACIAR Project (LPS/2008/054) on smallholder cattle fattening enterprises was both appropriate and timely.

While the use of expensive concentrates is an option to improve diet quality for feedlots, it is not a profitable option for smallholders, where the only viable option is the sustainable production of home-grown improved forage. In addition, the significance of forage quality is widely under-appreciated in Indonesia by farmers and extension workers alike. The early focus for forage improvement was on grass plantings as grasses provided bulk, and cutting of grass for cattle was almost a way of life in village communities; however, tropical grasses are generally not of high quality, especially when mature, and harvesting is labour intensive. While higher quality leguminous material was sometimes available, management of herbaceous legumes is more difficult and uptake has been minimal (Shelton *et al*. 2005).

Table 1. List of projects designed to support the Indonesian beef industry (2000- 2010)

Project code	Project title
AS2/2000/099	Strategies to improve Bali cattle - eastern Indonesia
AS2/2000/103	Developing an integrated production system for Bali cattle in the eastern islands of Indonesia
AS2/2000/124	Prospects for improved integration of high quality forages in the crop-livestock systems of Sulawesi, Indonesia
AS2/2000/125	Optimising crop-livestock systems in West Nusa Tenggara Province, Indonesia
AS2/2000/157	Leucaena management in West Timor and Cape York
LPS/2004/005	Improving smallholder crop-livestock systems in eastern Indonesia
LPS/2004/023	Strategies to increase growth of the weaned Bali calf
LPS/2006/005	Evaluating strategies to improve calf survival in West Timor villages
LPS/2007/115	The growth and phenology of three tropical forage legumes for model development
SMAR/2006/003 LPS	Integrating forage legumes into the maize cropping systems of West Timor
SMAR/2006/061 LPS	Building capacity in the knowledge and adoption of Bali cattle improvement technology in South Sulawesi
SMAR/2006/096 LPS	Scaling-up herd management strategies in crop-livestock systems in Lombok, Indonesia
SMAR/2007/013 LPS	Opportunities to use cocoa pods and forages to address feed gaps in the dry season in Southeast Sulawesi
SMAR/2007/100	Support for development of improved approaches to technology assessment and knowledge exchange

The most viable option to improve diet quality in eastern Indonesia is to feed cattle the foliage of forage tree legumes (FTL) (Final report ACIAR Project AS2/2000/157) Leucaena management in West Timor and Cape York). FTLs grow well in the region, provide feed year-round, and the best species have a number of positive attributes for smallholders. They are:

a. High in quality, especially in protein;
b. Deep rooted thus providing forage into the dry season when most needed;
c. True perennials and do not need to be replanted regularly;
d. Easily harvested and transported requiring less time for harvesting than grass;
e. Provide multi-purpose products for households e.g. timber, fuelwood and human food; and finally but importantly,
f. Afford gastro-intestinal parasite control (Alonso-Dı´az *et al*. 2008, personal communications with many farmers).

There are two specific examples of such systems in which cattle are fattened on FTL in Indonesia. They are sesbania (*Sesbania grandiflora*) (known locally as turi*)* in south-central Lombok, in NTB, and leucaena (*Leucaena leucocephala*) (known locally as lamtoro) in Sumbawa District in NTB and in Amarasi District of NTT. Both species are capable of greatly improving the protein nutrition of cattle: leucaena in the fertile well-drained uplands; and sesbania as boundary plantings surrounding rice paddies. The problem is that these two systems while locally successful have not been widely adopted outside these regions despite similar physical and socio-economic conditions.

We hypothesised that these FTL feeding practices can be successfully transferred to neighbouring districts provided an appropriate participatory extension effort is made, and specific technical issues that limit their use are resolved.

This project has strong relevance to both Indonesia and Australia in that poor quality feeding limits productivity in both countries and the opportunities to overcome this limitation via the promotion and uptake of FTL was equally significant. In Australia, large areas of leucaena pastures (>250,000 ha) have been planted to meet graziers' needs for a highly productive and profitable system producing "grass-fed" beef of superior quality. Other benefits that have accrued from increasing use of leucaena in Australia are improved market flexibility, superior capital appreciation of land planted to leucaena pastures, and positive animal welfare outcomes.

However, the current level of success of leucaena in Queensland has taken nearly 50 years to achieve since the first release of commercial varieties in the early 1960s (Shelton *et al.* 2005). Social factors may be important with many farmers converting marginal dryland cropping to leucaena pasture due to concerns about the impact of drought, global warming, decreased profitability and sustainability of dryland farming, coupled with the prospect of more stable returns from grazing cattle on leucaena (Shelton and Dalzell 2007) (Bowen *et al*. 2015).

It is important to note that Indonesian scientists, extension agents and smallholder farmers can immediately and directly benefit from the 50+ years of Australian research effort on leucaena. Given the technical maturity of the leucaena technology and the success of new technology transfer mechanisms (e.g. adaptive research/PRO approaches), accelerated uptake of the FTL technologies in NTB and NTT should be achievable. Understanding the reasons for this success will improve the efficiency of on-going extension programs both in northern Australia and Eastern Indonesia.

5 Objectives

4.1 Hypothesis and objectives

Project LPS/2008/054 was developed on the hypothesis that:

"FTL feeding practices can be successfully transferred to neighbouring districts provided the implications for diverse groups of farmers are identified and effectively tackled through participatory adaptive research and 'Roll-Out' efforts, and provided specific technical issues that might limit their use are resolved."

This hypothesis resulted in three clear research questions, namely:

a. Why have FTL feeding practices, already successfully used in specific regions of Indonesia and Australia, not been adopted in adjacent regions with similar socio-economic and biophysical parameters?
b. How can specific technical constraints that might limit adoption be overcome in Indonesia and Australia?
c. What are the mechanisms required to remove the barriers to adoption of the FTL feeding practices by farmers with diverse cattle management profiles?

Two factors that are strong incentives for these changes in Indonesia are the high farm-gate price, of approximately IDR 40,000/kg live-weight, and the expectation that the demand for beef will continue to grow.

The general aim was to lift rural income by increasing the rate of turn-off and sales from cattle fattening enterprises through increased use of high quality forage tree legumes (FTL) in cattle diets in Indonesia and Australia.

Specific objectives were to:

1. Identify the barriers to widespread application of FTL feeding practices in diverse cattle fattening systems/regions / hamlets in NTT and NTB
2. Resolve specific technical constraints that hamper adoption of the FTL feeding practices.
    a. Constraint 1. Subclinical toxicity experienced by cattle consuming leucaena in Indonesia and Australia is limiting intake of animals and therefore their ability to respond to the higher protein diet. It was important to determine the level of exposure of cattle fed leucaena to toxicity in Indonesia and Australia. Some additional funds were allocated to check level of exposure to leucaena toxicity in two non-partner countries Thailand and Mexico.
    b. Constraint 2. Lack of understanding and information on FTL bio-physical parameters and feeding systems Lombok is limiting ability to roll-out the system to other regions.
3. Determine the key factors and mechanisms required to achieve widespread adoption of FTL feeding practices in regions of Indonesia and Australia adjacent to those where successful adoption has already taken place and that have similar socio-economic and biophysical parameters.

    To address this third objective, we used a Pilot Roll-Out approach in two phases:

    a. Phase 1 consisted of a community-based needs and opportunity assessment. This comprised a design workshop to develop an extension strategy, followed by pilot implementation of the extension strategy on a small scale (10-20 farmers at two different locations at each provincial site), and finally monitoring and evaluation activities.

b. Phase 2 involved the revision of the extension strategy, consolidation of the communication strategy and production of media, the implementation of the improved model on a medium scale (250 farmers per province in various locations), monitoring and evaluation, final revision of the extension strategy, and capacity building of related organisations to carry it to large-scale implementation.

Project LPS/2008/054 was designed with an important proof of concept focus, to show that leucaena and sesbania are safe and productive for use, at high rates, in diets to fatten cattle and that these trees can be established and managed effectively by farmers.

4.2 Variations to project

In 2013, the project was adjusted to give greater emphasis to proof of delivery, and to delivery to next users. Success in overcoming technical barriers to adoption of FTL production and feeding systems was achieved quite rapidly so that a shift in emphasis was possible quite early in the project. The variations to the contract were established along with parallel SRAs designed to support a refocussing on socio-economic characterisation of the various target groups and models for scaling-out (extension strategies), as well as on economic and financial analysis of the beef fattening system being promoted.

Justification for formal ACIAR Variation to Project. Several other ACIAR projects in Southeast Asia, including Indonesia (LPS/2008/038) and Timor Leste (LPS/2009/036) are also attempting to utilize forage tree legumes (especially *Sesbania grandiflora* and *Leucaena leucocephala*) as ideal feed sources to improve cow-calf and fattening operations. These projects and future 'IndoBeef' initiatives, and many other projects funded by national and international agencies, are looking for advice as to how best to introduce and manage /scale-out of forage tree legume feeding systems. These projects and institutions are "next users" in the impact pathway for this current project and they need information on the barriers and drivers of adoption to ensure wider adoption of forage tree legume systems in the region.

Another justification for a variation was concern regarding the apparent lack of impact and uptake of improved forage options from past forage projects despite significant long-term investment. An ACIAR review of the impacts of investments in research on forages in Indonesia (IAS65) commented that field evidence of adoption was largely anecdotal. Similarly, other analyses of adoption of FTL in Southeast Asia (Fujisaka *et al*. 1999) (Shelton *et al.* 2005) identified a range of possible factors that negatively affected the decisions farmers make regarding adoption of forages in mixed crop-livestock systems.

Thus the revised project aimed to determine the principal barriers and drivers of adoption of FTLs, and establish and describe several case study sites where FTLs were successfully introduced into mixed crop-livestock systems. The objective was to more comprehensively inform the growing number of interested next users.

The variation to the project specifically addressed three recommendations of IAS65, namely, there is a need for:

a. An impact analysis (through case studies), including quantitative assessments and a comprehensive analysis of the barriers and drivers of adoption (incorporated into LPS/2008/054).
b. Verification of economic models to increase confidence and identify issues in future model development and to provide a better basis for subsequent impact analysis, especially where that analysis is undertaken in the early years of adoption.
c. Development of appropriate indicators that could provide guidance for updating impacts in future years (through the case studies). Ideally these indicators would be consistent with the incentives for extension workers and researchers to achieve their objectives. The principal indicators should relate to gains at the farm level,

numbers of farmers adopting which particular strategies and numbers of farmers pursuing specific strategies.

Other variations to project. The original concept for the project was prepared in 2008, yet project activities did not formally commence until 1 April 2011. Accordingly, it was necessary to make many minor and sometimes significant changes to both the administrative and the research focus of the project in response to changing circumstances and findings. The most important of these are listed:

- Soon after commencement of the project, for personal reasons, Dr Scott Dalzell resigned and Mr Michael Halliday accepted the position of research Fellow employed to work under the direction of the project leader Assoc. Prof. Max Shelton.
- It was shown early in the project that the original concept of working with farmer groups in selected criteria based locations (10-20 farmers per Province in Phase 1 and 250 farmers per Province in Phase 2) was too restrictive and unrealistic. Accordingly, we began to respond to new groups and individual farmers who asked for assistance for bull fattening. This quickly became a tsunami of requests greatly exceeding the original target of 250 farmers per province.
- We found early in the life of the project that the original belief that sesbania use was largely confined to central Lombok in NTB, and that leucaena feeding was largely confined to the Amarasi District of Timor in NTT was incorrect. Thus work on sesbania and leucaena was subsequently not confined to a particular province. Indeed, the best leucaena feeding sites were found to be among the Balinese villages on Sumbawa.
- The research program into leucaena toxicity showed that it was not necessary to continue to work on methods for inoculation of cattle with *Synergistes jonesii.* Accordingly, effort and funds were redirected to researching a major new and exciting pathway for neutralising leucaena toxicity. This pathway involved detoxification by the liver and has positive implications for the feeding of leucaena in Indonesia and throughout the tropical world.
- There was some minor redirection of expenditure to increase funding for travel, and annual meetings as we appreciated the central importance of regular communication among team members.
- There were a number of other minor adjustments to the project. There were some staff changes with recruitment of new Field Researchers to replace those who had resigned, and in Phase 2 in NTT, it was decided that all FRs should work together at all locations, rather working at individual locations as in NTB.

The methodology, findings and outcomes of ACIAR project LPS/2008/054, over the 5 years 2011-2016, are now described and analysed.

6 Methodology

5.1 Start up

A Workshop was conducted in December 2010 to plan detailed activities for the first years of the project. Prior to the workshop, visits were made to all proposed locations of work within NTT and NTB and meetings were held with local project stakeholders (Bupati, Dinas, NGOs etc) to inform them of the project's objectives and to investigate potential for collaboration. Key partnerships were identified and formalized e.g. with Dinas and NGOs.

5.2 Selection and training of field research team

From the outset, we decided that a field team was necessary to be responsible for field research, as well as for smallholder development and extension activities under the supervision of project leaders. Accordingly, nine young recent graduates, designated Field Researchers (FRs), were chosen after an intensive advertising, interview and selection process.

The FRs were trained in the technical topics associated with using FTL to fatten cattle, and in methodological topics and group dynamics associated with working with farmers. We understood that the success of their future work in villages rested strongly on their social and technical competence and confidence, and that this would influence how well they were regarded / respected by farmers. Initial training was conducted in Mataram in May 2011 and continued via a training and mentoring process for the duration of the project. Training in methodology and group dynamics covered the topics:

- Project background, objectives and goals;
- Introduction to the value of forage tree legumes (sesbania and leucaena) for cattle fattening;
- Agronomy and utilization of leucaena and sesbania;
- Ruminant nutrition, plant toxicity, and the importance of diet quality for fattening;
- Management, health and hygiene of animals housed in sheds (kandangs);
- Participatory research and extension strategies for working with farmers; and
- Methodology for data collection for the situation analysis study and research activities. This involved training in group dynamic exercises.

Mentoring Contracts were established for the senior Indonesian project staff to mentor the Field Researchers with the aim of improving their skills and technical competence in livestock R&D, methodological confidence in adaptive research and commitment to research data collection. The mentoring process was broadly based and encouraged the Field Researchers (FR) to achieve project, institutional and personal goals.

5.3 Selection of project sites

In Indonesia, the target unit for the project was initially the farmer group physically located at the hamlet level. Selection of groups to be engaged in trials and pilot roll-out activities was based on pre-determined criteria for selection, namely:- (1) the sub-district, (2) the village, (3) the hamlet, and (4) the farmer group. In each of the two provinces, we chose 1-2 locations where FTLs feeding systems already existed (but could be improved) and 2-3 locations where there was no history of intensive feeding with FTL.

Initial selection of potential sub-districts occurred during the Start-up Workshop in December 2010. A situation analysis study was conducted in the following villages and farmer groups in May 2011.

