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Final report

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Acronyms and commonly used terms

ACIAR	Australian Centre for International Agricultural Research
ASL	Above sea level
BAPPEDA	Badan Perencana Pembangunan Daerah (regional body for planning and development)
BPTP-NTT	Balai Pengkajian Teknologi Pertanian-Nusa Tenggara Timur (Assessment Institute for Agricultural Technologies)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cut & carry	Feeding strategy in which forage is cut and brought to cattle
QDAFF	The Queensland Department of Agriculture, Forestry and Fisheries
DINAS Peternakan	Department of Livestock Services
DINAS Pertanian	Department of Agriculture
NGO	Non-government organisation
Kabupaten	Regency; next smallest administrative division from province
SMK	Indonesian Agricultural High School
ENT	East Nusa Tenggara (province of Indonesia)

1 Acknowledgments

A number of organisations and many individuals have been critical to the success of the project. The project team wish to acknowledge the contribution of our host organisations, BPTP-NTT, CSIRO Australia and QDAFF for managerial support and to the many individuals from within these organisations who have contributed to the project. The project team also wishes to acknowledge the financial support of ACIAR and the on-going advice and mentoring by staff.

The ultimate indicator of project success will be improvements to the livelihoods of farmers in the province of East Nusa Tenggara, achieved through the adoption of herbaceous legumes. For this to occur, requires continuing effort by the Indonesian research, development and extension agencies, BPTP-NTT, BAPPEDA Ende, DINAS Peternakan, DINAS Pertanian and the non-government organisations that are already promoting legumes in local farming systems. We thank them for their involvement and wish them every success in their future endeavours. Finally, we would like to thank the farmers of West Timor and Flores for the unforgettable times spent in their company, their unconditional hospitality and their willingness to join us on this journey of exploration.

2 Executive summary

Animal production and the growing of the cereals, maize and upland rice, have long formed the basis of subsistence agriculture in the province of East Nusa Tenggara (ENT), Indonesia. In this semi-arid tropical environment, production of crops and animals is constrained by rainfall variability and seasonality. While average annual rainfall of >1000 mm is typical, the majority falls within the 4-5 month wet season which runs from December to March/ April. As a result, farmers have difficulty in feeding both their families and their animals, with food shortages common in the late dry season (September to December). The situation is further exacerbated by the low nitrogen status of the soils (alfisols, inceptisols and vertisols) on which most food production occurs, resulting in an average provincial maize yield of 2.3 t/ha, well below the national average of 3.53 t/ha (Badan Pusat Statistik 2011, 2000-2009 data[1]). This project has been researching methods for improving the productivity of cattle and subsistence cropping through the introduction of forage legumes to supplement animal feed supply and to contribute to the nutrition of subsequent cereal crops. Research has been undertaken at more than 20 locations in West Timor and Flores which represent a range of environments from the dryer and hotter coastal plains to the higher elevation (>1000m ASL), cooler and wetter environments.

Testing an hypotheses-using legumes in eastern Indonesian farming systems

Early research identified that the stored soil water remaining after the maturity of the wet season cereal crop, and traditionally underutilised for crop production, may hold the key to increasing overall system productivity. This led to the development of the hypotheses that it may be possible to grow an additional crop, a forage legume, into the dry season using late wet season rainfall and stored soil water, without impacting on food security. Subsequent research indicated that this was feasible, with three annual or short term perennial legumes species, *Clitoria ternatea, Centrosema pascuorum and Lablab purpureus* shown to produce significant quantities of dry season biomass (5 t/ha DM common) which was then available for the feeding of animals either fresh, or stored for later more strategic use. Supplementary feeding of cattle with forage legume resulted in higher live weight gains compared to the feeding of traditional native forages. Young cattle (~70 kg live weight) supplemented over a 320 day period gained weight at a rate 1.7 times higher than that for traditional native forages, with the largest difference occurring during the late dry and early wet seasons when the legume supplemented animals gained at a rate of 220 g/head.day, compared to those fed native forages which lost 65 g/head.day. In the same period, animals supplemented with the browse legume, *Leucaena leucocephala* gained weight at a rate of 320 g/head.day. Subsequent feeding trials indicated that larger bulls being fattened for live export and goats destined for the local market also benefitted from the feeding of forage legumes.

While research indicated the potential for legumes to contribute to animal production, the benefits to cereal cropping were less clear. Gains in cereal crop stover and grain yield were achieved as a result of the increased supply of nitrogen through legume fixed atmospheric N, however yield improvements were often low and inversely related to the amount of legume biomass removed for animal feeding. Overall, it was considered that the most efficient means of improving cereal production was to grow forage legumes in relay or rotation and to then apply small quantities of nitrogen fertiliser to the subsequent cereal crop e.g. ~10-20 kg/ha N, in combination with animal manures. The aim of this strategy was to increase yields and profits through the best use of available nitrogen resources but without unduly increasing the financial risk to the farmer.

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[1] *Badan Pusat Statistik, 2011. http://www.bps.go.id/tnmn_pgn.php?eng=0*

Crucial to the successful adoption of forage legumes was the need to develop provincial seed increase capacity to meet the requirements of research and to drive expansion. Demand was initially met through village-based seed increase, however it was clear that additional capability and capacity were required to meet increasing demand. In 2011, 6 agency staff undertook specialist seed increase training in Australia. In the following season, this led to an expansion of production area to 4 ha in West Timor and Flores and involved farmer groups, agricultural high schools and government and non-government agencies. Currently, demand for seed is being met and there are the first signs of the development of a seed market with demand being driven by sales to extension agencies wishing to expand areas of forage legumes. While the 3 legumes identified early in the project have been found to be well adapted to the environments of ENT and accepted by farmers, there have been concerns that basing activity on a limited genetic resource base posed risks to the long term sustainability of the technology. As a result, a second round of species evaluation was undertaken in 2010/11 with 9 additional legumes identified (*Centrosema molle cv.* Cardillo, *Centrosema pascuorum cv.* Bundey, *Clitoria ternatea* Q5455, *Macroptilium bracteatum cvv.* Cardarrga and Juanita, *Lablab purpureus* CQ3620, *Stylosanthes seabrana*, *S. guianensis* and *Vigna luteola cv.* Dalrymple). Seed increase for these plants is currently occurring before the wider testing across ENT environments.

Capacity building

One of the most important components of the project has been the building of individual and organisational capacity. Engagement of local research and extension agencies in the project has developed understanding of the potential for forage legumes to contribute to animal production, particularly their role in underpinning the Indonesian government policy of national self sufficiency in cattle production. This in turn, has led to the development of the capability of individuals in seed increase, and in pasture and crop agronomy, animal production and research management. The use of communal village feed lots, the controlled feeding of forage legumes and visits to other participating villages has contributed to animal owners and village-based junior extension officers learning forage legume production and animal feeding techniques and contributed to the increasing use of legumes in districts such as Nagekeo, Flores.

The training of research staff has been an important component of the project. Post-graduate training in Australia resulted in 2 staff being awarded their Doctorates in Social Science and Agriculture while 2 others have completed Masters degrees in agriculture from the University of Nusa Cendana in Kupang. All of the graduates are now contributing to the development of agriculture in ENT. The 10-month appointment of a VIDA (Volunteer for International Development from Australia) provided additional project capacity in soil and crop science and led to the particular individual planning a future research career in international agricultural development. Short-term development activities have provided individuals with the opportunity to improve their own skills and to contribute to project outputs. These have including training in laboratory techniques and the development of methodologies for specific chemical analyses, farming systems research methodologies including the use of simulation modelling in agricultural research, experimental design and field skills in crop management and soil equipment fabrication and the sampling for soil water and nutrients.

Using forage legumes in ENT farming systems will be most attractive to farmers who grow cereal crops to meet food security requirements and own and manage animals as a business enterprise, but where weight gains are constrained by a consistent supply of high quality forage. It is probable that farmers with surplus land and labour are the most likely to invest. However, as a result of the variable nutritional response of cereal crops grown subsequent to forage legumes, it is unlikely that farmers who do not own animals or those that keep animals as part of a traditional social system will see the value in investing, although this may change with advances in knowledge on legume management.

3 Background

This project addresses two of the high priority development issues for smallholder agriculture in the province of East Nusa Tenggara (ENT), Indonesia, improving food security and increasing the potential for farmers to generate income. The highly variable semi-arid monsoonal environment dictates the cropping cycle and is the single most influential driver of crop productivity and farmer livelihood. While average annual rainfall typically ranges between 1000 and 2000 mm, inter- and intra-seasonal variability is high.

Crop production is undertaken during the 4-5 month wet season (December to March/ April) with cropping lands commonly used for opportunistic cattle grazing during the remainder of the year. Maize and pulse production dominate in the rainfed uplands while rice is produced in the more fertile, irrigated lowlands. Small-holder farmers in West Timor grow ~251,000 ha of maize annually, producing ~589,000 tonnes of grain, used primarily to meet family food security requirements. The average provincial maize yield of 2.3 t/ha is well below the national average of 3.53 t/ha (Badan Pusat Statistik 2011, 2000-2009 data[2]) and the 4 t/ha considered achievable in ENT using improved genetic material, crop nutrition and crop husbandry (Faesal, et. al. 2006[3]). However, while there is potential to increase productivity, the current reality of low crop yield, small farm size (0.5 – 1.5 ha) (Darbas and Ngongo, 2013, in draft)[4] and large family size (average of 5) (Suek *et. al.* 2011[5]) often results in late dry season food insecurity, and in some cases, human malnutrition (FAO, UNICEF, WFP Joint Report (2010[6])).

In small-holder systems in ENT cattle influence an individual's wealth and status and often provide the only financial link that farmers have with the broader cash economy. Income is used to support the education of children and in times of medical emergency or social occasion. More than 400,000 head (predominantly Bali cattle (*Bibos banteng)*) are farmed in West Timor with over 40,000 fattened annually for live-export to meet demand in the population centres of western Indonesia. The efficient fattening of animals is hampered by the lack of a year-round supply of high quality forage to supplement the low quality grasses and crop residues which commonly form the basis of the animal's diet. Hence, while animals gain significant weight during the wet season, they lose much of it during the subsequent dry season when the quantity and quality of forage declines. As a result, animals gain weight erratically and take much longer to reach saleable weight.

The project challenge was to identify opportunities for improving the food security of small-holder farmers and their access to the cash economy, without jeopardising current production systems and exposing farmers to undue risk. At the least, if adoption was to occur, interventions had to have a neutral impact on farmer livelihoods.

It was hypothesised that the agricultural soils of ENT may hold the key to improving productivity of the farming system as a whole. In the traditional cropping system, cereals are grown during the wet season and mature in the early dry season. Local grasses and

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[2] *Badan Pusat Statistik, 2011. http://www.bps.go.id/tnmn_pgn.php?eng=0*

[3] *Faesal, Suryawati and Hosang, E. (2006) Teknologi produksi biomass jagung mendukung penyediaan pakan ternak sapi pada lahan sub-optimal. Prosiding Seminar Hasil Balai Besar Pengkajian dan Pengembangan Teknologi Pertanian. Bogor. ISBN 978 979 3566 573*

[4] *Darbas, T. and Ngongo, Y. (2013) Bali Cattle and Forage Development in West Timor: A Political Ecology Account. Submitted to Agricultural Systems (2013).*

[5] *Suek, J., Gabb, S., Kana Hau, D. and Dalgliesh N.P. (2011) Socio-economic study on households integrating herbaceous legumes fodder crops into rice and maize farms of West Timor and Flores, East Nusa Tenggara province. University of Nusa Cendana, Kupang, West Timor.*

[6] *FAO, UNICEF, WFP Joint Report (2010) Nutrition security and food security in Seven Districts in NTT province, Indonesia: status, causes and recommendations for response. Final Report, February 2010. http://documents.wfp.org/stellent/groups/public/documents/ena/wfp236825.pdf*

weeds are then allowed to grow for the remainder of the dry season and used in the feeding of cattle via either free or tethered grazing. The growth of these volunteer plants during the early to mid dry season indicates that soil water remains after wet season crop production, which it was hypothesised, could be used to grow a crop of increased value to the farmer. Research in tropical environments in South-East Asia, Africa and Australia suggested that annual and short-duration perennial forage legume species could utilise the available water, contributing to farmer livelihoods through production of high quality biomass for animal feeding and supply of nitrogen for subsequent cereal crops.

Pengelly and Lisson (2003[7]) (ACIAR project AS2/2000/125) proposed a relay cropping concept for the rice systems of south Sulawesi where there is a 3 month opportunity, after rice harvest, in which to utilise residual stored water for the production of annual legumes such as cowpea (*Vigna unguiculata*), lab lab (*Lablab purpureus*) and Mucuna (*Mucuna pruriens*). Their research suggested that it was possible to produce up to 3 t/ha of dry matter (DM) from cowpea during this period, with an average protein content of 15%. To feed 2 lactating Bali cows 7 kg/day/head DM for 120 days, with >10% protein, would require supplementation of 4 kg/day of dry season grass and crop residue, with 3 kg/day of legume. To grow the required 720 kg of legume would take 2400 m^2 of land. While the climate of ENT is drier than Sulawesi, using the same assumptions, 90 kg of legume dry matter per animal would be required monthly to provide a similar diet. It was considered that this may be possible given that the average West Timor farm, growing 0.6 ha maize would have the potential to produce in the order of 600-1800 kg (1000-3000 kg/ha) biomass over a three month growing season.

Studies in similar environments in tropical Australia have shown that forage legumes can contribute useful levels of nitrogen to subsequent crops. Work undertaken at Katherine in the Northern Territory (NT) (Alfisol soil; ~1000 mm annual rainfall, but hotter than ENT), showed that a sward of *Stylosanthes hamata* cv. Verano grown for one wet season and producing around 4 t/ha DM contributed between 33 and 50 kg N/ha to a subsequent maize crop, when above ground biomass was removed at the end of the wet season (Jones *et. al.,* 1996[8]). Another Katherine study indicated little difference between legumes in their ability to contribute nitrogen to a subsequent maize crop with *Stylosanthes hamata* cv. Verano, *Centrosema pascuorum* and *Alysicarpus vaginalis* all supplying around 40 kg N/ha to the following crop (McCown *et. al*., 1986[9]; McCown 1996[10]). In a higher rainfall environment at Douglas Daly, N.T. (annual ~1200 mm), a two year ley of *Centrosema pascuorum* cv. Cavalcade contributed 112 and 71 kg N/ha respectively to two consecutive grain sorghum crops (Cameron 1996[11]) while a heavily grazed two year ley contributed 88 kg N/ha to a following sorghum crop, through a combination of N fixation, breakdown of leaf litter and return of nutrients from animal dung and urine (Thiagalingam *et. al.,* 1993[12]). While these examples differ to that proposed in ENT, particularly in relation to length of

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[7] Pengelly, B.C. and Lisson, S.N. Strategies for Using Improved Forages to Enhance Production in Bali Cattle. In: Entwistle K. and Lindsay, D.R. eds, Strategies to Improve Bali Cattle in Eastern Indonesia. Proceedings of Workshop 4-7 February 2002, Bali, Indonesia ACIAR Proceedings No. 110, pp 29-33

[8] Jones, R.K., Probert, M.E., Dalgliesh, N.P. and McCown. R.L. 1996. Nitrogen inputs from a pasture legume in rotations with cereals in the semi-arid tropics of northern Australia: experimentation and modelling on a clay loam soil. Australian Journal of Experimental Agriculture, 1996, 36, 985-94.

[9] McCown, R.L., Winter, W.H., Andrew, MH., Jones, R.K., and Peake, D.C.I. (1986). A preliminary evaluation of legume ley farming in the Australian semi-arid tropics. In 'Potentials of Forage legumes in Farming Systems of Sub-Sahara Africa'. (Eds I.Haque,

[10] McCown, R.L. 1996. Being realistic about no-tillage, legume-ley farming for the Australian semi-arid tropics. Australian Journal of Experimental Agriculture, 1996, 36, 1069-80.

[11] Cameron, A.G. 1996. Evaluation of ley pasture plants. Australian Journal of Experimental Agriculture, 1996, 36, 929-35.

[12] Thiagalingam, K., Sturtz, J., McNamara, T. and Price, T. (1993). Nitrogen nutrition of no-till grain sorghum following Centrosema pascuorum cv. Cavalcade pastures. In 'The Proceedings of the 12th International Plant Nutrition Colloquium'. (Ed. N.J.Barrow) Kluwer Academic Press.

legume growing season, they do provide an indication of potential nitrogen fixation rates for some of the legumes proposed for evaluation.

The aim of the project was to provide farmers with an opportunity to enhance overall systems productivity through the use of shorter duration legumes, integrated into the cereal production system, where they would not only contribute to animal feed supply but to subsequent cereal crop nitrogen supply. It was initially considered that their use in relay with maize, planted as the cereal neared maturity, provided the best opportunity for subsequent dry season forage production. However, as the project evolved, collaborating farmers suggested a wider focus to include the annual rotation of the legumes with maize to increase overall productivity in situations where land and labour were not constraints to production. It was considered that the investigation of the use of short stature, annual and short-term perennial herbaceous legume species was complimentary to the existing widespread use of browse, or tree legume species such as *Leucaena leucocephala* which have been a mainstay of cattle feeding practice in Indonesia for many years (Horne and Stur 1997[13]; Shelton *et. al.* 1995[14]) but are less well suited to inclusion in cereal based cropping systems due to their stature and growth habit.

[13] *Horne, P. and Stur, W.W. 1997. Current and future opportunities for forages in smallholder farming systems of south-east Asia. Tropical Grasslands, 31, 359-363.*
[14] *Shelton, H.M, Piggin, C.M.and Brewbaker, J.L. (1995). Leucaena-Opportunities and Limitations.Proceedings of a Workshop held in Bogor, Indonesia 24-29 January 1994. ACIAR proceedings No.57, 241 pp. ISBN 1 86320 150 5*

4 Objectives

To quantify the drivers that contribute to adoption of forage legumes by implementing on-farm trials supported by on-station research and extension capacity development under the following objectives.

Objective 1: To evaluate forage legumes for potential integration into the maize cropping systems of West Timor

Activity 1.1: Identification and trialling of legume species with potential to contribute to the farming system.

Activity 1.2: Increased understanding of the contribution of forage legumes to maize based cropping systems including the optimisation of both legume and maize production within that system.

Activity 1.3: The piloting and assessment of forage legume integration in a range of farming systems and geographic and agro-ecological regions.

Activity 1.4: Development of a sustainable seed multiplication capability to ensure on-going support of forage legumes expansion within the province.

Objective 2: To assess the value of forage legumes to contribute to animal production through the supply of high quality forages for use during the dry season

Activity 2.1: Identification of farming systems in which there is potential for forage legumes to contribute to livestock enterprises.

Activity 2.2: The piloting and assessment of forage legume utilisation across a range of farming systems and geographic and agro-ecological regions which have animals as a major component.

Objective 3: To apply socio-economic information contributed by participating farmers to determine technology acceptability, potential broader impacts and extension strategies.

Activity 3.1: Utilise existing knowledge of the drivers of forage legume adoption and the experience of national agencies to identify farming systems and situations suitable for legume intervention.

Activity 3.2: Undertake benchmarking and longitudinal evaluation with project participants to gain an increased understanding of the drivers of technology adoption and the opportunities and risks associated with the introduction of forage legumes.

Activity 3.3: Use benchmarking and longitudinal evaluation to obtain feedback on progress and process to improve project activity and outputs.

Activity 3.4: Develop knowledge, skills and capacity within the farming and extension communities to ensure longer term expansion of forage legume technologies across ENT.

5 Methodology

5.1 Setting direction

This project aimed to show 'proof of concept' of the potential for forage legumes to contribute significantly to cereal based farming systems across a range of agro-ecological environments. The ability to respond quickly to interim research findings, and feedback from collaborators was critical to ensuring that research was focussed and addressing the issues considered of importance by stakeholders.

As would be expected, it was the researchers who proposed the initial direction of research. This should be no surprise, given that what was being proposed was very new to participating farmers. However, as the project progressed, and farmers began to understand the potential for forage legumes to contribute to their system, they became more willing to participate in direction setting, and in many cases took the basic building blocks of the research i.e. forage legumes and soil water, and designed ways in which to better use these resources in their local systems. Also, as the project matured and expanded into different geographical locations, other organisations, particularly government and non-government extension agencies, became more involved in direction setting and the management of local activities.

Direction setting occurred through a range of communication activities including annual project workshops at which farmers and researchers presented their perspective on the research and its potential impact, team meetings and regular farmer group meetings to discuss progress and future activity. Information gathered through these types of activities was further complemented by social research which aimed to benchmark initial farmer practice and village social systems and to understand the changes that occurred over time as a result of project intervention and other social and economic influences. An important component of this process was to provide project members and collaborators (farmers and researchers) the opportunity to make personal comment on project direction, and just as importantly, the research and engagement processes being used.

5.2 Personnel

Table 1: *Members of the LPS-2006-003 Project Team, their affiliations and specialist expertise*

Project member	Affiliation	Specialist expertise
Esnawan Budisantoso (2006-08)	BPTP-NTT	Livestock and forage production
Jacob Nulik (2006-12)	BPTP-NTT	Livestock and forage production
Debbie Kana Hau (2006-12)	BPTP-NTT	Animal production
Paskalis Fernandez (2006-11)	BPTP-NTT	Forage production
Sophia Ratnawarty (2006-09)	BPTP-NTT	Forage agronomy
Evert Hosang (2006-09)	BPTP-NTT	Crop agronomy
Yohanis Ngongo (2006-07)	BPTP-NTT	Social research
Dion Bria (2006-12)	BPTP-NTT	Agronomic research support
Marcel Meo (2006-12)	BPTP-NTT	Agronomic research support
Agustinus Dule Mata (2011-12)	BPTP-NTT	Agronomic research support
Neal Dalgliesh (2006-12)	CSIRO Australia	Farming systems
Toni Darbas (2006-09)	CSIRO Australia	Social research
Kendrick Cox (2009-12)	DAFF Queensland	Leg evaluation and seed production
Perry Poulton (2006-11)	CSIRO Australia	Farming systems
Brett Cocks (2006-11)	CSIRO Australia	Farming systems
Christine Hall (2008)	CSIRO Australia	Legume production
Jeremy Whish (2006-07)	CSIRO Australia	Farming systems
Steve Crimp (2011-12)	CSIRO Australia	Climatology
Lindsay Bell (2011-12)	CSIRO Australia	Farming systems
Skye Gabb (2010-11)	AVID	Farming systems, communication
Yustinus Namang (2009-11)	BPTP-NTT	Agronomist
Johanna Suek (2009-11)	University of Nusa Cendana	Social research
Nurhayati Purwantari (2009-11)	Animal Production, Bogor	Legume nodulation microbiology

5.3 Selection of research sites

The preliminary evaluation of a suite of forage legumes for use in ENT was undertaken during a 6 month scoping study commencing in January 2006. The subsequent research project (Phase 1) ‘*Integrating short term legume leys into the maize cropping systems of West Timor*’ commenced in October 2006 for 3 years with 2 further extensions (Phase 2), from 2009 until December 2012.

Figure 1: *Google Earth images of West Timor (a) and Flores (b) showing the locations of sites where project initiated evaluation of forage legumes was undertaken between 2006 and 2012.*

In Phase 1 (2006-09), research was focussed on a range of sites in West Timor that represented important agro-ecological environments where rainfed maize was the main food security crop and where there was potential for forage legume production. In Phase 2

(2009-12) research was expanded to include a range of environments in the Nagekeo and Ende districts of Flores where rainfed upland maize and rice, and lowland irrigated rice were the major food crops (Figure 1; Table 2).

The agro-climatological regions selected for research in both phases were typified by high, but variable rainfall (both within, and between seasons), variation in elevation, low annual temperature variation, high dry season radiation levels and soils which were likely to be low in nutritional status but able to hold significant quantities of water for crop production. Table 2 provides an overview of the locations where research was undertaken over the 7 years of research and includes information on elevation, rainfall distribution and amount and soil type.

5.3.1 Climate characterisation

Daily temperature, radiation and rainfall were automatically recorded at 4 research sites in West Timor (2006-12) and 3 (later expanded to 6) in Flores (2009-12) using low cost electronic met stations. Collected data were used to assist in interpretation of research results and as input to systems analysis, using the APSIM farming systems model (Keating *et. al.,* 2003[15]). Short-term simulation analyses of crop production were undertaken based on the daily met data provided by the project supplemented with BPTP-NTT regional met data collected between 2001 and 2009. The potential to compare the productive capacity and riskiness of particular systems over the longer term (>30 years) was limited due to a paucity of climate data for eastern Indonesia. To improve future data availability, 4 baseline met data files and 8 future climate scenario files were developed in 2012 from incomplete historical met records (for ENT regional sites, Kupang, Maumere, Waingapu and Alor) and NCEP reanalysis data (NOAA, 2012[16]) (this process is described in Appendix 3).

Elevation and temperature

Research locations were selected that ranged in elevation from near sea level to over 1000 m above sea level (ASL). Locations were reasonably evenly spread across the range with 7 sites at <200 m ASL, 9 between 300 and 700 m ASL and 4 sites higher than 700 m ASL (Table 2; Figure 1). Elevation impacted on daily temperature range with lower elevation sites having higher annual monthly means (both maximum and minimum temperature) compared to those at higher altitudes (Figure 2). Elevation also resulted in changes to rainfall pattern, incoming radiation levels and humidity which in turn impacted on plant growth rates and the prevalence of plant diseases and pests, making some agro-climatological regions more appropriate than others for the growing of particular legume species.

Rainfall

West Timor

The majority of research sites situated in West Timor (11 of the 14 sites) are subject to a uni-modal rainfall pattern with the majority of precipitation received during the tropical monsoon period between December and March/April. Figure 3 provides the comparison between Naibonat, located on the coastal plain, and Tobu at over 1000 m ASL. Between 2001 and 2009 both sites received an average of 1360 mm rainfall, but differences in seasonal distribution were marked, with a higher proportion of rainfall occurring during the

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[15] Keating BA, Carberry PS, Hammer GL, Probert ME, Robertson MJ, Holzworth D, Huth NI, Hargreaves JNG, Meinke H, Hochman Z, McLean G, Verburg K, Snow V, Dimes JP, Silburn M, Wang E, Brown S, Bristow KL, Asseng S, Chapman S, McCown RL, Freebairn DM, Smith CJ (2003) An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy* **18**, 267–288. doi: 10.1016/S1161-0301(02)00108-9.

[16] NOAA 2012. "NCEP/NCAR Reanalysis". NOAA. Retrieved 10 April 2012.

'dry' season at the higher altitude site. It is worth noting that the variability around the monthly rainfall means shown in Figure 3 are examples of the range of inter-seasonal variability found across project research sites and ENT in general.
Districts on the south coast of the island of Timor experience a bi-modal rainfall pattern with rainfall split between the monsoon season and a second wet season that generally occurs between July and August (Figure 4). While annual rainfall totals are similar to those of the uni-modal regions, the arrival of a second wet season provides cropping opportunities not available to those in the uni-modal areas. It was considered important that bi-modal rainfall areas be included in the evaluation of legumes, in particular the opportunities that a prolonged growing season held for increased legume forage and seed production (3 of the 14 sites in West Timor) (Figure 5).

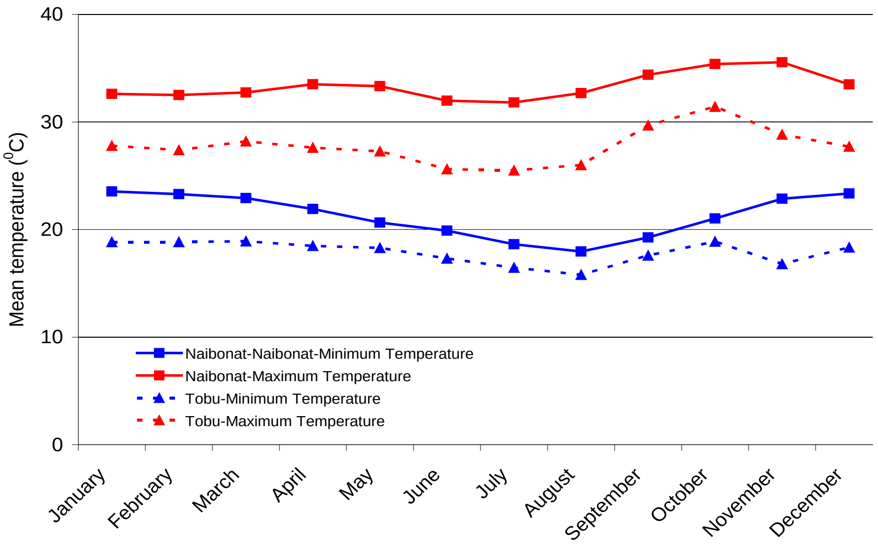


Figure 2: *Mean monthly maximum (red) and minimum temperatures (blue) for Naibonat, Kupang (28 m ASL) and Tobu, TTS (1074 m ASL) for the years 2001-2009 (BPTP NTT data).*

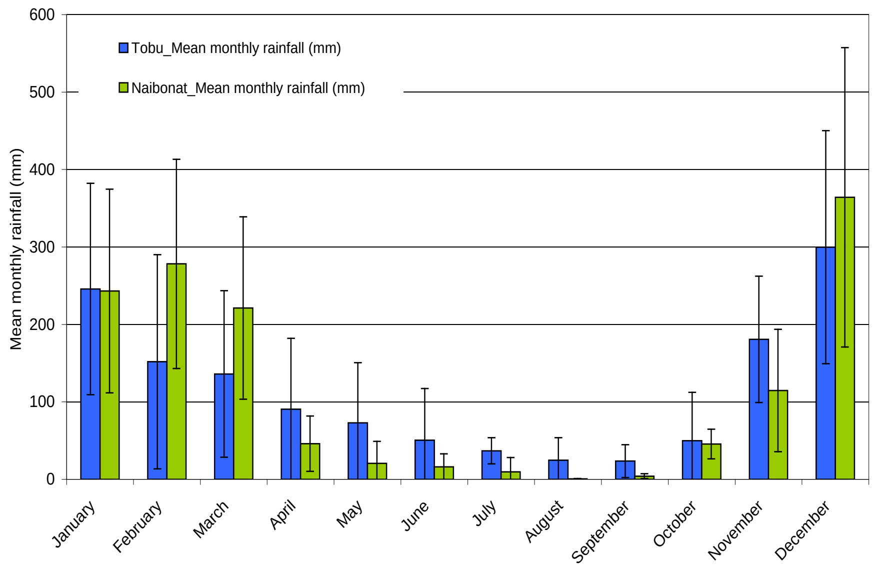


Figure 3: *Mean monthly rainfall amount, variability and distribution for Naibonat, Kupang (28 m ASL) (blue) and Tobu, TTS (1074 m ASL) (green) for the years 2001-2009 (BPTP NTT data). Average annual rainfall for both sites was approx. 1360 mm.*

Table 2: *Physical and climatic information of sites in ENT, Indonesia where research was undertaken between 2006 and 2012.*

Regency	Village (Research period)	Met recording (daily)	Co-ordinates; Lat, Long	Elevation (m above sea level)	Annual Rainfall (mm); seasonal pattern*	Soil Type (Order)
West Timor						
Kupang	Sillu (2006-08)	2006/08	-10.053, 123.960	440	800-1200; uni-modal	Alfisol, Entisol and Inceptisol
	Oebola (2008-11)	2008-13	-10.069, 124.006	557	800-1200; uni-modal	Alfisol, Entisol and Inceptisol
	Naibonat (2006-11)		-10.077, 123.863	28	1000-1800; uni-modal	Inceptisol (Vertic Ustropept) and Vertisol
	Fatukanutu (2009)		-10.156, 123.911	191	uni-modal	Inceptisol and Vertisol
TTS	Biloto (2006-08)	2006-08	-9.873, 124.222	560	1500-2000; uni-modal	Inceptisol, Entisol and Vertisol
	Soe (SMK) (2009-11)	2009-13	-9.855, 124.264	900	700-2300; uni-modal	Entisol, Inceptisol and Alfisol
	Tobu (2008-11)	2001-09	-9.567, 124.325	1074	1000-2000; uni-modal	Entisol and Inceptisol
	Soe (DINAS) (2008-11)		-9.812, 124.303	713	uni-modal	Alfisol, Vertisol
TTU	Usapinonot (2006-09)	2006-13	-9.452, 124.544	360	400-1000; uni-modal	Inceptisol (Vertic Ustropept) and Entisol
	Lapeom (2006-08)		-9.497, 124.576	360	400-1000; uni-modal	Inceptisol (Vertic Ustropept) and Entisol
Belu	Kakaniuk (2006-09)	2009-13	-9.578, 124.845	48	1500-2000; bi-modal	Inceptisol (Typic Ustropept)
	Kletek (2006-07)		-9.588, 124.933	70	1500-2000; bi-modal	Inceptisol (Typic Ustropept)
	Betun (2007-09)		-9.602, 124.929	10	1500-2000; bi-modal	Inceptisol (Typic Ustropept)
	Nurobo (2008-11)		-9.394, 124.828	460	1500-2000; uni-modal	Inceptisol and Entisol
Flores						
Ende	Nakuramba (2009-11)	2010-13	-8.754, 121.578	382	1500-2300;	Inceptisol
	Reworangga (2010-11)		-8.821, 121.672	152	1000-1600;	Inceptisol
	Wolomasi (2009-10)	2010-13	-8.771, 121.729	715	1500-2000; uni-modal	Inceptisol, Vertisol
Nagekeo	Mbay (2009-10)		-8.547, 121.296	20	1000-1500; uni-modal	Inceptisol
	Marapokot (2009-11)		-8.533, 121.310	16	1000-1500; uni-modal	Inceptisol
	Boawe (2011-12)	2012-13	-8.751, 121.164	408	1500-2000; uni-modal	Inceptisol
	Aeramo SMK (2011-12)	2012-13	-8.573, 121.336	21	1000-1500; uni-modal	Inceptisol
	Nagekeo Mission (2011-12)	2012-13 (rain only)	-8.639, 121.358	470	1000-1500; uni-modal	Inceptisol
	Ulupulu (2009-11)	2009-11	-8.732, 121.303	529	1500-2000; uni-modal	Inceptisols

*Uni-modal rainfall pattern: 1 distinct annual period of rainfall which commonly results in the production of 1 rainfed crop; Bi-modal rainfall pattern: 2 distinct annual periods of rainfall which opens up the opportunity for the production of multiple crops.