FTL Status	NTB		NTT	
	District	Sub-district	District	Sub-district
Existing FTL use	Lombok Tengah	Jonggat	Kupang	Amarasi
	Sumbawa	Rhee		
No FTL use but potential	Lombok Tengah	Jonggat	Kupang	Kupang Barat
	Lombok Utara	Gangga		Takari
	Sumbawa Barat	Rhee		Fatuleu
		Poto Tano	Sumba Timur	Pandawai

Criteria used to analyse and compare villages and hamlets included land and cattle ownership, predominance of cattle enterprise, availability of suitable land to plant FTLs, existing use of FTLs as cattle feed, village location and accessibility, and group functionality. The selection process involved the following steps in each sub-district.

Step	Activities
1. Visit relevant sub-district offices (Kantor Kecamatan, Dinas, extension service)	• Collection of secondary data • Interviews with local government officials • Prioritisation of all villages
2. Visit top 5 priority villages	• Acquaintance/interview with village officials • Group discussion with village officials, extension officer, and hamlet representatives conducting a ranking matrix exercise for hamlet selection • In case a village doesn't seem suitable at all for doing more in-depth exploration, visit the next village on the priority list
3. Visit top 3-4 hamlets per village	• Interviews with farmer group leader and random farmers • Observations on cattle management systems, feeding systems, cropping patterns • Prioritisation of hamlets visited in terms of suitability to conduct in-depth exploration and farmer group activities
4. Analysis and final site selection	• Comparison of all villages/hamlets visited for each sub-district • Selection of 4-5 villages/sub-district for in-depth exploration • Selection of 1 hamlet in each of the selected villages

Twenty-four farmer groups were selected in November 2011 in 8 sub-districts representing the variable conditions and cattle fattening systems based on comprehensive information gathered during the study. As the project progressed there were many changes to the locations of activities due to a multitude of reasons. For instance:

- Some villages became less interested when they found that significant hand-outs were not forthcoming;
- Farmer groups were inaccessible in wet weather;
- New groups asked to be included; and
- In some cases, individuals or first adopters asked to be involved.

5.4 Project communication and travel

From the outset we understood the importance of regular and effective communication among all team members in Australia and in Indonesia.

Accordingly, communication was conducted in several ways.

- Smartphones. Each FR received a smartphone and a regular credit allowance.

- A Facebook Site (TIM PLP) was established and used throughout the entire project to maintain regular contact with FRs and with Indonesian and Australian project staff.
- Emails were naturally used at all times as well as direct messaging apps such as: Whatsapp, BBM, Facebook, Messenger, Viber. This allowed instant communication 24/7.
- Our policy was to encourage regular visits to project sites from Australia and within Indonesia.
- Every year, annual site visits and annual meetings were held in either Indonesia or Australia to discuss and evaluate progress, and to plan the next year's activities.

6.5 Research methods for Objectives 1 and 3

5.5.1 Identification of barriers and opportunities for adoption of FTL

In order to achieve the first project objective to 'identify the barriers to widespread application of FTL feeding practices in diverse cattle fattening systems in Eastern Indonesia', a situation analysis was designed to investigate technical, economic and socio-cultural aspects of cattle farming in the target areas. The situation analysis served (1) to collect the necessary information to understand those opportunities and barriers for adoption of FTL feeding innovations, and (2) as a basis for well-informed selection of farmer groups with whom to collaborate during the next phase of the project.

Data collection was conducted in 32 hamlets (in 9 sub-districts, 6 districts, 2 provinces) during the period June – September 2011.

The study provided detailed profiles for each of the locations, and a general understanding of farmers' current cattle management practices and their perceptions on the use of FTLs as cattle feed. Initial barriers and opportunities to the adoption of leucaena and sesbania innovations were identified and informed the design of an outreach strategy; however, continuing follow-up assessment occurred to understand how increased knowledge of and access to FTL innovations influenced farmers' perceptions and practices.

An analysis workshop was held in Kupang on 31 October – 2 November 2011, in which all results of the study were presented by the FRs and analysed by the whole team. Main barriers and opportunities were extracted and categorised, and a framework for an Extension Strategy that responded to the barriers was drafted. The Extension Strategy contained mechanisms and activities that fulfilled the following functions:

- Collaboration with relevant stakeholders;
- Establishment and facilitation of farmer groups;
- Awareness raising, training (knowledge and skills) and demonstration (and adaptation);
- Facilitation of access to inputs (especially FTL seed) and credit; and
- Ways to overcome cultural barriers.

5.5.2 Design of Extension Strategy

The framework for the FTL Extension Strategy that emerged from the Analysis Workshop was further developed in collaboration with representatives from all stakeholder groups including:- heads of the hamlet and/or village of the project sites and farmers; representatives from the district extension or extension coordinators at sub-district level and agricultural extension officers; representatives from district livestock departments; and Project Leaders and Field Researchers. Activities involved in the development of the Extension Strategy are given in Table 2.

Although some major aspects were similar for all locations, there were location specific differences, depending on the FTL systems (sesbania versus Leucaena), cattle management systems, land management systems and cultural aspects.

Table 2. Activities involved in the development of the Extension Strategy

Category	Activity	Notes
1. Awareness raising regarding the use and benefits of FTLs in cattle farming	Study tour for farmers to a village with successful FTL management	Implemented during the pilot phase, but possibly replaced by the video in an extension phase
	Video featuring farmers in project pilot sites, showing how they manage FTLs	Produced full cycle during 2012 and part of 2013.
	Initial community “road show” with simulation game	Design of a field guide for the facilitation of a community “road show”. Simulation game involves scenario building of different feeding schemes.
2. Adaptive on-farm trial and demonstration of FTL management system	Establishment and management of FTLs	Learning plots on communal land and individual farmer fields
	FTL feeding and cattle weight measurement	Implemented with selected farmers
3. Capacity building on the management and use of FTLs	Design and piloting of a farmer training program with the following characteristics: Field based and year-long curriculum Thematic sequence of training sessions in accordance with seasonal conditions Involving farmer group learning and practice on own farms	Curriculum design and manual production: • Technical manuals on FTL management and cattle fattening • Facilitation manual containing training modules
	Design and production of supporting media: Video Brochures Training manual	Requirements for specific types of media will emerge from the training design process.
	Training of trainers (design and pilot), involving technical aspects of FTL management and feeding and facilitation skills	Curriculum for ToT will emerge from the farmer training curriculum.
4. Facilitate access to inputs and services related to FTL management	FTL seed/seedling production for availability at village level	Initially taken care of by the project, but autonomous systems need to be established
	Establishment of seedling producers and a distribution system	Designed and piloted by project, but continued by Dinas
	Facilitate access to credit schemes	Through information giving in training
5. Support to FTL/ cattle Farmer Groups	Establishment and guidance of functional FTL/cattle Farmer Groups	Building on but not limited to existing farmer group procedures. Groups are likely to be a sub-group of the standard “Kelompok Tani” in a village.
	Facilitation of collective decision making and action at the village level	Involvement of local government required
	Participatory monitoring, evaluation and impact assessment	Guidelines to be developed and incorporated in training manual
6. Establish and foster inter-institutional relationships	Collaborative workplan involving active involvement of all partners in planning, implementation, monitoring and evaluation of activities	Workplan to describe division of tasks, responsibilities and resource contribution by all partners during project
	Communication strategy for project implementation/collaboration	Establish mechanisms for invitations for events, reporting, sharing of ideas and experiences
	Design of an exit strategy	Workplan to describe division of tasks, responsibilities and resource use by all partners post project

5.5.3 Implementation of Pilot Roll Out (PRO)

A Summary of activities conducted under Objective 3 for implementation of Pilot Roll Out (PRO) is given below:

A participatory needs and opportunity assessment was conducted in regions adjacent to successful adoption areas of FTL feeding practices through community based focus group discussions and interviews with farmers, extension officers and community leaders. Participatory workshops were held to design and update the FTL Extension Strategy.

In Phase 1, small scale pilot of FTL Extension practices (2 groups per province with10-20 farmers/group) was implemented and evaluated, followed by revision of the Extension Strategy, and development of communication materials and media.

In Phase 2, medium scale pilot of FTL practices were implemented. Initially the plan was for 10 groups per province with 20 farmers/group, but in reality, due to ever-increasing requests to become involved by Government and NGO agencies, farmer groups, and individuals, participating farmers could not be neatly categorised as there were so many. Materials and media for expansion of FTL systems continued to be produced from late 2013 until the end of the project.

Training of trainers was conducted for extension officers and/or farmer facilitators of target districts for FTL systems in NTT and NTB. Forty to sixty facilitators were trained in expanding FTL practices to target communities. This activity occurred in the latter period of the project and continues post-project.

In Australia, transfer of new technological advances on the management and establishment of leucaena, as well as on management of leucaena toxicity was imparted to Australian farmers via UQ training activities / field days, DAF extension services and The Leucaena Network website. More than 500 farmers have participated in education and training activities at various locations around Queensland conducted by the UQ group.

5.6 Research methods for Objective 2

Methodology for the principal research projects undertaken is summarised for each of the major investigations. All investigations have been published as indicated in the chapter on outputs/ achievements.

5.6.1 Agronomy and feeding of Forage Tree Legumes

Agronomy and feeding leucaena. The growth of Bali bulls fattened with *Leucaena leucocephala* in Sumbawa, Indonesia was studied from April 2012 to March 2013 in the hamlet of Jatisari in Sumbawa district (Panjaitan *et al.* 2013).
Cattle fattening in Jatisari is based on feeding high leucaena diets in a cut-and-carry system to animals tethered in simple sheds. We found that farmers' normal management and trading practices resulted in constantly changing numbers of bulls being fattened. Parameters monitored included bull average daily gain (ADG), feed offered including amount of leucaena in diet, and sale weight. All cattle were weighed each month following an overnight curfew on feed and water. Fresh feed offered was determined over 3 consecutive days each month.

Agronomy and feeding sesbania. Bali bull fattening practices in Central Lombok, Eastern Indonesia, based on feeding of *Sesbania grandiflora*, were studied and reported by Dahlanuddin *et al*. (2013). The hamlet of Nyerot (8º40´S 116º13´E) in the subdistrict of Jonggat was monitored from January to December 2013. Criteria used to select the village were: existing use of sesbania as cattle feed in a predominant cattle fattening enterprise; private land ownership; village location and accessibility; and group functionality.

This process ensured that the hamlet of Nyerot was representative of best practice for fattening cattle using sesbania grown on the rice paddy bunds. In the hamlet, 34 farmers were independently fattening 1-2 bulls each but operated as a group in a shared cattle barn (for security reasons). Parameters measured in the longitudinal survey were: climatic conditions; area of land for rice and length of rice bunds planted to sesbania; agronomy and management of sesbania trees; monthly bull live weights following overnight fasting; purchase and sale weights from February to October 2013. Measurements were made on 3 consecutive days per month during February and March and 6 consecutive days per month from April to October.

5.6.2 Leucaena Toxicity

Prevalence of toxicity in Eastern Indonesia. The prevalence of DHP toxicity and *Synergistes jonesii* in ruminants consuming *Leucaena leucocephala* in eastern Indonesia was investigated (Halliday *et al*. 2013). Cattle, goats and buffalos from 5 villages in each of the eastern islands of Lombok, Sumbawa, Sumba, and Timor from existing leucaena fattening systems were selected for the study. Discussions with farmers revealed that leucaena ranged between 30%-100% of diet. Urine samples were collected from up to 10 animals within each village, preserved and analysed by HPLC for DHP. Rumen fluid was collected from 3 animals in each village for PCR detection of *S. jonesii* at CSIRO Animal, Food & Health Sciences lab in Brisbane.

Prevalence of toxicity in Australia. The prevalence of mimosine and DHP toxicity in cattle grazing *Leucaena leucocephala* pastures in Queensland, Australia was also investigated ((Dalzell *et al*. 2012). Toxicity status of 385 animals from 44 individually managed cattle herds on 36 properties from six regions of Queensland was tested in the summer of 2003–04. Regions selected included Far North (1 herd), Clermont/Capella (7 herds), Biloela/Moura/Theodore (15 herds), Injune/Rolleston (3 herds), Gayndah/South Burnett (13 herds), and Taroom/ Wandoan (5 herds). Herds were selected where animals were eating sufficient leucaena to determine toxicity status. Data regarding herd-management practices, animal performance, history of inoculation with *S. jonesii* and symptoms of toxicity were collected for each herd. The University of Queensland Animal Ethics Committee approved this research (AEC 654/03).

Prevalence of toxicity in Thailand. The incidence of subclinical toxicity in goats consuming leucaena in Thailand was studied and reported in Phaikaew *et al.* (2013). Goat herds were sampled in the major goat-producing regions of Thailand where leucaena was a major source of feed during the period 23 February to 31 March 2009. Urine was collected from 63 goats on six farms in four provinces: Ratchaburi, Petchaburi, Prachuap Khirikhan and Nakhon Ratchasima. Urine samples were diluted 1 : 4 with 0.1 M HCl, and then filtered, purified and hydrolysed. Then, 3,4-DHP and 2,3-DHP concentrations were determined in the hydrolysed samples by using high performance liquid chromatography analysis as described in Dalzell et al. (2012).

Toxicity in Mexico. Urinary excretion of mimosine metabolites by hair sheep fed foliage of *Leucaena leucocephala,* and inoculated with rumen fluid from leucaena-adapted crossbred cows, was studied in Mexico (Contreras-Hernández *et al*. 2013). The experiment was carried out at the Faculty of Veterinary Medicine and Animal Science, University of Yucatan, Mexico. Two crossbred cows adapted to the consumption of *L. leucocephala* were used as donors of rumen liquor for inoculation of twelve Pelibuey lambs of 20 kg live weight housed in metabolic crates. All urine excreted was collected and measured every 24 hours. The urine was processed and assessed for presence of DHP.

Effectiveness of inoculation with *S. jonesii* in Indonesia. The effectiveness of inoculation with rumen fluid containing *Synergistes jonesii* to control DHP toxicity in ruminants was studied in eastern Indonesia (Halliday *et al.* 2016 submitted). The experiment was conducted on the islands of Sumba and West Timor in December 2012. Donor animals selected were previously identified as protected by *S. jonesii*. Rumen fluid

from these donor animals was used to inoculate recipient animals from areas known to be prone to DHP toxicity. The success of inoculation was gauged by measuring the extent of urinary DHP excretion in the recipient animals.

Effectiveness of inoculation with *S. jonesii* in Australia. An experiment was conducted at The University of Queensland research farm to investigate the efficacy of a cultured *Synergistes jonesii* inoculum in degrading the *Leucaena leucocephala* toxins. Sixteen stall-housed *Bos indicus* steers naïve to leucaena were fed varying combinations of forage-harvested leucaena and Rhodes grass. The experiment was 10 weeks in duration, consisting of a 6-week pre-inoculation period, followed by inoculation with cultured *S. jonesii*, and a 4-week post-inoculation period. Mean daily dry matter intake (DMI) was recorded. Twenty-four-hour urine collections and rumen fluid samples were obtained weekly for analysis of total urinary DHP, and nested polymerase chain reaction (PCR) analysis including presence of single nucleotide polymorphisms (SNPs), respectively (Halliday *et al.* 2016 submitted).

Genetic diversity of *S. jonesii*. The genetic diversity in the 'leucaena bug' *Synergistes jonesii* (Padmanabha *et al.* 2013) was investigated in rumen fluid or faeces collected from Australian cattle in Queensland, and from cattle, sheep, goats, buffalos, native cattle from Indonesia, Thailand, Vietnam, China (including yak) and Brazil, mainly from local farmers. Microbial DNA was extracted from these samples and amplified with a set of 16S rDNA nested PCR primers specific for *S. jonesii*. PCR products positive for *S. jonesii* were then aligned against full-length *S. jonesii* 16S rDNA sequence for identification of SNPs.

7 Achievements against activities and outputs/milestones

Objective 1: To identify the barriers to widespread application of FTL feeding practices in diverse cattle fattening systems/regions / hamlets in NTT and NTB

no.	activity	outputs/ milestones	completion date	comments
1.1	Field Researchers (FR) recruited and training commenced	Achieved (see text)	Year 1	Satisfactorily completed
1.2	Target cattle fattening systems/regions / hamlets in NTT and NTB identified and profiled.	Achieved (see text)	Year 1	Satisfactorily completed
1.4	First list of barriers to adoption identified.	Achieved (see text)	Year 1	Satisfactorily completed
1.5	A Project Facebook site established	Achieved (see text)	Year 1	Satisfactorily completed
1.6	Surveys/interviews of graziers completed in Australia	Achieved (see text)	Not completed	Satisfactorily completed
1.1	Field Researchers (FR) recruited and training commenced	Achieved (see text)	Year 1	Satisfactorily completed

PC = partner country, A = Australia

Objective 2: To resolve specific technical constraints that hamper adoption of the FTL feeding practices …

no.	activity	outputs/ milestones	completion date	comments
2.1	Growth potential and best practice for cattle fattening with FTL	Achieved (see text)	Years 2-3	Satisfactorily completed
2.2	Survey of leucaena toxicity in E. Indonesia, Australia, Thailand & Mexico.	Achieved (see text)	Year 1	Satisfactorily completed
2.3	Feeding trials to test impact of DHP on animal performance.	Achieved (see text)	Year 1-3	Satisfactorily completed
2.4	Develop methods for inoculation against toxicity	Not achieved as not necessary(see text)	Year 2-3	Not completed
2.5	Identify rumen bacteria that degrade DHP from RF samples collected in Indonesia, Thailand	Partially achieved (see text)	Years 1-3	Partially completed

2.6	Document the agronomic and nutritional characteristics of Turi.	Achieved (see text)	Year 2-3	Satisfactorily completed

PC = partner country, A = Australia

Objective 3: To determine the key factors and mechanisms required to achieve widespread adoption of FTL feeding practices in regions of Indonesia and Australia adjacent to those where successful adoption has already taken place and that have similar socio-economic and biophysical parameters

no.	activity	outputs/ milestones	completion date	comments
3.1	Situation analysis to assess needs & opportunities	Achieved (see text)	Year 1	Satisfactorily completed
3.2	Participatory workshops to design extension strategy – Phase 1.	Achieved (see text)	Year 1-2 (to mid 2013)	Satisfactorily completed
3.3	Establish links with agencies interested in cattle fattening in preparation for Phase 2 PRO.	Achieved (see text)	Years 1-2 (to mid-2013)	Satisfactorily completed
3.4	PRO Phase 1: evaluation of small scale pilot of FTL practices (12 groups per province @ 1-20 farmers/group).	Achieved (see text)	Years 1-2 (to mid-2013)	Satisfactorily completed
3.5	PRO Phase 2: implementation of medium scale pilot of FTL practices Extension Strategy (development model)	Achieved (see text)	Years 3-5 (mid 2013 – 2016)	Satisfactorily completed

6.1 Barriers and Opportunities for adoption of FTL

The barriers and opportunities to adoption of FTL in Indonesia are now well understood. Our findings were first presented in paper (Kana Hou *et al*. 2013) then an updated list of barriers and opportunities for adoption was completed in year 5 (Table 6.1). This more detailed list of the barriers and opportunities for adoption of FTL is described under the principal categories:

1. Nature of the innovation
2. Technical constraints
3. Project leadership and staffing
4. Engagement with farmers
5. Socio-economic and agribusiness issues
6. Government policy and involvement

Table 6.1 Updated list of barriers and opportunities/solutions to adoption of FTL for cattle fattening in NTB and NTT.

Nature of the innovation	
Barriers	**Opportunities/solutions**
The proposed innovation does not meet the needs of farmers and does not match the socio-economic situation or skills of farmers.	Our proposal to use FTL for cattle fattening met the need of farmers for high quality forage, especially during the dry season. It was a profitable alternative land use, as well as being appropriate to the social and economic environment of the small holders. It lowered work load to harvest and feed cattle and it 'fitted' village farm life.
The proposed innovation is too novel or too far outside the experience of the farmers.	The innovation was already being used by some farmers and the species being promoted were well known to all farmers.
The proposed innovation is not the main limitation for development of the cattle industry and will therefore achieve limited success due to the negating influence of other factors.	Very poor feeding and nutrition of cattle is the main limitation to improving smallholder cattle enterprises. Others factors such as consumer demand for beef; access to market; access to credit; labour availability; supply of feeder stock; animal breed, health and housing; while able to be improved were not first order limitations.

Technical issues – Leucaena	
Barriers	**Opportunities/solutions**
Many farmers believed that the local variety of leucaena was not palatable to cattle.	A psyllid tolerant variety of leucaena (cv. Tarramba) was introduced to Eastern Indonesia in a previous ACIAR Project (AS2/2000/157) in 2002 and it has become the most popular first choice variety for planting. Farmers found that it was more palatable, productive, and tolerant of psyllid insects than the local variety. Some farmers independently produced and sold Tarramba seed, while others marketed Tarramba foliage to other farmers e.g. in the villages and cattle market in West Timor. It also provided straight timber for building and some farmers built their kandang using Tarramba poles.
Researchers and some famers believed that cattle will not consume leucaena unless inoculated due to toxicity.	While there was normally a short term aversion to consuming leucaena, experienced farmers in Sumbawa found that cattle adapted to long-term 100% leucaena diets. The reasons for adaptation are described in the section covering Objective 2.
Lack of effective working demonstration sites was a major barrier as demonstration sites were crucial tool in getting new farmers to adopt.	Several effective working demonstration sites were developed, including the upgrading of some pre-existing sites, sometimes at village or group level, and sometimes with single entrepreneurial innovative farmers (known as 'crazy farmers' for being first adopters). Cross visits to these demonstration sites were highly effective. Having a working demonstration site run by a farmer open to sharing his knowledge and experiences was the single most important tool in achieving adoption.

Lack of seed of best planting material	The project has supported a major Tarramba seed production effort. The village of Kuenheum in Timor was chosen due to lack of local weed leucaena and the enthusiastic support of the local authority. Procedures were introduced to ensure that a professionally produced and packaged product was available for commercial sale.
Farmers lacked knowledge and appreciation of the high nutritional value of FTL. They were often unaware of the poor nutritional quality of alternative forages such as dry grass or rice straw. They lacked skills and resources regarding FTL tree establishment, management and feeding for fattening cattle.	Farmers were encouraged to visit demonstrations of best practice and were trained to match nutritional requirements of cattle with the nutritional value of available forages. Farmer training also included instruction on need to provide sufficient forage water, adequate housing, hygiene and animal management to achieve the recommended sale weight >300 kg.
Technical issues - Sesbania	
Barriers	**Opportunities/solutions**
Lack of information on best practice for sesbania agronomy and management	A detailed study of best farmers informed best practice for establishment and management e.g. best row spacing, insect and pest control, cutting frequency and biomass productivity, and therefore carrying capacity. The findings of this study were published (Dahlanuddin *et al.* Anim. Prod. Sci. 2014)
Farmers dis not have enough land to plant (more) sesbania trees.	There were many areas where sesbania trees had not been planted on paddy rice buds, and other areas where the density of trees could be increased.
Sesbania trees on the bunds disrupted the development of the main crop in the paddy field by shading. In steeper areas in Lombok with very narrow bunds, sesbania roots damaged the bunds or caused water leaking.	The project focused on sesbania plantings on the heavy black soils found in the flat areas of Central Lombok which anchor the trees. Long experience indicated that there was minimal effect of the trees on the rice crop or damage to rice bunds in this environment.
Farmers fed insufficient sesbania in diets of cattle	On farms where sesbania had been planted on rice bunds, it was not possible to greatly increase the density of the sesbania plantings as there was insufficient room, and the area of rice was too small. This meant that it was rarely possible for farmers to feed the optimal 35% of diet as sesbania. Our study showed that in the village of Nyerot the median % sesbania in diet was only 12%.

Project leadership and staffing	
Barriers	**Opportunities/solutions**
Lack of leadership, enthusiasm and commitment of senior staff of principal counterpart agency for proposed innovation.	The leadership of our Indonesian project, and their mentorship of young field staff, were crucial to our success. They were respected locally giving us ready access to senior officials of National and Provincial Government. This was an important in gaining support and cooperation for our scale-up plans.
Lack of commitment of junior field staff employed by project to engage with farmers and implement project plans.	Over the life of the project, we employed approx.12 young field staff. Those who committed to learning and understanding the technical aspects of the innovation became experts, and were highly successful. Their advice was sort and respected by farmers. These young staff gained confidence and pride in their achievements. Others were not able to grasp the significance of the innovation, were less committed, and left the project. This experience underscored the importance of (a) choosing well motivated and capable young staff, and (b) training and mentoring them well.

Engagement with farmers	
Barriers	**Opportunities/solutions**
Appropriate engagement with farmers not employed.	Successful engagement occurred by working through hamlet heads and community leaders, and sometimes individual farmers, and conducting a situation analysis to understand their needs. Key findings were:-. • Field extension staff in charge needed to have strong practical and theoretical knowledge of the innovation in order to be respected by farmers. • Engagement with farmers was improved by building good communication and collaboration. Regular meetings should be conducted, with training and mentoring of farmers and farmer groups to improve their knowledge of nutritional issues in bull fattening. • The activities of field extension staff needed to fit in with farmer activities. • Collaboration among Field Researchers as a team overcame individual shortcomings and fostered greater engagement with the farmers. • It was important to understand the character of farmers, and strongly support .champion or pioneer farmers who wanted to try new fattening system. They were often regarded as 'crazy farmers' by their peers. • Opportunity should be provided for innovative and trained farmers to talk to other farmers (farmer to farmer extension). • It was important that Field researchers were responsive and available for frequently asked questions on establishment, feeding and fattening with FTLs at all times.
Farmers from different ethnic origins unwilling to learn from other ethnic and language groups.	In Sumbawa, we found that it was possible to take indigenous Sumbawanese farmers to visit the Balinese farmers even though they were from a different culture and religion. Both groups appreciated the opportunity, the Sumbawanese to learn and the Balinese to exchange information. Nevertheless, having early adopters of the same ethnicity and culture formed a stronger selling point and had greater impact.

Socio-economic and agribusiness issues	
Barriers	**Opportunities/solutions**
Some farmers have no ownership of land or cattle and therefore were not interested in adopting FTL.	We always endeavoured to work with groups interested in cattle fattening and even single individuals who had a strong interest to try fattening bulls. Some farmers fattened cattle on a share basis while other farmers were content to sell Tarramba seed or forage while they were waiting to obtain bulls to fatten.
Working with farmer groups sometimes not effective as they were motivated by belief they would receive free cattle by agreeing to participate.	We endeavoured to promote self-reliance so that farmers understood that bull fattening with FTL was profitable and self-sustaining. Nevertheless, some farmers groups dropped out on realizing that there were no free hand-outs. To avoid this issue, we worked with motivated individual farmers who were often successful as they were unhindered by group control.
Farmers with large areas of communal grazing lands available had no experience allocating resources and labour to tether or pen cattle and for cut-and-carry feeding and were reluctant to adopt.	Farmers in Sumbawa and Timor often owned large numbers of cattle and had land suitable for planting leucaena. The long dry season ensured very low productivity on communally grazed land i.e. high calf mortality, very low live weight gains. This poor production and shrinking access to communal free-grazing provided an incentive for farmers to convert to more intensive cut-and-carry feeding of tethered cattle.
Demonstration sites established a group basis were not effective as farmers often relied on others to do the work with the result the site was not managed.	We employed a communal approach for training and nursery management, but individual approach with farmers planting FTL on their own land and taking individual responsibility for management of the FTL plants.

Farmers with no access to credit to buy cattle, build housing and fences were unable to adopt the innovation.	Where possible assistance was provided to access credit for purchase of cattle, housing and fencing. Other opportunities for farmers were sale of corn or other farm animals in order to obtain cash to purchase young cattle to fatten e.g. Oebola Dalam.
Farmers have limited bargaining power with traders due to lack of knowledge. In many cases, the price received for cattle sales was often sub-optimum due to under-estimation of live weights by the trader.	We found that weighing farmers' cattle on a regular basis provided farmers with accurate information on the progress of their feeding and management strategy and potential sale price and bargaining position. Farmers with no access to scales were taught to use girth measurements to estimate live weight. There is also opportunity that proposed new modern slaughter houses will increase competition with Traders for sourcing fat bulls, and that the project can facilitate links with these buyers.
Farmers were reluctant to convert lands cropped for corn and other annual crops to leucaena for feeding cattle.	Many farmers assessed that it was more profitable to grow leucaena to fatten cattle than to plant corn, peanut, or cassava. Farmers have shown willingness to covert cropping land to FTL, or to integrate FTLs into their cropping lands. Planting leucaena with crops had the additional benefit of improved weeding as well as improved fencing to protect the annual crops and leucaena from free grazing animals.
Theft was a significant problem in many regions e.g. Lombok, Sumbawa, West Timor.	Building of kandangs close to owners house; or building of communal kandangs where farmers shared security duties afforded better protection e.g. Central Lombok.
Prices. A major potential threat to uptake and expansion of the systems is a possible decline in farm-gate prices. Short term variations occur based on season, festivals, timing of schools etc. etc. that farmers factor in and work around. But a greater threat is longer term price declines or over fattening period (e.g. 5 months) if there is a correction to current buoyant prices. This would make fattening unprofitable, and households would need to substitute into other activities	It is dangerous to read the "crystal ball", but most analysts are predicting ongoing demand for beef in Indonesia and Asian region due to broader economic conditions, policy and S/D.
In future the opportunity costs of labour may be a barrier for small scale farming is. In countries like China and Vietnam, where there has been rapid economic development, farmers could work in a factory or city, thus losing the incentive to raise cattle on a small scale	Most farmers in NTB and NTT are probably a long way from having these opportunities, but as Indonesia develops there may be certain areas that have these opportunities.