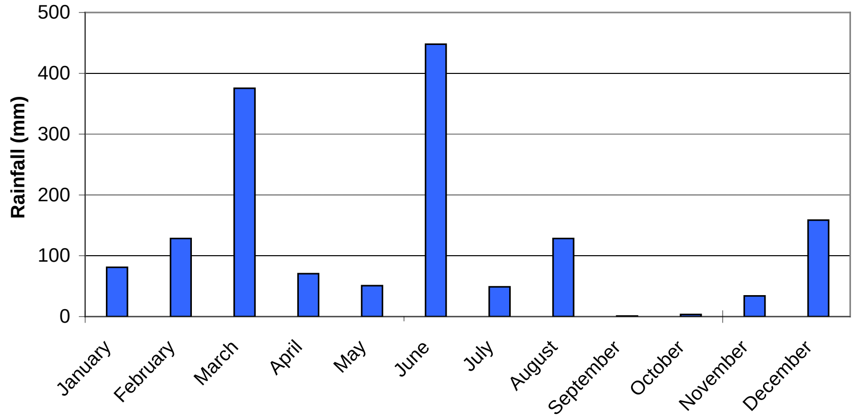


Figure 4: *An example of bi-modal rainfall distribution from Belu regency, West Timor in 2007 in which 848 mm fell during the first wet season (from November to April) and 681 mm during the second wet season (from May to October). The second wet season may be used to produce a second crop of maize or a grain (mungbean), or forage legume.*

Figure 5: *Multiple biomass harvests are common in bi-modal rainfall regions where prolonged wet periods allow production to extend through to August or September before soil water is expended. In this case* Clitoria ternatea *was harvested twice during the extended wet season with a total biomass yield of 7.6 t/ha DM achieved.*

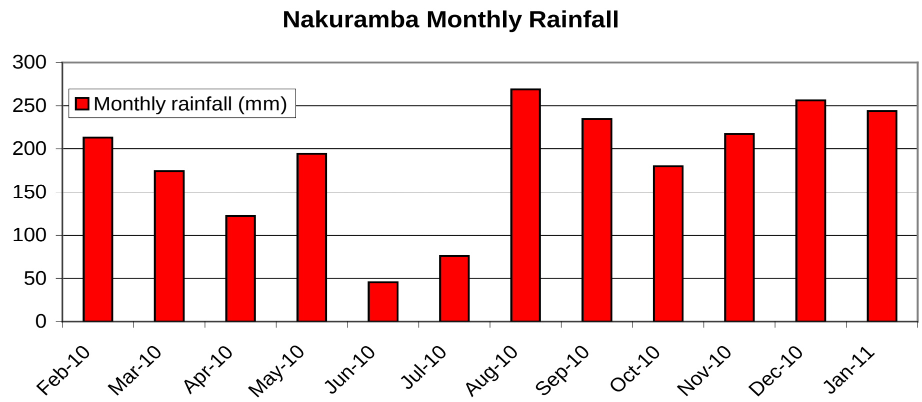


Figure 6: *Rainfall distribution at Nakuramba, Flores (382 m ASL) for the period February 2010 to January 2011. Rainfall of 2025 mm was recorded during this period with 900 mm falling between August and November.*

Flores

Flores also receives the majority of its rain during the monsoon period with coastal, low elevation sites (e.g. Nagekeo) being similar in rainfall quantity and distribution to low elevation, uni-modal locations in West Timor (e.g. Naibonat). Preliminary evidence, from the 2 years of available data for Flores, suggests that rainfall at the medium altitude research sites (380-715 m ASL) is more evenly distributed throughout the year compared to similar elevation sites in West Timor which were distinctly uni-modal. If longer term analysis confirms this short term observation, then opportunities arise for more intensive crop and pasture production in these areas (Figure 6).

5.3.2 Soils

Soils in West Timor are developed predominately from marine deposits while those in Flores are volcanic in origin. Alfisol, Vertisol and Inceptisol soils are the 3 most important upland agricultural soils in West Timor while Inceptisols predominate in Flores.

Alfisol soils

Alfisol soils (Figure 7) are alkaline and inherently low in organic carbon, nitrogen (N) and other nutrients including phosphorus (P) and potassium (K). They are prone to water erosion unless surface cover is present. Provided that nutrient deficiencies are addressed, forage legumes may be successfully grown, although plants are likely to senesce earlier than those grown on the heavier clay soils due to the soils lower capacity to store water for crop production.

Figure 7: *Alfisol soils in West Timor are red/brown in colour and sandy clay loam in texture*

Figure 8: *Inceptisol soil at Nakuramba, Ende, Flores*

Figure 9a: *Vertisol soil at Naibonat, Kupang, West Timor.*

Figure 9b: *Severe vertical cracking on the same soil after extraction of water by a crop.*

Vertisol and Inceptisol soils

Inceptisols (Figure 8) and Vertisols (Figure 9) are both heavy clay soils, generally grey, black or brown in colour. Vertisols are formed from montmorillonite or smectite clays which shrink and swell as water content changes. This results in both vertical and horizontal cracks forming when the soil is dry, a defining feature of these soils (Figure 9b). Vertisols hold significant amounts of water for crop production and are highly fertile in their natural state. Inceptisols are more recently developed soils and are shallower to bedrock. As a consequence, water holding capacity is likely to be lower than that of a Vertisol. They are reasonably high in nutrient status.

5.3.3 The opportunity-linking the elements of resource availability

A key requirement of any planned cropping intervention was that it not be detrimental to existing wet season food production. The reality is that on small-holder farms, where labour is the main limiting resource to increased agricultural production, any wet season intervention would have been difficult from both the agricultural and social perspectives. The early understanding that the agricultural soils of the province had the potential to hold significant quantities of water for crop production was a key learning. This allowed

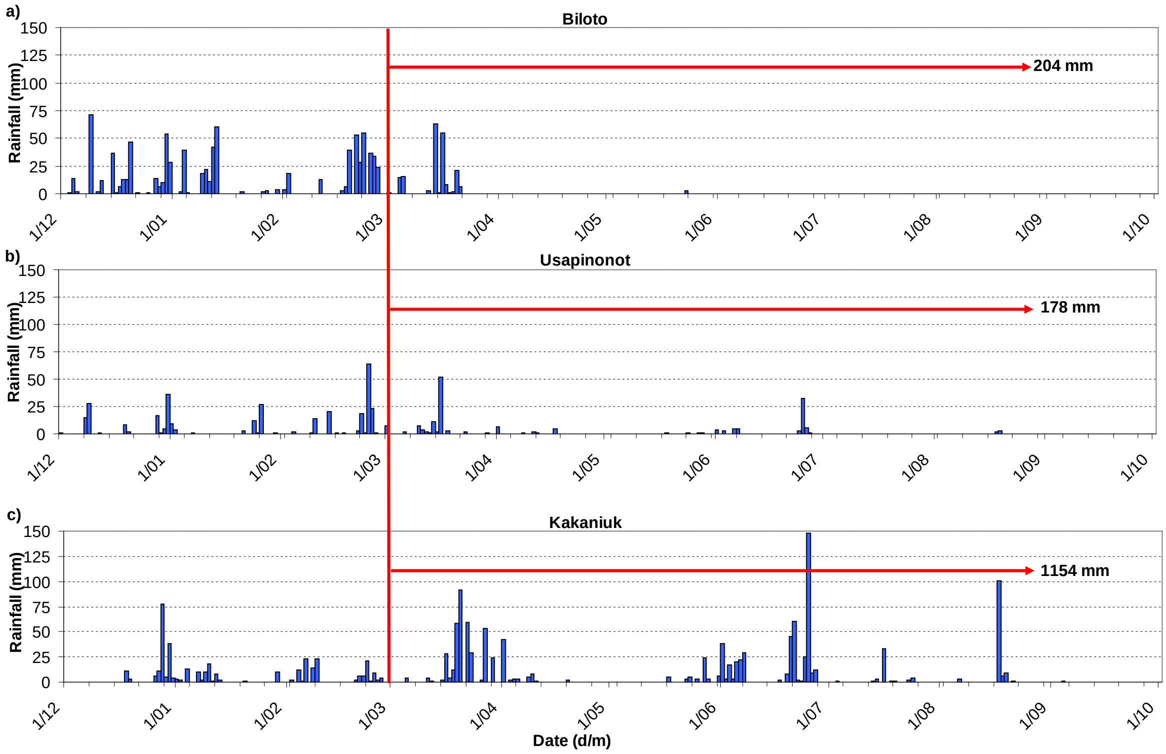


***Figure 10:** 2006/07 rainfall distributions for the villages of a) Biloto, b) Usapinonot and c) Kakaniuk in West Timor showing the variability in annual rainfall, and in rainfall after the end of February until the start of September.*

researchers to hypothesise that stored soil water remaining after wet season production, and topped up by late wet season rainfall, could be used for 'out of season' production, thus adding value to the overall farming system without detriment to food security. It was knowledge of rainfall and soils that allowed researchers to understand the potential for early dry season forage legume production. Figure 10 provides examples of annual rainfall patterns for 3 West Timor research locations. Rainfall after the end of February is highlighted to show the quantity that falls after maize crop maturity. In traditional small-holder cropping systems this rainfall is not used in meaningful crop production, at best being used to support the production of low quality, volunteer weeds which are sometimes used for forage during the dry season.

Understanding key soil attributes

Figure 11: *Soil characterisation for PAWC being undertaken at Wolomasi, Flores*

To test the research hypotheses that the soils of ENT had the ability to hold significant quantities of water for subsequent crop production required the development of information on the plant available water capacity (PAWC) of soils at research locations. Techniques based on Dalgliesh and Foale (1998)[17] were modified to suit local conditions (Figure 11). This required the determination of the key soil physical parameters (bulk density-BD; crop lower limit-CLL and drained upper limit-DUL) and the calculation of PAWC (Figure 12). Table 3 provides information on the PAWC for soils and crops at research sites in West Timor. Soils were partially characterised at 3 sites in Flores but were unable to be completed due to flooding.

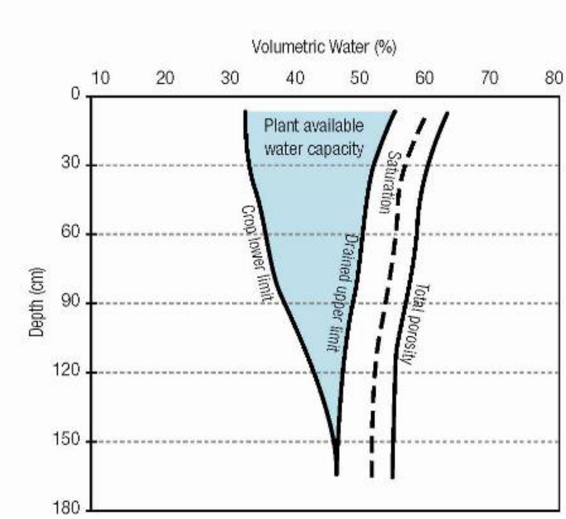


Figure12: *An example of a soil water profile showing the volumetric water % at drained upper limit (DUL), crop lower limit (CLL), saturation (SAT) and total porosity (PO) for a soil of 180 cm depth. The Plant Available Water Capacity (PAWC) of the soil is the difference between DUL and CLL (highlighted in blue).*

While the determination of PAWC is important in its own right, it really becomes useful from a crop production perspective when the temporal status of plant available water (PAW) is also known (Figure 13 and 14). The combination of PAWC and PAW provide information on the size of the water reservoir for a particular soil and the quantity of water stored in the reservoir and available for subsequent crop use at a particular point in time (Figure 15).

This information allowed researchers to understand the potential for late wet season soil water to drive dry season legume production. Monitoring for PAW was undertaken for each of the legume evaluation and farming systems trials undertaken by the project. Cores were taken to a depth of 150 cm and divided into increments of 0-15, 15-30, 30-60, 60-90, 90-120 and 120-150 cm for the analysis of gravimetric water content and nitrate nitrogen. Nitrate N was analysed in the BPTP Lab using a colorimetric analytical system (Merck RQeasy[18]) and a testing protocol developed by the project (Gabb *et. al.* 2011[19]).

[17] *Dalgliesh, N.P. and Foale, M.A. (1998) Soil matters-Monitoring soil water and nutrients in dryland farming systems.* CSIRO/Agricultural Production Systems Research Unit. *Technical Manual-ISBN 0 643 06375 7*

[18] http://www.merck-chemicals.com/australia/food-analytics/nitrate-test-rqeasy-/MDA_CHEM-117961/p_626b.s1LvtAAAAEWm.IfVhTl?WFSimpleSearch_NameOrID=rq+easy&BackButtonText=search+results S. Gabb, A. Doa, Sumarti, J. Nulik (2011) Protokol analisis nitrat tanah dengan menggunakan Merk RQeasy Nitrat (Analysis protocols for the measurement of soil nitrate using an Merck RQeasy Nitrate). Developed as part of the ACIAR project LPS/2006/003, Integrating forage legumes into the maize cropping systems of West Timor.

[19] *S. Gabb, A. Doa, Sumarti, J. Nulik (2011) Protokol analisis nitrat tanah dengan menggunakan Merk RQeasy Nitrat (Analysis protocols for the measurement of soil nitrate using an Merck RQeasy Nitrate). Developed as part of the ACIAR project LPS/2006/003, Integrating forage legumes into the maize cropping systems of West Timor.*

***Figure 13:** Soil water monitoring at Biloto, West Timor*

***Figure 14:** Farmers at Nakuramba, Flores preparing coring tubes for soil water monitoring.*

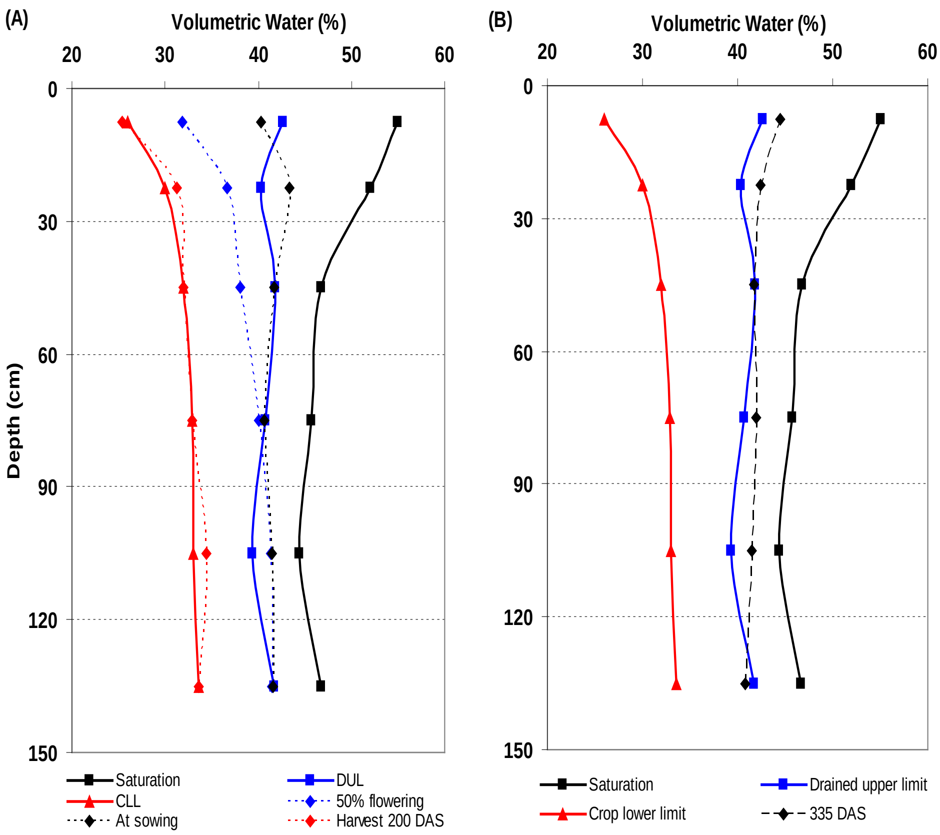


***Figure 15(a):** Soil water profile for an Inceptisol soil at Biloto, TTS, West Timor showing soil parameters related to its plant available water capacity (PAWC) - DUL (■), CLL (▲), SAT (■) and PAW for* Centrosema pascuorum *(to a depth of 150 cm) at legume sowing in late January (♦), at flowering (100 DAS) (♦) and at crop senescence (192 DAS (♦). **Figure 15(b):** The soil water in January of the following year (335 days after the initial measurement) (♦).*

Figure 15 provides an example of the water dynamics discussed above. At time of planting of *Centrosema pascuorum* at Biloto in West Timor in January the soil profile was at drained upper limit (DUL) (144 mm PAW) (Figure 15a). Soil sampling at the time of legume flowering in early May (100 days after sowing - DAS) showed that there was 107 mm PAW still available for crop production. By the 3rd of September (192 DAS) however, the legume had exhausted available water and senesced. The legume yielded 2.8 t/ha DM, the majority of which was produced during the dry season. The profile was then allowed to re-charge with the onset of the subsequent wet season and was again at DUL when next checked (150 mm PAW, 335 DAS) (Figure 15b).

Table 3: *The plant available water capacity (PAWC) for a range of forage and cereal crops grown at sites in West Timor showing the differences in PAWC between soils and locations, and individual crops grown on a particular soil at a location. PAWC is shown to a depth of 180 cm, however it should be noted that for short lived perennial legume species water extraction is likely to be to a depth greater than what is able to be measured.*

Regency	Village	Latitude, Longitude; elevation (m ASL)	Soil Type (Order)	Crop	PAWC to 180 cm depth (mm)
Kupang	Sillu	-10.032, 123.962; 440 m	Alfisol	Maize	105
				Clitoria ternatea	194
				Centrosema pascuorum	170
				Lablab purpureus	172
				Macroptilium bracteatum	172
	Oebola	-10.067, 124.006; 557 m	Alfisol	Maize	151
				Lablab purpureus	209
				Macroptilium bracteatum	217
	Naibonat	-10.077, 123.863; 28 m	Inceptisol	Maize	155
				Clitoria ternatea	308
				Centrosema pascuorum	319
				Ground Nut (peanut)	196
				Mungbean	170
TTS	Biloto	-9.878, 124.226; 560 m	Vertisol	Maize	154
				Clitoria ternatea	161
				Centrosema pascuorum	161
				Macroptilium bracteatum	161
TTU	Usapinonot	-9.487, 124.558; 360 m	Inceptisol	Maize	245
				Clitoria ternatea	191
				Centrosema pascuorum	219
				Macroptilium bracteatum	206
Belu	Kakaniuk	-9.574, 124.845; 48 m	Inceptisol	Maize	155
				Clitoria ternatea	200
				Centrosema pascuorum	183
				Macroptilium bracteatum	190
	Kletek	-9.573, 124.936; 70 m	Inceptisol	Maize	129
				Clitoria ternatea	146
				Centrosema pascuorum	149
				Lablab purpureus	144
				Macroptilium bracteatum	149

5.4 Research approaches

5.4.1 Village based on-farm research

Where practical, an in-village, on-farm participatory research approach was used in which researchers and farmers worked collaboratively to explore issues of interest to both groups. This approach was backstopped by on-station research when it was considered that more control was required to investigate a particular component of the system.
All on-farm agronomic research was undertaken in collaboration with already established village farmer groups. These were critical to the success of the research as it enabled group members to be involved in trial activities which developed local experience in aspects of legume production including land preparation, the management of cereal and legume crops and seed harvesting and cleaning.
Animal production trials were also done in-village utilising farmer owned animals (cattle and goats) housed in communal feed lots. Farmers were responsible for the experimental feeding of their animals under the supervision of locally-based Dinas/ NGO animal production staff that were also responsible for the routine weighing of cattle.

Selecting farmers for collaboration

Initial selection of in-village research sites was based on the knowledge of local researchers and their past experience of working in regions of interest to the project. Preliminary selection was then followed by in-depth interviews within the villages. These were undertaken by a joint team of social and agricultural researchers and included individual interviews with the village leadership, and individual and communal interviews with members of the selected farmer groups (Appendix 1).
As well as benchmarking farmer practice, these were used to develop a basic understanding of the farming systems and the challenges of agricultural production that were being faced by the farmers. These interviews were also aimed at developing understanding of the social context in which production took place, including village and farmer group governance, linkages with higher levels of government, challenges to increased and/or improved agricultural production and access to information and marketing systems. This information formed the reference point for longitudinal evaluation later undertaken to assess the impact of project led interventions.
Learning from earlier experience, and insights gained through longitudinal evaluation, selection criteria were tightened for later village and farmer group selections (particularly during the expansion to Flores in 2009) to include the following:

<u>Ownership of cattle</u> - whilst this may seem like an obvious selection criteria for a project investigating the integration of forage legumes, it is the subtleties of animal ownership that need to be clarified. Whilst many farmers will indicate that they own cattle, the reality may be that they are actually keeping the animals for another individual and have little financial interest in the particular animal. Consequently there is little interest in improving management. Also, in a traditional village social structure animals are seen as a means of storing wealth for use in times of emergency or for education and there is little incentive for these animal ‘keepers’ to optimise animal production. The project therefore, aimed to identify farmers who saw animal production as a business and were interested in improving animal live weight gains and the speed of animal turn off.

<u>The existence of a well functioning farmer group</u> - having a cohesive farmer group that is focussed on a common village/production goal is critical to community collaboration. The group becomes the focus of the research work which is either undertaken on a group member’s farm or on land managed by the group. Many groups also reserve particular days for group activities which may include community development work or, in the case of agricultural research, the undertaking of weeding or harvesting or other management practices.

<u>A high level of farmer group and village governance</u> - the villages and groups that work well are those that have strong leadership which is recognised by the community. This results in local policies being developed that ensure the successful running of the organisation and the management of the community. An example of this is the development of local 'rules' designed to reduce conflict between land owners caused by the free grazing of cattle which requires that cattle be tether grazed.

Using past experience and the above criteria resulted in the identification of the 20 research sites listed in Table 2. All were involved in a particular project activity for at least one season, with 8 (of 14) villages in West Timor and 4 (of 6) in Flores committing to project activity over multiple years. This was particularly important for the testing of farming systems options where it was necessary to undertake research over sequential seasons.

As can be expected in on-farm research, some groups (3) and individuals lost interest over time, and it was mutually agreed that project activity would cease. One of the main reasons for disengagement involved the issue of animal ownership, and the timely provision of cattle through government and non-government schemes. In a number of cases, farmers, with a real interest in producing forage legumes, lost interest because they could not rely on the on-going supply of animals. For a number of farmers, competition for labour between management of food security crops and forage legume production was also a major stumbling block to longer term adoption of forage legumes.

5.4.2 On-station research

When it was considered appropriate, more detailed investigation of particular aspects of the system was undertaken at the BPTP-NTT Naibonat Research Station. This was particularly important in the evaluation of new legume species where routine observation was required and in legume seed increase where the availability of irrigation provided security of production. Collaboration with Soe Agricultural High School in West Timor (Table 2) provided a quasi research station environment for the evaluation of legume species at higher altitudes as well as providing a training venue and work experience for students in new agricultural technologies.

5.5 Component and systems research

The basic research aim was to improve the quality of animal nutrition and cereal nitrogen supply through the utilisation of stored soil water to produce forage legumes during the early dry season. Research focussed on the 4 key components of the system, a) the identification of appropriate legumes, b) the integration of legumes into cereal based cropping systems, c) legume seed increase and, d) the feeding of forage legumes to animals.

5.5.1 Selection of suitable legumes

The integration of forage legumes into the cereal-based farming systems relies on the availability of adapted species that are compatible with the existing farming system. Successful adoption requires that plants:

a) Are of a type does not physically compete with a cereal crops when grown in a relay or rotation i.e. relatively short in stature with minimal twining
b) Establish easily and consistently
c) Do not become an invasive weed within cropping lands or in surrounding areas
d) Be palatable to stock
e) Produce significant quantities of biomass and seed which is able to be harvested and processed by hand
f) Be reasonably tolerant of insects and diseases

West Timor (2006 and 2007)

Initial legume evaluation was undertaken at the BPTP Naibonat Research Station in early 2006. Selection of legume species for testing in a replicated trial was done using a process of peer review and expert knowledge, including the use of the Tropical Forages Interactive Selection Tool (Cook *et al* 2005[20]). Ten species were selected for evaluation (Table 4) and assessed on the above criteria. This resulted in *Centrosema pascuorum*, *Clitoria ternatea* and *Macroptilium bracteatum* being identified for further evaluation. In the following season (2006-07) replicated evaluation trials were established at 5 village sites representing a range of West Timor environments differentiated by elevation and rainfall pattern (Figure 18). A combination of 2006 short-listed species and others considered to have potential were evaluated using similar criteria to the previous year with species varying between sites as a result of differences in environment and soil type (Table 4). Evaluation resulted in *Centrosema pascuorum*, *Clitoria ternatea* and *Lablab purpureus* being identified as having the necessary attributes for testing in a cereal-based system and were included in farming systems trials which commenced in 2008/09 (Figure 19).

West Timor and Flores (2009-11)

With the commencement of phase 2 in 2009, and the expansion into new environments in Flores, the decision was made to review the existing suite of legumes and to investigate other potential candidates with suitable traits. This followed the discovery, following multi-site field evaluations, of potential deficiencies in some of the better performing legumes, particularly: occasional but significant defoliation of 'Milgarra' *Clitoria ternatea* by lepidopterous larvae, the troublesome harvest of 'Cavalcade' *Centrosema pascuorum* seed and the perceived unsuitability of 'Highworth' *Lablab purpureus* by some farmer groups. The aim was to complete comparative growth experiments at sites of contrasting soil-type and elevation in West Timor and Flores during the 2009/10 and 2010/11 seasons with village and broader-scale seed production undertaken concurrently (Figure 18).

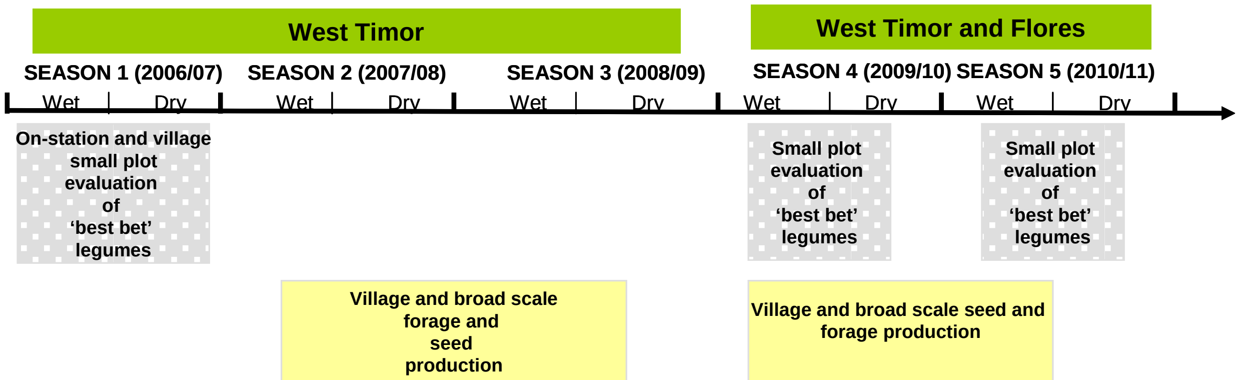


Figure 18: *Timing of legume evaluation research and subsequent seed production of selected species*

Legumes with potential use for maize-legume relay and rotation systems were identified by DAFF Queensland and DPIF Northern Territory pasture specialists. The final selection included 14 legumes plus 'Milgarra' *Clitoria ternatea*, 'Cavalcade' *Centrosema pascuorum* and 'Highworth' *Lablab purpureus* (Table 4). Seed was sourced from Queensland and Northern Territory Government stocks and from seed companies for more readily available varieties. Replicated experiments were planned for sowing during early 2010 at three sites: BPTP Naibonat Research Station, West Timor; SMK Soe, West Timor; and MTM farmer group site, Ulupulu, Flores. The West Timor sites at Naibonat and Soe were sown in March/April, using irrigation to supplement unseasonally low rainfall. The Flores site was not able to be sown because of dry conditions and a lack of access to irrigation.