Government policy and involvement	
Barriers	**Opportunities/solutions**
Government and provincial policies not supportive of proposed innovation.	Both Central Government and provincial authorities strongly supported investment in smallholder cattle industry as a way of improving livelihoods of poor farmers.
Lack of leadership, enthusiasm and commitment of Government agencies outside project group to accept, cooperate and actively promote the innovation, thus limiting scale-up.	We endeavoured to select and work with agencies that had good leadership and enthusiasm for our proposals e.g. Dinas in Sumbawa, whereas Extension Dept in Sumbawa was less committed. Nevertheless, inertia and lack of commitment and resources needed to be overcome.
Previous negative experiences. In the past, Government supported cattle breeding and distribution projects that often failed due to famers having insufficient forage to feed the new animals.	Interestingly, a history of unsuccessful efforts to promote smallholder cattle fattening had led to recognition that lack of feed was the common limitation. We found that farmers who planted areas to FTL attracted participation of Government agencies who were willing to supply cattle to farmers who had forage available. Local village authorities also expressed willingness to introduce village regulations to limit free grazing of animals and hence provide more favourable conditions for FTL plots to establish.

Government workers (and project staff) often became involved in outside business ventures to supplement their income and this distracted (e.g. cattle fattening) them from their regular Government job.	While this seemed like a potential conflict of interest, in practice it provided additional practical training and engendered increased enthusiasm of the staff involved. These staff were often the most effective extension agents.

6.2 Implementation of the Pilot Roll Out (PRO)

6.2.1 Range of extension materials

Excellent promotional videos have been produced that can be used with farmers, extension workers, and policy makers to encourage and support the adoption of FTL-based fattening systems. Both still photographs and videos are being used for the promotion of general principles.

The range of extension materials that has been developed includes 12 videos. These extension materials have already been widely used to more than 60 government extension staff and more than 100 farmer leaders. They will also be promoted to educational institutions in eastern Indonesia and across the country. A complete set is included on a CD for use in future projects, as well as by major partners in NTT and NTB, and in other regions of Indonesia.

These videos are also available online on YouTube at:
https://www.youtube.com/channel/UCzJ2nYUlS5No28HaI_2SdnA

Instructional videos presenting the basic principles of how to undertake each step in the process of developing and managing FTL feeding systems have been produced e.g. videos on topics of seedling preparation, transplanting, fattening, management, and animal husbandry.

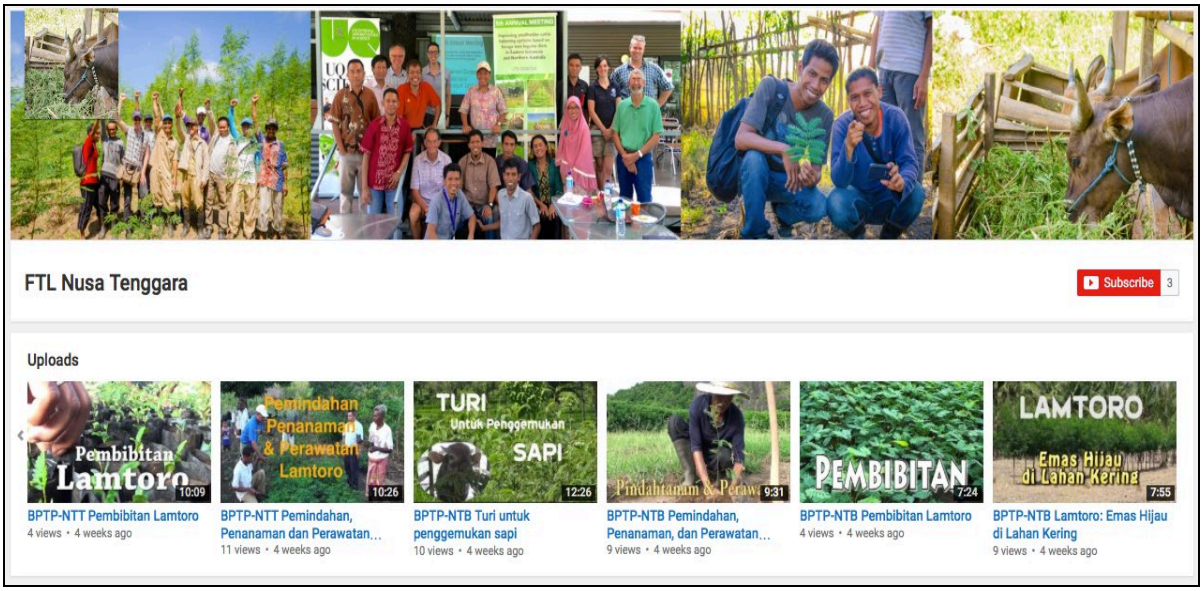


Figure 6.1. Selection of videos uploaded onto Project YouTube page promoting various aspects of FTL use.

6.2.2 Working with farmers

During the establishment of the demonstration sites and the two phases of roll-out, the project has worked with about 2,000 farmers in NTT (Timor and Sumba) and NTB (Lombok and Sumbawa) (Table 6.2). The direct contact with farmers and farmer groups has been largely handled by the Field Researchers under the supervision and mentorship of the Indonesian project leaders.

The FRs were responsible for the initial data collection and were then the in-the-field drivers of roll-out, both critical steps in the establishment of the demonstration sites. The best case study sites are now being used for engagement with officials at different levels of government. The primary contacts have been with extension staff of Dinas Peternakan at the District, Sub-District, and even the Provincial levels. High level provincial administrative officers have also been involved. For instance, in the District of Kupang in NTT, the Office of the Bupati, the administrative head of the Kabupaten, has provided strong support as has the Governor and secretary of NTT Province. All levels of government in NTT are enthusiastic about the expansion of cattle fattening based on leucaena and are keen to support and facilitate the adoption. This approach to and involvement of government agencies is being continued post -project.

Table 6.2 Farmers trained, seedlings planted or ready to plant, bulls fattened

FR	Location	FTL	Total # of farmers worked with	# trained trainers	# trained farmers	# seedlings planted	# seedlings ready to plant	# bulls fattened
Utie	Central lombok	Sesbania	291	2	9	43800	261800	550
Kurniawan	North Lombok	Sesbania	266	12	4	25523	25523	294
Fauzan	Sumbawa	Leucaena	434	10	20	74100	1080000	1188
Sutartha	West Sumbawa	Leucaena	101	6	8	94000	320000	137
Charles	Oebola	Leucaena	115	4		226000		110
Daniel	West Kupang	Leucaena	476	11	42	394975		6
Petrus	Amarasi	Leucaena	219	6		50000		60
Darius	Sumbawa	Leucaena	150		15	5000		28
NTB			1092	30	41	237423	1687323	2169
NTT			960	21	57	675975	0	204
Total			2052	51	98	913398	1687323	2345

6.2.3 Case studies

Seven active successful demonstration sites have become case study sites and are being used for training. They are:- a village group in Oebola on Timor; a village group in Setetes Madu on Timor; several farms in the village of Labangka on Sumbawa; Balinese farmers in village of Jati Sari on Sumbawa; the individual farms of Mr Samsidar and Mr Muin on Sumbawa; and the village group in Nyerot on Lombok.

The case studies were developed by the project in collaboration with SRAs lead by Dr Elske van de Fliert (sociologist) and Dr Scott Waldron (economist). It was expected that the SRAs would contribute to a better understanding of the FTL systems and provide both better social and economic documentation for use in promotion to farmers, extension workers, and policy makers.

We also present case studies as published papers on the management and productivity of bull fattening in Jatisari) on Sumbawa (Panjaitan *et al*. 2013) and Nyerot on Lombok (Dahlanuddin *et al*. 2014).

Case study – Mr Muin. One such Case Study was that of Mr Pak Muin, a successful farmer in West Sumbawa. He is a former member of a farmer group (Senap Semu) in Senayan village. Originally the group fed local grasses to breeding cattle with financial assistance from the Bank of Indonesia. The focus at Senap Semu has now shifted to solely fattening based on leucaena, with each farmer planting Tarramba leucaena on their own land. Pak Muin was of one of the most successful farmers from this group and, along with his son, he has established 6 ha of Tarramba. With funding from the Bank of Indonesia, he has built a new fattening shed and he has started their own farmer group with 6 members.

Mr Muin fattens weaners up to 170-200kg and makes a profit by on-selling these to other fatteners. This approach keeps his cash flow more regular than fattening to slaughter himself. With enough cash flow, he has employed a staff member to help him maximize productivity from his leucaena.

Mr Muin receives visitors several times a week, and he provides seedlings for them to plant their own Tarramba leucaena. His leucaena plantings are so successful that neighbours from all around the area are coming to him for seed, forage and advice. Twenty six other farmers are starting to follow his example with 12 having already planted Tarramba.

Mr Muin has recently won a local competition for best farm, and he has become a respected leader and valuable source of knowledge to new farmers.

Photos of some case study sites

Farm of Mr Muin who has planted 6ha of Tarramba leucaena for bull fattening (Sumbawa)

Farmer in village of Jati Sari on Sumbawa - fattening bulls with leucaena is a profitable business

Farmers in village of Nyerot on Lombok are long-term fatteners using sesbania grown on rice bunds

Case study – Setetes Madu. At the start of Phase 2, a farmer group “Setetes Madu” in Timor fenced off and converted 20ha of thick “*Chromolaena*” dominated bush land into

cultivated maize followed by planting of > 24,000 polybag Tarramba seedlings. They were so successful that an extension is planned for expansion of area to cover 84 ha.

Village group in Setetes Madu have recently planted 20ha of Tarramba leucaena and have begun bull fattening

Case study – Amtoas. A second Group in Timor in “Amtoas” village had 43 ha of established *Sesbania grandiflora*, and are now replacing *S. grandiflora* with Tarramba leucaena. They are receiving assistance from project FRs and from Field Extension officers of the District Livestock Dinas. They started fattening 40 cattle but increased to 53 Bali Bulls in 2015/2016.

Case study - Oebola Dalam. Oebola Dalam in Timor has become an excellent learning

Village of Oebola Dalam

and cross visit site, and replaces historical interest in Ponain Amarasi. At a recent visit of Transfer of Technology (TOT) participants, a senior Field Extension commented that: “This is the best example of dry-land cattle fattening and should be promoted by

Extension Staff in their respective regions. In a visit by the Argentina Ambassador he commented: “We have been visiting several sites today, but Oebola Dalam is the best and the example should be multiplied into many areas in NTT to improve beef production and farmer’s income”.

6.2.4 Engagement with Government and NGO stakeholders

NTT has been especially successful in linking with and gaining support for project activities from agencies at Provincial and Kabupaten Levels. Examples include:

- At a meeting in May 2014 with the Secretary to the Governor of NTT, the Head of Dinas Peternakan, the Head of the budget Planning Division of NTT Bappeda, the Head of collaboration division of Bappeda NTT and the Secretary of Provincial Dinas Petrnakan, the importance of forage to the success of cattle development projects was emphasised. Strong support including funding was offered for our program.
- Provincial Bappeda (Planning Board of NTT) agreed to provide financial support for Phase 2, for BPTP NTT and Stations of Provincial Livestock Dinas in Timor, Sumba and Flores.
- Links and support have been established with PUSKUD, ILO, UNDANA University, PLD, AIP-PRISMA in NTT and with Agricultural High Schools in NTT.

NTB

In May 2014, the project team met with number of agencies to discuss plans for cattle fattening and involvement of their staff. Memorandums of understanding (MOUs) were prepared to formalise linkages between project activities and Government giving us power to negotiate cooperative arrangements: - MOUs were signed by Bupati of West Sumbawa; the Head of Dinas in Sumbawa District, and the Head of Dinas in Central Lombok.

Signing MOU with Bupati in West Sumbawa

Meeting with Head of Extension in NTT

6.3 Level of Adoption

Whilst large scale adoption is the ultimate goal of the project, this is largely expected to occur post-project. However, significant adoption has already occurred during the project, well in excess of planned goals.

In Phase 2, the medium scale pilot-roll-out of FTL practices planned to reach 10 groups per province at 20 farmers/group. In reality due to ever-increasing requests to become

involved by Government and NGO agencies, farmer groups, and individuals, participating farmers could not be neatly categorised and there were many more adopters than originally planned (see Table 6.2).

Adoption of FTL-based fattening systems has been swift with farmers who owned cattle and had sufficient feed, especially in the dry season e.g. the Balinese farmers who planted leucaena on Sumbawa. Local farmers on Sumbawa were initially less interested in FTL-based feeding systems as they had sufficient grazing but they became increasingly interested when they observed the greater productivity of cattle being fattened by the Balinese on smaller areas of land, and the areas of communal grazing gradually diminished. The greatest challenge occurred with farmers/villages without cattle; however, Dinas Peternakan programs are now supplying feeder cattle to allow farmers to get started with fattening provided they have already planted Tarramba leucaena. This has created a significant incentive to plant FTL.

The level of adoption during the life of the project can be measured in several ways e.g. number of FTL seedings planted, number of bulls fattened, number of farmers involved (see Table 6.2). For instance, >2000 kg of Tarramba leucaena seed has been distributed throughout every province in Indonesia. Dinas Peternakan is the largest purchaser of seed, but there have been multiple smaller purchases from many organisations, NGOs, private farmers, as well as farmer to farmer sales. More than >1,000,000 FTL trees have been planted to fatten bulls.

6.4 The value of Tarramba leucaena and supply of seed

Cultivar Tarramba was first introduced to Indonesia as a component of ACIAR Project AS2/2000/157 Leucaena management in West Timor and Cape York (1 January 2001 to 31 December 2003). Among other activities, this project evaluated new and existing forage tree-legume germplasm and how the best accessions might be propagated. It was demonstrated that: while the hybrid leucaena variety KX2 was very promising in terms of its growth rate and yield potential, it was ultimately not successful due to propagation difficulties.

However, there was recognition of the superior value of the introduced cultivar Tarramba which was found to be preferred by cattle, less affected by psyllids, leafier, lasted longer into dry season, and yielded better poles. This was the major achievement of ACIAR Project AS2/2000/157. Tarramba now has a huge reputation among Government officials and farmers alike - it is widely accepted as vastly superior to local or Cunningham varieties. There is now strong demand for seed. Thus lack of availability of Tarramba seed was a potential barrier to adoption. Accordingly, much effort was put into both the technical aspects of seed production and the logistics of establishing an on-going seed supply network.

LPS/2000/054 has worked with smallholders and Government agencies - BPTP and Dinas Peternakan – to establish seed orchards of this cultivar. The development and use of Tarramba have been highly supported by Provincial Bappeda and Livestock Dinas, Distrcts Livestock Dinas, etc. BPTP-NTT is now the major supplier of Tarramba for Indonesia, organised by Ms. Debbie Kana Hau (Tables 6.3 and 6.4).

Table 6.3 Leucaena seed cultivar Tarramba produced 2012-2015

Year of production	Location							Total (kg)
	Kuanheun	Ponain	Oebola Dalam	Uel	Naibonat	Lili	Sumba	
2012		100		-	-	120		220
2013	14	100	150	-	-	80		344
2014	130	192	508	-	-	150	75	1055
2015	80	24	800	40	250	100	3	1297
Sub Total	224	416	1,458	40	250	450	78	2.916 kg

Table 6.4 Leucaena seed cultivar Tarramba distributed 2012-2015

Stakeholder	**Year of Distribution**				
	2012	2013	2014	2015	Total
PUSKUD	5	5	40	30	80
PRISMA			15	30	45
CARE			123		123
ILO			5		5
Disnak Prov.		160	413	70	603
BPTP NTT			30	5	35
BPTP Bali					10
BPTP West Sumatera	15		5	15	35
Private			72	114	186
Disnak kupang			350	600	950
Disnak Alor				50	50
BP4K Nagekeo			22		22
Sub-Total					**2,144**

While leucaena forage is the principal product of leucaena plantings due to better cattle weight gains, sale of Tarramba seed has attracted the interest of farmers as this provides an interim income prior to the sale of the first fattened bulls. Farmers obtain excellent prices for good quality seed e.g. farmers from Oebola Dalam received up to 45 M IDRs for 600 kg of Tarramba seed in 2015. During the life of the project, >2,000 kg seed has been distributed to various locations within and outside NTT and NTB.

Future plantings for seed production are best done by individually owned plantings as profit sharing from communal plantings has created difficulties. As NTT has > 800,000 ha of potential land to grow Tarramba, seed supply will be needed for at least the next 20 years. Ultimately, a private investor or investors should be encouraged to organize the seed business to ensure a sustainable market supply as demand increases.

Tarramba leucaena seed production

Tarramba leucaena seed produced by smallholders

6.5 Scientific outcomes from technical research

There were very substantial advances made in addressing technical constraints. The findings were major highlights of the project and will have major impacts on the livelihoods of smallholder farmers in NTB and NTT, as well as in other regions of Indonesia and Australia, and beyond.

6.5.3 Productivity of Cattle fattening with FTLs

As part of the on-farm research and demonstration of FTL systems (Objective 2), there were extensive feeding and demonstration trials of cattle fattening with leucaena and sesbania. These multi-site trials and demonstrations showed the high value of leucaena and sesbania for cattle fattening, especially compared to the standard animal diets based on a wide range of feeds, which were mostly of quite low quality. The farmers (and government extension staff) had a generally poor understanding of the major quality differences of the different components of the diet and especially of the very high quality of the FTLs. Thus promoting the importance of the high quality of FTLs was critical.

Lefroy and Ibrahim (2016) noted that “All of the feeding demonstrations involved measuring the amounts of feed, as well as the proportion that was from FTLs, monitoring the LWG, and improving the overall management of the animals and their feeding systems, including housing, feed boxes, watering, cleanliness, health management, and more. Monitoring LWG not only led to a better understanding by farmers of the benefits of improved diets based on FTLs, it also prepared the farmers for negotiating with traders with respect to purchase based on estimated live weight”.

(a) Leucaena

The study of bull fattening with leucaena in the village of Jati Sari on Sumbawa showed that farmers had three fattening periods each year (Panjaitan *et al*. 2014). The average fattening period was 127 ± 58 days. The number of bulls purchased and fattened during the wet season was more than twice that of the dry months due to increased feed resources available. The initial weight of bulls varied within and between farmers with an average of 191 ± 41 kg at 18 ± 7 months of age. The average sale weight of bulls was 229 ± 27 kg, well below the accepted standard for slaughtering beef (300 kg), thus contributing to the low dressing percentage.

Timing of animal sales was generally based on the need for money, rather than on optimal bull parameters. Farmers were also concerned about theft of animals that we kept too long and were of high value. The ADG over the 11 months was 0.42 ± 0.12 kg/d. The highest average point of 0.61 kg/d was obtained early in the dry season in June while the lowest average point of 0.23 kg/d occurred at the end of the dry season in October. However, bulls belonging to the best farmers achieved ADGs of 0.83 kg/d over the 11 month period including ADGs of ≥1 kg/d for May, June and August. As most bulls were under-nourished on arrival, the highest ADGs were achieved in the initial month due to compensatory weight gain.

It was not possible to determine the precise amount of feed consumed. Nevertheless, the highest amount of fresh feed offered was at the end of the wet season in May while the lowest offered occurred in the dry season between August and October. The average percentage of leucaena in diets over the year was approximately 80% followed by corn straw 13% and native grass 7%. The percentage of leucaena in the diet was highest (100%) between May and July, and lowest (approximately 50%) in October.

The work with leucaena showed that, as long as the leucaena was introduced gradually, diets of 100% leucaena can be used productively, with healthy animals. It was concluded that increasing supply of leucaena to bulls, either by planting more leucaena or by altering the number of bulls to fit available feed supply, increased growth rates to near the potential for Bali bulls was possible. These strategies enabled smallholders to more quickly achieve the appropriate sale weight of 300kg for which they received a premium price.

Wider adoption of the feeding and management strategies employed by the best farmers of Jatisari on Sumbawa showed the way to increase the output of fattened bulls from other smallholders in other regions of West Nusa Tenggara and East Nusa Tenggara. This potential can be achieved as we now have a thorough knowledge of leucaena establishment, improved management, housing and hygiene of the bulls, and an understanding of the barriers to adoption.

There was also some preliminary work on the impact of leucaena and sesbania on controlling gastrointestinal parasites in NTB (Luh Gde Astiti *et al*. 2013). These results suggested that the higher tannin content of leucaena may make it effective for control of parasites. However, as sesbania feeding was undertaken in a wetter environment, the potential for re-infection was far greater. This aspect is an area worthy of further investigation.

An effective outreach and Extension Strategy was developed that addressed barriers to implementation that was also comprehensive, long term, and involved multiple stakeholders.

(b) Sesbania

Similarly, high amounts of sesbania can also be fed productively to achieve high daily live weight gains. While the feeding of cattle with *Sesbania grandiflora* grown on the bunds of lowland rice paddies in Lombok was quite well established, there was much to be learned about this system concerning both the production of sesbania and feeding practices.

Surveys and field trials demonstrated that good LWGs can be achieved with bulls fed a high proportion of their diet as sesbania (Dahlanuddin *et al.* 2014). It was found that:

- Farmers planted an average of 406 sesbania trees on bunds surrounding 0.6 ha of rice paddy. Growth of sesbania seedlings was rapid reaching 5m height in 12 months. Sesbania was harvested by lopping the lower side branches, never defoliating single trees and allowing 25 days for recovery. The median values for the main forages cut and fed to bulls were elephant grass (78% of diet), sesbania (12% of diet) and concentrates (5% of diet). The farmers fattened an average of 1.6 bulls at a time achieving an average monthly live weight gain of 0.41 kg/bull/day. Best farmers averaged 0.82 kg/bull/day. Positive correlations were found with total forage fed but not with other parameters due to variability of data.
- New bulls were purchased at an average live weight of 203 kg while the average sale weight was 260 kg. Purchase and sale prices were high at A$3.27 and A$3.29 respectively. The average fattening period was 5 months.

From the data collected we concluded that:

- Moderate rather than excellent live weight gains were achieved by farmers as they were unable to feed sufficient sesbania due to the limited rice bund available for planting sesbania.

- The best farmers had (a) good skills in selecting feeder stock; (b) fed good quality green forage and sesbania daily; (c) frequently offered supplements; (d) owned more sesbania trees; and (e) employed better hygiene and sanitation. Most bulls were sold below 300 kg reflecting the common practice of early sale after a short fattening period.

- The survey has confirmed the moderate productivity of the sesbania fattening system. There is opportunity to improve management and scale-up its use to other regions.

Some evaluation of different varieties and accessions of sesbania was initiated, although the main finding on sesbania production was that there are options to increase the amount of sesbania available in these rice-based systems for feeding through planting more of the bunds to sesbania and at a higher density. There was also good information on the best practices for managing the sesbania in terms of the frequency and methods of cutting, and the degree of defoliation at each cutting (e.g. Dahlanuddin *et al.*, 2014).

Much can and should be done to promote sesbania production and feeding systems in Central Lombok, in other parts of NTB and NTT, and throughout rice-based farming systems in Southeast Asia. In addition, sesbania production in forage blocks, not just on rice bunds, was shown to be a good source of high quality feed that should be promoted across these same areas. One obvious difference between leucaena and sesbania is that leucaena can be maintained for many more years, while sesbania needs to be re-established more regularly but grows more quickly. Thus, there is the option of starting production and feeding based on sesbania and then moving increasingly to leucaena by under-planting leucaena among established sesbania trees.

6.5.2 Leucaena toxicity

The scientific and practical outputs on leucaena toxicity are very exciting and the potential for impact elsewhere cannot be underestimated. There are some very interesting findings on the presence and nature of the bacterium *Synergistes jonesii* that was thought to be the primary pathway in the breakdown of the leucaena toxin mimosine to non-toxic products. Our findings are summarised as follows:

S. jonesii

- *S. jonesii* was found to be indigenous in all countries tested and across all ruminant species (also non-ruminant species) but present in the rumen at low levels, regardless of presence or amount of leucaena in diet.
- Discrete mutations (SNPs) were detected in *S. jonesii* 16S rDNA gene sequences indicating genetic diversity at the species level; these differences were associated with geographical location and ruminant species, and may indicate varying ability to degrade DHP.

DHP metabolism

- High levels of urinary DHP (usually highly conjugated) were found in animals consuming high leucaena diets (i.e. DHP was not being fully degraded), despite being positive for *S. jonesii*; these animals were healthy and lacked clinical signs of toxicity.
- Since 2003, 2,3-DHP has been reported as the dominant isomer excreted, contradicting the notion of 2,3-DHP as a transitory isomer.

Detoxification of DHP

- HPLC, LCMS, and colorimetric techniques have identified high levels of conjugated DHP in urine of cattle, on high leucaena diets, bound as a glucuronide produced in the liver. Conjugation is thought to result in decreased toxicity of DHP due to: (a) increased water-solubility of DHP increasing the rate of excretion; and (b) binding at an hydroxyl group, reducing both anti-thyroid effects and affinity to chelate with essential minerals.

Effectiveness of inoculation with *S. jonesii.*

- In the Australian trial, indigenous strains of *S. jonesii* were sporadically detected in PCR analysis, indicating *S. jonesii* was present prior to inoculation but at the lower limits for detection. After inoculation there was no change in the rate of total DHP degradation or the frequency of detection of *S. jonesii*, although there was increased rate of degradation of 2,3-DHP. SNPs indicated the presence of different strains of *S. jonesii* in both indigenous and cultured *S. jonesii*. It was concluded that the cultured *S. jonesii* inoculum did not fully protect animals against leucaena toxicity.
- In the Indonesia trial, there was no effect of inoculation in recipient animals within the monitoring period. Urinary DHP levels in recipients were initially high and did not decrease to levels of statistical significance from the control treatment after inoculation, remaining above threshold levels for subclinical toxicity. This result highlighted the difficulties in achieving successful transfer of *S. jonesii* through eastern Indonesian islands.

These findings suggest a new management paradigm:

- *S. jonesii* is ubiquitous, but not degrading all DHP in animals on high leucaena diets. Animals appear to cope with high levels of DHP in blood by a process of conjugation and neutralization in the liver.
- These findings if confirmed, will lead to a dramatic change to our understanding of how animals consuming leucaena world-wide should be managed: e.g. Indonesian Bali bulls do not require inoculation, but do need gradual introduction to leucaena to adapt to mimosine, and to induce conjugation pathways to neutralize DHP.
- It appears that through a gradual introduction of leucaena into the diet, and without the need for an inoculation with *S. jonesii*, animals can be healthy and have high LWGs on a diet with a high proportion of leucaena. These findings mean that there

is no longer a need to focus on inoculation with *S. jonesii*, as the primary detoxification pathway, as was proposed in the original project document.

Further work is required to confirm the significance of this detoxification pathway in Australian cattle consuming leucaena, where we know that conjugation occurs, but the extent is unknown.

Full details of this work are given in the published papers (e.g. Halliday *et al.* 2013).

6.6 Communication and dissemination

There have been extensive communication and dissemination activities to maximise social and technical contact among team members, and with other stakeholders. Communication was conducted in several ways. For day to day communication, we used:

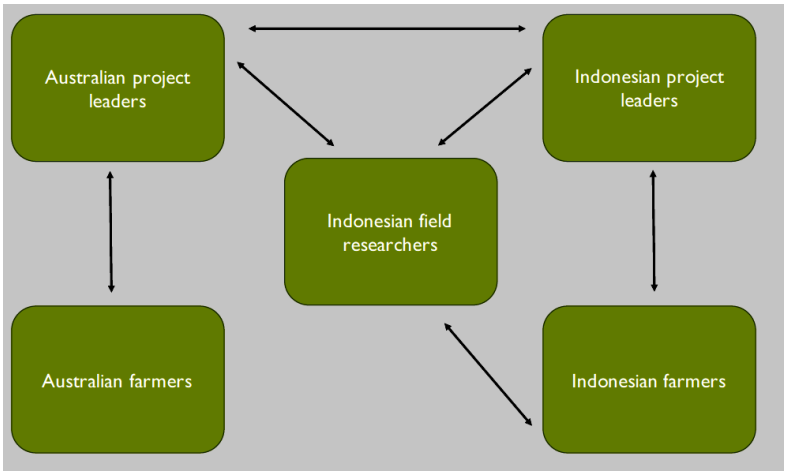
Smartphones. Each FR received a smartphone and a regular credit allowance. This expedited real time communication, and information transfer, and improved data management in the field. Apart from emails, direct messaging apps such as:- Whatsapp, BBM, Facebook, Messenger, and Viber were inexpensive and allowed instant communication 24/7 regarding urgent questions. They also encouraged friendships to be built and maintained.

The Facebook Site (TIM PLP) set up at the beginning of the project was used throughout the entire project to share images, receive comments, and generally allowed regular contact. It helped to maintain team spirit among FRs located in provinces, islands, and countries. This site is continuing post project and enables continuing communication at project technical and personal level.

We held regular meetings, discussions with many farmer groups and individuals as well as with Government and non-government agencies. There were also regular field visits involving a large number and diversity of people including visiting Australian scientists, graziers, as well as many Indonesian Government personnel.

Annual site visits and **meetings in Indonesia and Australia** were a powerful method for sharing of knowledge. They gave motivation to prepare data and maintain good data management practices. The Annual Meetings were used by Indonesian and Australian project leaders to reflect on the year's activities and plan for the new year. They also were useful in building team morale and a sense of team unity. Beautiful locations were chosen to increase enjoyment to the process. The last meeting was held in Australia at the Carnarvon Gorge and included visits to several properties, including the Larson's (home of Tarramba), as well as to leucaena growers in the Carnarvon region. We also visited UQ, tourist sites in CBD Brisbane, leaving via Sydney for a look at the Opera House.