[20] *Cook, B.G., Pengelly, B.C., Brown, S.D., Donnelly, J.L., Eagles, D.A., Franco, M.A., Hanson, J., Mullen, B.F., Partridge, I.J., Peters, M. and Schultze-Kraft, R. 2005. Tropical Forages: an interactive selection tool., [CD-ROM], CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia.*

Table 4: *Legume species evaluated at locations in West Timor and Flores in 2006, 2006/07 and 2009-11*

Species	**Cultivar**	**Location (Soil)**													
		Naibonat (Vertisol)	**Biloto (Inceptisol)**	**Kletek (Inceptisol)**	**Kakaniuk (Inceptisol)**	**Sillu (Alfisol)**	**Usapinonot (Inceptisol)**	**Soe (Alfisol/ Vertisol)**	**Naibonat (Vertisol)**	**Marapokot X 2 (Inceptisol)**	**Usapinonot (Inceptisol)**	**Wolomasi (Inceptisol)**	**Nakuramba (Inceptisol)**	**Naibonat (Vertisol)**	**Soe (Alfisol/ Vertisol)**
		2006	**2006/07**					**2009-10**		**2010-11**					
Aeschynomene americana		●				●	●								
Alysicarpus vaginalis	Buffalo Clover	●				●	●								
Arachis pintoi	Pinto Peanut	●	●			●	●								
Centrosema pascuorum	Cavalcade	●	●	●	●	●	●	●	●					●	
Centrosema pascuorum	Bundey							●	●			●		●	●
Centrosema molle	Cardillo							●	●	●	●	●	●	●	●
Clitoria ternatea	Milgarra	●	●	●	●	●	●	●	●				●	●	●
	Q5455							●	●						
Desmanthus virgatus			●	●	●										
Des. pernambucanus		●	●	●	●	●	●								
Lablab purpureus	Highworth	●	●	●	●	●	●	●	●						
	CQ3620													●	
	Endurance							●	●						
	Rongai							●	●						
Macrop. bracteatum	Juanita	●	●	●	●	●	●	●	●						
Macrop. bracteatum	Cardaarga							●	●	●	●	●	●	●	●
Macroptilium triloba		●				●	●								
Macroptilium gracile	Maldonado					●			●						
Mucuna pruriens	CPI86105								●						
Stylosanthes hamata	Verano	●			●	●	●								
Stylosanthes guianensis	Brazilian		●	●	●										
	ATF3308								●						
	ATF3309								●						
	CIAT184			●											
Stylosanthes seabrana	Caatinga		●	●	●										
Vigna luteola	Dalrymple							●	●					●	●
Vigna unguiculata	Arafura							●	●						

Small-plots were established by ‘dibbling’ seeds into unfertilised, cultivated seed beds. Each plot was divided into two, one half each for measuring biomass and seed production. Plant biomass was measured at 8, 16 and 24 weeks after sowing using quadrats and cutting at a height of 5 cm and drying to a constant weight. Regrowth after cutting was visually assessed. Reproductive development was measured in the other half of each plot, where A-frame trellises (~1.5 m high x 1 m wide) had previously been erected in plots containing twining or sprawling legumes. Inflorescence and pod counts were conducted at two-weekly intervals and mature seeds hand-harvested for estimation of yield. Second-year (2010-11) biomass production, but not seed production, was measured at Naibonat and Soe for species regrowing vigorously after the first year.

A multi-site comparison of legume growth and village demonstration of promising legumes from the 2010-11 experiment was conducted during 2010-11 (Table 2). These sites were also used to produce seeds for local use. Five sites were established on Flores and new areas established at Naibonat and SMK Soe in West Timor. Each plot was split into biomass and seed production sections as for the previous year, and similar measurements of biomass and plant population completed. The key difference was that the plots were to be cut to 5-10 cm and material removed after completing the quadrat cuts used to estimate biomass production. Notes were also collected on flowering times and seed development and seed yields measured at the Naibonat site.

5.5.2 Using legumes in the farming systems

The farming systems trials (Table 5) aimed to explore the operational and production aspects of the inclusion of a legume in a cereal-based system. The original hypothesis proposed that forage legumes would be grown in relay (Figure 16) with a cereal crop (such as maize or upland rice) and provide benefits to both animal and cereal crop production. This was subsequently modified to include the growing of legumes in annual rotation with cereal crops (Figure 17).

Information was collected on legume (biomass and growth rate) and cereal crop productivity (grain and stover yields) and on the drivers of production including daily weather, and seasonal soil water and nitrogen availability. Cereal crops grown subsequent to the legumes were used as bioassays to determine the contribution of legume-fixed nitrogen to cereal production. Replicated trials, initially using 3 replications, but later increased to 4 to account for variability, were used in all cases. Legumes were grown in rows at configurations appropriate to the experimental design (Table 11; Figures 23, 24, 30).The open pollinated maize variety, Lamuru, was used in all experiments at a standard plant configuration and density (80 x 40 cm with 2-3 seeds planted at each point).

Relay cropping

It was envisaged that a legume, grown as a relay would be planted between the rows of maize at around the time of crop anthesis and grown out into the dry season using stored soil water and late wet season rainfall to sustain production. The forage legume biomass would then be used to feed animals including cattle and goats. Initially it was considered that the legume biomass would be dried and stored for use in the late dry season when alternate sources of quality forage material were in short supply. However, as a result of farmer feedback, this was later modified to include the continual feeding of the material as it became available in the early dry season (Figure 16).

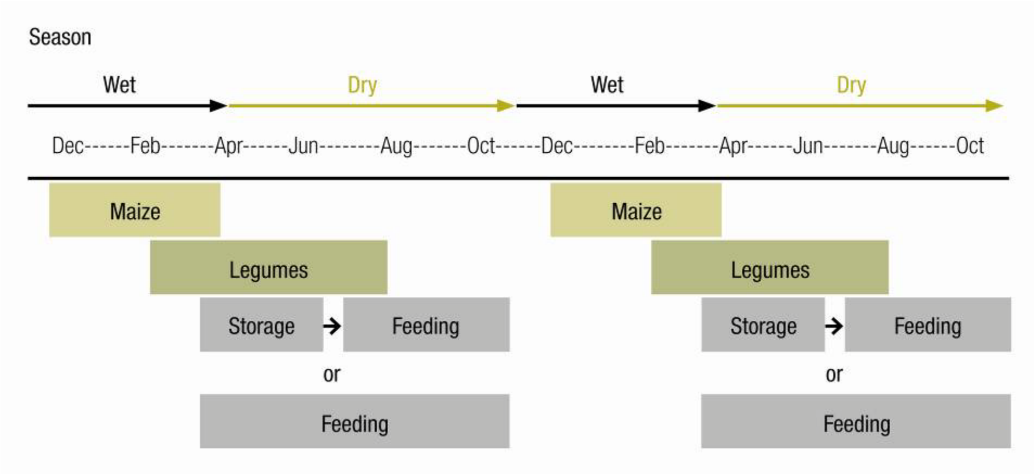


Figure 16: *A relay cropping sequence in which a forage legume is grown in relay with maize during the first wet season. Legume biomass is either fed directly (as green material) to animals or dried and stored for late dry season use. The same sequence is used during the subsequent wet and dry seasons.*

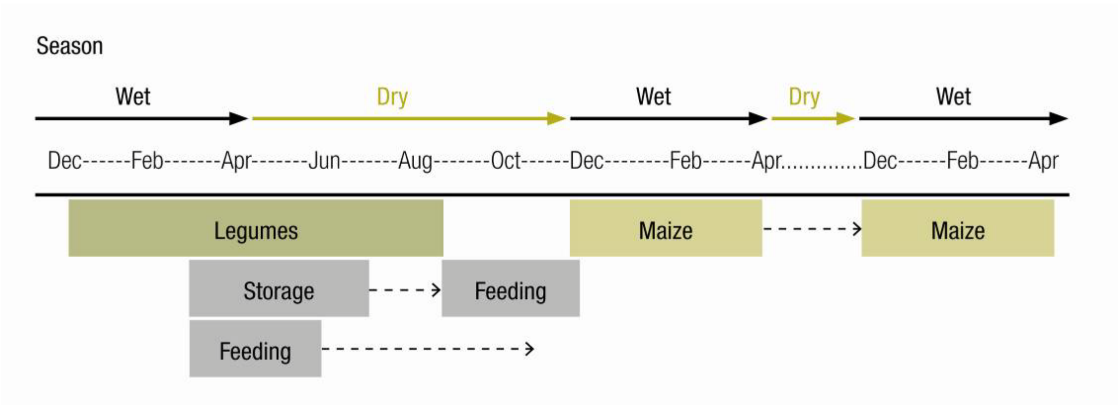


Figure 17: *A forage legume/maize rotation in which the legume is grown through one wet and dry season before maize is planted to utilise any nitrogen 'fixed' by the legume.*

Rotation cropping

Also, as a result of farmer involvement in research direction setting, the use of legumes in annual rotation with cereal crops was also tested. In this scenario every second or third cereal crop is replaced by the legume, with biomass again used for dry season animal feeding (Figure 17). As a result of the lack of competition from a cereal crop, and the ability to plant the legume earlier, this scenario had the potential for higher biomass yields although it requires that land and labour is available to manage the additional production.

West Timor (2006-09)

The 3 legume species identified through village evaluation (*Centrosema pascuorum*, *Clitoria ternatea* and *Lablab purpureus*) produced significant quantities of biomass during the early to mid dry seasons and were able to produce seed which was relatively easy to harvest. Importantly farmers considered they were appropriate for use in the maize-based cropping system. Testing of their potential as either relay (Figure 16) or rotation (Figure 17) crops in a maize based system was undertaken at the sites indicated in Table 5 between 2007 and 2009 (Figure 19). In addition, maize was grown as a nitrogen bio-assay crop over the plots of the 2006/07 legume evaluation trial at Kakaniuk to assess the impact of legume fixation on maize productivity.

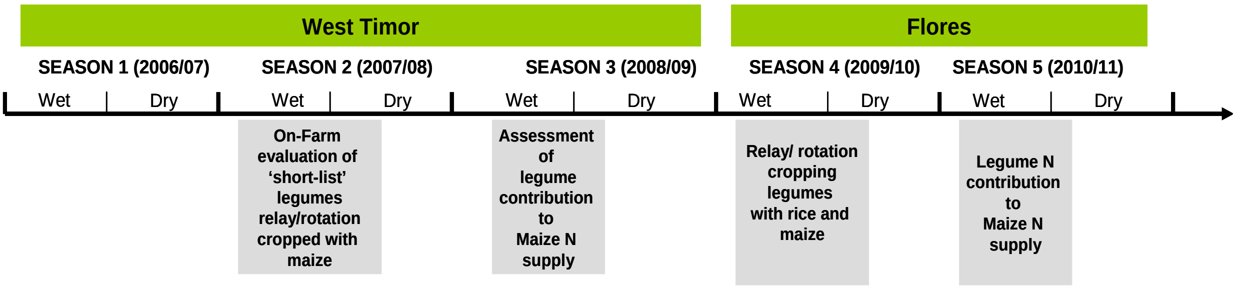


Figure 19: *Timing of legume-cereal rotation research*

Table 5: *Locations of farming systems trials in West Timor and Flores from 2006 to 2011*

Village location	Trial	Season				
		2006/07	**2007/08**	**2008/09**	**2009/10**	**2010/11**
Usapinonot (W. Timor)	Relay x 2		Maize + 3 legumes	Maize bioassay		
	Rotation x 1		3 legumes	Maize bioassay		
Oebola (W. Timor)	Relay x 1		Maize + 3 legumes	Maize bioassay		
Kakaniuk (W. Timor)	Rotation (after legume evaluation trial)	5 legumes	Maize bioassay			
Nakuramba (Flores)	Relay x 1				Maize/rice + 2 legumes	Maize and rice bioassay
Ulupulu (Flores)	Relay x 1				Maize/rice + 2 legumes	Maize and rice bioassay
	Rotation x 1				2 legumes	Maize bioassay

Flores (2009-11)

In 2009-11 similar experiments were conducted at 2 locations in Flores to assess the potential for maize and upland rice to be grown in relay with two legumes (*Clitoria ternatea* and *Centrosema pascuorum*) (Table 5).

5.5.3 Seed research and increase

While the project was not specifically tasked with detailed seed research, nor broad scale extension or distribution of legume seed, it was necessary to have a good understanding of the agronomy of the legume species and the seed resources available to meet the demands of project activity. As a result, seed research and increase have been continuing aspects of project activity.

West Timor (2006-09)

Seed increase may be divided into the village level collection required to sustain supplies at the individual farmer level and larger scale production required for the broader expansion of the technology. *Ad hoc* village level collection was undertaken by collaborating farmers keen to expand their area of production. In 2009 this approach was refined when farmer groups were trained in the use of low cost trellising which increased seed yield and ease of harvest. The broader demand for seed and forage biomass to support project activities (agronomic experiments and animal feeding), as well as demand from other organisations such as Dinas, quickly resulted in the need to establish larger areas of seed increase. This commenced in 2007/08 with the planting of 4.2 ha of *Centrosema pascuorum* and *Clitoria ternatea* and increased in the following year to more than 5 ha.

The conflict between the need to either manage a crop for seed production or biomass production resulted in poor yields of seed in some instances. However, sufficient seed (and biomass) was produced to allow the project to continue to undertake research and to supply other organisations. Production focused on the regency of Belu (bi-modal) and the villages of Oebola (Kupang regency) and Usapinonot (TTU regency) (both uni-modal). Belu was found to be more suited to biomass production because of the high levels of seed spoilage caused by rainfall at harvest (bi-modal region), whereas, the uni-modal areas were better suited to seed increase because of the dry conditions experienced at harvest.

West Timor and Flores (2009-12)

A seed increase program was instigated during late 2009 (for 2010 sowing) to generate seed urgently needed for demonstration and adoption of the forages and to improve understanding of the potential and risks for seed production. The initial focus was on the three previously high-performing legumes, Milgarra *Clitoria ternatea*, Cavalcade *Centrosema pascuorum* and Highworth *Lablab purpureus*. The range was extended during 2010-11 and 2011-12 to include 6 legumes which had showed promising performances in the 2010-11 plant evaluation experiment – Cardillo *Centrosema molle*, Bundey *Centrosema pascuorum*, CQ3620 *Lablab purpureus*, Cardaarga *Macroptilium bracteatum*, Juanita *Macroptilium bracteatum*, Dalrymple *Vigna luteola*). Around 0.3 ha of increase area was established in 2009/10; 0.85 ha in 2010/11 and 2.7 ha in 2011/12. These seed production activities were in addition to seed collection associated with the legume evaluation experiments.

Seed increase was undertaken at facilities of collaborating Indonesian organisations (BBPT, Dinas, and SMKs) and in villages on West Timor and Flores. Seed crops were grown by employees of the respective organisations or by farmers working in farmer groups, with advice from the project team. The reasons for growing seed crops varied with the needs of the particular organisation, and can be grouped into three types:

1. Seed production by BPTP or Dinas to support research, demonstration and adoption programs
2. ‘Contract’ seed production to BPTP, and later Dinas to support their activities
3. Seed production for local use to support livestock feeding or sale.

In some cases villages undertook a combination of 2 and 3, opting to sell surplus seed.

Seed increase was completed on a range of soil types under differing growing environments (rainfall, elevation) and management systems. In general, there were two scales of seed production, a) ‘village-scale’ production, based on relatively small areas and methods suited to maximising seed production e.g. hand-cultivation, sowing by ‘dibbling’, using trellises, and b) ‘large-scale’ (up to 1 ha) where herbicides and mechanical cultivation were sometimes used to control weeds before sowing, row planting was often used and trellises were not a sensible option. Combinations of these methods were used as the grower(s) saw fit.

Simple monitoring of crop development and seed production was conducted by BPTP staff through regular visits and the recording of crop management and physiological and phenological traits including plant population, timing of flowering, seed development, pod shattering, insect and disease incidence and seed yield. A strategy employed to foster seed production expertise in ENT was to train seed production specialists within key collaborating agencies. Six BPTP, Bappeda and Dinas staff received Crawford Fund support to undertake training with DAFF, Queensland. This resulted in the development of seed production plans which were used to manage seed crops on West Timor and Flores during 2011-12.

5.5.4 Animal production research

Three cattle and a goat feeding trial were undertaken by the project (Table 6). These were aimed at understanding the impacts on live weight gain of supplementary feeding of forage legumes. All were undertaken in village feed lots in West Timor or Flores with the animal owners responsible for daily feeding and watering of animals and the process supervised by locally based Dinas or NGO staff (Figure 20).

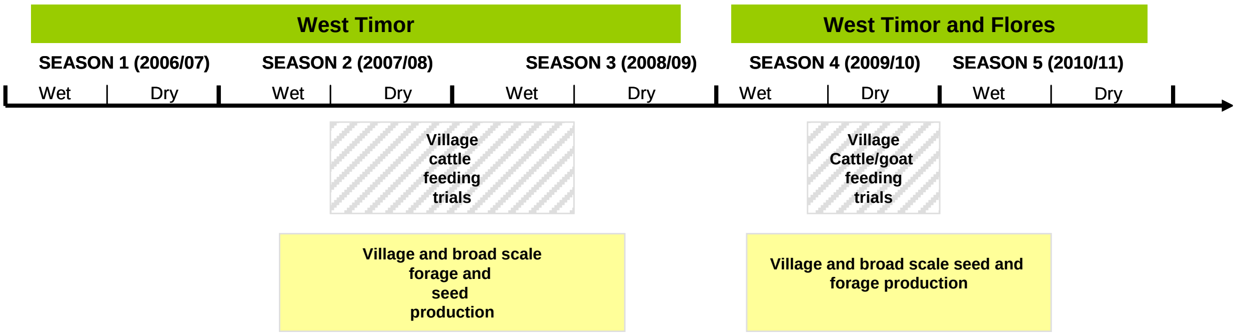


Figure 20: *Timing of animal feeding trials (cattle and goats) undertaken by the project*

Table 6: *Animal feeding trials undertaken as part of the project in West Timor and Flores between 2008 and 2011.*

Trial No	Island	Village/ Regency	Animal type (weight)	Animal Number/ length of trial	Treatments
1	West Timor	Usapinonot, TTU (2008/09)	Cattle (weaners (70-100 kg)	3 treatments, 5 animals/treat (11/4/08-25/2/09)	• Tether grazed, self selection • 60:40 grass: forage legume • 60:40 grass: browse legume
2		Oebola, Kupang (2008)	Cattle (weaners: 70-100 kg)	3 treatments, 5 or 6 animals/treat (31/3-29/9/08)	• Tether grazed, self selection • 60:40 grass/ forage legume • 60:40 grass/ browse legume
3	Flores	Marapokot, Nagekeo (2010)	Cattle (bulls: 160-220 kg)	2 treatments, 10 animals/treat (15/7-7/10/10)	• 80:20 grass/*Clitoria ternatea* • 80:20 Grass/*Centrosema pascuorum* • Local grass/legume mix (long term data)
4		Ulupulu, Nagekeo (2010/11)	Goats (females: 20 kg)	3 treatments, 5 animals/treat (1/11/10-1/1/11)	• Native grass *ad libitum* • 100% *Centrosema pascuorum* • 100% *Clitoria ternatea*

Trial 1 and 2: Usapinonot and Oebola, West Timor (2008/09)

These trials were undertaken in collaboration with LPS/2004/023: *Strategies to increase growth of the weaned Bali calf.* The growth rate of weaners, tether grazed and allowed to feed on native pastures, *ad libitum*, was compared with animals housed in feedlots and fed a diet of native grasses supplemented with either *Leucaena leucocephala* or forage legumes at the rate of 15g DM/kg LW/day. Each treatment contained 5 animals which were weighed fortnightly. The trial commenced in April 2008 and continued to September 2008 at Oebola and February 2009 at Usapinonot.

Trial 3: Marapokot, Nagekeo, Flores (2010)

This trial was focussed on the fattening of bulls, comparing the supplementary feeding of either *Centrosema pascuorum* or *Clitoria ternatea* hay at a rate of 1 kg DM/head.day in conjunction with locally sourced grass and rice straw. Animals weighed in the range of 160 to 220 kg at the commencement of the trial and were separated into treatments (10 animals in each) based on live weigh. No control treatment was implemented as it was considered that the long-term regular measurement of live weight by Dinas provided a good estimate of non-legume supplemented weight gain in the district. The trial ran for ~3 months and was managed by the Tunas Baru Farmer Group in collaboration with the Agency for Food Security and Agricultural Extension.

Figure 21: *Marapokot feedlot with dried and baled forage legume material on a specially constructed mezzanine floor above the animal pens. The hand press in the foreground was used to produce the bales of hay.*

Forage legume material was sourced from a dry season irrigated production area established to investigate the potential for replacing 1 of the 3 annual irrigated rice crops with a forage legume. Material was stored as bales at the feedlot (Figure 21).

Trial 4: Ulupulu, Nagekeo, Flores (2010)

As goats are commonly provided to farmers as part of NGO managed animal ownership schemes it was considered appropriate that the project assess the potential for legumes to contribute to their productivity. This experiment was undertaken over a 2 month period during the 2010/11 wet season and compared the *ad libitum* feeding of sole forage legume hay (either *Centrosema pascuorum* or *Clitoria ternatea*) with the feeding of native grasses. As village goats had previously been allowed to free graze, the farmer group was required to build a feed lot for the trial. The legume hay was supplied from irrigated production at Mbay.

5.5.5 Social research

Social research in the first 3 years of the project was undertaken by scientists from CSIRO and BPTP-NTT. Their contribution in the areas of village identification and preliminary benchmarking was important to the project. These researchers continued on to undertake the first of the longitudinal evaluations which were designed to capture early changes in farmer thinking and to provide a conduit for feedback on project direction.

In 2009, as a result of staff changes (organisational changes and post-graduate study), the University of Nusa Cendana in Kupang was contracted to provide a social science capability to the project. This resulted in the university, in collaboration with BPTP-NTT, undertaking benchmarking activities in Flores, and longitudinal evaluations in both Flores and West Timor. There were two areas in which social science contributed to the progress and outcomes of the project:

Identification of appropriate villages and farmers for collaboration-benchmarking social systems and farmer practice

To ensure that long term collaboration was undertaken with villages and farmers that were representative of the broader social and farming systems in West Timor (and later Flores) was critical. This was determined through individual and group interviews with discussion focussing on the social and production issues that influence an individual's decision making in terms of agricultural production (Table 7). These included information on land tenure, marketing and access to animal supply schemes, constraints to agricultural production, availability of inputs and information, and sources of off-farm income. Group and village leaders were also interviewed to gain an understanding of local governance and linkages to higher levels of government, the impact of governance on agricultural production, the management and access to animal supply schemes, and how farmers access production and marketing information relating to agriculture. An example of the interview pro-forma is provided in Appendix 1. Twenty villages (14 in West Timor; 6 in Flores) were identified using this process (Table 2).

Table 7: *Interview schedule for village identification and baseline and longitudinal evaluation.*

Timing	Location	Type of evaluation	Interviewees	Number
October 2006	West Timor	Baseline	Farmers and local govt	7 villages (51 participants)
June 2007	West Timor	Longitudinal	Farmers and local govt	6 villages (10-20 participants/village)
July 2008	West Timor	Longitudinal	Farmers, researchers and extension	6 villages, 39 interviews, 99 respondents
Nov 2009	Flores	Baseline	Farmers, local extension	3 villages, 41 respondents
April 2010	West Timor	Longitudinal	Farmers, extension	2 villages, 24 respondents
July 2011	West Timor and Flores	Longitudinal	Farmers, extension, government	65 respondents from 12 villages/ organisations

Longitudinal evaluation of project impact on participating villages, farmers and researchers

Longitudinal evaluation, through structured interviews was undertaken to ascertain project impacts on participating farmers, their communities and participating researchers (Table 7). This process also provided the opportunity to receive feedback on local research and suggestions on future direction and project process. Routine visits to collaborating villages and discussions with farmers were invaluable in providing anecdotal information on current activities within villages, particularly those where farmers had used their own initiative to formulate and test new ways of using the forage legumes within their system. Annual project workshops, in which farmers were formally requested to provide input, were also valuable in understanding their perspective on the use of the legumes. The synthesis of information from a range of sources provided an overview of the potential constraints to the adoption of project technologies and influenced later project direction, particularly in the areas of collaborator selection, the importance of seed production and the imperative for increased involvement of extension agencies in project activities.

5.6 Communicating outcomes

Communication of research outcomes was undertaken with a range of stakeholders including funding agencies, Indonesian research and extension organisations, non-government organisations, project collaborators, other researchers and farmers. Differing groups had differing information requirements which required a range of communication strategies and tools. The 2011 communication plan (Appendix 2) provides an example of the types of activities which were being planned and implemented as the project progressed.

Farmer and extension communication

At the most basic level communication involved researchers regularly visiting groups to undertake research activity and to discuss project outcomes. Cross visits between collaborating and non-collaborating villages were a powerful means of communicating outcomes with many examples of impacts occurring as a result. These activities were supported by presentations on research progress and graphical tools developed by the project including a set of 6 wall posters describing the role of forage legumes in cereal-based systems. These posters were distributed to collaborating farmer groups and generally hung in their meeting rooms for future perusal.

Engagement with extension agents from Dinas, BAPPEDA and NGOs varied between regions and organisations and depended heavily on the research interest and commitment of their managers. At the most committed locations this included regular updates of staff, training in aspects of the work and daily involvement in project activity e.g. seed increase and animal feeding trials. Representatives of farmer groups and extension agencies also participated in annual project workshops which were conducted in Kupang and later extended to Mbay and Ende in Flores.

An important communication tools developed by the project is the manual '*Using forage legumes in crop and livestock systems of Eastern Indonesia'* which is due for publication in mid-2013 (English and Bahasa Indonesia). It will provide users, particularly researchers, extension staff and students, the necessary information to introduce forage legumes into cereal based farming systems. Section 9 of this manual discusses a range of communication strategies which have been used in the project and are suggested as options for extension agencies tasked with working with farmers to increase forage legume production.

Extension and research management communication

The excellent professional network that exists amongst senior agricultural research and extension staff in ENT has provided the opportunity for *ad hoc* communication of project outcomes. It has also proved invaluable in gaining project access to particular organisations and regions which has led to substantial collaborative work being undertaken. The conduct of annual project workshops provided a more formal venue to update local and provincial research and extension management. These workshops were conducted annually in Kupang (and later Flores) and generally attracted ~20-40 participants from a range of government and non-government agencies.

Other researchers

Research papers which highlighted the progress and outcomes of the research were presented at a number of national and international conferences by project staff.

Funding agencies

Annual reporting, detailed trip reports and personal communication with program managers were used to keep funding agencies informed on project progress.

5.7 Building and maintaining capacity

Because of the lack of experience in the growing and integration of forage legumes into cereal-based cropping systems, training was necessary to fill knowledge gaps within the projects technical and research ranks. On-the-job training in technical aspects of the work was sufficient in many cases. Where this was not the case, staff were provided with external training in Australia under the auspices of the Crawford Fund (Table 8). An example of this was the training of 6 staff from 4 organisations in seed increase and production techniques which was undertaken in Walkamin by DAFF Queensland. This has had a major impact on the regional capacity to produce legume seed for continuing expansion in both Flores and West Timor.

Post graduate training was provided to a number of BPTP-NTT staff with 2 undertaking MSc degrees at the University of Nusa Cendana in agriculture related topics and 2 receiving John Alwright scholarships to undertake PhDs in Australia in social science and agriculture.

Staff of the BPTP analytical laboratory were assisted to develop capacity in the analysis of soil water and nitrate nitrogen. This was done through a combination of improvements to facilities, on the job mentoring and the development of the training manual '*Analysis protocols for the measurement of soil nitrate using an Merk RQeasy Nitrate meter'* (Bahasa Indonesia and English) for use by the laboratory technicians. This has resulted in capacity now being available for other projects undertaking research at Kupang.

Table 8: *Formal and informal training undertaken by the project between 2006 and 2012*

Training requirement	Staff (No)	Location of training	Trainers	Outputs
Soil monitoring and characterisation techniques	BPTP technical (3)	On the job	CSIRO staff	Well skilled local team in soil monitoring
Pesticide application	BPTP research and technical (4)	Naibonat	CSIRO staff	Ability to apply pesticides in a safe and accurate way
Weather station management and data collection	BPTP technical (1)	On the job	CSIRO staff	Network of weather stations (7) and a protocol available for station management
Agronomic monitoring	BPTP technical (3)	On the job	CSIRO staff	Operational plans and data sheets developed annually
Systems research and APSIM modelling	BPTP research (3)	Toowoomba	APSRU staff	Basic understanding of modelling and data requirements
Smallholder seed increase	BPTP technical, farmers (6)	On the job	DAFF Qld staff	Improved field techniques in seed increase
Legume seed production	BPTP, BAPPEDA and Dinas (6)	Atherton	DAFF Qld staff	Increased capacity to undertake seed increase using best practice
Legume seed production	BPTP research (1)	Thailand	Thai seed prod'n staff	An understanding of seed increase in a smallholder environment
Soil laboratory techniques	BPTP lab (2)	Naibonat	University of Queensland and CSIRO	Local capacity to analyse soils for water and nitrate N
Post graduate	BPTP research (2)	Kupang	University of Nusa Cendana	MSc in Agricultural Science (2)
	BPTP research (1)	Toowoomba	University of Southern Queensland	PhD in Agricultural Science (1)
	BPTP research (1)	Brisbane	University of Queensland	PhD in Social Science (1)

6 Achievements against activities and outputs/milestones

Objective 1: To evaluate forage legumes for potential integration into the maize cropping systems of West Timor

No	Activity	Outputs/ milestones	Achievements against activities
1.1	Identification and trialling of legume species with potential to contribute to the farming system	Identification of a suite of legumes appropriate for use in maize and rice based farming systems in ENT(PC)	-Evaluation of 27 legume species and cultivars assessed through on-station and on-farm evaluation between 2006 and 2012 (Table 4) with a set of suitable species identified.
		Legumes (5-10) with appropriate traits for inclusion in ENT F/Systems identified, field tested and shortlist for future assessment (PC)	-The legumes *Clitoria ternatea, Centrosema pascuorum* and *Lablab purpureus* were identified as being appropriate for use in cereal-based farming systems, produce significant quantities of biomass which is palatable to cattle and goats and are well accepted by farmers. -The additional species *Centrosema molle, Macroptilium bracteatum* and *Vigna luteola* show potential as plants appropriate to cereal-based cropping systems although more widespread testing is required. -*Stylosanthes guianensis* and *S. seabrana* produce high levels of biomass throughout the dry season and are suitable for use in grazing system although seed increase is more difficult due to the small seededness of these species.
		Improvements in knowledge of legume production and seed increase leading to increased availability of seed for research and production in ENT (PC)	-Australian training of 6 research and extension staff from 4 organisations (Crawford Fund) has resulted in well developed expertise in seed increase including agronomic management, legume establishment, the testing and management of hardseededness, and seed quality determination. -The training and mentoring of the 6 staff has seen an upward trend in regional seed production by Dinas, BAPPEDA, BPTP-NTT, Soe SMK and the Universities of Flores and Nusa Cendana resulting in more seed being available for research and distribution to farmers. In 2011/12 254 kg seed of various species was produced on 2.6ha.
1.2	Increased understanding of the contribution of forage legumes to maize-based cropping systems including the optimisation of both legume and maize production within that system	Legume/maize bioassay: Site (1) identified, legume swards established, soil monitoring undertaken (Year 1). Maize bioassay sown, N treats imposed, monitoring of production and harvesting completed (Year 2) (PC)	-Four legumes (*Clitoria ternatea, Centrosema pascuorum*, Ground Nut and Mungbean) successfully produced significant biomass and seed in 2009/10, however in the following year flooding destroyed the maize bioassay crop resulting in the failure of the trial.