The flow of communication is illustrated in the diagram.



An example of the many activities that are shared on the Facebook site

The Tim PLP group Facebook site

	Phase 1			Phase 2			TOTAL
FR	# Phase 1 farmers contacted	# Phase 1 bulls being fattened	# FTL planted	# Phase 2 trainers to be trained	# Phase 2 trainers already trained	#Phase 2 farmers to be contacted	# Tarramba seed already distributed (kg)
Utik	132	444	37460	5	0	125	
Kurniawan	137	334	12576	3	0	125	
Fauzan	121	751	64300	10	0	250	
Sutartha	28	174	31150	10	0	250	
Charles	46	56	65435			181	
Darius	43	18	15800			23	
Petrus	33	37	10500			136	
Daniel	12	20	16985			81	
NTB				28	0		
NTT				20	20		1394
NTA							738
Total	552	1834	254206	76	20	1171	2132

The Facebook site was used to distribute and check data

Messaging apps used for instant communication

The project team attending Annual Meetings in Indonesia and Australia

6.7 Training

Training of the Field Researchers was a continuing on-going priority. Monitoring / working with the farmer groups provided excellent experience for the FRs on collecting and analysing data on growth and management of FTL, as well as on animal feeding, production, health and marketing issues.

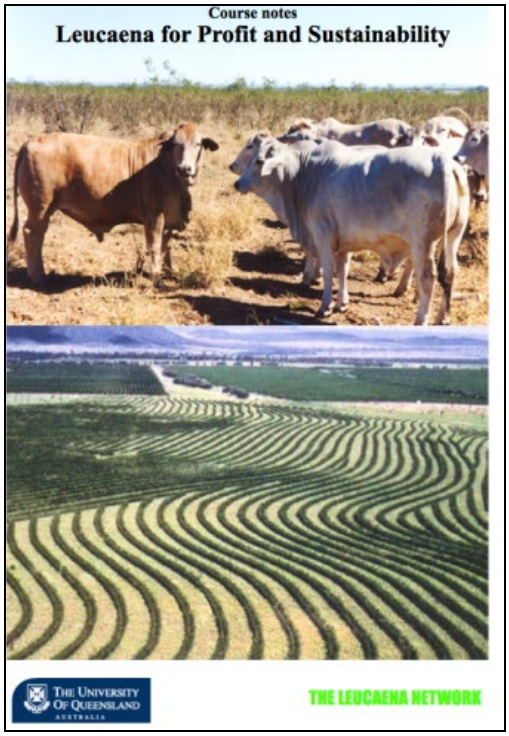
Most of the young Field Researchers responded well and demonstrated greatly improved capacity; however, some did not respond well, usually for personal reasons, and were replaced including 3 of the 4 FRs in NTT.

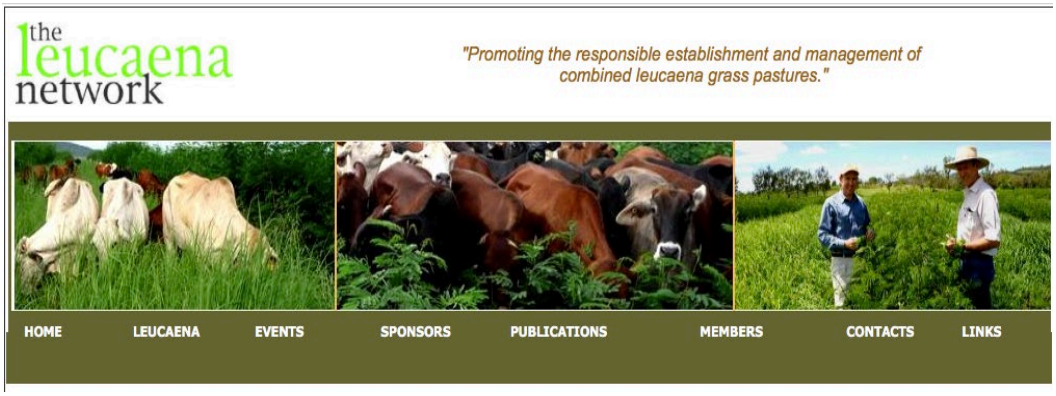
We prepared and delivered training courses for extension staff from Livestock and Extension Departments. The first of these training courses commenced at the end of 2014 and continued into 2015 and 2016. These courses were supplemented with specifically designed course materials including videos that highlighted various aspects of cattle fattening with FTL. As shown in Table 6.2, we have worked with >2000 farmers in NTB & NTT. We will have trained >60 Government extension staff, >100 farmer leaders.

Training videos. Twelve Training videos have been completed highlighting various aspects of feeding FTL including: Promotion of FTL use; Seedling preparation;

Transplanting; Fattening, management, and animal husbandry. These were presented during farmer/trainer training sessions.

Leucaena for Profit and Sustainability Short Courses in Australia. In Australia, two short courses (Leucaena for profit and Sustainability) were given to graziers and Santos staff at Roma (30-31 October) and at Wallumbilla (1-2 November, 2012) by the University of Queensland. The course provided information on all aspects of planting, management and feeding leucaena. Australian staff also presented talks to The Leucaena Network Meetings (Australian graziers), including latest research findings, in 2012, 2013 (Redlands), 2014, (Emerald), and 2016 (Atherton).



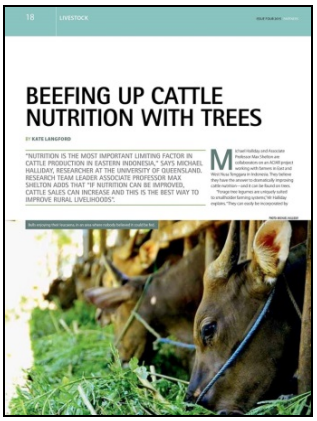


6.8 Research outputs and publications

The Project has had a prodigious publication output. There were 9 journal papers on leucaena toxicity issues and 5 on the agronomy and feeding of FTLs to cattle, and the adoption of FTL systems. More scientific papers can be expected. This will include further findings regarding leucaena toxicity as well as papers on leucaena-grass interactions. Publications include:

- 14 published papers in journals
- 19 conference presentations and papers
- Article in Partners Mag.; in local Indonesia magazines
- Indonesian radio ads
- TLN Newsletter and several AGM meetings
- Article of “Update on leucaena toxicity”
- article in SAFS newsletter
- extra activities of by Indonesian staff
- Indonesian presentations to groups, agencies, IAARD, etc

There has been a major focus on participation in conferences with at least 19 presentations or posters, including a major presence at the International Grasslands Congress (IGC) in 2013, and participation in a number of other international and national meetings in Australia, Indonesia, and elsewhere. There have been many other approaches to promoting the findings of the project, through the Leucaena Network Newsletter, the ACIAR Partners magazine, radio, and many other fora.



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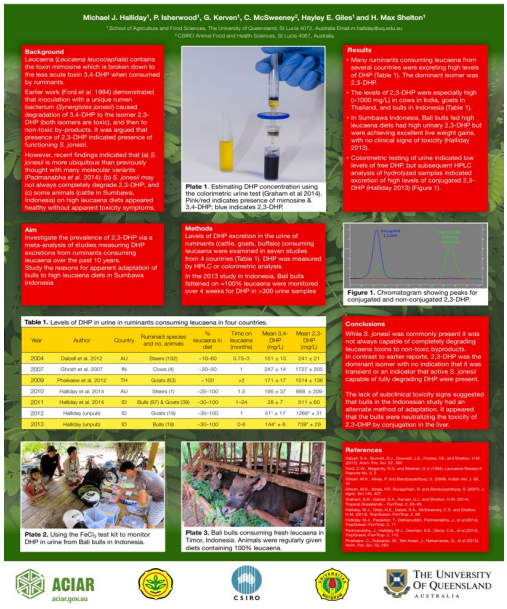

8 Key results and discussion

7.1 Management, collaboration and cooperation

Lefroy and Ibrahim (2016) reported that “The project leaders in Australia and Indonesia led the project very enthusiastically. They led an excellent team in NTT, NTB, and in Australia. An important factor in the good running of the project was the establishment of strong communications and support programs. The value of good communications within such projects cannot be over-estimated, so the efforts to involve as many forms of communications, including establishing a team Facebook page, provision of smartphones to the Field Researchers, and the widespread use of emails, direct messaging, and other support apps, must be applauded. Other important communications and team building events were regular field activities supported by regular visits, regular annual meetings, and a group trip to Australia. The specific role of Mic Halliday in initiating and supporting many of the communications and his time spent in the field, undertaking research, joint research, and contributing to mentoring, must be acknowledged, along with strong leadership from Dr. Tanda Panjaitan and Dr. Max Shelton”.

“The groups in NTT and NTB worked extremely well and Dr. Tanda Panjaitan did a fantastic job as the team leader in Indonesia and in direct involvement in field work. There was very good collaboration and cooperation between and within the groups in Indonesia, in NTB and NTT, as well as with the Australian partners. The Field Researchers were an important part of this process”.

The annual meetings obviously provided excellent opportunities for team building, for the review of progress, and for the discussion and development of small changes in the focus and activities. Most changes in the planned objectives, sub-objectives, and activities were in line with the results that were emerging from the project.

7.2 Situation analysis

Lefroy and Ibrahim (2016) reported that “The situation analysis mentioned under Objective 1 was aimed in part at preparing the Extension Strategies for the PRO phases 1 and 2. The process involved significant training of staff, particularly the Field Researchers, and methodology for development. This approach, which sought a systematic analysis of the livestock feeding systems, aimed to work in locations with high cattle populations (starting from the kabupaten and moving down to the kecamatan, desa, and dusun, or district, subdistrict, village, and hamlet), good accessibility, and adequate land for growing FTLs”.

“While the concept of a systematic analysis was good, it consumed too much time, involved all staff at each site, and much of the output was unusable”.

“There was insufficient attention paid to the resources of the farmers. As an example, farmers were chosen because of the presence of cattle and land in the village, although in some cases the selected farmers did not own the cattle or had sufficient land for planting FTLs”.

“The principles behind the situation analysis were good, but initial implementation showed too much focus on working with whole groups of farmers, whereas in quite a number of cases it was better to work with individuals within groups or very small groups. Working with larger groups was often slow initially, but ultimately gave good impact. The initial focus was too much on the ultimate target group whereas it was subsequently demonstrated that it was better to focus on people willing and able to try the FTL systems. The resources of individual farmers, and the importance of first-adopters and subsequent adopters was paramount”.

“Nevertheless, the project moved effectively from identifying and addressing constraints to adoption of FTLs to effective roll-out of FTL innovations. The establishment of demonstration sites was a critical component of this work. They allowed for the

assessment and refinement of practices, the development of extension materials, and they were used for important cross-visits to promote good management practices. Models were developed for cattle fattening which were an integrated package comprising the establishment, management and feeding of both leucaena and sesbania, and included recommendations for provision of water, hygiene and health, and more. The project developed a basic model of a fattening shed (kandang) which could be easy replicated by farmers or farmer groups, in single or multiple units, either exactly as recommended or modified for local construction materials".

7.3 Understanding animal nutrition

Fundamental to successful fattening of cattle was an understanding of the nutrition of cattle and the vital role for FTLs in providing high nutritive value forage that can be safely fed to cattle. One reason for not adopting FTLs was legitimate concern about the safety and nutritive value of leucaena.

There was a lack of appreciation of the nutritional needs of animals, and especially of fattening bulls, and the comparative nutritive value of the various feeds available to smallholder farmers. Many farmers do not have adequate appreciation of the differences in nutritional value of rice straw and other crop residues, grasses, banana stems and other feeds available on farm, let alone the value of FTLs (see Figure 7.1).

Sesbania from rice bunds

Sesbania from trees on rice bunds

Rice straw from rice paddy

Planted elephant grass from rice bunds

Banana stems from rice bunds

Figure 7.1. Rice paddy in Central Lombok providing a variety of forages of variable quality for fattening of beef cattle (quality of sesbania > tropical grass > banana stems > rice straw).

7.4 Where can FTLs be grown?

Project staff have good understanding of the biophysical constraints and opportunities for planting FTLs, especially for NTT and NTB. There is a strong argument to document this biophysical suitability information for others, especially the requirements for FTL production in terms of soils, climate, altitude, etc., based on expert knowledge from the project and elsewhere, with direct reference to c.v. Tarramba and to Indonesia. This has already been done for NTT in Project AS2/2000/157.

Agro-ecological zoning (AEZ) is a tool for use in agricultural planning. AEZ maps provide comprehensive information on the biological potential of a region and provide direction on alternative land use/suitability. NTT has been mapped at 1:250,000 using bio-physical criteria of slope, altitude, humidity and soil drainage characteristics. A brief description of AEZ criteria for each of the three main islands of NTT Province is given in Table 7.1.

Table 7.1. *Leucaena* - biophysical requirements for growth

Characteristic	Non-limiting	Minor limitation	Moderate limitation	Severe limitation	Unsuitable
Toxicities					
pH	>5.5	5.2-5.5	4.8-5.1	4.5-4.8	<4.5
Al saturation (%)	<5	5-20	20-40	40-60	>60
EC (dS/m)	<2	2-4	4-8	8-15	>15
ESP (%)	<6	6-10	10-15	15-40	>40
Fertility					
P conc (ppm)	>20	15-20	10-15	5-10	<5
S conc (ppm)	>5	4-5	3-4	<3	
K conc (Meq/100g)	>0.2	0.15-0.2	0.1 -0.15	0.05-0.1	<0.05
CEC (Meq/100g)	>10	8-10	5-8	3-5	<3
Rooting conditions					
Soil depth (m)	>2	1.5-2.0	1.0-1.5	0.5-1.0	<0.5
Soil moisture					
Annual rainfall (mm)	>1500	1000-1500	600-1000	400-600	<400
Dry season (months)	<3	3-5	5-7	7-9	>9
Flooding (weeks/year)	None	<1	1-3	3-8	>8
Drainage	WD	MWD	ED	P	VP
Temperature					
Mean maximum (ºC)	28-33	25-28, >33	22-25	19-22	<22
Mean minimum (ºC)	>22	18-22	14-18	10-14	<10

Drainage: WD - well drained; MWD - moderately well drained; ED - excessively drained; P - poor drainage; VP - very poor drainage

Since the Amarasi Sub-District, has relied heavily on leucaena for feeding and fattening of cattle, this area can be used to validate GIS suitability domains. The Amarasi area is dominated by the IIIay, IIay and Iay (Figures 7.2 and 7.3). Using these criteria, districts of NTT suitable for introducing, developing and establishing leucaena as cattle fodder include South Central Timor District, North Central Timor District, Belu District, Kupang District and East Sumba District. This result is in accordance with the Location Quotient (LQ) value for cattle commodity in the province (Nulik *et al*., 2003).