		Maize agronomy: Implemented on-station/on-farm research program exploring manipulation of agronomic variables to improve production at ~2-4 sites (PC)	-A series of on-farm trials (8 in total) were conducted in Oebola, Usapinonot, Ulupulu and Wolomasi between 2007 and 2011 investigating aspects of the integration of forage legumes into cereal systems (maize and rice). The majority were successful although 3 in Flores were affected by wet seasonal conditions.
		Maize agronomy: Completion of data analysis for all sites, systems simulation and communication of 'best bet' options to collaborators (PC)	-Analysis of research results of maize agronomy program were communicated to collaborators and stakeholders as part of routine visits and annual workshops conducted in West Timor and Flores. Results showed small biomass and yield responses to improved N supply from legume N fixation. Sites in Flores were affected by high in-crop rainfall.
1.3	The piloting and assessment of forage legume utilisation across a range of farming systems and geographic and agro-ecological regions	4-6 village pilot/demonstration sites identified through survey and interaction with collaborators (3.1) (PC)	-2006-09: 11 legume demonstration sites representing the agro-climatological regions of West Timor were identified in collaboration with farmers and extension agencies. -2009-11: 6 legume demonstration sites in Flores were identified in collaboration with farmers and extension agencies representing a range of agro-ecological zones.
		4-6 pilot/demo sites showcasing the use of forage legumes in particular farming systems established (PC)	-Six sites were established to demonstrate the potential for the legumes to be grown in relay and rotation with maize (all sites), upland rice (2) or irrigated lowland rice (1). The majority of trials ran for one legume/cropping cycle of 2 years although sites at Ulupulu and Wolomasi were affected by high rainfall.
		Agronomic data analysed for all sites and results communicated to collaborating and regional farmers and extension agents (PC)	-Results of systems research were communicated to collaborators and stakeholders as part of routine visits and annual workshops conducted in West Timor and Flores. -Well managed rainfed legume crops yielded between 1.5 and 11 t/ha (overall dry season production) DM, and supplementary irrigated crops 9-11 t/ha DM. -The response of subsequent cereal crops to improved N supply varied between nil to 1.7 t/ha (increased grain) depending on the proportion of leaf litter returned to the system (the more litter, the higher the yield increase). -Failures in legume production occurred at 5-6 sites due to variability in rainfall (both too much and too little), disease, insect attack and sub-optimal management.
1.4	Development of a sustainable seed multiplication capability to ensure on-going support of forage legumes expansion within the province	Strategy for the multiplication of seed at the village and small business levels developed and implemented (PC/A)	- 2006-09: Substantial larger scale (~3-6 ha) on-farm seed increase was undertaken in the bi-modal region of Belu and at Oebola, Kupang. This was supported by small-scale production in collaborating villages. -2009-12: A review of seed multiplication capability was undertaken in 2009 which led to more efficient village-based seed production and improved training of research and extension staff in seed production. This has resulted in marked increases in seed supply for the 3 main legume species with a total of 254 kg being produced in 2011/12.
		Seed sourced, imported and available for use in pilot/demo trials (PC/A)	-2006-09: Seed of identified species was imported from Australia in 2006 to support initial legume evaluation and trial work. -2009-12: As a result of the desire to increase the number of legumes under evaluation, small quantities of seed were imported for testing, with self sufficiency for short-listed species subsequently achieved.

		2-3 farmer collaborators trained in seed multiplication, cleaning and processing in each of the 4-6 pilot/demo villages. Sale of seed to other farmers commenced (PC/A)	-2006-09: Training focussed on farmer collaborators in Belu and Kupang regencies who developed larger seed increase areas with support from project staff and Dinas. The majority of produced seed was used by the project and for trialling by extension agencies. -2009-11: Training focussed on farmer group members in each village and was based on the use of a plant trellising system which improved seed yield and efficiency of harvest. Because the seed produced on the trellises was a communal resource, no seed was sold, however areas of forage production increased in villages where this occurred e.g. Marapokot and Ulupulu.
		2-3 small business collaborators supported in larger scale seed multiplication, cleaning and processing (training and financial support). Seed now available for sale to extension agencies and farmers (PC)	-As there has been insufficient market pull to attract small business investment in seed production all seed increase has been conducted within the project or by extension agencies such as Dinas, BAPPEDA and NGOs. -2007-12: Smaller scale seed increase has been conducted by Dinas Belu with seed used to develop pastures for the Dinas cattle herd and small quantities provided to farmers to trial on their own farms. While the original Dinas aim was to encourage farmers to grow legumes as part of an animal provisioning scheme, there has been no evidence of this occurring. -2009-12: Capacity development has been increased by the training of 6 Dinas, BAPPEDA and BPTP staff in seed production as part of a Crawford Fund training scholarship (Australia 2010). This has increased seed availability in the province with significant quantities being produced and used to support extension and research activities. A seed market which is mostly related to agency demand is developing. Seed prices have increased to a similar level to what is being offered for pulses such as mungbean. This has made seed increase a more attractive option than in the early years when prices were too low.

PC = partner country, A = Australia

Objective 2: To assess the value of forage legumes to contribute to animal production through the supply of high quality forages for use during the dry season

No	Activity	Outputs/ milestones	Comments
2.1	Identification of farming systems in which there is potential for forage legumes to contribute to livestock enterprises	Strategic & operational planning completed for Objective 2 with plans available for use by the project team (PC/A)	-Strategic planning was undertaken at the commencement of the project and reviewed through annual meetings with partners -Operational plans and research protocols for each experiment were developed annually
		Short list of regions and villages that meet criteria of animal ownership identified (based on surveys conducted in 3.1) (PC)	- 2006-09: During initial collaborator identification, villages were selected on their interest more than their need. 8 villages were initially selected with 3 ceasing engagement over the life of the project. -2009-12: The criteria used to select villages during the project expansion into Flores were modified based on earlier learnings and included the requirement for a high level of animal ownership, interest in animal production (as opposed to keeping), a need for improved feed supply and a well established farmer group with good management. Based on these criteria, 5 villages were identified initially in 2009 with the number being later expanded to 9.

2.2	The piloting and assessment of forage legume utilisation across a range of farming systems and geographic and agro-ecological regions which have animals as a major component	4-6 village pilot/demonstration sites with an animal component identified from shortlist in 2.1 (PC)	The sites selected represented agro-ecological regions differentiated predominately by rainfall, seasonality and elevation. -2006-12_West Timor: 8 villages were initially identified with an interest in animal production and project involvement. While 3 villages ceased engagement others became involved over time resulting in a total of 14 villages having involvement with the project. -2009-12_Flores: In 2009 5 villages were identified which met the animal production selection criteria. Cattle were the animal of choice in 4 villages, with goats in the other 1. Engagement later expanded to 9 villages/SMKs although not all owned animals. 1 village ceased engagement during this time.
		Feeding trials established at the pilot/demo sites to showcase the benefits of forages to animal production (cattle, goats) Data analysed and results communicated to collaborating and regional farmers, researchers and extension agents (PC)	-2006-09: Cattle feeding trials were established at Usapinonot and Oebola to compare the tether grazing of native forages to weaner cattle with legume supplementation. At Usapinonot young cattle (~70 kg live weight) supplemented for 320 days gained weight at a rate 1.7 times higher than for those fed native forages, with the largest difference occurring in the late dry and early wet seasons when supplemented animals gained at a rate of 220 g/head.day compared to the loss of 65 g/head.day for animals fed native forages. In comparison, animals fed leucaena gained at a rate of 308 g/head.day, a rate 2.2 times higher than for native forages. Tethered animals at Oebola actually gained weight at a faster rate than the legume interventions because of the presence of a naturalised legume which was available to the grazing animals. -2010: A cattle feeding trial at Marapokot, Flores (in collaboration with Dinas and managed by the farmer group) compared supplementation with *Centro pascuorum* and *Clitoria ternatea* to the feeding of local grass and legume forages. Animals supplemented with the introduced legumes gained weight at a daily rate between 446 and 525g, whereas animals fed on local grasses and legumes gained weight at a rate of 350-400 g/day. -2010: Goats fed for 60 days on sole *Centro pascuorum* or *Clitoria ternatea* at Ulupulu, Flores gained 58 and 33 g/day respectively whilst those fed on local grasses lost 33g over the same period. -Results of animal production research were communicated to collaborators and stakeholders as part of routine visits and annual workshops conducted in West Timor and Flores.

PC = partner country, A = Australia

Objective 3: To apply socio-economic information contributed by participating farmers to determine technology acceptability, potential broader impacts and extension strategies.

No	Activity	Outputs/ milestones	Comments
3.1	Utilise existing knowledge of the drivers of forage legume adoption and the experience of national agencies to identify farming systems and situations suitable for legume intervention	Strategic & operational planning completed for Objective 3 with plans available for use by the project team (PC/A)	-Strategic planning was undertaken at the commencement of the project and reviewed annually at operational planning meetings with partners. -Operational plans and research protocols for each experiment were developed annually.

		Potential geographic/agro-climatological regions for piloting of legume technologies short listed (PC)	-2006-09: Discussions were conducted between partners and collaborators to develop an understanding of the main geographic and agro-ecological regions in West Timor that were to be represented in the agricultural research. -2009-11: A similar process was used in selecting sites in Flores although more emphasis was placed on the identification of regions where animal and crop integration was an important component of the farming system.
		Organisational surveys and data analyses completed, recommendations made on regions, systems and villages for pilot/demo activity (PC)	-2006-09: Social evaluation was conducted to assess suitability of the villages nominally selected for collaboration (Dec 2009). This resulted in the selection of sites in Kupang regency (Sillu, later replaced by Oebola), TTS (Biloto and later Soe SMK), TTU (Usapinonot and Lapeom) and Belu (Kakaniuk and Kletek). These sites represented environments from the coastal lowlands to the uplands with sites located on the 3 main agricultural soil types (Vertisol, Alfisol and Inceptisol). Both uni- and bi-modal rainfall systems were represented. -2009-11 Flores: Based on expert knowledge (from BPTP, Dinas, BAPPEDA and NGO-YMTM), districts were identified that represented a range of agro ecological environments. Villages were then visited and an assessment made of their suitability based on criteria including the level of animal ownership, interest in animal production (as opposed to 'keeping' mentality), the need for improved feed supply and the strength of the farmer group.
3.2	Undertake benchmarking and longitudinal evaluation with project participants to gain an increased understanding of the drivers of technology adoption and the opportunities and risks associated with the introduction of forage legumes	Benchmarking surveys undertaken in 4-6 selected focus villages where pilot/demo sites are planned (PC)	-2006-09: Benchmarking surveys relating to current farmer practice and the social systems supporting farmer livelihoods were undertaken by project social scientists (Indonesian and Australian) in each of the 6 selected villages (Oct 2006). -2009-11: Benchmarking surveys were undertaken by BPTP agriculture researches in collaboration with a UNDANA social scientist (Dec 2009) in prospective villages in Nagekeo and Ende districts of Flores.
		Longitudinal surveys undertaken in 4-6 focus villages where pilot/demo sites located (PC)	2006-09: July 2006: A longitudinal survey involving 39 interviews with 99 participants from all 6 collaborating villages was undertaken in West Timor (included farmers, local govt officials, project researchers and extension personnel). 2009-12: -April 2010: This survey targeted farmers and govt officials in Tobu, TTS and Kapitanmeo, Belu, where adoption of legumes was particularly high at the time of survey. 12 interviews were conducted in each village. -July 2010: Longitudinal survey done in Flores and West Timor to gauge project impact. 67 individuals (31 in West Timor and 36 in Flores) were interviewed individually or as part of 13 separate community groups or organisations.
		Data analysis completed and results used in developing future extension strategies (PC)	-Data analysis was undertaken at the completion of each of the surveys. Internal reports were provided to the project to assist in developing future plans and direction.

3.3	Use benchmarking and longitudinal evaluation to obtain feedback on progress and process to improve project activity and outputs	Longitudinal surveys (2.2) inform on project progress, direction and need for change. Changes implemented where required (PC)	-Benchmarking and longitudinal data was used to inform on both project direction and process. An example of this is the decision to trial the use of legumes in rotation with cereal crops-this suggestion came from farmers through interview. -Insights gained through the surveys also helped to develop the criteria used in the selection of farming communities in the second phase of project work (2009-11)
3.4	Develop knowledge, skills and capacity within the farming and extension communities to ensure longer term expansion of forage legume technologies across ENT	Strategy for the communication of research results to farmers, extension agents and policy makers developed and implemented. (PC/A)	-Results of social science research activities formed part of communication to collaborators and stakeholders during routine visits and annual workshops conducted in West Timor and Flores.
		Extension materials (tech notes/posters) on forage legumes developed and distributed to extension agencies (PC/A)	-A series of 6 posters providing farmers and extension staff an overview of legume integration into the traditional farming system, N fixation, the identification of legumes and their contribution to animal production were produced and distributed to farmer groups in collaborating villages in West Timor (2007) and Flores (2010). -A 2010 calendar was produced showing components of the system (with local farmers depicted) and distributed to collaborating villages in Flores.
		Meetings held with the farmers and their extension agents in the 4-6 collaborating villages to communicate the goals and outcomes of the research (at least annually) Annual science updates conducted to inform researchers and extension organisations of research progress (PC)	-Routine visits (approx. monthly) were made to each collaborating farmer group to discuss research progress -Facilitated cross visits were made between villages to provide examples of successful adoption of a component of the system e.g. groups from Ulupulu and Nakuramba visited Marapokot (all Flores) to see how a successful feed lot was run and to discuss the use of legumes in feeding. This resulted in an expansion of cattle and goat numbers at Ulupulu and Nakuramba -Farmers were key participants in annual science update meetings held in Kupang, Ende and Mbay (generally ~30-60 research, extension personnel and farmers present). Farmers presented on their personal experiences with forages, formed part of discussion panels and were active in general discussion.
		Communication of research outcomes undertaken at the regional policy level to inform on the potential for the technologies to impact on food security and the livelihoods of individual farmers (1 event late Year 2) (PC)	-The key government planning authority, BAPPEDA, was actively involved in project activities in Ende, Flores, hosting science and planning meetings and receiving regular briefings on project activity and outcomes. -Dinas in both Flores and West Timor were actively involved in project meetings and activities with BPTP having occasional briefing meetings with the management of these organisations.

		Training activities completed for extension staff in forage legume use and seed multiplication (PC)	-Training of 6 Dinas, BAPPEDA and BPTP staff in seed production was undertaken at Walkamin, Queensland in July 2011. The Crawford Fund training scholarship was awarded to BPTP project staff and those from collaborating extension agencies that had expressed an interest in extending the use of forage legumes in animal production systems. -Training included the requirement for each individual, on return to Indonesia, to develop a plan for expansion of seed production in their district. This resulted in significant areas being developed and substantial seed being produced.
		Manual on the growing and use of forage legumes in eastern Indonesian farming systems written and distributed to extension agencies and farmers in ENT (PC/A)	-The manual "*Using forage legumes in crop and livestock systems of Eastern Indonesia*" is currently being published by ACIAR in both English and Bahasa Indonesia. -The manual is designed for use by use by researchers and extension staff tasked with the expansion of forage legumes in ENT and by students at both the high school and university levels. It will also have applicability in other regions and countries with similar environments and needs. -Authorship is shared across BPTP-NTT and Australian researchers with sections covering the use of legumes in cropping system and their impact on crop and animal production.
		Seed multiplication tech notes developed and distributed to extension agencies, farmers and small business (PC/A)	-Seed multiplication forms part of the manual "*Using forage legumes in crop and livestock systems of Eastern Indonesia*"
		3-4 scientific papers written on ENT forage-based farming systems for inclusion in journals and conference proceedings (PC/A)	-11 refereed conference papers, 2 technical manuals and 1 technical report have been produced by the project. Papers were presented at 7 national and international conferences by Indonesian and Australian researchers.

7 Key results and discussion

Research investigating the potential for forage legume-based technologies to improve farmer livelihoods, without substantially increasing production risk has been the focus of project activity. This has involved the investigation of aspects of the proposed system that fall under the three areas of:

a) The production of the legumes and their incorporation into the cereal-based farming system,
b) The feeding of the forages to animals
c) The development of an understanding of the social context in which small-holder farming takes place and where forage legumes might fit

This section discusses the key research findings from activities undertaken as part of achieving these overall objectives.

7.1 Identifying forage legumes for use in cereal-based farming systems

Legume species, which were compatible with the existing farming systems were essential to any planned modification. Section 5.5.1 provides a summary of the criteria used in the selection of legumes. Evaluation activities covered a range of agro-environmental conditions, firstly at the Naibonat Research Station, and subsequently at village-based sites in West Timor (~20 months from the start of 2006 until the end of the 2007 dry season). Legumes identified during this period formed the basis of all farming systems research undertaken in West Timor until 2009. As a result of the expansion of the project to the island of Flores in 2009, it was considered appropriate to re-assess suitable species in the different agro-environmental conditions found on that island (2009-12).

7.1.1 West Timor – Initial species evaluation (2006)

Evaluation commenced at Naibonat with the planting of 10 species on a Vertisol soil in March 2006 (Table 4). Five of the 10 species successfully established and grew into the dry season using stored water to drive production (Figure 22). Flowering (50%) of the 5 species occurred between 49 and 63 days after sowing (DAS), with pod set occurring between 60 and 84 DAS (Table 9). The time to maximum biomass yield varied between species and ranged from 56 to 111 days. Legumes varied in season length with the annual species *Centrosema pascuorum* and *Macroptilium bracteatum* senescing in the mid-dry season while the short-term perennial plants, *Clitoria ternatea* and *Desmanthus pernambucanus* continued to grow through the dry season and into the following wet. Maximum biomass production of >3 t/ha DM was achieved with *Centrosema pascuorum*, *Desmanthus pernambucanus* and *Clitoria ternatea*. *Centrosema pascuorum* produced 3.3 t/ha in 84 days (Table 9 and Figure 23). Seed yields of >1 t/ha were achieved from *Centrosema pascuorum* and *Clitoria ternatea*.

Table 9: *Phenology, biomass and seed production of the top 5 legume species evaluated at Naibonat Research Station in 2006 dry season.*

Species	50% flowering (DAS)	50% pods (DAS)	Seed production (kg/ha)	Biomass production (kg/ha)
Aeschynomene americana	12 May (50)	22 May (60)	408	1150 (56DAS)
Centrosema pascuorum	11 May (49)	31 May (69)	1389	3300 (84DAS)
Clitoria ternatea	11 May (49)	8 Jun (77)	1131	3060 (111DAS)
Desmanthus pernambucanus	25 May (63)	15 Jun (84)	373	4400 (111DAS)
Macroptilium bracteatum	18 May (56)	25 May (63)	496	1080 (84DAS)

Figure 22: *Growth of a)* Centrosema pascuorum *and b)* Clitoria ternatea *60 DAS at Naibonat in May 2006*

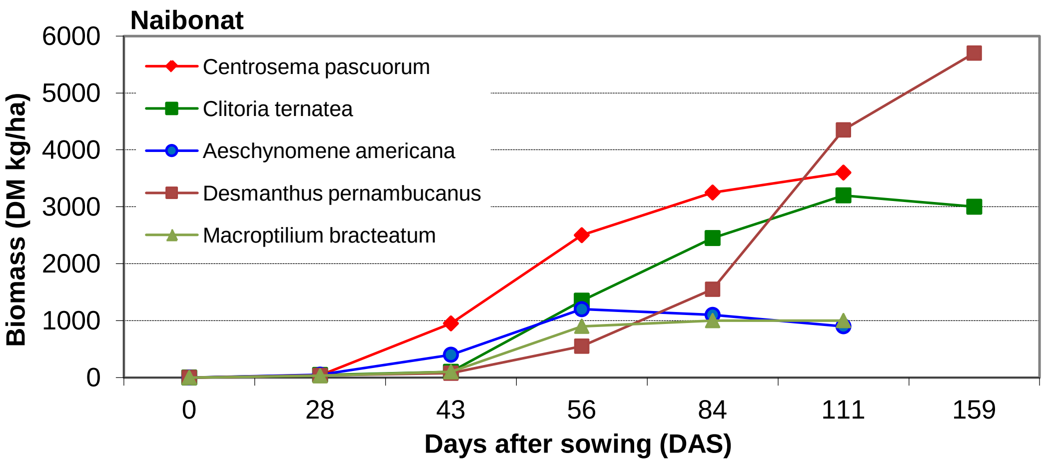


Figure 23: *Legume biomass production during the 2006 dry season from sowing (23rd March) to 159 DAS. Graph shows the total biomass present at each harvest point.*

The farmers perspective

Social evaluation was undertaken to gain insight into whether farmers saw value and applicability in using forage legumes as a component of their maize cropping systems. Twenty six farmers visited the research site (at 76 DAS) with 20 completing a questionnaire relating to the use of forage legumes. Table 10 shows that the legumes producing the most biomass were preferred by farmers with the 2 top-ranked species being selected for planting by 65% of farmers. Farmers indicated that they were impressed by the fast growth rates of the top legumes and their potential as animal feed. They also considered that these particular legumes would be effective in water erosion control.

Table 10: *Farmer ranking of growth performance (where 1 represents the best and 8 the poorest performance) and sowing preference for the top 5 legumes.*

Species	Growth performance rank by farmers	Sowing preference (% of farmers)
Clitoria ternatea	1	40
Centrosema. pascuorum	2	25
Aeschynomene americana	3	20
Desmanthus pernambucanus	4	10
Macroptilium bracteatum	5	5

When asked how they would use the legumes in their farming system, the farmers responded in the following order, (1) planted after maize, (2) alley cropping with maize, mungbean, peanut and forage legumes, (3) as a hedge adjacent to maize, (4) a rotation of maize and beans in the first year followed by forage crops in the second year, and (5) relay cropping with maize.

Outcomes of research

Forage legumes, sown in March on a Vertisol soil with high water holding capacity, provide the opportunity to produce quantities of biomass for dry season animal feeding. The most promising legumes, from both an agronomic and farmer preference perspective, were *Centrosema pascuorum* and *Clitoria ternatea*. Both were able to produce high levels of biomass and were well regarded by the farmers. While *Desmanthus pernambucanus* had the potential to produce good quantities of biomass for mid to late dry season feeding, the plants tall stature made it unattractive for use in relay with maize. *Aeschynomene Americana, Macroptilium bracteatum*, *Stylosanthes hamata* and *Macroptilium triloba* were not well adapted to the heavy clay soils, nor the wet conditions and did not produce competitive levels of biomass. Importantly, both *Centrosema pascuorum* and *Clitoria ternatea* were also able to produce substantial quantities of seed which was comparatively easy to hand harvest, important considerations for successful legume adoption. *Centrosema pascuorum* and *Clitoria ternatea* were selected for village-based species evaluation

7.1.2 West Timor – village-based species evaluation (2006-07)

In the following season (2006-07) replicated evaluation trials were established at 5 village sites representing a range of West Timor environments differentiated by elevation and rainfall pattern (Table 2; Figure 18). The 2006 short-listed species and others considered to have potential were evaluated using similar criteria to the previous year. Legume species varied between locations, selected on soil type and environment (Table 4). Table 11 provides an overview of mean biomass production over time at the 4 sites at which experiments were successfully concluded. The fifth site, located on an alfisol soil at Sillu, failed due to poor legume establishment and crop management.

Seasonal legume biomass production for crops grown at 3 of the sites is shown in Figure 24. This figure provides some insight into the differences in physiological response of legumes to the environmental conditions, particularly in terms of establishment and early biomass production. Whilst some species grew quickly e.g. *Centrosema pascuorum*, others, such as the *Stylosanthes spp.* were slow to develop, not producing significant biomass at 3 of the sites until >90 DAS.

Again, *Centrosema pascuorum* and *Clitoria ternatea* showed that they were well suited to a range of environments with *Centrosema pascuorum* achieving yields of between 2.4 and 3.5 t/ha DM in ~90 days at 3 sites. It then continued to produce biomass to ~150 DAS at 2 of the sites before senescing as available water reserves were exhausted. At Usapinonot however, it continued to grow, producing 4.4 t/ha DM in 197 days. *Clitoria ternatea* produced an average of 3.25 t/ha DM in 94 days at Biloto, with the highest yield (4.2 t/ha DM) achieved at Kakaniuk in 209 days; the bi-modal rainfall at this site favoured the short-duration-perennial species (Figure 24 and Table 11). In 2009, the potential for *Clitoria ternatea* to survive the dry season and to produce significant quantities of biomass, during and after the subsequent wet season, was put to the test at Biloto, a uni-modal site. An additional 2.7 t/ha of DM was harvested in April of the following year i.e. 14 months after planting.

Table 11: *Summary of biomass production (t/ha) for the suite of legume grown at 4 locations in West Timor. Legumes were planted in February 2007 (uni-modal) and March/April (bi-modal). Biomass (DM kg/ha) was harvested and recorded for each harvest point.*

Legume species	Usapinonot (uni-modal)			Biloto (uni-modal)			Kletek (bi-modal)			Kakaniuk (bi-modal)		
	Harvest Timing (DAS)											
	84	153	197	94	150	197	90	155	205	90	140	209
	Biomass yield (t/ha DM)											
Centrosema pascuorum	2.70	2.93	4.40	3.51	2.88		0.86	1.62		2.44	3.27	
Clitoria ternatea	1.31	2.05	2.31	3.25	3.05	3.80	0.81	1.93	3.48	2.38	2.86	4.17
Desmanthus pernambucanus	0.89	2.61	4.16	0.00	0.47		0.43	1.09	2.41	0.83	1.79	7.10
Desmanthus virgatus	0.51	0.40	1.60	0.88	0.08		0.28	0.49	1.98	1.50	1.17	2.17
Lablab purpureus		1.40		4.25				1.42				
Macroptilium bracteatum	0.26	1.36	2.22	1.50	1.76	4.95	1.81	2.23	3.05	0.65	0.96	4.85
Stylosanthes guianensis	0.75	2.14	4.61	1.36	2.32	6.48	0.05	1.28	3.09	0.05	0.39	3.92
Stylosanthes seabrana	0.23	3.50	5.90	1.93	4.02	9.80	0.26	4.08	5.05	0.54	2.65	7.87

While *Macroptilium bracteatum* produced high yields of between 2.2 and 5 t/ha DM, it was not selected for further evaluation because of poor germination and uneven plant stand which resulted in weed incursion. The twining habit of this legume was also considered by farmers to make it less acceptable for use a relay in a cereal cropping system due to concerns that it may affect cereal yield. However, in 2010, it was again included in evaluation studies at Naibonat, Kupang and established well and yielded >5 t/ha DM.

Lablab purpureus is already used in ENT as a dual purpose crop for human and animal consumption. Yields of between 1.4 and 4.3 t/ha DM were recorded in a period from 94 to153 days before exhaustion of soil water and onset of crop senescence. It was considered that this annual plant had potential for relay cropping as it was unlikely to impact significantly on the cereal crop and would not be a potential weed in the system.

The highest yielding legume was *Stylosanthes seabrana* which was slow to establish and did not produce significant biomass until after 90 DAS. This deep rooted perennial legume then took advantage of deep placed soil water and continued to grow through the late dry and subsequent wet seasons (as did *S. guianensis*). Figure 24 and Table 11 show that both *Stylosanthes spp.* yielded well at all sites, although care needs to be taken in interpreting the data as more mature plants of both species have a high proportion of woody stem which is unpalatable to animals. To achieve optimal production of palatable feed from these plants requires regular cutting so as to maintain a higher leaf to stem ratio. Farmers who observed the *Stylosanthes spp.* considered them unsuitable for direct inclusion in a cereal-based farming system due to their perenniality, plant height, slow establishment and woodiness.

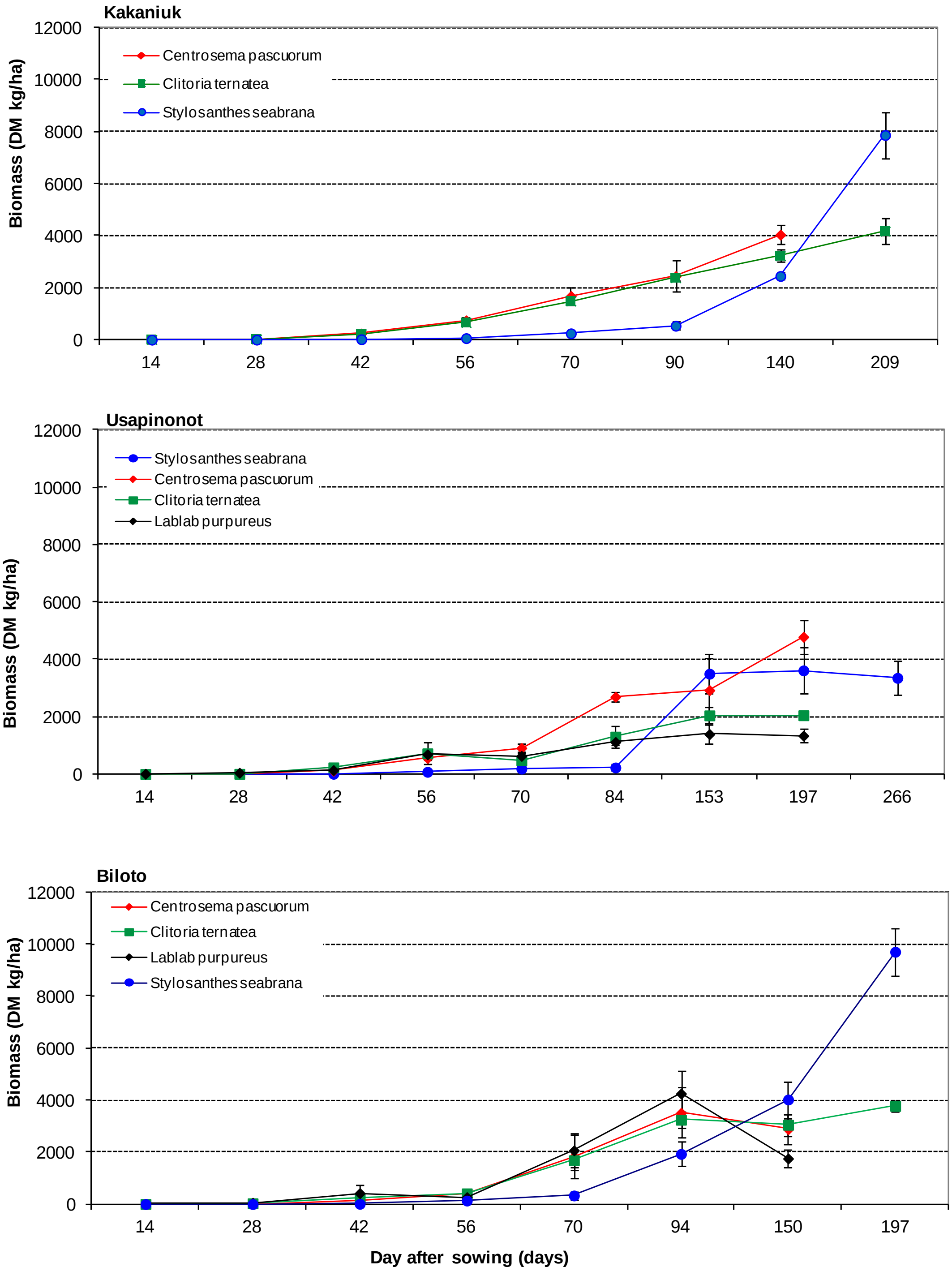


Figure 24: *Legume biomass (kg/ha) production during the 2007 dry season from a February plant at Usapinonot (TTU; 360 m ASL) and Biloto (TTS; 560 m ASL) and an April plant at the bi-modal site, Kakaniuk (Belu; 48 m ASL). All sites were on Inceptisol soils.*

Table 11 shows that some of the other legumes achieved quite high yields at particular sites. *Desmanthus pernambucanus*, for example yielded 4.2 t/ha DM at Usapinonot and 7.1 t/ha DM at Kakaniuk. These species were excluded from future research based on farmer/researcher evaluation which considered them inappropriate for use in a cropping system. The five legumes, *Desmanthus pernambucanus, Desmanthus virgatus, Macroptilium bracteatum, Stylosanthes guianensis and Stylosanthes seabrana* all fall into this grouping.

Outcomes of early legume evaluation research

Legume evaluation at the 5 sites showed that almost all of the species selected had potential for production in the environments of West Timor. Some however, were not considered appropriate for use within cereal based systems. Three species (*Centrosema pascuorum*, *Clitoria ternatea* and *Lablab purpureus*) were considered by farmers as being appropriate and included in farming systems trials which commenced in 2008/09.

7.1.3 West Timor and Flores–species evaluation (Naibonat and Soe 2009-11)

The sowing of the replicated West Timor experiments at Naibonat (sown 12/3/10) and SMK Soe (31/3-6/4/10) was delayed because of difficulty importing seeds from Australia and dry conditions during February/March. At Naibonat (vertisol, lowland), all legumes except the two *Colletotrichum* resistant *Stylosanthes guianensis* and Arafura cowpea (*Vigna unguiculata*) grew well. The *Stylosanthes* lines were yellow and stunted, possibly due to poor nodulation and the cowpea succumbed rapidly to leaf diseases beginning in April. The *Macroptilium gracile* was slow to establish. Once established the other legumes grew vigorously until flowering and the production of green and mature pods (Table 4). Most were tolerant of insect damage. However, leaf chewing insects were moderately damaging to *Clitoria ternatea,* some *Lablab purpureus* and *Vigna luteola* (Table 12a). The legumes exhibited varying capacities to regrow after seed production and cutting, the best being *Centrosema molle*, *Clitoria ternatea*, *Lablab purpureus* CQ3620, *Macroptilium bracteatum* and *Vigna luteola* (Table 12b). All regrew after cutting in January 2011 and underwent reproductive development. Insect damage was again noted in *Clitoria ternatea* and *Vigna luteola*, although this did not kill plants.