Thus GIS mapping indicates that most of East Nusa Tenggara Province, with its tropical climate and soils of neutral to alkaline in pH, is suitable for growing *Leucaena* spp.. Socio-economic factors such as location of animal populations and interest of farmers in commercial cattle raising will determine where adoption of the technology is most likely to occur. The full potential of GIS mapping for planning areas suited FTL development is yet to be realized. There is a need to digitize soil and socio-economic data to refine/increase the precision of mapping. Once fully functional, GIS will be a valuable tool in planning rural

development. GIS suitability maps have not yet been prepared for East Nusa Barat Province.

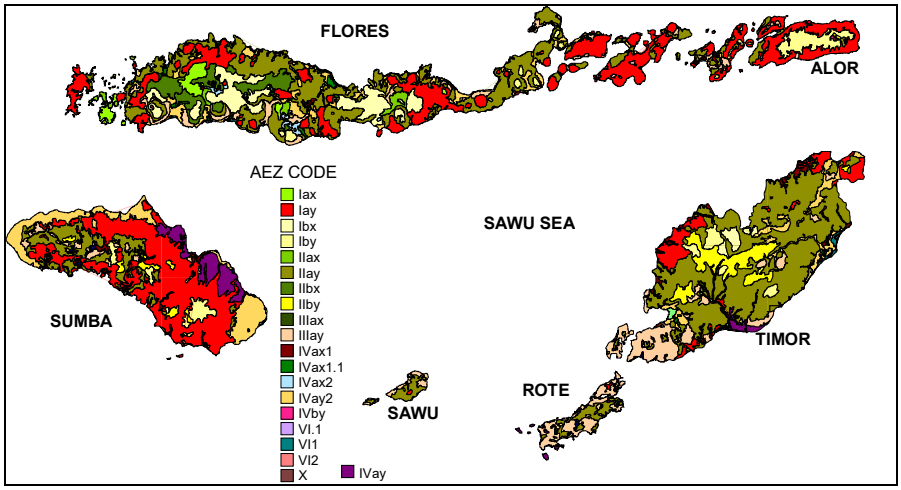

Figure 7.2. Agro-ecological zones in East Nusa Tenggara

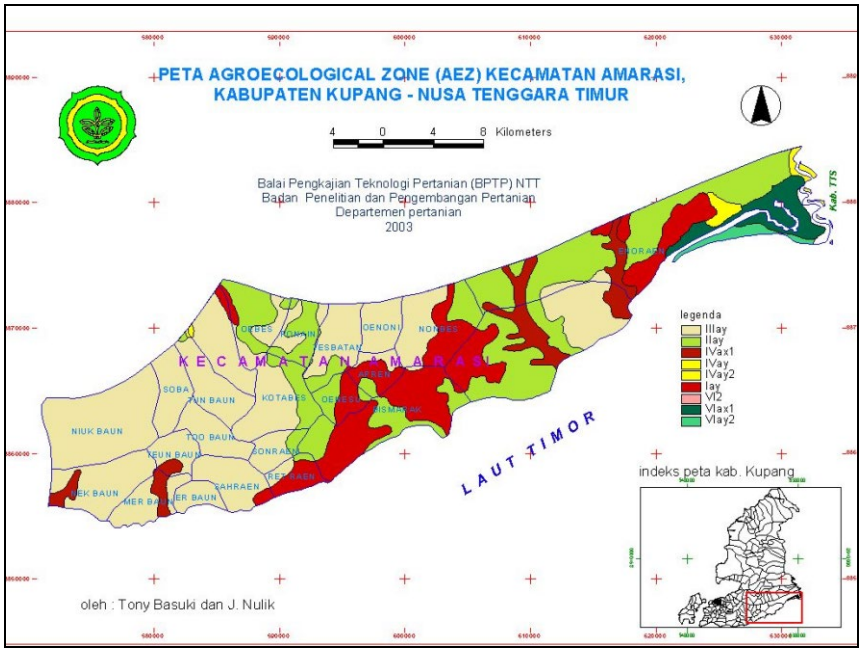

Figure 7.3 . Agro-ecological zones in Amarasi District

7.5 Lessons learned (Lefroy and Ibrahim (2016)

Lefroy and Ibrahim (2016) made a number of valuable points in his review of the project:

1. *This project demonstrates some of the best aspects of the ACIAR model for project implementation.*

2. *There was a very strong and capable project team, with excellent complementary skills in several scientific fields, in Australia and Indonesia, in field work, and in the interest and ability to engage with policy makers.*

3. *The team worked very effectively, with good to excellent communications between the team members, largely as a result of very proactive foci on facilitating strong communications – this did not happen by chance.*

4. *There were clear technical issues that were answered quite categorically, especially in terms of the safety of feeding leucaena and the demonstrated high productivity of diets based on even 100% FTLs.*

5. *Perhaps it was fortuitous that the answer to these problems fitted well with easy expansion of FTL feeding, but the critical issue was that there were clear answers to the key questions on leucaena toxicity and on the productivity of fattening bulls with leucaena or sesbania.*

6. *The adoption by farmers may not have been quite so easy or so rapid if the solution to feeding leucaena had been for a coordinated inoculation program with S. jonesii, but at least the way forward would have been clear.)*

7. *The strong scientific findings were translated into significant development impacts, both in terms of the national goal to increase domestic beef production and the goal to improve the livelihoods of farmers in the target areas*

8. *Strong links to and involvement with government agencies, particularly in NTT, resulted in facilitation of the roll-out to other farmers and the likelihood that such scaling out will continue In spite of these positives, there are a number of less positive experiences from which lessons can be learned.*

9. *The clear goals and objectives of the project should have been developed into a better project log-frame that could have been used more easily and accurately in monitoring and evaluation of the project by the project team and by ACIAR.*

10. *The project should have included a component to address some of the macro and farm level economic and market issues from the beginning. The farm level economics/budgeting would have been much more valuable if undertaken, even if only at a first attempt, early on in the project as this could have helped focus the field research and demonstrations and assisted in the development of effective and efficient roll-out models.*

11. *The project should have included a stronger component on the systematic development of approaches to scaling out of proven technologies.*

12. *When the project variation was undertaken, to include these two issues, on economics and markets issues and on knowledge management and sharing issues, it would have been better if all of these components had been designed as integral to the project, rather than outside the project.*

13. *The Field Researchers were a critical part of the project team and many project successes can be attributed to them, however, the establishment of these positions and the recruitment and mentoring could have been managed better.*

14. *Some of the criticisms above have resulted from the success of the project. If the project had remained primarily a technical project, then many of the issues of scaling out and economics and markets would not have been so important. With clear,*

categorical, and relatively easy solutions to the research questions, which could not necessarily have been expected, the focus swung more to impact.

15. *Despite some critical comments, many of which have resulted in part from the success of the project, the project must be considered a resounding success that has had significant impacts on the ground and provides extremely useful outputs for uptake directly by farmers, by future ACIAR projects, by other donors and development agencies (NGOs, etc.) and by Indonesian government agencies. The continued high price for cattle and beef will generate a great deal of interest in the outputs and examples of this project and so facilitate further expansion of impacts beyond the demonstration sites, the PRO sites, and the areas of in Kupang District of NTT where government agencies will be facilitating further scaling out.*

7.6 Reasons for success (reflections from Assoc. Prof. Max Shelton).

1. For 40 years, consultants have been writing about the shortage of quantity and quality forage for feeding of ruminant livestock in tropical developing countries, especially in the dry season. Over the past decade, ACIAR has made a significant investment into cattle production in Eastern Indonesia using modelling to confirm there is shortage of quantity and quality feed, especially in dry season.

2. Historically, cattle projects have often failed because they started with improvements in the genetics of the cattle, and then as an after-thought looked for local feed resources, which were usual lacking. There was much investment in importing improved genetics, embryo transfer, AI, cattle distribution programs; which failed because they did not know how to feed the animals.

3. Our overall Project Concept worked as it had clearly defined objectives and research questions, complementarity of interests between Australia and Indonesia, alignment with policy objectives at both Provincial and National levels, and relevant Australian expertise

4. We had a great team with excellent Indonesia leadership & well trained FRs providing strong communication among all team members, with Indonesian partners well connected to other Government and NGO agencies. There was strong Australian complementary expertise

5. Our project had the solution. We started with seed (not with cattle), planted forage, then brought in cattle once feed supply was established. And we promoted concepts that worked by providing high quality FTL in the dry season, and thereby met the needs of the farmers.

6. Changing circumstances lifted interest in planted forages from the mid to late 90s due to (a) **i**ncreasing value and demand for cattle (now ~$4/kg LW); (b) higher quality of the meat product is now required, before quality was not a factor; (c) less communal land available and declining access to free forage; (d) high labour requirement to herd free range animals.

7. Despite success and high levels of adoption of improved grasses – mostly elephant grass, the productivity of cattle has remained quite low. This has occurred as the introduced grasses did not satisfy dry season need for high quantity and high quality forage.

8. Our FTL concept worked because we advocated a viable / sustainable intensification of land use. FTL provided an intensification solution to reduced access to free grazing due to inheritance, privatization, and encroachment of weeds.

9. We did not introduce totally new concepts but built on existing knowledge and practices. The principal legumes (leucaena and sesbania) were not new, many farmers already knew of, and some were already using them. The concept was simple and uncomplicated, and culturally and work load appropriate.

10. FTLs provided a means for weed control. For instance, the dominance of leucaena gave control of serious weeds such as *Chromolena*, which is not possible with smaller less vigorous herbaceous legumes. Other benefits of FTLs over herbaceous legumes are greater longevity, better forage supply into the dry season due to deep-rooted habit, less vulnerability to wandering livestock, and supply of timber and fuelwood.

11. We introduced a new variety – Tarramba – which now has huge reputation among Government officials and farmers alike. It is preferred by cattle, less affected by psyllids, leafier, lasts longer into dry season, yields better poles. This was major achievement of ACIAR Project As2/2000/157

9 Impacts

There have been many positive impacts within the life of the project and this is expected to continue to increase beyond completion of the project in 2016.

8.1 Adoption

In Phase 2, the medium scale pilot-roll-out of FTL practices planned to reach 10 groups per province at 20 farmers/group. In reality due to ever-increasing requests to become involved by Government and NGO agencies, farmer groups, and individuals, participating farmers could not be neatly categorised and there were many more adopters than originally planned (see Table 6 .2).

Adoption of FTL-based fattening systems has been swift with farmers who owned cattle and had sufficient feed, especially in the dry season e.g. the Balinese farmers on Sumbawa. Local Sumbawa farmers on Sumbawa were initially less interested in FTL-based feeding systems as they had sufficient grazing but become interested when they observed the greater productivity of cattle being fattened by the Balinese. The greatest challenge was with farmers/villages without cattle; however, Dinas Peternakan programs are supplying feeder cattle to allow farmers to get started with fattening provided they have planted Tarramba leucaena. This has created a significant incentive to plant FTL.

We used the 'Adopt' program sponsored by ACIAR, UWA, DAFWA, CSIRO, GRDC, DPI Victoria, Future Farm Industries CRC, Charles Sturt University. The output is summarised in Table 8.1.

Table 8.1. Summary output from Adopt program**.**

Predicted years to peak adoption	11.8
Predicted peak level of adoption	95%
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	63.5%
Predicted adoption level in 10 years from start	94.6%

The predictions of 1) 'Peak Adoption Level' and 2) 'Time to Peak Adoption Level' are numeric outputs that are provided to assist with insight and understanding and like any forecasts should be used with caution.

8.2 Economic impacts

Dr Scott Waldron reported from his study of household budgeting that:

"Under all measures of profitability, representative (cattle fattening) households at all sites were profitable in wet season. As could be expected, "return to person days" in the dry season were lower than average off-farm wages. Thus, while cattle fattening is unlikely to make a household "rich" it generates cash income, increasingly required to pay for cash

expenses in modern rural Indonesian society. These returns were far higher than fattening systems without leucaena/ sesbania (based on cut grass, residues and purchased feeds) which were not viable by any measure of profitability. In general, returns were (in order of importance) sensitive to weight gains, input-output price alignments, capacity utilisation and capital costs".

The economic impacts have also been summarised by Lefroy and Ibrahim (2016). The project has worked with more than 2,000 farmers using FTLs to fatten cattle, distributed more than 2000kg of Tarramba seed, farmers have planted more than 900,000 FTL trees, with an additional 1.5 million trees ready for planting. This expansion of uptake is continuing spontaneously so it is no longer possible to know the full extent of uptake. However, we have documented the activities of farmers working with project personnel; they have sold more than 2,300 bulls – most likely an under-estimate of the real situation. At an average weight of 250kg and an average price of IDR25,000 per kg live weight, these 2,300 bulls had a gross sale value of approximately AUD1.5 million equivalent to about 85% of the value of the project.

Farmers previously involved with fattening bulls, and interviewed during the project review, said that they were turning off fattened bulls at about three times the previous rate as a result of faster growth and more consistent supply of feed allowing them to fatten for longer periods. Thus the actual benefit derived from the project is the additional gross income gained as a result of using FTLs which might be estimated as 66%. It is clear that the project has had significant economic impact for these farmers.

Many farmers said that cattle fattening had become more of a business for them; and that they had shifted from being keepers of cattle selling poorer quality animals when cash is required or when feed is limited, to producers of cattle who keep and sell animals more regularly, in better condition, and at higher body weights. Such changes in cattle fattening constitute a significant increase in beef production potential, in the efficiency of production, and in improvements in household incomes.

Other productivity gains associated with improved feeding regimes were (a) higher body weight and condition leading to improved dressing percentage and increased turnoff of beef; (b relatively easier access and lower labour requirements for harvesting forage leading to greater productivity per unit of labour compared to traditional grazing systems, and other cut and carry systems.

Due the success of the demonstration sites, and the training programs, the number of farmers involved in fattening cattle has increased throughout the implementation of the project, and many new farmers are spontaneously following the successful examples they have observed in their neighbours.

The demand for Tarramba seed continues to increase. This is indicative of the interest in expanding FTL production and sale of seed in the first year after planting provides an attractive additional source of income for farmers or farmer groups. Currently, Tarramba seed sells for approximately Rp50,000/kg. BPTP-NTT have recognised this demand and led the program of Tarramba seed production and distribution by establishing a network of seed suppliers. Some farmers are even selling surplus Tarramba forage.

The rate of expansion of FTL plantings and demand for seed continues to increase as government support for expansion increases. In Kupang District of NTT, the project has very effectively engaged with various levels of government including the Governor's Office, the Bupati and the Dinas. This close connection has facilitated the expansion of FTL-based fattening systems. Dinas has become the major purchaser of Tarramba seeds and they have major programs in place to support the expansion of leucaena planting for cattle fattening.

8.3 Social impacts

There have been many positive impacts within the life of this project, and this is expected to continue to increase on completion of the project in 2016.