Plant growth at Soe (alfisol, upland) was poor overall (Table 13). Most legumes established successfully although plant populations were low in *Centrosema pascuorum*, Q5455 *Clitoria ternatea* and Dalrymple *Vigna luteola*. Most of the legumes succumbed to an unidentified disease, presumed soil-born, which coincided with a cool, drizzly period during June and July 2010. The cowpea was affected by disease, as it had at Naibonat, and grew poorly from the onset. Most legumes died out by October. The notable exception was the *Centrosema molle* which maintained vegetative growth until the end of the dry season. Some of the same legumes, badly affected on the red soil (alfisol), were apparently unaffected in nearby (200 m away) seed increase crops on vertisols, indicating that the effect could be a combination of soil type and growing conditions.

Biomass production

Leaf and stem biomass was highest at Naibonat where growing conditions, soil type and management appeared well-suited to plant growth (Table 14). Overall, most legumes were considered to have grown well under minimal management (no fertiliser, or pest or disease control) and hot and dry conditions. Total biomass, measured every 8 weeks after sowing (during May, July and September), varied considerably between legumes, and there appeared three distinct groups:

1. Early biomass types – *Centrosema pascuorum, Lablab purpureus* (annual types) and *Mucuna pruriens*. These had highest biomass values (5-8 t/ha DM) after 16 weeks, declining thereafter as growth slowed and leaves senesced. The annual-type lablabs and *Mucuna pruriens* showed poor persistence into the second year.
2. Late biomass types – *Centrosema molle, Clitoria ternatea, '*perennial' *Lablab purpureus*, *Macroptilium bracteatum* and *Vigna luteola*. These continued to grow over the dry

season producing highest biomass 24 weeks after sowing. Maximum biomass was in the order of 5-6 t/ha DM. Most of these showed the capacity to continue growth into a second season.

3. Low biomass types – low biomass yields were recorded for *Macroptilium gracile* (slow establishment), *Vigna unguiculata* (disease-affected) and *Stylosanthes guianensis* (possibly poor nitrogen fixation).

Table 12: *Development of legumes grown in replicated plots at Naibonat, West Timor, 2010-2011.*

a) 2010	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**
Centrosema molle (Cardillo)/CM	S		T		F	G,M	M		reshooting
Centrosema pascuorum (Bundey)/CP1	S		T	F	G,M	G,M			new plants
Centrosema pascuorum (Cavalcade)/CP2	S		T	F	G,M	G,M			new plants
Clitoria ternatea (Q5455/NT3364)/CT1	S		T	F,G,I	F,G,M	F,G,M	G,M	F,G,M	reshooting
Clitoria ternatea (Milgara)/CT2	S		T	G,I	F,G,M	F,G,M	G,M	F,G,M	reshooting
Lab-lab purpureus (CQ3620)/LP1	S		T		F,G	G,M	M	F,G,M	reshooting
Lab-lab purpureus (Endurance)/LP2	S		T	F	G,M	M	M		reshooting
Lab-lab purpreus (Highworth)/LP3	S		T	G,I	G,M	M	M		reshooting
Lab-lab purpureus (Rongai)/LP4	S		T	I	F,G	G,M	M		reshooting
Macroptilium gracile (Maldonado)/MG	S		T	F	G,M	M			
Macroptilium bracteatum (Cardaarga)/MB1	S		T	G	G,M	G,M		G,M	reshooting
Macroptilium bracteatum (Juanita)/MB2	S		T	G	G,M	G,M		G,M	reshooting
Mucuna pruriens (NT7617 CPI86105)/MP	S		T	F	G,M	G,M			new plants
Stylosanthes guianensis (ATF3308)/SG1	S	S		poor vigour (yellow)					no growth
Stylosanthes guianensis (ATF3309)/SG2	S	S		poor vigour (yellow)					no growth
Vigna luteola (Dalrymple)/VL	S		T	F,I	G,M	G,M		G,M	reshooting
Vigna unguiculata (Arafura)/VU	S	F	G,M	M,I,D					

S = sown; I = insect; D = disease: T = trellis
F = flowering; G/M = green/mature pods healthy unhealthy harvest dead

b) 2011	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**
Centrosema molle (Cardillo)/CM	C (11/1),T		I			F	G,M
Centrosema pascuorum (Bundey)/CP1	C (11/1),T			F	F,G	F,G	G,M
Centrosema pascuorum (Cavalcade)/CP2	C (11/1),T			F	F,G	F,G	G,M
Clitoria ternatea (Q5455/NT3364)/CT1	C (11/1),T	F	F,G,I	F,G,M	F,G,M,I	F,G,M,I	F
Clitoria ternatea (Milgara)/CT2	C (11/1),T	F	F,G,I	F,G,M	F,G,M,I	F,G,M,I	F
Vigna luteola (Dalrymple)/VL	C (11/1),T			F	F,G	F,G	I,G,M
Macroptilium bracteatum (Cardaarga)/MB1	C (11/1),T		F,G				
Macroptilium bracteatum (Juanita)/MB2	C (11/1),T		F,G,M,I				

C = cut; I = insect; D = disease: T = trellis
F = flowering; G/M = green/mature pods healthy unhealthy harvest dead

Table 13: *Development of legumes grown in replicated plots at Soe, West Timor, 2010.*

Soe 2010	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**
Centrosema molle (Cardillo)/CM	S,T							
Centrosema pascuorum (Bundey)/CP1	S,T							
Centrosema pascuorum (Cavalcade)/CP2	S,T		F					
Clitoria ternatea (Q5455/NT3364)/CT1	S,T		F					
Clitoria ternatea (Milgara)/CT2	S,T		F					
Lab-lab purpureus (Endurance)/LP2	S,T							
Lab-lab purpreus (Highworth)/LP3	S,T							
Lab-lab purpureus (Rongai)/LP4	S,T							
Macroptilium bracteatum (Cardaarga)/MB1	S,T	F	G		many plants died, slow growing			
Macroptilium bracteatum (Juanita)/MB2	S,T	F	G		many plants died, slow growing			
Vigna luteola (Dalrymple)/VL	S,T		I					
Vigna unguiculata (Arafura)/VU	S,T	F	G,I,D					

S = sown; I = insect; D = disease: T = trellis
F = flowering; G/M = green/mature pods healthy unhealthy harvest dead

Table 14: *Cumulative biomass (t/ha) of legumes grown at Naibonat, West Timor and sown on 12/3/10.*

Species	**Variety**	**Plant biomass (t/ha DM)**		
		12/5/10	**14/7/10**	**15/9/10**
Centrosema molle	Cardillo	0.74	2.07	5.83
Centrosema pascuorum	Bundey	2.29	7.24	6.61
Centrosema pascuorum	Cavalcade	3.04	7.95	4.32
Clitoria ternatea	Q5455	2.10	3.23	5.48
Clitoria ternatea	Milgarra	2.41	3.85	5.20
Lablab purpureus	CQ3620	4.45	4.62	6.73
Lablab purpureus	Endurance	2.62	2.91	3.92
Lablab purpureus	Highworth	3.24	4.90	3.84
Lablab purpureus	Rongai	3.58	3.86	5.90
Macroptilium gracile	Maldonado	0.99	1.96	2.32
Macroptilium bracteatum	Cardaarga	4.00	5.34	4.91
Macroptilium bracteatum	Juanita	3.28	5.45	5.89
Mucuna pruriens	CPI86105	3.54	7.52	3.29
Vigna luteola	Dalrymple	1.83	3.37	4.97
Vigna unguiculata	Arafura	2.09	2.98	1.93
LSD (P=0.05)		0.87	1.40	1.78

The identification of early and late biomass types is considered useful for developing crop/fodder systems in ENT. The early biomass types could, for example, be useful in short crop-rotations and relays in areas with short wet seasons, whereas the late biomass types could be better suited to areas with more extended wet seasons or bimodal rainfall patterns. The biomass produced by most of the legumes (over 5 t/ha DM), indicates the legumes could contribute considerably to livestock production and contribute appreciable amounts of nitrogen to the soil if used as a green manure.

Second year biomass at Naibonat site was only recorded for legumes which did not hay off and mostly die after seed harvest during September-October. Regrowth eight weeks after cutting ranged from 0.8 to 4.3 t/ha DM depending on the legume and time of cutting (Table 15). The experiment confirmed the capacity for *Centrosema molle, Centrosema pascuorum* and *Clitoria ternatea* to persist into the second growing season under cutting in ENT, and emphasised the value of *Centrosema pascuorum* for biomass production.

Low biomass values were recorded at Soe (data not presented), reflecting poor growth and disease damage, with only annual type *Lablab purpureus* (Rongai, Highworth) producing more than 1.5 t/ha DM. *Centrosema molle*, the only legume to tolerate the disease pressure and survive until the end of the season, grew slowly, but produced only 1 t/ha DM by the end of the year. The experiments confirmed the value of *Clitoria ternatea*, *Centrosema pascuorum* and *Lablab purpureus* for crop/livestock systems in ENT, but also demonstrated some limitations due to insect damage and poor adaptation to some environments (alfisols at Soe). It was considered there was merit in further evaluating some new legumes for relay and rotation systems in ENT. These were late biomass types and included, Bundey *Centrosema pascuorum,* which appeared to have a longer growing season than Cavalcade, Macroptilium *bracteatum*, particularly Juanita, Dalrymple *Vigna luteola*, Cardillo *Centrosema molle* and CQ3620 *Lablab purpureus*.

Table 15: *Regrowth of five second-year legumes eight weeks after defoliation at Naibonat, 2011.*

Species	**Variety**	**Mean dry biomass (t/ha DM)**(*standard error*)		
		4/3/11	**4/5/11**	**3/7/11**
Centrosema molle	Cardillo	0.91 *(0.04)*	1.13 *(0.14)*	0.83 *(0.17)*
Centrosema pascuorum	Bundey	.745 *(0.128)*	2.77*(0.49)*	1.5 *(0.51)*
Centrosema pascuorum	Cavalcade	1.62 *(0.22)*	4.31 *(1.01)*	1.6 *(0.27)*
Clitoria ternatea	Q5455	1.91 *(0.10)*	2.07 *(0.15)*	1.27*(0.18)*
Clitoria ternatea	Milgarra	1.98 *(0.13)*	2.27 *(0.19)*	1.17 (*0.15)*

Reproductive development and seed production

The time until the onset of flowering at Naibonat varied between legumes (Figure 12), although death due to disease meant the onset of flowering of some legumes could not be measured at Soe (Figure 13). The two *Macroptilium bracteatum* cultivars were the earliest to flower (May 2010) and most of the others began to flower during June. Late flowering types included *Centrosema molle* (weak flowering) and two *Lablab purpureus*. Mature seed was produced between late July and October 2010. Seed was hand harvested between 9 September and 15 October as seeds matured. Flower or pod damaging insects (*Nezara* viridula and *Helicoverpa*) were observed, and caused considerable damage to *Lablab purpureus* as evidenced by shrivelled and chewed seeds. The other legumes were not badly affected by these pests.

The A-framed trellises (installed in May 2010) were readily colonised by *Centrosema molle*, *Clitoria ternatea*, *Lablab purpureus, Macroptilium bracteatum* and *Mucuna pruriens*, and it was speculated the increased canopy surface area contributed to useful seed yields. The sprawling/twining types, like *Centrosema pascuorum* and *Vigna luteola,* only covered trellises when lifted by hand onto them, whereupon they began to twine around vertical poles. For these species, it may be necessary to install trellises earlier to assist climbing. Some legumes, like *Centrosema molle*, did not cover the entire trellis, but wrapped tightly around vertical poles. A closer spacing of poles, to ~0.2-0.4 m apart, may have improved flowering and seed yield for these species.

Mean seed yields were highly variable between species (Table 16). Not surprisingly, the large seeded annual *Mucuna pruriens* produced the highest seed yield (over 2,000 kg/ha). Seed yields of the other large-seeded legume, *Lablab purpureus* were low (0-370 kg/ha) due to insect damage. Of the smaller-seeded legumes, the highest yields were achieved for *Clitoria ternatea* and Juanita *Macroptilium bracteatum (*around 450 kg/ha) with useful yields also achieved for *Centrosema pascuorum* (270-310 kg/ha) and Cardaarga *Macroptilium bracteatum* (180 kg/ha). Insect damage may have contributed to low yields of *Vigna luteola* (~100 kg/ha) and weak and late flowering resulted in very low yields of *Centrosema molle*.

Dried pod weights were measured to allow interpretation of expected seed yields from pod weight. These varied between species, but were typically 80-120% of the weight of cleaned and dried seed. It is reasonable, therefore to expect the final cleaned and dried seed yield to be 40-60% of the total dried weight of harvested material (seed-in-pod). The exceptions were Dalrymple *Vigna luteola*, which had a mean pod weight of only about 50% of the weight of dried and cleaned seed, and *Centrosema molle* which had a high proportion of pod (~200%) in harvested material.

Outcomes of research

Legumes were identified which were complimentary, or alternative, to the previously identified legumes, Milgarra *Clitoria ternatea*, Cavalcade *Centrosema pascuorum* and

Highworth *Lablab purpureus*. The new legumes include free-seeding types which have vigorous early season growth (*Mucuna pruriens* and *Lablab purpureus*) and growth which extends into the dry season (*Lablab purpureus* CQ3620, *Macroptilium bracteatum* (2) and *Vigna luteola)*. These all performed well on vertisols, a key soil type in ENT, in a lowland, coastal environment. *Centrosema molle* also showed promise because it was the only legume to survive wet conditions on red sandy loam (alfisol) soils in an upland environment. However, this legume flowered weakly in the first year and produced low seed yields.

Table 16: *Hand harvested seed yields of legumes grown at Naibonat, 2010.*

Species	**Variety**		**Seed (kg/ha)**	**Pod (kg/ha)**	**Total (kg/ha)**
Centrosema molle	Cardillo	Mean *(Std. err.)*	9 *(3)*	19 *(9)*	28 *(12)*
		Max. rep. yield	14	29	41
Centrosema pascuorum	Bundey	Mean *(Std. err.)*	314 *(145)*	258 *(134)*	572 *(279)*
		Max. rep. yield	585	516	1101
Centrosema pascuorum	Cavalcade	Mean *(Std. err.)*	271 *(55)*	212 *(34)*	480 *(85)*
		Max. rep. yield	358	246	594
Clitoria ternatea	Q5455	Mean *(Std. err.)*	445 *(63)*	521 *(89)*	966 *(152)*
		Max. rep. yield	572	697	1269
Clitoria ternatea	Milgarra	Mean *(Std. err.)*	479 *(63)*	556 *(109)*	1032 *(174)*
		Max. rep. yield	605	774	1379
Lablab purpureus	CQ3620	Mean *(Std. err.)*	235 *(21)*	271 *(59)*	505 *(80)*
		Max. rep. yield	256	330	586
Lablab purpreus	Highworth	Mean *(Std. err.)*	373 *(69)*	293 *(47)*	665 *(115)*
		Max. rep. yield	507	385	892
Lablab purpureus	Rongai	Mean *(Std. err.)*	28 *(12)*	31 *(15)*	42 *(11)*
		Max. rep. yield	51	59	60
Macroptilium gracile	Maldonado	Mean *(Std. err.)*	53 *(16)*	44 *(15)*	98 *(31)*
		Max. rep. yield	81	71	152
Macroptilium bracteatum	Cardaarga	Mean *(Std. err.)*	180 *(66)*	141 *(60)*	321 *(125)*
		Max. rep. yield	277	218	495
Macroptilium bracteatum	Juanita	Mean *(Std. err.)*	472 *(40)*	310 *(106)*	793 *(94)*
		Max. rep. yield	551	521	967
Mucuna pruriens	NT7617 CPI86105	Mean *(Std. err.)*	2133 *(126)*	1882 *(288)*	4015 *(414)*
		Max. rep. yield	2259	2169	4428
Vigna luteola	Dalrymple	Mean *(Std. err.)*	103 *(9)*	52 *(19)*	156 *(28)*
		Max. rep. yield	3	9	12

Note: It was difficult to ensure all seed was harvested from each plot, therefore the highest replicate yield for each legume is presented to help estimate seed yield potential.

7.1.4 West Timor and Flores–species evaluation (Naibonat, Soe and Flores sites 2011)

Replicated trials -West Timor

In a stark contrast to the previous year, the 2011 growing season was characterised by high rainfall, which resulted in prolonged flooding of the lowland Naibonat site (vertisol) a few weeks after sowing. This reduced establishment and most plots had to be re-sown during March. The legumes recovered relatively well and continued to grow until August, when seeds were hand-picked (two times) from plots where appreciable amounts of seeds were present (the experiment ended then with the return of the Australian project officer to Australia) (Figure 17). Flowering in *Centrosema pascuorum, Clitoria ternatea* and *Macroptilium bracteatum* were noticeably earlier than *Centrosema molle* (latest to flower in July), *Lablab purpureus* and *Vigna luteola*. Despite seed harvesting being completed prematurely, appreciable seed yields (~250 kg/ha) of *Clitoria ternatea* and *Macroptilium bracteatum* were achieved.

Legume growth in the March-sown trial at Soe (alfisol) was poor, and legumes may again have been affected by cool, wet weather on the red soil (data not presented). *Centrosema molle,* again, was the only legume to grow throughout the season. These plants had fully covered the plots, flowered and a small amount of seed harvested in August.

Figure 17: *Development of legumes sown on 22 January and grown in replicated plots at Naibonat, West Timor, 2011.*

2011	Mar	April	May	June	July	Aug	Seed (kg/ha)
Centrosema molle (Cardillo)/CM	S	T			F,G	G,M	0
Centrosema pascuorum (Bundey)/CP1	S	T	F	F,G	F,G	G,M	93
Centrosema pascuorum (Cavalcade)/CP2	S	T	F	F,G	F,G,M	M	100
Clitoria ternatea (Milgara)/CT2	S	F,T	F,I	F,G,I	F,G,I	G,M	292
Macroptilium bracteatum (Juanita)/MB2	S	T	F	F,G,M	F,G,M	M	272
Lablab purpureus CQ3620	S	T		F	F,G	G,M	19
Vigna luteola (Dalrymple)/VL	S	T	I	F,I	I,G,M	M	0

S = sown; I = insect; D = disease: T = trellis
F = flowering; G/M = green/mature pods

healthy | unhealthy | harvest | dead

Non-replicated evaluation sites on Flores

The four non-replicated demonstration sites on Flores were sown in late February 2011. Other planned sites were either not sown due to delays associated with wet weather (two sites on West Timor) or were flooded (one on Flores). Establishment of seed sown by 'dibbling' was excellent and early growth was vigorous. However, dry conditions from May slowed growth, particularly at the upland site at Ulupulu. Poor control of weeds at Wolomasi also resulted in poor growth later in the season.

Table 18: *Biomass production (70 DAS), and regrowth after cutting (above 5 cm height) (63 days later) of promising legume varieties established at Naibonat, West Timor in Feb 2011.*

Species	**Variety**	**Mean dry biomass (kg/ha)** (*standard error*)		
		4/05/2011	**3/07/2011**	**Total**
Centrosema molle	Cardillo	91 *(37)*	450 *(126)*	541
Centrosema pascuorum	Bundey	2250 *(330)*	1850 *(525)*	4100
Centrosema pascuorum	Cavalcade	3300 *(714)*	1600 *(525)*	4900
Clitoria ternatea	Milgarra	1850 *(661)*	1400 *(283)*	3250
Lablab purpureus	Q5455	1600 *(294)*	300 *(58)*	1900
Macroptilium bracteatum	Juanita	142 *(87)*	600 *(283)*	742
Vigna luteola	Dalrymple	1700 *(311)*	550 *(236)*	2250

Leaf and stem biomass production

Plant biomass for legumes grown on the replicated site at Naibonat, West Timor and non-replicated Flores sites are presented in Tables 18 and 19, respectively. Most of the flood-affected legumes at Naibonat recovered to produce acceptable amounts of dry biomass 70 DAS. The highest biomass was produced by Cavalcade *Centrosema pascuorum* (3.3 t/ha DM), while Bundey *Centrosema pascuorum*, Milgarra *Clitoria ternatea*, Q5455 *Lablab purpureus* and Dalrymple *Vigna luteola* also grew well (1.6-2.25 t/ha DM). Leaf damage caused by insects likely decreased biomass of *Clitoria ternatea* and *Vigna luteola*. Although healthy, the biomass of Cardillo *Centrosema molle* above 5 cm was low (<100 kg/ha). The *Macroptilium bracteatum* was worst affected by the flooding.

Table 19: *Cumulative leaf and stem biomass (above 5 cm height) of promising legume varieties established in Flores (Feb 2011).*

Site		***Centrosema molle* Cardillo**		***Centrosema pascuorum* Bundey**		***Clitoria ternatea* Milgarra**		***Macroptilium bracteatum* Juanita**	
		Mean dry biomass (kg/ha) (*standard error*)							
		8 wks	16 wks	8 wks	16 wks	8 wks	16 wks	8 wks	16 wks
Marapokot	Lowland vertisol	347 *(167)*						320 *(0)*	
Nakuramba	Upland loam	507 *(201)*	827 *(46)*			613 *(185)*		400 *(288)*	1360 *(720)*
Ulupulu	Upland vertisol	200 *(183)*	480 *(139)*					347 *(46)*	693 *(244)*
Wolomasi	Upland loam	373 *(167)*	747 *(122)*	347 *(122)*	1387 *(739)*	40 *(277)*	1627 *(1104)*		

Regrowth after cutting at Naibonat varied between legumes (Table 18). The highest yielding legumes (63 days after the May 2011 cut) were the 2 *Centrosema pascuorum* and the *Clitoria ternatea*. Legumes, which initially yielded poorly, but which substantially increased growth after cutting included *Centrosema molle* and *Macroptilium bracteatum*. The *Vigna luteola* and *Lablab purpureus* both produced comparatively lower biomass after cutting. Overall, the highest February-July 2011 biomass was produced by the two *Centrosema pascuorum* (4.1 and 4.9 t/ha DM) and *Clitoria ternatea* (3.25 t/ha DM). Lower biomass yields were achieved at the Flores sites, but the relative performance of the legumes was similar.

Outcomes of research

Although of shorter duration than desirable, the adaptation and cutting experiments conducted during 2011 provided some useful insights into the more promising legumes for ENT. Once again, the value of Cavalcade *Centrosema pascuorum* and Milgarra *Clitoria ternatea* in a low input system were highlighted, although insect damage to Milgarra was observed once again. Susceptibility to leaf damage by insects also seems to be a feature of *Vigna luteola.* Of the other legumes, Bundey *Centrosema pascuorum,* Juanita *Macroptilium bracteatum* and Cardillo *Centrosema molle* seem well adapted to a range of environments in ENT and have the capacity to regrow after cutting. Satisfactory seed production was demonstrated in all but Cardillo *Centrosema molle*, which flowered weakly and late in the season after a February sowing.

7.2 Developing a self sustaining seed increase capacity

7.2.1 Seed increase to support project activities (2009-11)

Seed crops were sown in Flores and West Timor, with particular emphasis on increasing seed production of Milgarra *Clitoria ternatea*, Cavalcade *Centrosema pascuorum* and Highworth *Lablab purpureus* (Table 20). As described above, the 2009-10 season was characterised by dry conditions during the normally wet summer, resulting in delayed or abandoned sowings, followed by a significant component of dry season rainfall in most regions. This enabled the harvest of late-season (June to November) seed crops on both islands where flowering responses allowed. Some crops succumbed to diseases during this time, particularly in upland areas (Tobu, West Timor). In 2010-11 seed increase was moved from BPTP Naibonat to nearby Lili, due to flooding. Significant June rainfall enabled further sowings in this environment and the use of irrigation enabled late season harvests under dry conditions. Seed crops on Flores were ripe for harvest during July-September, although some were damaged by a lack of moisture for crop maturation.

The methods used to establish and grow seed crops were influenced by site and size of the plot. Most village sites in Flores and West Timor (fewer) were established using dibbling into land prepared by hand cultivation or the use of glyphosate applied with a knapsack. Trellises were used for *Clitoria ternatea* and *Lablab purpureus* to increase seed yield in small areas. Larger-scale sites where ‘contract’ seed increase was undertaken (mostly on West Timor) included a higher use of glyphosate application and/or mechanical cultivation and row planting (although dibble planting was still favoured in some instances) and trellises were not used. Pests and diseases were not controlled and fertiliser was generally not applied. Harvesting was completed by hand-picking (all legumes) or using the cut, dry and thresh method (*Centrosema pascuorum*). With the exception of Lili, crops were not irrigated after establishment.

The seed crops generally established and grew well provided there was sufficient, but not excessive, rainfall. The *Catopsilia* caterpillar damaged some seed crops of *Clitoria ternatea* grown in West Timor. Accidental damage by grazing animals occurred at SMK Soe (cows) and Usapinonot (goats). Failure to control weeds also resulted in low yields or the abandonment of some crops (Wolomasi). The performance of the various species in these first two seasons were as follows:

***Clitoria ternatea* (Milgarra and Q5455)**
This proved to be a flexible species, highly suited to seed increase in ENT at both lowland and upland sites. Plant growth was vigorous and plants readily climbed trellises (including maize trellises) although seed crops could also be achieved without them. Flowering appeared insensitive to daylength, and seed crops were harvested during the mid- and late dry season. *Catopsilia* larvae were occasionally damaging to seed crops during April/May, particularly in areas of West Timor (Usapinonot was abandoned and yields at Oebola were significantly reduced). However, plants regrew if cut at this time and could form another seed crop provided there was sufficient soil moisture to do so. Hand-picking was typically conducted over 1-2 months as the crop progressively flowered and pods matured (without shattering). The highest seed yields were typically achieved when grown on trellises, with over 1 t/ha cleaned seed harvested on Flores in lowland and upland areas. Some crops regrew well to produce useful (680 kg/ha) second season seed yields.

Table 20: *Performance of seed crops grown in ENT 2009-11.*

Location	Site features[1]	*Centrosema molle* Cardillo	*Centrosema pascuorum* Cavalcade	*Centrosema pascuorum* Bundey	*Clitoria ternatea* Q5455	*Clitoria ternatea* Milgarra	*Lablab purpureus* Highworth	*Macroptilium bracteatum* Juanita	*Vigna luteola* Dalrymple
		Seed yield (kg cleaned seed/ha)[2] Harvest months, method[3]							
2009-2010									
Flores									
Marapokot1	L:V:E		160f A,hp			680t J-O,hp	1600t J-O,hp		
Ulupulu	U:V:E		360 ND,hp			1333t ND,hp			
Wolomasi	U:L:E		0w			0w			
West Timor									
SMK Soe	U:A:S		0d			0d			
SMK Soe	U:V:S		875 ON,ct			250t ON,hp			
Tobu 1	U:V:E		500 Oct			Low,ei	330ei SO,hp		
Tobu 2	U:V:E		360ed Ohp			320e SOhp			
Tobu 3	U:V:E		0ed			0ted			
Usapinonot	U:V:S					0ti			
2010-11									
Flores									
Marapokot1	L:V:E		0r			680t JlA,hp	?t Jl,hp		
Oasis Ende	L:L:E		0r			300 D-F,hp			
Wolomasi	U:L:E	0w	0w			0w			
West Timor									
Lili (irr.) June sowing	L:V:S	0f	0f	0f	833 S-D,hp	50i S-D,hp	833 S-D,hp	333 S-D,hp	167i S-D,hp
Lili (leuc) Mar. sowing	L:V:S	0f	145e Jl-S,hp	542 Jl-S,hp		136i Jl-S,hp		6e Jl-S,hp	0e
Oebola	U:V:S	0f	630 Jl,ct			12i M-Jl,hp			
SMK Soe	U:V:S		17a Jl,ct			0a			
SMK Soe (hort)	U:V:S		321 A,ct						
Tobu 1	U:V:E		400t J-A,hp			? M,hp	400t J-A,hp		
Usapinonot	U:V:S	0a	0a			0a			

[1] Site features: (elevation) L = lowland, U = upland: (soil type) A = alfisol, I = inceptisol, Lm = loam, V = vertisol: (seasonal rainfall) E = extended, S = short

[2] a = damaged by animals, f = weak flowering, d = damaged by disease, e = excessive rainfall, h = difficult to harvest, i = damaged by insects, r = insufficient rainfall, t = grown on a trellis, w = overrun with weeds

[3] Harvest months: J,F,M,A,M,J,Jl,A,S,O,N,D ; method hp = handpick, ct = cut dry and thresh

***Centrosema pascuorum* (Cavalcade and Bundey)**
This species grew well in most environments and readily flowered at most times of the year provided there was sufficient soil moisture. There were no significant insect pests in seed crops, but crops at Tobu and Nakuramba appeared to be badly affected by disease associated with wet and cool conditions. Seed developed progressively and was usually enveloped by the leaf canopy as it grew. This may have reduced the level of pod shattering through delaying drying of pods. Useful seed crops were achieved between April and December, depending on when sown, with the best Cavalcade yields (over 800 kg/ha) achieved using the cut, dry and thresh method for harvest. In general, seed yields were higher on West Timor than Flores, perhaps reflecting greater experience with seed increase. The one harvested Bundey seed crop yielded 542 kg/ha, indicating good potential for this variety as well as Cavalcade. Crops only regrew after harvest if there was sufficient soil moisture to maintain growth.

***Lablab purpureus* (Rongai)**
Highworth *Lablab purpureus* typically grew vigorously and was harvested between June and December. Although this cultivar is regarded as short-day sensitive for flowering at higher latitudes e.g. north Queensland at 17°S, the stimulus seemed less influential in ENT (~10°S). The pods were targeted by butterfly larvae and maturing seeds by seed piercing insects. Despite this, useful yields were achieved by hand-picking without control of insects, particularly when grown on trellises (1.6 t/ha). Bruchid eggs were observed on harvested seeds in some areas and exit holes (adults) observed in seeds stored in ambient conditions. Rongai regrew poorly after harvest which is normal for this cultivar.

***Centrosema molle* (Cardillo)**
Cardillo centro grew vigorously with no obvious pests or diseases and climbed trellises, but first year flowering was typically weak and didn’t occur in some instances. This was presumably due to the lack of an appropriate daylength for floral initiation and/or an interaction with temperature (through elevation). An earlier sowing e.g.December, may overcome the need for a juvenile phase before flowering (presuming there is one) or provide long-day stimulation if this is required. More research is required to understand the flowering response of this species.

***Macroptilium bracteatum* (Juanita) and *Vigna luteola* (Dalrymple)**
Of the two Juanita crops sown, the one grown at Lili under irrigation after a June sowing produced an encouraging seed yield (330 kg/ha handpicked between September and December). The other, earlier, sowing at the same site succumbed to excessive rainfall. Pods of this species readily shatter under hot, dry conditions, so higher seed yields may be achieved if seed is collected from the ground (sweeping). The performance of Dalrymple was similar to Juanita at Lili, except yields (160 kg/ha) of the better crop were likely reduced by insect damage to leaves.

7.2.2 Seed processing, storage and quality

Harvested seed was mostly processed by hand, including hand-threshing or shelling to remove seeds from pods and sieves and winnowing to clean down to naked seeds. Most seed lots were of satisfactory quality for sowing, containing mostly plump, intact seeds. The exceptions were seeds damaged by caterpillar larvae (mostly *Lablab purpureus*) or seed sucking insects (a small proportion of the other legumes).

Local approaches to seed storage were also used effectively: air-drying of seeds in shaded, well-ventilated areas and storing in moisture-proof bags or bottles in cool dry areas of buildings. Bruchids were occasionally found in *Lablab purpureus* seed, but not seed of the other legumes. There is increasing awareness of the importance of seed storage, particularly by staff of BPTP, as seed increase expands.

Ad hoc seed testing at BPTP Naibonat revealed most seed to be of moderate to high planting value. High hardseed levels were found as is typical for some species (*Macroptilium bracteatum*), but levels were generally not high enough to warrant routine scarification to overcome dormancy. In any case, the 'dibbling' method of placing 3-5 seeds into each hole mostly guaranteed a suitable plant population. More attention to seed quality and dormancy will be required as larger, row-planted crops become more common.

7.2.3 Seed increase in ENT beyond the project (2011-12+)

The 'seed production specialists' directly supervised most of the seed crops grown in ENT during 2011-12, the key exception being SMK Soe and villages in West Timor, where teachers or farmers continued to grow seed crops (BPTP staff were in regular liaison with these groups). Again, the key focus was on the three cultivars previously identified as the most useful legumes, with fewer seed crops of the later identified species and cultivars. The seed crop areas were generally larger than for previous years and were located at BPTP and Dinas sites, villages and SMKs.

The start of the 2011-12 growing season was more conducive to seed increase than the two previous years. The seed crops were mostly sown during January-February as planned, although sowing was delayed until March at Soe. A range of methods were used to prepare (tractor cultivation, minimum till using glyphosate and hand cultivation) and sow (row plant or dibble) based on local resources. Good establishment practices, weed control and timely rainfall ensured excellent early growth of crops. Irrigation was planned for some sites (where possible) as a precaution against poor rainfall.

Most crops grew well and there were some excellent seed yields of each of the key species: 400 kg/ha Cavalcade *Centrosema pascuorum*, 1300 kg/ha Milgarra *Clitoria ternatea* and 860 kg/ha Rongai *Lablab purpureus*. Most crops were harvested between May and August, although some crops on Flores were still being harvested after this time. However, water stress during seed crop development significantly reduced potential seed yields of the key species at sites on both islands (*Centrosema pascuorum* was the most affected). Insect damage and disease damage was low overall, although *Catopsilia* larvae likely reduced the yield of Milgarra *Clitoria ternatea* grown at Lili.

Although beyond the scope of this report, it should be noted that seed increase was continued into 2012-13, with supervision mostly by the aforementioned organisations and seed specialists. These include seed crops in lowland and upland areas of Flores and West Timor, focussing primarily on the areas where the adoption of herbaceous legumes is gaining momentum. Some are considerably larger than previous *e.g.* a 5 ha crop of *Clitoria ternatea* at a BPTP facility. The incorporation of seed increase into BPTP, Dinas, Bappeda and SMK programs is encouraging for the adoption of forage legumes in ENT.

7.2.4 Future approaches to seed increase and distribution

The generation and use of legume seeds to demonstrate the use of herbaceous legumes to livestock owners is currently entirely managed and funded through government programs (BPTP, Dinas, Bappeda and SMKs). This approach is working well and seems sustainable as long as funding is available. Private enterprise would presumably become involved as demand for seeds increase following demonstration and wider adoption of the technologies.

A two-stage model for seed increase and distribution has been developing over the last few years:

1. Seed increase conducted or contracted (to villages and SMKs) by Government organisations (BPTP, Dinas) and demonstration of forages by these organisations within villages with access to livestock.

2. In-village seed increase for own use (livestock) or local distribution or sale following demonstration by the government agencies.

The establishment of two seed storage and distribution facilities, one managed by Dinas Nagekeo in Flores and the other by BPTP Naibonat in West Timor has been considered. Each organisation would be involved in contracting, purchasing, processing and distribution/sale of seed as government programs and private operations demand. To be effective, a seed testing (for viability and dormancy) component would need to be incorporated into the operations. Over the next few years a decision needs to be made whether government organisations (like BPTP and Dinas) become integrated commissioners of seed production, processors, testers and distributors or whether elements become part of private enterprise. The former approach seems sensible in the short term, with BPTP and Dinas supplying ‘start-up’ seed for forage evaluation/demonstration and local, village level seed increase then conducted to produce seed for longer term local use and sale.

7.2.5 Outcomes of research

The multi-site seed increase conducted over the last three years, although not completely systematic or conducted as rigorous comparative experiments has provided useful information on seed increase capacity, generated seeds for in-village evaluation and demonstration by government agencies and provided experience to extension and research organisations and to growers. This information was incorporated into a seed production training course and the ACIAR manual *Integrating herbaceous legumes into crop and livestock systems in eastern Indonesia* to be published in mid-2013.

The observation of seed crop development in lowland and upland areas of Flores and West Timor using a range of soil types, sowing times, management and harvesting methods has provided useful insights on:

- Site suitability and preparation
- Crop development timetables
- The use of trellises (artificial and crop)
- Key pests and diseases
- Effective harvest methods
- Potential seed yields

An important development has been the improved pricing of *Centrosema pascuorum, Clitoria ternatea* and *Lablab purpureus* seed purchased by BPTP and Dinas. Initially valued at ~Rp7000/kg (based loosely on mungbean prices) seeds are currently valued at Rp25-30 000/kg for Milgarra *Clitoria ternatea* and Cavalcade *Centrosema pascuorum* and Rp20 000/kg for Highworth *Lablab purpureus*. While it is recognised prices may decline in future as seed production increases in scale, these higher prices are considered to better estimate the real costs of producing legume seeds, particularly the costs associated with harvesting, and provide a realistic incentive for farmers to grow seeds.

7.3 Using forage legumes in the cropping system

Preliminary testing of the legumes in cereal-based farming systems either in relay or rotation with maize was undertaken in 2007/08 and 2008/09 at two medium elevation sites in West Timor (Usapinonot and Oebola). With the expansion to Flores in 2009, systems work was conducted at the villages of Nakuramba and Ulupulu which are also medium elevation sites (Table 2). Table 5 provides an overview of the research undertaken during this period.

7.3.1 Using forage legumes in relay with a cereal crop

The original hypothesis proposed that forage legumes could be grown in relay (Figure 16) with a cereal crop (initially maize but expanded to include upland rice in Flores) and provide benefits to animals and subsequent cereal crops. In the first season (2007-08), maize sown in December (conventional farmer practice) was sown to a legume relay at maize flowering in February (Figure 16). Seed was planted in 3 rows between the maize rows as shown in Figure 25 at rates to achieve target plant populations (Table 21). Relay trials undertaken in rainfed, upland rice systems in Flores in 2009-11, used the legume planting configuration shown in Figure 26 where 1 row of legume was sown between the existing rice rows.

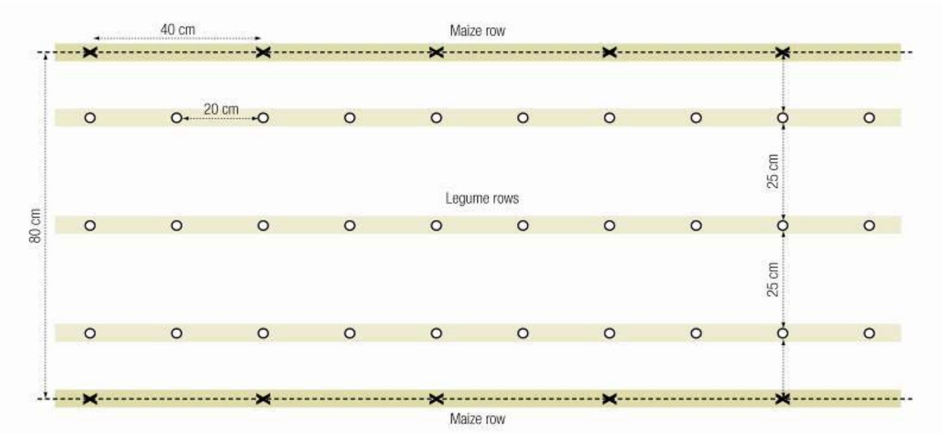


Figure 25: *Dibbling (planting seed in individually formed holes) configuration for small and medium seeded legumes species planted into a maize crop as part of a relay cropping system. Within-row spacing was set at 25 cm for large seeded species.*

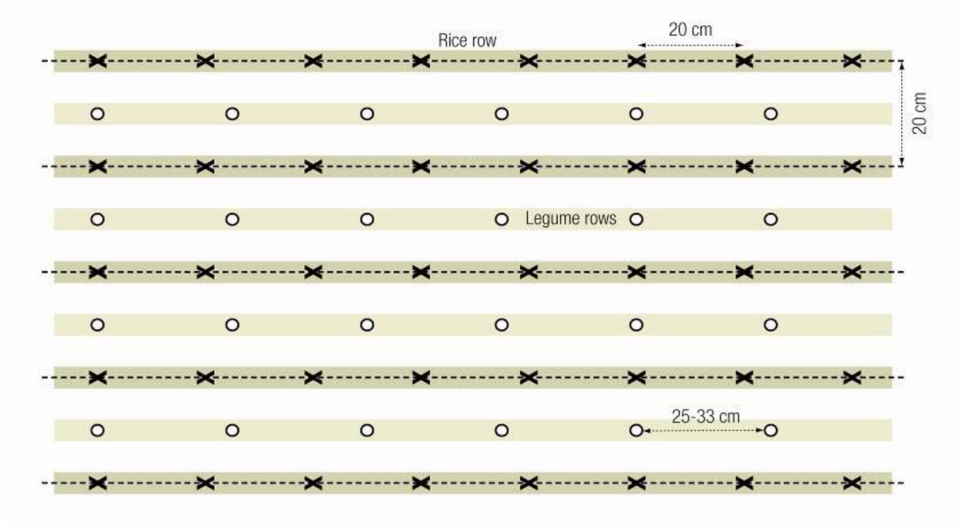


Figure 26: *Dibble configuration for small and medium seeded legumes species planted into an upland rice crop as part of a relay cropping system. One row of legume is dibbled up the centre of each rice inter-row with dibble points spaced every 25 cm for small and medium seeded species and 33 cm for larger seeded species.*

Table 21: *Sowing rates for legumes dibbled into relay and rotational sequences with maize and rice. Rates require increasing by 20% when small and medium seeded species are broadcast onto the soil surface.*

				Rotation systems: maize and rice (assuming a legume row spacing of 40 cm)		**Relay systems: maize** (assuming 3 rows of dibbled legume between each 2 maize rows spaced at 80 cm)		**Relay systems: upland rice** (assuming 1 row of dibbled legume between each 2 rice rows spaced at 20 cm)	
Species and seed size	**Expected germination**	**Survival factor**	**Average seed weight**	**Target plant number**	**Sowing rate**	**Target plant number**	**Sowing rate**	**Target plant number**	**Sowing rate**
	(%)[1]	**(%)[2]**	**(seeds/g)**	**(plants/m²)**	**(g/m²)**	**(plants/m²)**	**(g/m²)**	**(plants/m²)**	**(g/m²)**
Clitoria ternatea (medium)	70	70	25	20*	1.6	37*	3.0	37[+]	3.0
Centrosema pascuorum (medium)	70	60	55	20*	0.9	37*	1.6	37[+]	1.6
Lablab purpureus (large)	90	90	4	10[#]	3.1	15[#]	4.6	15[@]	4.6

[*] Assuming approximately 2 seeds/dibble at 20 cm in-row spacing; [#] Assuming approximately 1 seed/dibble at 25 cm in-row spacing; [+] Assuming approximately 2 seeds/dibble at 25 cm in-row spacing; [@] Assuming approximately 1 seed/dibble at 33 cm in-row spacing; [1] For a quality seed batch after treatment for hardseededness (if necessary); [2] Estimates based on seed size and experience

Legume production in relay with a cereal

Biomass production in relay systems was lower than anticipated (Figure 27). A combination of later planting (compared to rotation) and resource competition with the cereal crop reduced the production potential of the legumes. It is considered that reduced radiation levels, as a result of shading by the maize crop in the first weeks of growth, and an overall reduction in water supply due to use by the maize crop were the main contributors to reduced yields. Particularly affected were the annual legumes, *Lablab purpureus* and *Centrosema pascuorum* which were unable to produce large quantities of biomass before soil water was exhausted and plants senesced. Figure 27 shows that levels of production for these 2 species was <500 kg/ha DM in the majority of cases, the exceptions being in 2008 at Oebola and Usapinonot where *Lablab purpureus* yielded ~1 t/ha DM.

Biomass production was also reduced when the short term perennial *Clitoria ternatea* was grown in relay, although in 3 out of the 6 trials shown in Figure 27 yields exceeded 2 t/ha DM. The best of these occurred at the higher elevation site of Nakuramba in Flores where more regular winter rainfall provided the necessary water resources for *Clitoria ternatea* to produce a mean yield of 2.8 t/ha DM in relay with rice and 2.2 t/ha in relay with maize over 200 days of growth (Figure 6). Being a perennial, *Clitoria ternatea* also had the potential to re-grow at the commencement of the following wet season. This then allowed the farmer to either use the legume as part of a rotational sequence with a cereal or to utilise the early wet season legume production for animal feeding, before preparing the land for cereal production. This was tested at the village of Biloto (not shown) where *Clitoria ternatea* was planted in February 2008 and allowed to grow through until April 2009. During this time it produced 2.7 t/ha DM of biomass, 2.5 t of which was produced using rainfall from the second (2008/09) wet season.

Maize yield and bioassay

Maize (rice at some locations in Flores) was used as a bioassay in the season following the growing of the legume relay crop to determine the impact of the legume on soil nitrogen supply. Table 22 and Figures 28, 29 and 30 provide an overview of results from the relay trials conducted at Oebola and Usapinonot. Variability in grain and stover data was high at both sites, reflecting the challenges of undertaking relatively detailed research in an on-farm environment. Replication (from 3 to 4) and plot size were subsequently increased an attempt to counter this problem. It should also be noted that legume biomass was not removed from plots during the relay phase and likely contributed to soil N supply. This differs from the commercial situation where it would be more typical for biomass to be removed to feed animals. Therefore, any contribution to N supply from the legumes in these experiments is likely to be at the higher end of the scale.

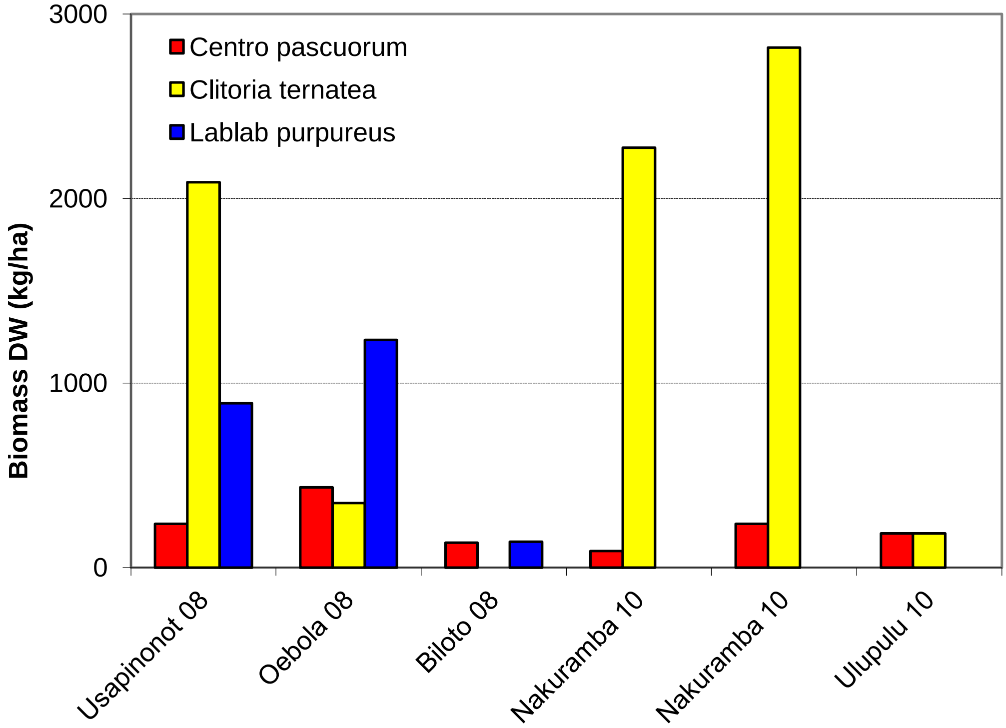


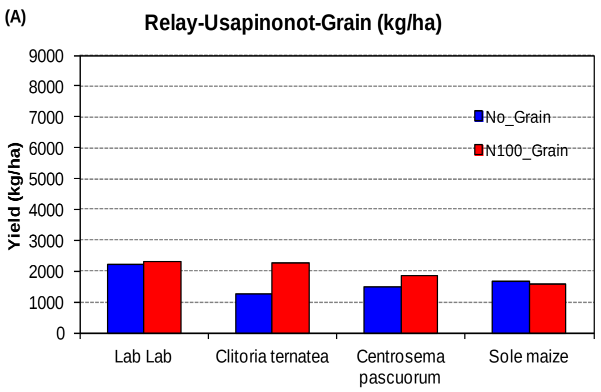
Figure 27: *Dry season biomass production (kg/ha DW) for 3 of the best adapted forage legume species grown in relay with maize (and upland rice in 2010) at a range of locations in West Timor and Flores between 2008 and 2010. The legumes were planted at around time of cereal crop anthesis in February.*

At Oebola (Figure 28), maize grown in the wet season following the relay cropping of *Clitoria ternatea* and *Centrosema pascuorum*, with no additional N applied, increased in grain yield by ~800 kg/ha and stover by ~1000 kg/ha DW compared to the maize control. At Usapinonot (Figure 29), *Lablab purpureus* was the only relay where there was an increase in maize yield compared to the control (+560 kg/ha for grain and 460 kg/ha for stover). The application of urea fertiliser at a rate of 100 kg/ha of N impacted markedly on production at Oebola with a doubling of grain yield from 2.6 t/ha to 5 t/ha and stover from 3.4 t/ha to 6 t/ha DW. No yield differences were recorded at Usapinonot. Probable reasons for the differences in site yields include, a) the soils at Oebola are inherently more fertile than those at Usapinonot, and b) growing-season rainfall at Usapinonot was half that of Oebola (324 mm vs. 634 mm).

Table 22: *Mean yield (t/ha) (grain, stover and total), plant population ('000/ha) and harvest index for Lamuru maize grown at Oebola and Usapinonot, West Timor as a bioassay to determine the impact of 1 season of relay cropped legume production on nitrogen supply to the subsequent crop. Within rows, species which are significantly different are shown by different letters.*

N Rate (kg/ha)	**Maize plant component**	***Maize after Lablab purpureus***	**Maize after *Clitoria ternatea***	**Maize after *Centrosema pascuorum***	**Maize after maize (control)**	**Factor**	**Sig**
Oebola, Kupang Regency							
0	Grain (t/ha)	2.23^{b}	3.33^{a}	3.48^{a}	2.60^{b}	Spp	**
100		5.14	6.80	6.37	4.96	NRate	***
0	Stover (kg/ha)	3.47^{b}	4.45^{a}	4.36^{ab}	3.39^{b}	Spp	*
100		6.54	7.87	6.39	6.05	NRate	***
0	Total (grain & stover) (kg/ha)	5.71^{b}	7.77^{a}	7.83^{ab}	5.99^{b}	Spp	**
100		11.68	14.67	12.77	11.01	NRate	***
0	Plant population ('000/ha)	61.8	74.0	68.1	67.0		
100		67.0	70.5	72.6	68.8		
0	Harvest Index	0.38^{b}	0.42^{a}	0.44^{a}	0.43^{a}	Spp	*
100		0.43	0.46	0.50	0.45	NRate	***
Usapinonot, TTU Regency							
0	Grain (t/ha)	2.23	1.25	1.48	1.67	Spp	ns
100		2.32	2.25	1.86	1.58	NRate	ns
0	Stover (kg/ha)	3.59	2.72	2.90	3.12	Spp	ns
100		4.25	3.69	4.20	2.75	NRate	**
0	Total (grain & stover) (kg/ha)	5.82	3.98	4.39	4.79	Spp	ns
100		6.57	5.94	6.06	4.32	Nrate	*
0	Plant population ('000/ha)	63.9	61.1	61.1	63.4		
100		64.4	60.6	64.8	60.2		
0	Harvest Index	0.38	0.31	0.32	0.34		
100		0.35	0.38	0.30	0.36		

*ns-not significant; *-P=0.05-0.1; ** -P=0.01-0.05; *** -P=<0.01*



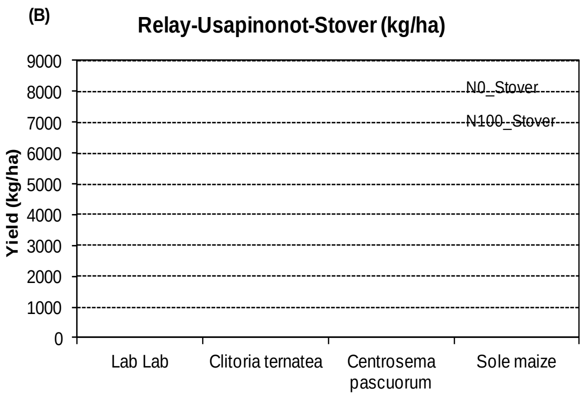


Figure 28: *Mean grain (A) and stover (B) yield (kg/ha) for Lamuru maize grown as a bioassay at Oebola, Kupang with either no applied nitrogen, or 100 kg N/ha split between a basal application and 30 DAS (50/50 split).*

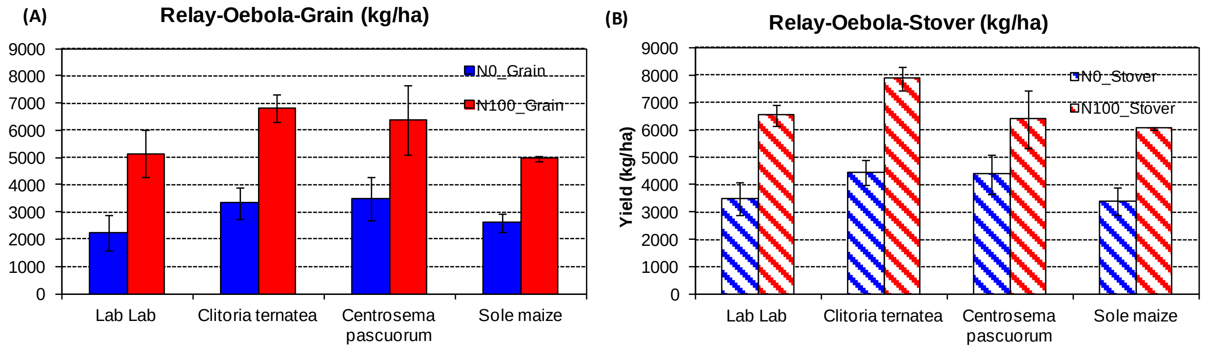


Figure 29: *Mean grain (a) and stover (b) yield (kg/ha) for Lamuru maize grown as a bioassay at Usapinonot, TTU with either no applied nitrogen, or 100 kg N/ha split between a basal application and 30 DAS (50/50 split).*

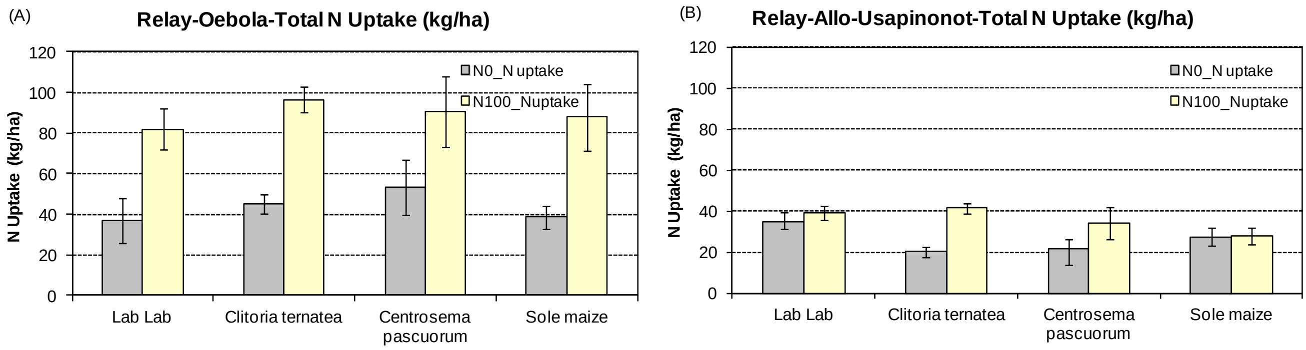


Figure 30: *Total plant nitrogen uptake (kg/ha) for the maize bioassay crops grown at Oebola (A) and Usapinonot (B) and described in Figures 28 and 29 (Total N uptake based on N content of grain and stover at maturity).*

Estimating legume contribution to nitrogen

Soil tests indicated that the maize control treatment (maize on maize) at Oebola had access to ~100 kg/ha nitrate nitrogen (NO3-N) (to a depth of 150 cm) at the time of maize planting which was used to produce 2.6 t/ha (Table 22) of grain. When 100 kg/ha of fertiliser N was applied the mean yield increased to 5 t/ha (Table 22). Using these data in conjunction with those from maize grown in relay with legumes, provides the opportunity to apportion nitrogen supply to differing sources i.e. mineralised N, fertiliser N and legume-derived N. Assuming a linear response to additional N between these two control treatments, (Figure 31) a yield of 3.4 t/ha achieved in maize following *Centrosema pascuorum* without applied fertiliser N), suggests the crop obtained ~30 kg/ha of N from the previous legume. This estimate is similar to results at Katherine, Australia (Jones *et. al.,* 1996[21]), which showed that a one year ley crop of Verano Stylo (*Stylosanthes hamata*) supplied ~30 kg/ha N to a subsequent maize crop, although legume biomass production was higher (~3-4 t/ha DM) than that reported for Oebola (Figure 27). A maize crop which had both the benefit of a preceding legume relay (*Centrosema pascuorum)*, and additional fertiliser N achieved a mean yield of 6.4 t/ha. This suggests that this crop had access to around 260 kg/ha of nitrogen, 100 kg of which was present in the soil prior to the planting of the maize, 100 kg from inorganic fertiliser and 60 kg through fixation (Figure 31).

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[21] *Jones, R.K., Probert, M.E., Dalgliesh, N.P. and McCown. R.L. 1996. Nitrogen inputs from a pasture legume in rotations with cereals in the semi-arid tropics of northern Australia: experimentation and modelling on a clay loam soil. Australian Journal of Experimental Agriculture, 1996, 36, 985-94.*

In 2009-11 relay cropping of legumes with maize and upland rice was trialled at two Flores locations (Ulupulu and Nakuramba). Again, legume growth was slowed due to competition from the accompanying cereal crop with both *Clitoria ternatea* and *Centrosema pascuorum* producing <200 kg/ha DW in 86 days (February plant) at both sites. At Nakuramba however, *Clitoria ternatea* continued to grow and produce 2.8 t/ha DM in 200 days in relay with upland rice, while *Centrosema pascuorum* succumbed to disease and insect attack, a result of the wet and cool conditions. Cereal bioassays undertaken at these sites during the 2010-11 wet season were inconclusive due to high rainfall and poor crop growth.

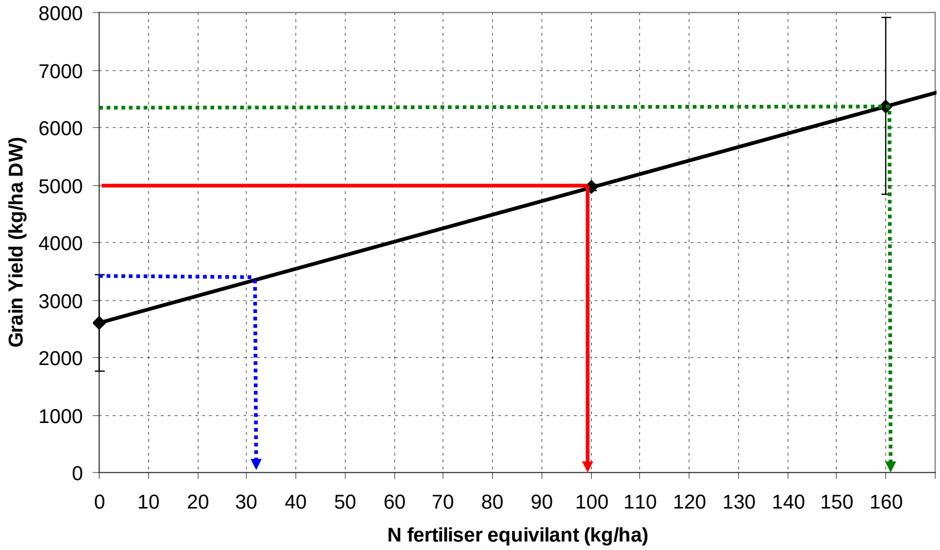

Figure 31: *Contribution of fixed nitrogen to maize growth from one season of relay cropped* Centrosema pascuorum *grown at Oebola, Kupang showing maize grown on mineralised soil N with no contribution from a legume relay (- - -); grown with mineralised soil N and after a* Centrosema pascuorum *relay (-----) and grown with mineralised soil N, 100kg/ha fertiliser N and after a* Centrosema pascuorum *relay (- - -).*

7.3.2 Using legumes in rotation with a cereal crop

The growing of legumes in annual rotation with cereals was shown to be a better option for legume biomass production. Compared to relay cropping, there is no competition for light or water resources and the legumes are able to be planted earlier in the wet season, taking advantage of the longer growing season. However, the issue is whether land surplus to food security requirements and the labour required to manage it are available. Commonly, farmers in ENT indicate that labour availability is the major limiting resource.

Legumes grown as a rotation crop were established in rows 40 cm apart (Figure 32) using the sowing rates indicated in Table 21. Land was either ploughed, which was considered to be labour intensive, or weeds controlled using a herbicide before the dibbling of seed. Figure 33 provides an overview of biomass production over 2 seasons at sites in West Timor and Flores. *Centrosema pascuorum and Clitoria ternatea* produced well with biomass yields of >5 t/ha DM common. These species were less well adapted to the wetter and cooler conditions experienced at 2 locations in Flores and yields suffered as a result (<2t/ha DM). *Lablab purpureus* was grown at 2 locations with average biomass yields of 2 and 5 t/ha. At Betun in the bi-modal regency of Belu, the prolonged wet period provided the necessary soil water resources for *Clitoria ternatea* to produce a total of 7.6 t/ha DM during the dry season (2 harvests). At Naibonat, over a period of 200 days (spanning the late wet and dry seasons), *Clitoria ternatea* produced 6.7 t/ha and *Centrosema pascuorum* 11.4 t/ha DM, with the *Centrosema pascuorum* being the highest seasonal rainfed yield recorded by the project (Figure 33 and 34).

Rotations also lend themselves to irrigated production. This was trialled at Mbay, Flores where the legumes were rotated with lowland irrigated rice. This provided an example of the potential for replacing 1 of 3 annual rice crops with a forage legume to supply local cattle requirements. *Centrosema pascuorum* and *Clitoria ternatea* both received 2 irrigations and were harvested at 90 and 210 DAS producing a total of 9.6 t/ha and 7.9 t/ha DM respectively (Figure 33).