Lefroy and Ibrahim (2016) reported that “Social benefits flow from the economic benefits from sale of greater numbers and higher value cattle. There have been clear improvements in living conditions of households as profits from cattle fattening have been put into improvements in housing and other essential family needs. The purchase of assets such as motorbikes is another benefit. Improvements in education and health are likely consequences of increased cash income, especially on a more regular basis, and particularly through the dry season. While no supporting documentation was seen, the case study of Oebola village provided many specific indicators of positive social impacts (see Figures 8.1 and 8.2).

The improved labour productivity through easier collection of feed and higher growth rates can provide benefits through allowing expansion of cattle fattening, and increases in other on-farm and off-farm enterprises, and potentially greater involvement in education.

The adoption of biogas systems by farmers involved in cattle fattening has social and economic impacts through the provision of light and heating. The value of Tarramba leucaena for timber and poles is a subsidiary benefit.

Figure 8.1. Families in the village of Oebola (NTT) benefit from planning Tarramba leucaena and commencing cattle fattening enterprises

Oebola family with poor housing including a dirt floor

Oebola children benefit form increased family cash income

Planting Tarramba leucaena has attracted many benefits

Project field research with Oebola farmer in new Tarramba leucana planting

Figure 8.2. Families in the village of Oebola (NTT) benefit from planning Tarramba leucaena and commencing cattle fattening enterprises

Harvesting Tarramba leucaena forage for cattle fattening

Regrowth of tarramba leucaena after harvest

Feeding Tarramba leucanea for bull fattening

Additional income from bull fattening used to upgrade family house

Biogas digester for household energy supply

Household lights powered by biogas

8.4 Environmental impacts

There are a number of environmental benefits from the adoption and expansion of FTL based cattle fattening systems.

- Environmental benefits from growing forage tree legumes (FTL) can be realized at the farm, catchment and global levels. Farm level benefits occur as FTL such as leucaena can withstand regular cutting and can buffer unexpected drought or extended dry periods. Being deep-rooted, it is an ideal drought mitigation strategy. It also has high water use efficiency and can enhance soil fertility through cycling of biologically fixed N.
- Ecosystem benefits are delivered by enabling smallholders to intensify cattle production allowing them to rest overgrazed communal pastures reducing habitat destruction, loss of biodiversity, soil erosion and weed ingress.
- Catchment level benefits accrue from the large-scale adoption of FTL due to their ability to mimic the water use of woodland vegetation and maintain the hydrological balance of catchments.
- Global level benefits accrue as FTL plantings have the potential to positively impact the global environment by improving greenhouse gas balance. They (a) sequester C in their woody frame and roots and in accumulated soil organic matter; (b) reduce emissions of methane by improving the diet quality of ruminants; and (c) they are long-lived and sustainable thereby minimizing greenhouse gas inputs.
- An obvious benefit is the adoption of biogas linked to intensified housing and feeding systems. Such systems provide heating and lighting which have direct economic and social benefits, but can also have significant environmental benefits through reduction of reliance on wood and purchased fossil fuel. There is also a benefit from managing waste, and the use of the slurry as a fertilizer.
- The trees can also provide both firewood and poles for building, thus reducing the pressure on other forested areas as well as providing associated economic and social benefits.

8.5 Capacity-building impacts

The project has improved capacity at several levels, namely the skills of our senior project leaders and our junior field researchers (FRs), as well as other stakeholders such as Provincial Livestock Department and Extension personnel.

Perhaps the most important improvement in capacity has occurred with most, but not all, of our young field researchers (FRs). Much of this improvement can be ascribed to the mentoring activities of our Indonesian Project Leaders. Since the beginning of the project, there has been tremendous improvement in the skills, knowledge and understanding of the FRs. We see this in their ability and their capacity to facilitate farmers and farmer groups. They have become more independent and more confident to implement planned activities. They are also able to assist other stakeholders and decision makers who visit demonstration sites e.g. other farmers, government officers, and extension workers.

Initially methodological training was given, but now the most common topic at the regular monthly meetings is how to solve problems faced when working with farmers. They are now seen as young researchers with experience in conducting village assessment, data entry, data analysis and interpretation (not just understanding the theoretical concept). Most of the FRs are able to make decisions and solve problems using their own judgment and have begun networking with relevant agencies demonstrating skills and knowledge, thus opening opportunities for their future career. They have been encouraged to take further study where appropriate.

Among the senior staff, there has been a focus on building the scientific capacity of project partners through the implementation of high quality applied research and then communication of outputs. This has produced impressive outputs that have been communicated across a wide range of media, including peer-reviewed journals, workshops to scientists and users, popular articles, radio broadcasts, YouTube videos, and more. As mentioned above, the project has produced some very important results, especially on leucaena toxicity and feeding regimes for FTLs, and these have been communicated widely.

Young Field researchers made an impressive contribution to project activities

8.6 Scientific impacts

Lefroy and Ibrahim (2016) stated that “The scientific impacts of this project are impressive and broad ranging; from technical research through to applied field research aimed more at development impacts, and from peer reviewed journal articles to many other forms of written and oral communication”.

There are 9 journal papers on leucaena toxicity issues and 5 on the agronomy of FTLs, the feeding of FTLs to cattle, and the adoption of FTL systems. More scientific papers can be expected, either directly from the project or from research associated closely with the project. This will include further findings on the leucaena toxicity issue as well as papers on leucaena-grass interactions, on impacts of saline irrigation, and perhaps on the processes of adoption of FTLs.

There has been a major focus on participation in conferences with at least 19 presentations or posters, including a major presence at the International Grasslands Congress (IGC) in 2013, and participation in a number of other international and national meetings in Australia, Indonesia, and elsewhere. There have been many other approaches to promoting the findings of the project, through the Leucaena Network Newsletter, the ACIAR Partners magazine, radio, and many other fora.

8.6.1 Scientific methodology and rigour:

The project included a wide range of scientific studies with a consequent wide range of methods. Experiments, approaches, and methods were modified as results were analysed so that topics originally planned as important, such as the work on *S. jonesii* inoculum were reduced and more effort put into studying the conjugation of DHP. This involved the development of new methods for sample storage so conjugation could be collected and studied effectively. Similar rigorous approaches were employed on the molecular studies of the presence of *S. Jonesii* and the related genetic studies.

Effective trials on feeding FTLs to bulls for fattening had great value for capacity building of research and extension staff and were excellent learning exercises for extension workers and farmers. These field experiments also became important demonstration sites that provided excellent cross-learning opportunities for farmers and provided strong indications for policy makers on the potential for improved cattle fattening with FTL.

9.1 Communication and dissemination activities

See section 6.6

10 Conclusions and recommendations

Project outcomes demonstrate that it is possible to double productivity of small holder cattle fatteners in Indonesia; and improve the livelihoods of farming families by improving the nutrition of cattle based on feeding leucaena and sesbania. The results of this project present a huge opportunity for ACIAR / DFAT to enhance all future cattle projects in Indonesia and other tropical developing countries where cattle improvement projects are planned.

Project LPS/2008/054 has produced some important technical results that have proven the concept of feeding FTLs as a high quality feed for fattening bulls. The project also provided proof of delivery to over 2,000 smallholder farmers by either improving their FTL feeding practices, or introducing them to productive FTL cattle fattening systems. The project showed that diets based on FTLs, even up to 100% FTL, are nutritious, productive, and profitable.

The project has also demonstrated that a sustainable supply of either leucaena or sesbania can be established, maintained, and managed for feeding and fattening cattle. The project has also established a network of suppliers of seed of the leucaena variety Tarramba.

The project has produced extension materials that can be used to promote the innovations with policy makers. The materials are well packaged and have been distributed widely, although some materials remain to be completed. Local government agencies and NGOs have been engaged, especially in NTT, and are very supportive of further scaling out as they see cattle production as a very important component of the economy and livelihoods in the province.

There was a prodigious level of significant scientific output ranging from in-depth scientific knowledge to applied research on practical aspects of cattle fattening systems. The implications of these findings have had significant livelihood impacts during the life of the project for thousands of farming families in rural communities of West Nusa Tenggara (Nusa Tenggara Barat, NTB) and East Nusa Tenggara (Nusa Tenggara Timor, NTT). These impacts are expected to increase dramatically in subsequent years. The level of eventual impact will depend on the extent of adoption of our findings by Indonesian Government agencies (which is already substantial) and by the extent that project outputs can be used by ACIAR, and other donors, and development agencies. Our reviewer commented that “With no further effort, the impacts of the project are impressive, but with well-coordinated follow-up the impacts can be very large”.

In addition to encouraging and supporting the scaling out of FTL establishment, production and feeding, some additional work is recommended.

9.1 Sumbawa beef

While the pilot roll-out has been successful everywhere, Sumbawa has been given highest priority as there is huge unrealized potential to scale out the feeding system developed initially by the Balinese to the broader Sumbawa population.

The concept of a Sumbawa Beef project is being promoted strongly by our Indonesian Project Leaders. This project is strongly supported by all members of our Project Team.

Key elements of the concept are:

- It represents one of the best opportunities to consolidate the outcomes from the large expenditure on cattle in eastern Indonesia into one final project, ensuring Australian programs receive appropriate recognition and consolidate their success.

- All 4 district Buparti have already agreed to come together to invest in Sumbawa Beef. Beef production would be based on green fed, hormone free, environmentally clean beef; eventually an organic line could be produced. Initially, it may be marketed as herbal beef for which there is already brand recognition in Jakarta. Sumbawa beef would be of high quality as it would be produced from leucaena fattened animals.
- Logistically, the project would need 15 to 20 FRs to train Dinas staff. The Buparti would need to ensure the participation of Dinas and provide funding. Outside funding has already been obtained from the NZ Government which is investing around $2M in a cattle corn project at Dompu, one-hour east of Bima. The funds are being channelled through UNRAM.
- On the Australian side, funds have already been committed to the Indo-beef project. However, in the short term, it might be possible to request a SRA of $150k. Funds could also be channelled via the UNRAM / BPRP Livestock Consortium.

9.2 Manuals on establishment and feeding of leucaena and sesbania:

Clear and instructive extension materials for the scaling out of FTL production and feeding strategies are needed for a wide range of possible next users (Recommendation 7 of Lefroy and Ibrahim (2016) report.)

An urgent requirement is for detailed manuals to be prepared describing the best practices established for the establishment, management and feeding of leucaena and sesbania.

These practical publications would include information as follows:

- Leucaena Story – How Jatisari evolved and was discovered, and their production model. Information on the establishment, management and feeding of leucaena including production outcomes.
- Sesbania Story – How the development of sesbania in rice paddies evolved and succeeded in Lombok. Information on the establishment, management and feeding of leucaena including production outcomes.

9.3 GIS Mapping of suitability

Maps indicating biophysical suitability of the various agro-ecological zones for growing *Leucaena leucocephala* and *Sesbania grandiflora* are needed to promote the areas of greatest opportunity for expansion of FTLs. Some preliminary work has been done for NTT (see section 7.4 this report) but suitability maps need to be prepared for NTB as well. This could be a relatively straightforward project or a small part in a future R&D activity.

9.4 Seed production of Tarramba

There is strong demand for seed of the Tarramba variety of leucaena. Seed production is currently coordinated by BPTP-NTT and they are producing sufficient seed to satisfy present demand. With likelihood that increased production of seed will be needed, future plantings for seed production are best done by individually owned plantings as profit sharing from communal plantings creates difficulties. As NTT has > 800,000 ha of potential dry land to grow Tarramba seed supply will be needed for at least the next 20 years. Ultimately, a private investor or investors should be encouraged to organize the seed business to ensure a sustainable market supply as demand increases.

9.5 Continuing and new research or related activities

There are a number of research areas that need to continue from the activities of the project and new activities that need to be undertaken:

9.5.1 Anthelmintic properties of leucaena

There was some preliminary work on the impact of leucaena and sesbania on controlling gastrointestinal parasites in NTB (Luh Gde Sri Astiti *et al*. 2013). These results suggested that the higher tannin content of leucaena may make it a more effective control of parasites, although as the sesbania feeding was undertaken in a wetter environment, where the potential for reinfection was far greater, the comparison may not be valid. This is an area worthy of further investigation.

9.5.2 Psyllid resistant leucaena

The susceptibility to attack by psyllid insects is a barrier to adoption.

Promotion and use of Tarramba was made easier because of its psyllid-tolerance, but not psyllid resistance. This highlights the need to consider next steps in broadening the genetic based of leucaena in eastern Indonesia, and reduce reliance on just one new variety plus the older “local” varieties. Thus an important next step will be the introduction of cv. Redlands, a psyllid resistant variety recently released in Australia. Negotiations with the owner of the PBR rights, MLA / Uniquest were positive but it was decided that Australian graziers should be given first access. This is now occurring so the prospects for the introduction of a psyllid resistant variety are now good.

9.5.3 Leucaena toxicity

The work on leucaena toxicity has far-reaching implications for all tropical countries wishing to incorporate leucaena into ruminant diets. Thus the work in Indonesia where Bali cattle on high leucaena diets were found to be able to neutralise DHP toxicity by a process of conjugation which occurs in the liver is of utmost importance. This work needs to be completed to better understand the mechanisms and investigate the possibilities for dietary management to encourage/facilitate conjugation to reduce or eliminate toxicity.

9.5.3 Other topics for future work as recommended by Lefroy and Ibrahim (2016) include:

- *Knowing that cattle can be fattened very well on 100% diets of leucaena and sesbania, such diets should be evaluated to see if they can be further improved with locally available feeds, presumably starting with an assessment based on proximate analyses and nutrition tables and then on feeding trials. In this respect, a ready reckoner for diets to fatten cattle based on FTLs and other locally available feeds should be developed (Recommendation 10).*
- *Improved feeding strategies, most likely using some FTL feed, should be developed for cow/calf systems and for raising weaned calves to weights ready for fattening.*
- *The work on evaluation of* S. grandifora *varieties should be completed.*
- *Land suitability assessments for leucaena and sesbania should be prepared for different parts of Indonesia (Recommendation 11).*
- *The possibilities for greater and better integration of FTLs into a range of farming systems, particularly intercropping and strip-cropping systems, should be investigated.*
- *The engagement of government agencies to facilitate further scaling out of FTL feeding practices needs to continue in Kupang District of NTT and be expanded to other Districts in NTT, to NTB, and beyond (Recommendation 8).*

- *The possibilities to further increases in labour efficiency and productivity should be investigated. One possibility will be to investigate partial grazing systems to reduce the labour requirement for cutting and carrying FTL materials.*
- *The possibilities for increased utilisation of manure and/or biogas slurry to improve crop and FTL production should be assessed and promoted*
- *The work on the geographic, host species, and genetic differences in S. jonesii should be completed, to finish off this area of leucaena toxicity, although this is not expected to affect these FTL feed strategies in Indonesia and northern Australia*
- *In future projects, recruitment and mentoring of Field Officers should be considered in terms of (i) secondment from agencies that will be involved in continued support for scaling out, (ii) have FRs operate in pairs, (iii) seconding and recruiting staff with backgrounds in research and in extension and with the idea of future employment possibilities.*

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