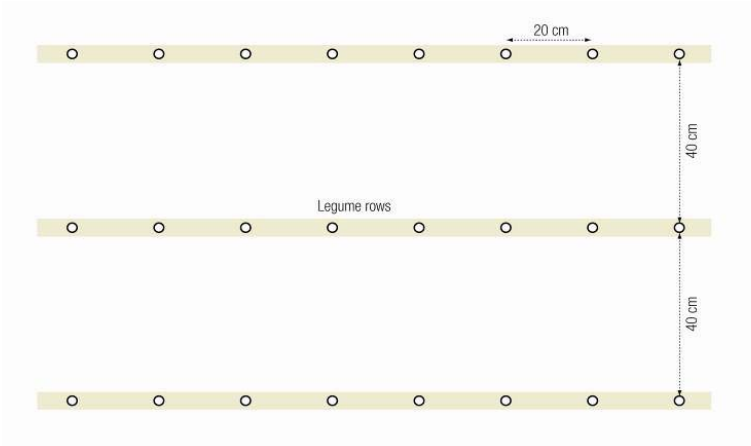

Figure 32: *Planting configuration for legumes grown in <u>rotation</u> with maize or rice.*

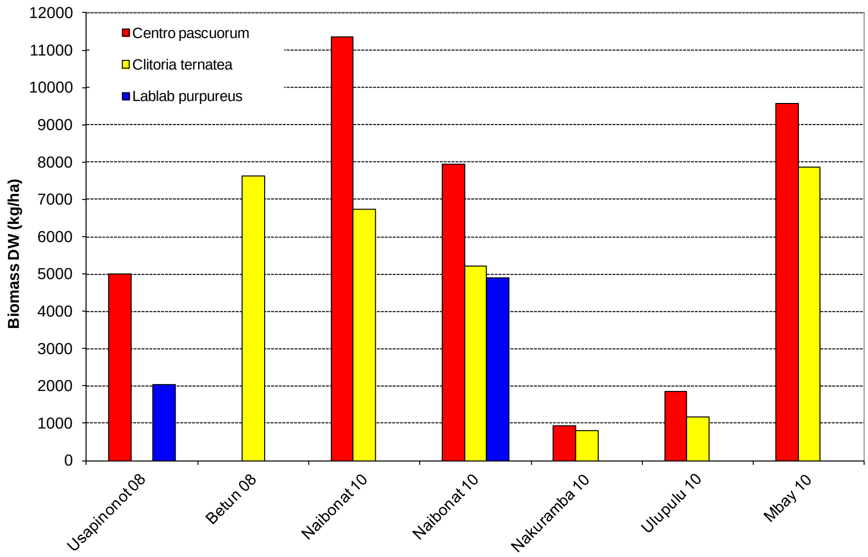

Figure 33: *Rainfed and irrigated (Mbay only) biomass production (kg/ha DW) from 3 of the best adapted forage legume species grown in <u>rotation</u> with maize (and rice in 2010) at a range of locations in West Timor and Flores.*

Figure 34: *Farmer Andreas Bisik proudly shows off his commercial area of* Clitoria ternatea *at Betun, Belu regency, West Timor which yielded 7.6 t/ha DM from 2 harvests.*

Maize yield and bioassay

The contribution to N supply of a legume grown in annual rotation with a cereal was assessed at Kakaniuk, Belu (2007-08) and Usapinonot, TTS (2008-09). It should be noted, that with the exception of the *Clitoria ternatea* grown at Usapinonot, no legume biomass was removed from plots during, or at the end of the rotation phase. This differs from the likely commercial situation where the biomass would be harvested to feed animals. It is therefore probable the contribution of biological N to crop yield in the trials will be higher than in commercial practice.

At Kakaniuk, a bi-modal site, the 3 legume compared (Table 23) all contributed to subsequent maize production through biological N fixation and leaf drop. Compared to the non-legume control, stover production increased within the range of 2000-4200 kg/ha DW while grain yields increased in the order of 1400 to 2700 kg/ha DW (Figure 35).

At Usapinonot, a uni-modal site, results were less definitive (Table 23). A mean increase in grain yield of 570 kg/ha DW was recorded with the introduction of *Centrosema pascuorum* (Figure 36). Small responses in stover yield (400-500 kg/ha DM) were recorded for both *Clitoria ternatea* and *Centrosema pascuorum* due to increased biological N supply. As expected, the application of an additional 100 kg/ha of N as Urea resulted in grain yield increases after all legumes although this result was confused by the poor yield recorded for the N100 control treatment. The variable response to fertiliser N was considered to be a result of the low 2008/09 wet season rainfall not being sufficient to drive additional grain production.

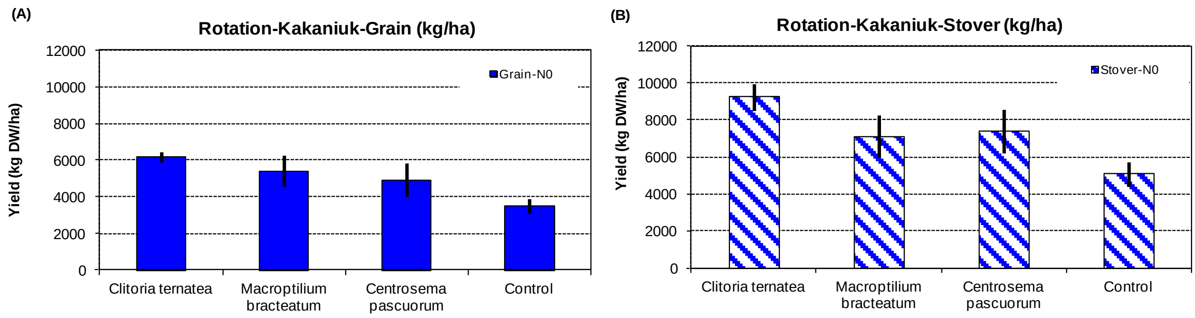

Figure 35: *Mean grain (A) and stover (B) yield (kg/ha) for Lamuru maize grown as a bioassay at Kakaniuk, TTU to determine the impact of 1 season of forage legume production on cereal crop N supply.*

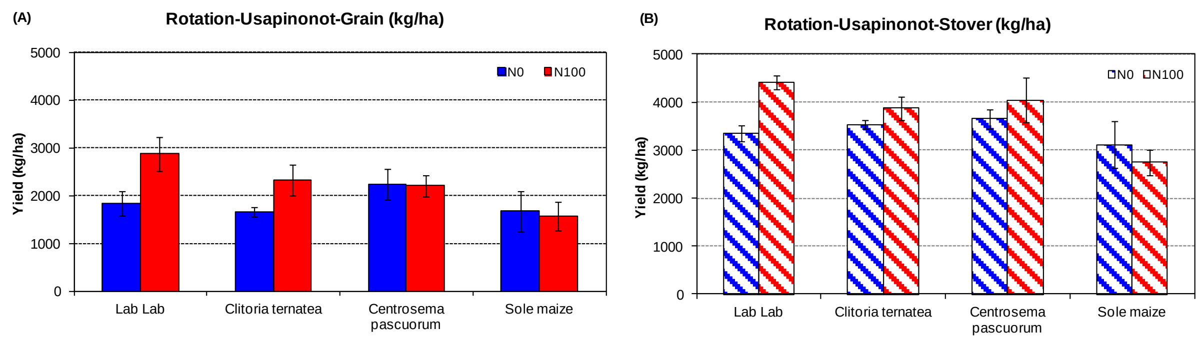

Figure 36: *Mean grain (A) and stover (B) yield (kg/ha) for Lamuru maize grown as a bioassay at Usapinonot, TTU with either no applied nitrogen fertiliser, or 100 kg N/ha split between a basal application and 30 DAS (50/50 split). Maize was grown to determine the impact of 1 season of forage*

Table 23: *Maize cv. Lamuru grain and stover yield components (t/ha) when grown in rotation following 3 forage legumes and maize (control) at Kakaniuk (2007/08) and Usapinonot (2008/09). Within rows, species which are significantly different are shown by different letters.*

Kakaniuk, Belu Regency							
N Rate (kg/ha)	**Maize plant component**	***Macroptilium bracteatum***	***Clitoria ternatea***	***Centrosema pascuorum***	**Maize (control)**	***Factor***	***Sig***
0	Grain (t/ha)	5.42 [a]	6.19 [a]	4.93 [ab]	3.52 [b]	Spp	*
0	Stover (t/ha)	7.11	9.25	7.40	5.08	Spp	ns
0	Total biomass (t/ha)	12.53 [ab]	15.44 [a]	12.33 [ab]	8.60 [b]	Spp	*
Usapinonot, TTU Regency							
N Rate (kg/ha)	**Maize plant component**	***Lablab purpureus***	***Clitoria ternatea***	***Centrosema pascuorum***	**Maize (control)**		
0	Grain (t/ha)	1.83	1.66 (a)	2.24	1.67	Spp	ns
100		2.87	2.33	2.21	1.58	NRate	*
0	Stover (t/ha)	3.35 [a]	3.54 [a]	3.66 [a]	3.12 [b]	Spp	**
100		4.42	3.88	4.04	2.75	NRate	ns
0	Total Biomass (t/ha)	5.18 [a]	5.19 [a]	5.90 [a]	4.79 [b]	Spp	**
100		7.29	6.21	6.25	4.32	NRate	*
0	Plant population ('000/ha)	63.9	62.5	60.19	63.43		
100		62.0	63.9	63.0	60.2		
0	Harvest Index	0.35	0.32	0.38	0.34		
100		0.39	0.37	0.35	0.36		

*ns-not significant; *-P=0.05-0.1; ** -P=0.01-0.05; *** -P=<0.01*

7.3.3 Water use in relay and rotation crops-understanding the drivers of biomass production

Water availability and use is central to understanding why legumes grown in relay with a cereal crop produce much lower quantities of biomass than those grown in rotation. An understanding of the dynamics of the water balance was developed through the characterisation of soils for their water holding capacity and through the seasonal monitoring of soil water availability. A comparison of the water use of *Centrosema pascuorum* grown in rotation and in relay with maize was undertaken. Figure 37 shows that both profiles were at or above field capacity at legume planting in late February. However, by flowering 76 days later, the extraction patterns were quite different. While water was being extracted to depth (to 90-150 cm) in both treatments, relay legume water use was lower in the surface layers than for the rotation, as indicated by the water bulge in the 15-60 cm soil layer. This suggests that the 155mm of rainfall that occurred during the period was not well utilised by the legume. By flowering, the rotation had produced 2700 kg/ha DM of biomass and the relay 213 kg/ha. An additional 24 mm of rainfall in the 28 days after flowering, in combination with the remaining stored soil water provided the resources for the rotation crop to produce an additional 2.3 t/ha DM (total production of 5 t/ha DM) compared to the relay crop which produced an additional 209 kg/ha (422 kg in total).

The inefficiency in relay crop water extraction continued throughout the season. Even though water in surface soil layers continued to be replenished by rainfall it remained under-utilised by the relay crop. While the process is not fully understood, it can be hypothesised that the lower water use may be the result of a lower legume plant population and/or leaf area, resulting from poor early plant vigour under the lower levels of radiation available to a relay cropped legume growing under the canopy of the maize crop.

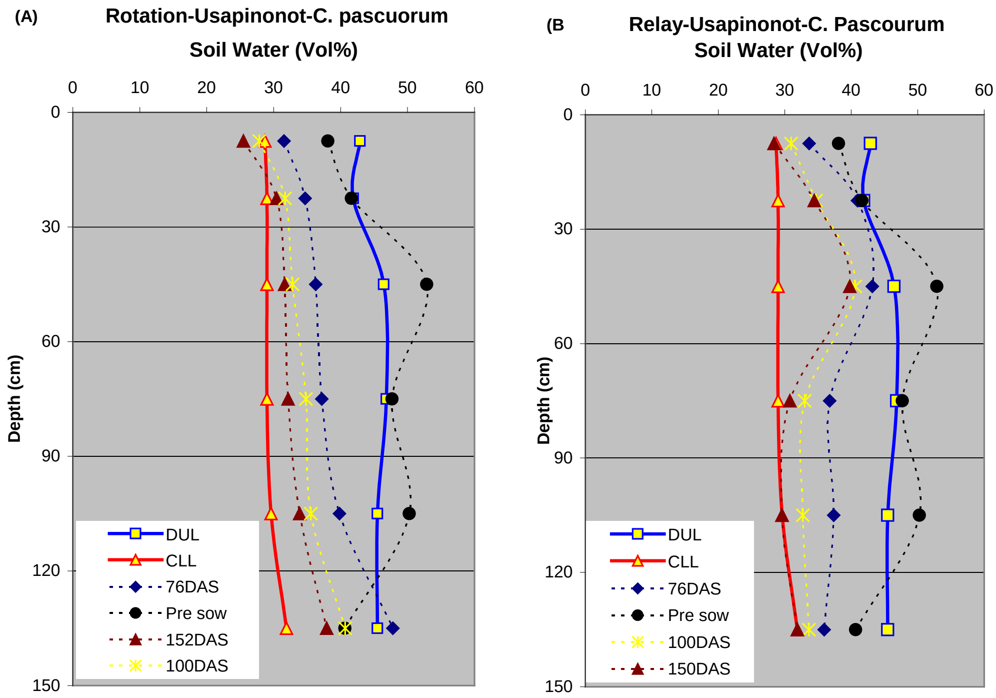

Figure 37: *Soil water extraction by* Centrosema pascuorum *grown in rotation (a) and in relay with maize (b) showing water extraction patterns measured prior to legume planting (●), 74DAS (♦), 104 DAS* (x) *and 152 DAS (▲). The upper storage limit (DUL* **□***) and the lower limit of water extraction (Δ) define the Plant Available Water Capacity for this soil x crop combination. Trial work was conducted in adjacent plots.*

7.3.4 The Longer-term production and analysis of risk of legumes in cereal-based farming systems

It is well known that seasonal climate variability impacts significantly on the livelihoods of farmers in ENT and at times may lead to food security issues. Given the requirement for forage legumes to be produced without detriment to wet season food security crops such as maize, rice and pulses, it was seen as an important issue to examine. The riskiness of production of forage legumes was undertaken using the APSIM simulation model (Keating *et. al.* 2003[22]) parameterised using the longer-term daily climate record for Naibonat (Figure 38), the water holding capacity of the local soil and appropriate management rules for the production of forage legumes. Figures 39 and 40 provide examples of this technique and an insight into the reliability of rainfall and soil water available for legume production.

Note: Currently long term eastern Indonesian climate records are limited to data collected by BPTP-NTT at a small number of sites between 2002 and 2010. Daily temperature, radiation and rainfall data collected as part of this project at sites across West Timor and Flores (Table 2) will contribute to a longer-term climate record for use by other projects.

[22]*Keating, B.A., Carberry, P.S., Hammer, G.L., Probert, M.E., Robertson, M.J., Holzworth, D., Huth, N.I., Hargreaves, J.N.G., Meinke, H., Hochman, Z., McLean, G., Verburg, K., Snow, V., Dimes, J.P., Silburn, M., Wang, E., Brown, S., Bristow, K.L., Asseng, S., Chapman, S., McCown, R.L., Freebairn, D.M., Smith, C.J., 2003. An overview of APSIM, a model designed for farming systems simulation. European Journal of Agronomy 18, 267–288*

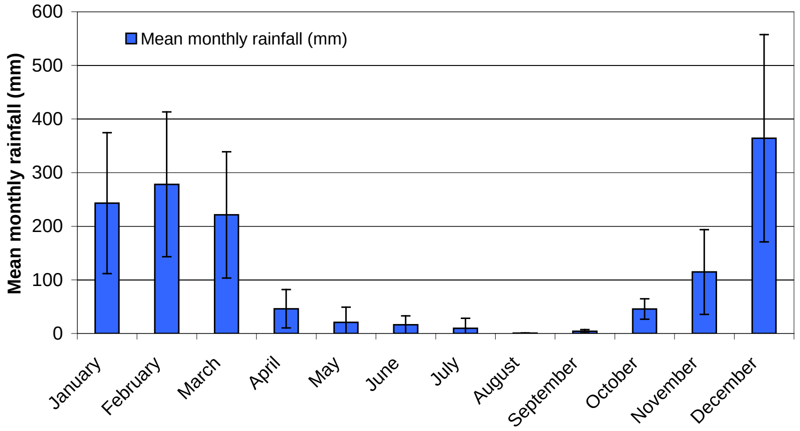

Figure 38: *Mean monthly rainfall for Naibonat, West Timor for the period 2002 to 2010. Mean annual rainfall of 1835 mm was recorded although with high monthly seasonal variability (as shown by the standard error whisker plots)*

Figure 39 provides a prediction of the February plant available water at Naibonat for each of the years from 2002 to 2010, the time when farmers would consider planting a legume in relay or rotation with a cereal. This suggests that in all 9 years of simulation >100 mm of plant available water would be present at this time to support maize grain fill and/or legume production. What this analysis does not show however, is that even though there has been high February rainfall in all years, there may have been conditions, such as a short-term drought, which affected establishment, or longer-term productivity. Figure 40 provides an example of this issue with simulation suggesting that *Clitoria ternatea* would have failed in 1 out of the 9 years but would have produced >1.5 t/ha DM in the other 8 when planted in February and grown using late wet season rainfall and stored soil water.

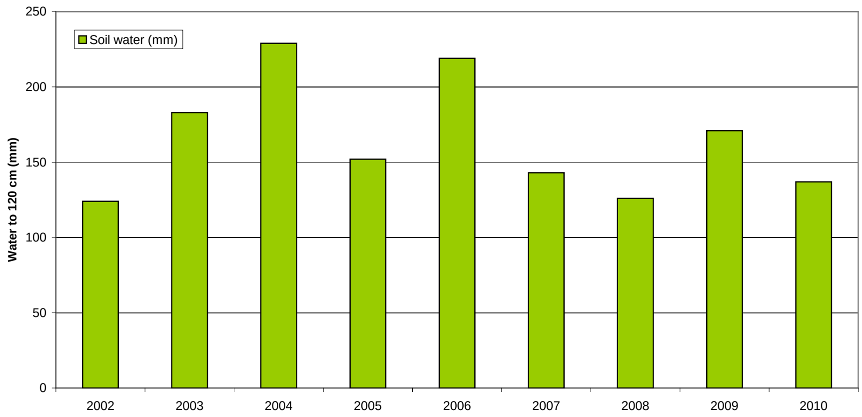

Figure 39: *Simulated soil water present to a depth of 120 cm at time of maize grain fill in February for the years 2002-2012 at Naibonat, West Timor.*

Given that Naibonat is at the drier end of the annual rainfall scale for West Timor and Flores, it is reasonable to suggest that there is a high probability of successful long-term dry season production of legumes across the province. However, there will also be the occasional season when failure occurs because of poor weather conditions, particularly related to seasonal rainfall variability (both quantity and distribution). It should also be noted, that in some of the higher altitude, cooler environments, high rainfall may be a disadvantage for those species less well adapted to these conditions e.g. *Centrosema pascuorum*.

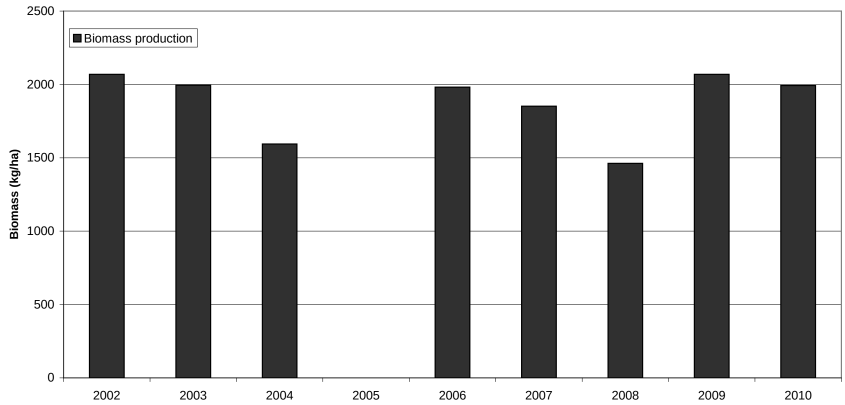

Figure 40: *Simulated biomass production (kg/ha) for* Clitoria ternatea *planted in February at Naibonat, West Timor and allowed to grow into the dry season using stored soil moisture and rainfall.*

7.3.5 Endemic vs. introduced nitrogen-fixing bacterial strains

In the first 3 years of research it was considered inappropriate to inoculate legumes with specific rhizobial bacteria strains, trusting instead that legumes would utilise those endemic to the region. This decision was made because the technology was unavailable in ENT and on-farm research results would not have been relevant to local farmers. As this decision may have been to the detriment of some species an evaluation of the presence of appropriate rhizobial strains for 2 legumes was undertaken in 2009-10. The Research Institute for Animal Production, Bogor collected nodule samples from ENT trial sites, isolated bacterial strains and undertook pot trials to screen their ability to nodulate and fix nitrogen in *Centrosema pascuorum* and *Clitoria ternatea*. The 6 Indonesian strains (2 from ENT) were compared against 2 recommended commercial strains (Table 24).

Is legume inoculation necessary?

Shoot production of *Centrosema pascuorum* cv. Cavalcade was the highest when inoculated with strain BPT01. This strain was isolated from nodules of *Centrosema pascuorum* cv. Cavalcade collected from Kampung Neilera, ENT. Total shoot nitrogen content in plants grown in N free media was used as an indicator of nitrogen fixation effectiveness. The most effective strain for Cavalcade was again BPT01 although the N uptake level was only 70% of that of the N fertilized control plants (Table 24). Inoculation of *Clitoria ternatea* with the same rhizobium strains increased shoot dry mass for all lines, however the commercial strains, ER01 and ER02 were the highest (Table 24). Total shoot N content for both commercial lines was around 13 mg/pot which was approx. 80% of the level of N uptake of the +N control (Table 24 and Figure 41).

This investigation suggests that inoculation of *Centrosema pascuorum* was unlikely to be necessary because of its ability to utilise endemic rhizobial strains. *Clitoria ternatea* was more problematic with the 2 commercial strains having N uptake levels double those of local strains. This suggests that there may be scope to improve N fixation levels for this legume through inoculation. While this is important information and may explain some of the variability in maize response to biological N, it is unlikely that commercial rhizobia strains will become available to farmers in the near future.

Table 24: *Origin of root nodule bacteria strains used and their effects on the dry weight (g), N concentration (%) and total shoot nitrogen present (mg/pot) when inoculated onto* Centrosema pascuorum *and* Clitoria ternatea*.*

			Centrosema pascuorum			***Clitoria ternatea***		
Code	**Host**	**Origin**	**Shoot dry weight/ pot (mg)**	**N conc. (%)**	**N in shoot (mg/pot)**	**Shoot dry weight (mg/pot)**	**N conc (%)**	**N in shoot (mg/pot)**
BPT 01/10	*Centrosema pascuorum*	Neilera, ENT	1102	3.46	38.1	116	2.66	3.09
BPT 02/10	*Clitoria ternatea*	Naibonat, ENT	642	3.63	23.3	206	3.07	6.32
BPT 03/10	*Medicago sativa*	Ciawi, Bogor	630	2.72	17.1	282	2.97	8.37
BPT 04/10	*Lablab purpureus*	Subang, Jawa Barat	968	3.65	35.3	250	2.89	7.22
BPT 05/10	*Stylosanthes scabra*	Gn.Kidul, Yogyakarta	408	3.39	13.8	222	3.15	6.99
BPT 06/10	*Arachis pintoi*	Ciawi, Bogor	602	2.95	17.8	150	3.51	5.26
ER 01/10	*Centrosema pubescens*	commercial	300	3.57	10.7	378	3.40	12.85
ER 02/10	*Macroptilium atropurpureum*	commercial	400	3.36	13.4	442	2.97	13.13
+N			1522	3.62	55.1	502	3.29	16.52
-N			370	3.47	12.8	146	3.08	4.50

Figure 41: Clitoria ternatea *plant growth inoculated with a range of Indonesian and commercial strains and +/- N controls.*

7.3.6 Summarising farming systems research

The research has shown that legumes can be grown as part of cereal-based farming systems and produce significant quantities of biomass. By far the most efficient means of producing legume biomass is as part of an annual rotational sequence with maize or rice, however the downside is that the farmer must have access to surplus land and the labour to manage it. There is also a place for the relay cropping of legumes, particularly in land constrained systems, and understanding of the factors affecting low productivity of legumes in this system requires further investigation. While overall biomass production of relay cropped legumes was lower than those sown in rotation, useful quantities of biomass can be produced if appropriate legumes are used (e.g. short duration perennials), they are well managed and able to take full advantage of available soil water and late wet season rainfall.

The question of the contribution of nitrogen through fixation to subsequent cereal crops has only been partly answered. While responses in grain yield to fixed nitrogen were observed it was generally where legume leaf drop had contributed to N supply. Where biomass was removed crop responses to fixed nitrogen were less clear and only observed in stover yield. Current evidence suggests that the contribution of fixed N to cereal production is low either due to low N fixation or minimal returns once shoot biomass is removed. Even were N fixation rates to be improved through the identification of legume-specific rhizobial strains e.g. for *Clitoria ternatea*, it is expected that atmospheric N would still only provide a portion of total crop N supply. It is considered that to optimise cereal crop productivity, investments in small quantities of inorganic fertiliser are required to compliment organic manures and residual N from forage legumes. However, further research involving simulation modelling is suggested to investigate this further.

7.4 Animal feeding of forage legumes

In addition to their potential benefits to cereal crop productivity, a key driver for the adoption of forage legumes will be for the benefits they provide to animal production. This project set out to provide some preliminary evidence of the impact of feeding forage legumes on livestock growth rates.

7.4.1 Feeding trials

Four animal feeding trials were conducted with 3 focussed on the fattening of cattle for the Indonesian live export market and the other on the fattening of goats for the provincial market. The trials were undertaken in collaboration with village-based farmer groups using the local feedlot (Table 6). Individual owners were responsible for the feeding of their animals with Dinas and NGOs providing a co-ordinating role including the monitoring of feed supply and the regular weighing of animals (generally every 2 weeks).

Trial 1 and 2: Feeding weaners forage legumes (Usapinonot and Oebola)

The trials undertaken in Usapinonot and Oebola were aimed at understanding the potential for forage legumes to contribute to improve growth rates of weaned Bali cattle (70-80 kg live weight).

Usapinonot

Tether grazed cattle, able to self-select diet based on availability, were compared with animals housed in a feedlot and supplemented with either forage or browse legume material over a period of 320 days. The legume material was fed at a daily rate of 15 g/kg animal live weight as part of a balanced diet that consisted of 40% legume and 60% local grasses. Forage legume material consisted of a mix of dried and baled *Clitoria ternatea* and *Centrosema pascuorum* or the browse legume, *Leucaena leucocephala* which was harvested daily and fed fresh. Water was made available *ad libitum*. Daily feeding rates were calculated based on an assumed moisture content of the material.

Supplementation with forage legume during the early to mid dry season (151 days from April to early September) resulted in little improvement in animal growth. Average daily live weight gain of animals supplemented with forage legume was 242 g/head.day compared to tether grazed animals that gained an average of 237 g/head.day. Animals fed *Leucaena leucocephala* in a balanced ration gained at a higher rate of this period, an average of 308 g/head.day (Figure 42 and Table 25).

From the mid dry season to the mid wet season (109 days, from early September until the end of December) the benefits of forage legumes was far greater. Average daily live weight gain for animals supplemented with forage legume or *Leucaena leucocephala* was 220 and 273 g/head.day, respectively (Figure 42 and Table 25), while tether grazed animals lost 65 g/head.day. Over the mid to late wet season (60 days, from late December to late February), the daily live weight gain for tether grazed animals increased in comparison to the preceding period (from -65 to 229 g/head.day) as feed quality and quantity improved and animals were able to make some compensatory weight gains. Growth rates of 192 g/head.day and 243 g/head.day were recorded for those animals supplemented with forage or browse legumes (Table 25). It should be noted that the supplemented animals were 30-45 kg heavier than the tethered animals and hence had a higher requirement for maintenance.

This experiment showed that animals fed native forages experienced a distinct decline in live weight gain during the late dry season and early wet season, compared to a steady increase in live weight for those supplemented with legume (Figure 42). Overall, *Leucaena leucocephala* and forage legume supplemented animals gained weight at rates 2.2 and 1.7 times higher than those fed native forages. This equates to an additional 30 kg live weight gain during the period for those supplemented with forage legumes and 49 kg for *Leucaena leucocephala*.

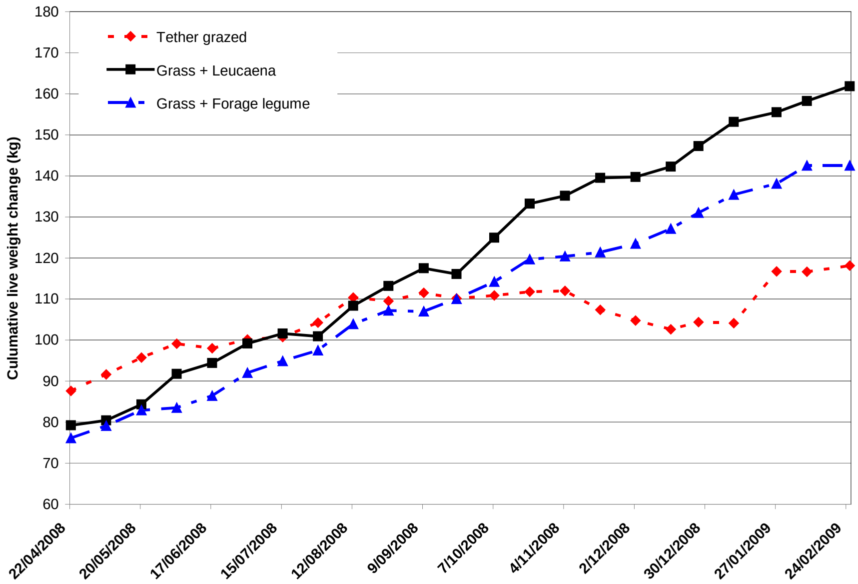

Figure 42: *Comparison of the cumulative live weight gains of weaner cattle at Usapinonot, TTU, West Timor (2008/09) either, a) tether grazed and allowed to self select their own feed, b) fed a balanced ration of grass and forage legume, or c) fed a balanced ration of grass and* Leucaena leucocephala*. Animals were fed for a total period of 320 days.*

Table 25: *Comparison of the live weight gains of weaner cattle at Usapinonot (TTU) when a) tether grazed and allowed to self select their own feed, b) fed a balanced ration of grass and forage legume, or c) fed a balanced ration of grass and* Leucaena leucocephala*.*

Treatment	**Mean animal weight and number per treatment**	**Early to mid dry season** April to early-September (151 day period)		**Mid dry to mid wet season** September to December (109 day period)		**Mid-late wet season** late December to late February (60 day period)		**Overall** April 07-Feb 08 (320 day period)		**Mean animal weight**
	Day 1	LWG /day	LWG over period	LWG /day	LWG over period	LWG /day	LWG over period	LWG /day	LWG over period	Day 320
	(kg)	(g)	(kg)	(g)	(kg)	(g)	(kg)	(g)	(kg)	(kg)
Tether grazed	76 (n=4)	237	36	-65	-7	229	14	132	42	118
Grass + forage legumes	71 (n=5)	242	37	220	24	192	12	225	72	143
Grass/*L. leucocephala*	71 (n=6)	308	47	273	30	243	15	284	91	162

Oebola

The same feeding treatments were imposed in the Oebola village trial run over 180 days in the early to mid-dry season (March-September). Results were confused by the selective grazing of a legume (thought to be *Macrotyloma uniflorum*) endemic to the area which resulted in control animals achieving higher daily live weight gains (360 g/day) than those supplemented with controlled rates of legume (288 g/head.day-forage legume; 226 g/head.day-browse legume). Given the Usapinonot experience, even without the presence of the endemic legume in the tethered grazing treatments, differences in weight gain may not have been evident during the period of this trial.

Trial 3: Fattening bulls (Marapokot)

While the feeding trials at Oebola and Usapinonot were aimed at live weight gain in weaner cattle, this trial was focussed on the fattening of bulls, comparing the supplementary feeding of either *Centrosema pascuorum* or *Clitoria ternatea* hay (at a rate of 1 kg DM/head.day) with fibre provided through the feeding of fresh local grasses and rice straw. Supplementation with *Centrosema pascuorum* or *Clitoria ternatea* hay resulted in mean live weight gains of 446 and 525 g/head.day, respectively (Figure 43 and 44). The long term live weight recording program at this feedlot suggests that bulls being fattened (>200 kg live weight) on native grass and rice straw typically grow at a rate of 350 to 400 g/head.day. It should be noted that the feeding of legume at a rate of 1 kg DM/head.day is half that recommended by BPTP for a Bali bull of 200 kg live weight. At the recommended overall feeding rate of 2.5% of live weight/day an animal should have received a total ration of 5 kg DM/day, 40% of which would have been legume (i.e. 2 kg of legume per day).

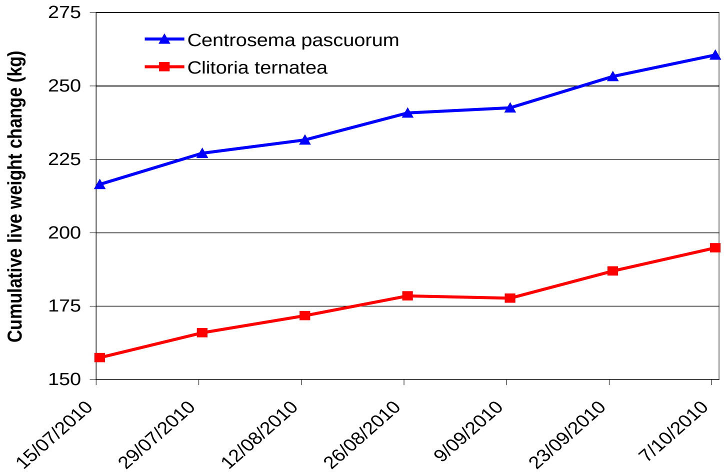

Figure 43: *Live weight gains for Bali cattle fed* Centrosema pascuorum *and* Clitoria ternatea *at Marapokot, Nagekeo, Flores.*

Figure 44: *Regular weighing of cattle at Marapokot was undertaken by local Dinas staff.*

Figure 45: *Goats being fed a sole diet of* Clitoria ternatea *at Ulupulu, Nagekeo, Flores.*

Trial 4: Feeding goats (Ulupulu)

The trial was undertaken at the village of Ulupulu, Flores for 2 months during the 2010-11 wet season. Goats fed *ad libitum* on a diet consisting entirely of either *Clitoria ternatea* or *Centrosema pascuorum* hay achieved live weight gains of 33 and 58 g/head.day, respectively, whereas animals fed native grass *ad libitum* lost 33 g/head.day, over the same period (Figure 45 and 46). This trial was conducted through the wet season when native grasses were actively growing and contained high levels of moisture which may have caused some scouring in the control animals.

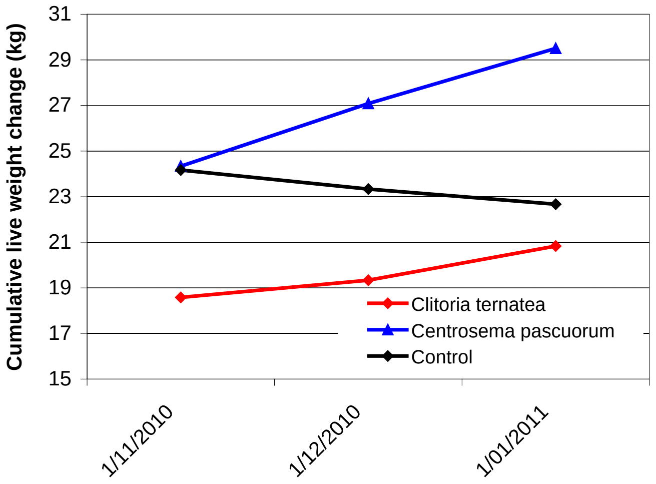

Figure 46: *Live weight gains for goats fed* Centrosema pascuorum *and* Clitoria ternatea *compared to native grass (control) over an eight week period at Ulupulu, Nagekeo, Flores.*

7.4.2 Developing recommendations for the feeding of cattle

Recommendations were developed to assist those fattening bulls for the live export market to better utilise feed resources. Table 26 forms the basis of a ration for this purpose based on a daily legume intake of 10 g/kg LW and an overall daily feed intake of 2.5% live weight. This results in a daily ration consisting 40% forage or browse legume material with the remaining 60% consisting of grass, crop stover or fibre from other sources. As these calculations are done on a dry weight basis, actual moisture contents of the various feed types needs to be considered when calculating actual feed requirements.

Table 26: *Recommended daily feeding rates (kg, based on forage moisture content) of legume and fibre to maintain a well balanced ration across a range of cattle live weights. Data assumes that the diet is fed at a rate of 60% fibre to 40% legume. Feeding rates are dependent on the moisture content of the feed.*

	Legume Daily animal feed requirement				**Grass/ Straw Daily animal feed requirement**			
Cattle live weight	**Oven dry**	**Hay+**	**Fresh+ (Dry season)**	**Fresh+ (Wet season)**	**Oven dry**	**Hay+**	**Fresh+ (Dry season)**	**Fresh+ (Wet season)**
	(~100% DM)	(90% DM)	(40% DM)	(25% DM)	(~100% DM)	(90% DM)	(40% DM)	(25% DM)
(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
100	1	1.1	2.5	4	1.5	1.7	3.8	6
150	1.5	1.7	3.8	6	2.3	2.5	5.6	9
200	2	2.2	5	8	3.0	3.3	7.5	12
250	2.5	2.8	6.3	10	3.8	4.2	9.4	15

+Calculation of feed requirement are based on reasonable moisture contents, however, if there is concern that actual moisture contents of a particular feed source are markedly different to those stated, they should be checked prior to feeding.

7.4.3 Feeding fresh or dried legume material

The original project hypothesis was that forage legumes could be grown during the early to mid dry season with biomass stored for feeding in the late dry and early wet seasons when high quality feed was most needed and generally unavailable. While hay is often stored as a loose stack, it was considered to be more effective to produce compacted bales due to their space efficiency and ease of stacking and handling. A hand operated press was designed by BPTP NTT to produce a bale weighing 10-12 kg in less than 5 minutes (Figures 47 and 48). While the press improves the efficiency of hay storage, it also provides a convenient ‘portion control’ mechanism for farmers feeding animals and for extension agents making recommendation on feeding rates. Individual units cost around A$300 to fabricate and currently rely on an imported jacking mechanism, although discussions have been held with government engineers in Bogor to develop a local alternative. Approximately 15 units were produced by the project and are being used by a number of projects in ENT. A training video was produced to demonstrate the use of the device.

As farmers began growing forage legumes in cereal based cropping systems, many made the decision to feed legume material as it became available in the early dry season and to reserve browse legumes e.g. Leucaena, for later dry season use. This was a logical decision by farmers as biomass could be fed fresh with no requirement for storage. However, from a perspective of optimising the efficiency of use of quality forage material, the feeding trial at Usapinonot (Figure 42) suggests that maximum benefit is derived from legumes fed in the late dry and early wet seasons and hence, the development of labour efficient and cheap storage systems is a necessary consideration.

Figure 47: *Legume biomass being placed into the compression box of the hand operated hay press.*

Figure 48: *The pressed bale of hay (10-12 kg) ready for storage.*

7.5 Building and maintaining capacity

7.5.1 Farmer and extension staff training

Farmer engagement and developing awareness

During the establishment phase of the project when sites were being selected for collaboration, meetings were conducted in prospective villages to gauge interest and support for longer term collaboration. In all cases existing farmer groups established by NGOs or government agencies were used as the basis of engagement. As the project progressed meetings were conducted 2-3 times a year with each participating group. These were used to provide and receive feedback on project activity and as an opportunity to increase farmer knowledge on the potential for legumes to contribute to the farming system. To reinforce farmer understanding on the use and value of legumes, a series of 6 posters was developed and placed in village meeting houses (see below). *Ad hoc* farmer feedback, supported by more formal baseline and longitudinal social evaluation were important in understanding the farmer perspective on legume use and were an important influence on future research planning and implementation.

Project update and planning meetings

Group leaders from each participating village and local extension staff (Dinas, BAPPEDA and NGOs) participated at annual project meetings held in Kupang, and later Ende and Mbay, Flores. Producer forums, conducted as part of these gatherings, provided respected farmers with the opportunity to inform organisational managers on the issues of importance to them and to provide their perspective on the use of legumes in local cropping systems. Ten meetings were conducted over the life of the project with 10-25 farmers actively involved at each.

Extension activities

Cross visits between farming communities in West Timor and Flores were used to expose farmers to research outcomes and to the experiences of their peers. Around 8 were conducted during the project. Visits to the Naibonat Research Station provided the opportunity for farmers to see research in progress and to provide input into the selection of legumes for use in their local environments. This feedback was invaluable in identifying particular species for later on-farm deployment.

Two field days were conducted at Oebola and Belu at which the Regional Director of Livestock Services, extension officers, sub-district chiefs and farmers were shown results of the project. 40-50 people attended each function.

Of particular interest were the extension activities undertaken by farmer groups without the involvement of the project. This occurred in Oebola and Usapinonot where local farmers invited other farmer groups to see the impact of the research on animal and crop production. At Oebola, the group leader provided each of the visiting farmers (4 groups comprising 29 farmers and 4 extension staff) with a small quantity of seed to trial on their own farms. The seed had been produced locally by the group members.

While the project was tasked with researching the potential role of legumes in ENT farming systems and was not particularly focussed on extension, both BPTP and DINAS included the use of forage legumes in their development/research agendas. This occurred at a number of locations including Tobu (TTU) where forage legumes were introduced as part of the national Primatani animal production initiative (BPTP and DINAS) and the SMAR Young Scientist Support Program. Sophia Ratnawarty (SMAR young scientist) introduced 3 farmer groups to legume production with the groups producing and selling seed (Figure 48) and feeding cattle from a hectare of *Clitoria ternatea, Centrosema pascuorum* and *Lablab purpureus*. The groups also tested the potential of relay cropping legumes into maturing maize.

DINAS Animal Production in Nagekeo, Ende, Kupang and Belu, and the agricultural high school at Soe, TTS regency all developed legume seed increase programs (particularly *Clitoria ternatea and Centrosema pascuorum*) to meet local and provincial demand. Interest and expertise in seed increase has improved in these districts over the past 2 years, a result of support from the Crawford Fund for the training of 6 extension/research officers in seed production techniques in 2011.

Figure 48: Tobu-Farmer managed seed production of *Clitoria ternatea*, *Centrosema pascuorum* and *Lablab purpureus.*

7.5.2 Development of extension resources

Forage production manual

The production of the manual "*Using herbaceous legumes in crop and livestock systems of Eastern Indonesia"* has been a major output of the project. While extension agents are the primary audience for the manual it will also be of value to students (high school and university) and researchers. The manual is currently in the final stages of editing with versions in Bahasa Indonesia and English planned by mid-2013.

Posters

A series of posters was developed to provide a focus for discussion during farmer group training and as a longer term prompt to farmers on aspects of using legumes in cropping systems. Individual posters cover:

1. The traditional farming system
2. Farming systems options
3. Why legumes?
4. Identifying legumes
5. Feeding cattle-the role of legumes
6. Legume biomass storage

Posters were provided to each of the 12 collaborating farmer groups in West Timor and Flores. In the majority of cases posters were displayed in the village meeting house.

7.5.3 Change manager communication

The main mode of communication with the managers of BPTP, Dinas Livestock and Agriculture, the Universities and NGOs has been through the conduct of annual project meetings held in Kupang and later Ende and Mbay, Flores. 10 of these meetings were conducted with 30-50 people commonly attending. While this included the more senior managers of organisations it also included many junior project staff, or others interested in project activity. Farmer representatives were also involved and actively participated. These meetings were used as a platform to inform collaborating organisations of project activity and, over the course of the project, led to good linkages with BAPPEDA and Dinas in regencies including Kupang, TTS, TTU, Belu, Nagekeo and Ende. Involvement with the Agricultural High Schools at Soe, Aeramo and Boawe has led to collaborative research and seed increase and involvement in the development of curriculum for high school students focussing on the use of legumes.

7.5.4 Staff Skills development

Short term and work place training

Sampling soils to determine nutrient and water status
As the APSIM farming system model requires comprehensive soil and crop information, it was necessary to sample soils to a higher level of intensity than is generally required. At the commencement of the project skills were not available in BPTP to characterise soils for Plant Available Water Capacity (PAWC) or to routinely monitor soil water and nutrient status. Appropriate sampling equipment was purchased or fabricated and 3 staff trained in sampling and processing techniques (Figures 11, 12, 13 and 14) and the maintenance of equipment. Soil monitoring became a routine procedure for local technical staff and resulted in all research experiments being monitored for nutrient and soil water availability and the determination of PAWC on 7 soils in West Timor and 3 (partially characterised) in Flores (Table 3).

Laboratory analysis of soil and plant material (2007 and 2008)
Whilst it was recognised that BPTP-NTT had good laboratory facilities at Naibonat Research Station there was a requirement for staff to be trained in aspects of soil and plant analysis. This resulted in the University of Queensland (UQ) providing a 12 day training course in soil and plant analyses techniques to 11 BPTP staff (funded by the Crawford Fund). Subsequent to the training, a simple and relatively rapid method for the analysis of soil nitrate was developed based on the Merck RQ Flex proprietary analysis system. To ensure consistency in analytical techniques, the manual "Protokol analisis nitrat tanah dengan menggunakan Merk RQeasy Nitrat (*Analysis protocols for the measurement of soil nitrate using an Merk RQeasy Nitrate Meter)"* was developed by the project VIDA volunteer in collaboration with laboratory staff. Feedback from staff indicated that it was the first time that they had understood the relevance of the analyses they had been asked to undertake. This method is now being used by other client projects of the BPTP Naibonat Analytical Lab.

Climate monitoring
Knowledge of local weather conditions are critical to the interpretation of results from agronomic experimentation and are a basic requirement for the meaningful simulation of farming systems. As official climate data collection in ENT is focussed on the larger towns, small, relatively cheap electronic weather stations were installed at 12 research locations (6 in West Timor with 4 currently operating; 6 in Flores) with the majority monitoring daily temperature, radiation and rainfall (Table 2). A protocol "*Setting up a met station for the measurement of temperature, radiation and rainfall*" was developed to allow local technical staff to download data and maintain the units. Data for each station are available for the periods specified in Table 2. Due to maintenance challenges associated with the isolation of the stations there are periods within the record where data was not recorded.

On-farm research planning – designing the question (2006)
This 2 day course was facilitated by Dr Jeremy Whish from CSIRO with ~15 BPTP researchers and technical staff attending. The aim was to develop strategies to assist researchers in teasing out an appropriate research question from the cloud of options and opportunities surrounding a particular issue.

Using simulation modelling in agricultural research (2007)
Three BPTP research staff (Budisantoso, Leki Seran and Ratnawarty) attended 2 weeks of training in Australia in farming systems research and systems modelling techniques. The training was aimed at providing a basic overview of simulation modelling to enable researchers to better understand the physical data requirements for simulation modelling (soil, climate, crop information). Participants were exposed to a range of Australian on-farm research activities, and model training which included the use of crop and soil parameters collected in West Timor to develop basic models for Maize, *Centrosema pascuorum* and *Clitoria ternatea*.

Practical training in tropical legume and grass seed production (2011)
It was recognised that legume seed production needed to be a focus of research and development if they were to become a major component of the ENT farming system. Six staff from 3 organisations (BPTP, Dinas and BAPPEDA) in West Timor and Flores undertook specific seed production training in Australia at the QDAFF Walkamin Research Station. The course included key principles of seed production and practical demonstration using examples of the legumes used in ENT. Training materials were prepared for the course and seed production plans developed for use on return to ENT. The majority of these staff are now actively involved in seed increase for their respective organisations.

Two staff also undertook a study tour of seed production in Thailand hosted by Ganda Nakamanee from the Nakhonratchasima Animal Nutrition Research and Development Centre at Pakchong. This was an opportunity for staff to see how a highly successful seed increase enterprise operated in a country with many similarities to Indonesia.

Post-graduate training

The project supported the post-graduate training of 4 staff. Two were awarded Masters Degrees from the University of Nusa Cendana with the direct support and supervision of project staff, while 2 were awarded John Alwright Fellowships for study in Australia. All are employees of BPTP.

a) **Sophia Ratnawarty** (MSc 2007-08). Undertook research on the fixation of nitrogen in forage legumes and has gone on to undertake her Doctorate in legume management in Bogor.
b) **Alex Leki Serran** (MSc 2007-08). Undertook research on the development of parameters for the modelling of forage legumes and has progressed to the management of BPTP projects in West Timor.
c) **Yohanis Ngongo** (PhD 2008-2012) was awarded a John Alwright Fellowship to undertake a PhD in social science at the University of Queensland. His thesis was titled *"The Political ecology of agricultural development in tropical savannahs of West Timor, Indonesia"*. He was awarded his Doctorate in 2012.
d) **Evert Hosang** (PhD 2009-2013) was awarded a John Alwright Fellowship to undertake a PhD in agriculture at the University of Southern Queensland. His thesis was titled "*Improving Seed handling and soil fertility to increase the production of landrace maize in West Timor".* His thesis has been submitted and it is anticipated that he will be awarded his PhD in 2013.

VIDA placement

Australian graduate, Skye Gabb, was appointed as a VIDA (Volunteer for International Development from Australia) in October 2010 and worked as a research officer in tropical forage and crop production for 10 months based at Naibonat Research Station. Skye did an excellent job of mentoring BPTP soil analysis staff and worked alongside researchers and technical staff undertaking field research in West Timor and Flores. Her specific contributions to training and extension include senior authorship of the soil analysis protocol (see above), editing of the forage legume production manual (see above) and the development of operational and communication plans for the project (Appendix 2).

Conferences

Staff attended a number of international conferences at which both oral and poster presentations were made. These included:

- International Grasslands Congress, Mongolia - Budisantoso *et al* (2008)
- 14th Australian Agronomy Conference, Adelaide - Dalgliesh *et al* (2008)
- Asia/Aust Animal Science Congress, Hanoi - Dalgliesh *et al* and Budisantoso *et al* (2008)
- 15th Australian Agronomy Conference, Christchurch - Dalgliesh *et al* and Hosang *et al* (2010)
- SAADC Conference, Thailand - Kana Hau *et al* (2011)
- 16th Australian Agronomy Conference, Armidale - Hosang *et al* (2012)

Presented papers are noted in Sections 8.3 and 10.1

7.6 Social considerations for integrating forage legumes into farming systems

The social research program was designed to aid in the identification of appropriate communities for collaboration, the benchmarking of farmer practice within those communities and the longitudinal evaluation of change as a result of project intervention. As part of this process regular feedback was also sought from collaborators and project researchers on research direction and recommendations for modification.

7.6.1 Identification of collaborating villages and farmers

In the interests of expediency, the initial selection of villages for collaboration was based on the knowledge of local researchers and their past experience of working in agro-climatological regions of interest to the project. During the 7 years of the project, the work of the social scientists, complemented by input from biophysical researchers, led to an evolving set of criteria for the selection of villages and groups which, by the time of selection of sites in Flores in 2009, had developed into the following criteria:

Ownership of cattle

While it may seem like an obvious selection criteria for a legume/cattle/crop integration project, it is the subtleties of animal ownership that required clarification. In traditional villages, animals are seen as a means of storing wealth for use in times of emergency or to fund education. There is little incentive for these animal ‘keepers' to optimise production. In many cases farmers indicated that they owned cattle and that they were destined for live export, but the reality was often different. These farmers often had an agreement with an absentee owner e.g. cattle trader, to care for the animals and manage their grazing on local native pastures. When the animal reached the desired weight it was sold by the trader, with the ‘carer' receiving a payment for services. Social research indicated that this payment did not include any incentive to optimise feed quality despite it being in the interests of the owner i.e. the trader. This learning also suggests that traders are key stakeholders in developing legumes for animal feeding and are likely to have significant influence on the incentives for small-holders to utilise forage legumes.

Government and non-government animal (cattle and goats) provisioning schemes, where animals are provided to farmers on a profit sharing basis, also muddy the waters of ownership and interest in improved animal nutrition. Again, it would seem logical that a farmer who had been provided with an animal on a 70:30 profit sharing basis would aim for fast animal turn-off to increase throughput and maximise profits. However, social research uncovered the reality that farmer demand for animals from donor schemes often outstripped supply, with a wait of 2-3 year not uncommon before an individual farmer was able to re-stock on the sale of an animal. This stop/start process was a disincentive to investment in improved nutrition. The project therefore, aimed to engage with farmers who privately owned animals, or were able to access government loans for the outright purchase of them, and who saw themselves as producing animals for financial gain, rather than just animal keepers. The project identified that smaller or poorer farmers would be unlikely to gain direct advantage from animal ownership and the benefits of forage legume use, although it was considered that they may be able to derive some benefit through seed production or the provision of legume biomass to animal owners.

The collaboration of a well functioning farmer group

Having a cohesive farmer group focussed on a common village goal was critical to community collaboration. Such groups became the focus of research activity which was either undertaken on a member's farm or on land managed by the group. Many groups reserved particular days each month for communal activity in which members were expected to participate. Communal work included village development activities, or in the case of agricultural research, the undertaking of weeding or harvesting or other management practices.

A high level of farmer group and village governance

A well functioning farmer group generally only occurs under strong group and village leadership structures which are supported by the broader community. This results in the development of local policies that ensure the successful running of the farmer organisation. A common example of this was in the setting of a community rule to make the tethering of animals compulsory to reduce conflict caused by the free grazing of cattle. Strong leadership was also central to the development of village infrastructure required for animals (e.g. feedlots) and communal arrangements for sharing animal production returns.

Government and NGO extension agencies support at the village level

Support from village-based government and non-government agencies provided the project with local expertise of farming systems and existing networks with local farmers and farmer groups. They generally had a good rapport with the farmers which eased the way for a new project entering the village. Support of farmer groups in the conduct of animal feeding trials is a good example of where extension agents were beneficial to project outcomes.

7.6.2 Benchmarking social systems and farmer practice

Preliminary village selection was followed by in-depth interviews within each village (Table 27) to confirm suitability. These were undertaken by a joint team of social and agricultural researchers and included individual interviews with the village leadership, and individual and communal interviews with members of the selected farmer groups. Interviews focussed on developing understanding of the characteristics of the individual farming family and their ownership of land and cattle. Information was also sought on family income and the challenges they faced in food production.

Table 27: *Social research benchmarking survey locations and respondent numbers.*

Island (survey timing)	Regency	Village	Farmer respondent	Local government respondent	Extension respondent
			(No.)	(No.)	(No.)
West Timor (2006)	TTU	Usapinonot	6		
		Lapeom	8		
	TTS	Biloto	7		
	Kupang	Sillu	7		
		Ponain	6		
	Belu	Kletek	6		
		Kakaniuk	11		
Total			**51**		
Flores (2009)	Ende	Nakuramba	9	1	3
		Wolomasi	11	1	1
	Nagekeo	Ulupulu	12	1	2
Total			**32**	**3**	**6**

West Timor 2006

Fifty one farmers (46 male, 5 female) were interviewed in 7 villages in the first round of interviews undertaken in 2006. Five villages were representative of the upland Meto tribal grouping and 2 the lowland, coastal Tetun grouping. Tetun society is matrilineal with women the head of the household and owners of the land. The average age of respondents was 47 with 60% indicating that they had <6-8 years of formal schooling. 60% had at least 41 years of farming experience. Land was characterised on usage (Table 28) with the uplands being the most important for rainfed agriculture. Fifty of the 51 respondents indicated that they owned upland areas that ranged in size from 0.45 to 1.5 ha and located in 1 to 9 separate parcels. Disaggregation is an important logistics and crop security issue with parcels that are further from the house being less well serviced or secure. The area of upland held by a farmer dictates the potential production area for annual rainfed crops, although the amount planted is dependent on land security, the amount of land in fallow or estate crops, the food requirements of the family and labour availability, either sourced from within the family or through hire. Farmer groups have an important role in enabling individuals to maximise their production area through communal support for labour intensive operations such as land preparation (Figure 49).

Table 28: *Range in land ownership and land types owned by the 51 farmers from 7 villages in West Timor interviewed in 2008.*

Type of land	Farmer	Land parcel	Total farmer holding	Cultivated
	(No.)	(No.)	(ha)	(ha)
Upland	50	1 - 9	0.5 - 6.5	0.45 - 1.5
Rice field-irrigated (2 villages)	4	1 - 3	0.20 - 0.5	0.20 - 0.50
Agro-forestry	3	1 - 2	0.1 - 0.4	0.1 - 0.4
Other *	3	1 - 3	0.20 - 1.5	0.20 - 1.5
Fallow land	11	0 - 6	0.5 - 4.5	

* Teak/forest land, forage or mixture of trees and forage

Seventy percent of those farmers interviewed owned cattle, with individuals managing between 1 and 10 animals (Table 29). Ownership was weighted towards breeding (110 of 167 animals) and fattening with 53 head sold during 2005. Only 9 animals were purchased or provided by donors over the same period (Table 30), indicating that farmers were either breeding the majority of their replacement animals or herd numbers were declining.

An analysis of the income (total production x farm gate price - input costs) of the farmer respondents indicated that those who grew upland crops and owned cattle had an average annual household income 60% higher than those who relied solely on upland crops (Table 31). These farmers also had an average income 27% higher than those who grew a combination of upland rainfed crops and lowland irrigated rice. Given that the sale of rainfed upland crop production only occurs after family food security requirements have been met, it is hardly surprising that those farmers who rely solely on this source of income are disadvantaged. Cattle provide the means to move out of the subsistence economy and access the broader cash economy without detriment to food security. These findings suggest there is significant incentive and pull for technologies such as forage legumes to further enhance financial gain through the inclusion of animals in the production system.

Figure 49: *Farmer group support for labour intensive activities such as land preparation allows the individual farmer to optimise their area of production.*

Table 29: *Cattle ownership range and total number (2005) owned by the 51 farmers interviewed in 7 villages in West Timor.*

Animal class	Farmers	Ownership	Total cattle in interview group
	(No)	(No/range)	(No)
Bull	17	1 - 4	28
Cow	29	1 - 10	88
Young bull	17	1 - 3	26
Heifer	16	1 - 3	22
None	15		
Total			167

Table 30: *Cattle sales/purchases (2005) by the 51 farmers interviewed in 7 villages in West Timor.*

Cattle Sales		Cattle purchases	
Farmer number	27	Farmer number	6
Cattle sold	53 head	Cattle purchased	9 head
Total value (Rp. ‘0000)	969	Total value (Rp. ‘0000)	890
Av price/head (Rp. ‘0000)	182	Av. price/head (Rp. ‘0000)	988

Table 31: *Household incomes (2005) derived from a range of agricultural enterprises undertaken by the 51 farmers interviewed in 7 villages in West Timor.*

Land use	Commodities	Income	External input costs	Net income
		(Rp. ‘0000)	(Rp. ‘0000)	(Rp. ‘0000)
Upland Only	Upland food crops	246.2		246.2
Upland + Low land irrigated rice	Upland food crops Irrigated rice	244.1 225.0	 19.0	
Total		469.1	19.0	450.1
Upland + Cattle	Upland food crops Cattle	241.4 387.6	 12.5	
Total		629.0	12.5	616.5
Upland + agro-forestry	Upland food crops Agro-forestry	51.5 400.0		
Total		451.5		451.4

Notes: (a) Similar types of farming were grouped and counted as average production
(b) Income = total production (kg) x farm gate price (Rp)
(c) External inputs = fertilizers (urea, SP-36, KCl), pesticides, vitamins, vaccination, etc..

When asked to consider the challenges that they faced as small-holder farmers, the agricultural issues that were most cited included the limited access to capital, the shortage of labour, climate variability and management of the weed, *Imperata cylindrica* which infests large tracts of land across ENT. With regard to cattle fattening, farmers indicated that dry season feeding was their biggest challenge, both in terms of sourcing suitable forage material and in finding the labour to harvest and transport it to the feedlot. This helped highlight the niche and relevant socio-economic questions for forage legumes in these systems.

When asked to comment on longer-term production trends, the majority considered that while crop area had remained the same, yields were declining and therefore food security was also dropping. This was considered to be a result of an increasingly variable climate and decreasing soil fertility. There was also a general consensus that cattle numbers were declining due to the sale of animals at an earlier age (including breeding females) which was a result of the attractive prices being offered by live exporters. Farmers indicated that they felt forced into selling cattle to support family food security which had been jeopardised by poor crop harvests.

Flores (2009)

Forty one interviews were conducted in 3 villages in Flores (Table 32). The majority of interviewees were farmers (32) although local government leaders (3) and extension staff (6) were also interviewed to gain a broader picture of governance and village level demographics. Upland, rainfed farming predominated in all 3 villages with around 80% of households involved. Around 70-80% of respondents were primary school educated e.g. 69% of women and 77% of men in the village of Ulupulu, with the reminder attending high school. From 1 to 3% attended university. Over 79% of those engaged in agriculture owned their own land with farm size ranging between 0.5 and 3 ha. Average farm size was quoted as 0.5 ha although it is thought that this more closely represented annual crop production area than total available land in villages like Nakuramba where swidden agriculture was practiced. In this village a move to a new production area occurred every 4-5 years because of the extreme slope of the land (40-80 degrees), the shallow depth of the soil and the high erosion rates which result in nutritional run down (Figure 50). There was also a higher reliance on estate crops (candle nut and cacao) in this village.

The differences in cattle and goat ownership between the villages of Nakuramba and Ulupulu (data was not recorded at Wolomasi) are a reflection of the different emphasis of NGO and government extension groups. Prolonged NGO engagement and financial support of cattle production at Ulupulu resulted in a focus on this animal, whereas at Nakuramba support for goats from BAPPEDA and Dinas, including the establishment of a communal feedlot, resulted in 140 households owning goats.

Table 32: *Demographics for 3 villages in Flores showing the number of households engaged in farming and the levels of animal ownership (2009).*

Village*	Households engaged in farming	Land area: household number	Land portions/ household	Mean Distance to farm from house	Households owning animals
	(No)	(ha:No)	(No)	(km)	(No)
Nakuramba	286 (213 own land)	<1 ha: 60HH 1 to 5ha: 226HH Mean = 0.55 ha	2-3	4	Cattle: 4HH (31 animals) Goats:140HH (340 animals) Pigs: 24HH (315 animals)
Ulupulu	246 (210 own land)	<0.5 ha: 105 HH 0.5-3ha: 105 HH Mean = 0.47 ha	2-3	2.2	Cattle: 80HH Goats:35HH Pigs: 125HH
Wolomasi	-	0.1-1.5 ha Mean = 0.6 ha	3-4	1.2	-

Analysis (Table 33) indicates that food, estate crops and animal production all contribute significantly to on-farm income, however when compared against their West Timor peers (Table 31) Flores farmers earn 30-40% less. The lower income reflects a higher predominance of animal 'keepers', an increased emphasis on lower value animals (goats), differences in farm size and lower average crop yields.

Table 33: *Mean on-farm and off-farm income for 32 farmer respondents from 3 benchmarked villages in Flores (2009)*

Source of income	Ulupulu		Nakuramba		Wolomasi	
	(Rp. '0000)	(%)	(Rp. '0000)	(%)	(Rp. '0000)	(%)
On-farm income:						
Food crops	188.6	46	165.9	42	155.8	35
Estate crops	77.9	19	102.7	20	106.8	24
Forestry	20.5	5	23.7	6	31.2	7
Animal production	102.5	25	102.7	26	124.6	28
Off-farm income	20.5	5	23.7	6	26.7	6
Total	410.0	100	418.7	100	445.1	100

Figure 50: *Swidden agriculture at Nakuramba, Flores surrounded by the estate crops of candle nut (in flower) and cocoa.*

7.6.3 Longitudinal evaluation of project impact on participating villages, farmers and researchers

Identifying farmers likely to use forage legumes

There is no doubt that farmers and extension authorities see value in the use of forage legumes in cereal-based farming systems. Two hundred and fifty interviews with members of farmer groups, extension staff and local government authorities, undertaken as part of longitudinal evaluation in 2007, 2008 and 2011 (Table 6) indicate that the production of forage legumes is attractive to particular types of farm enterprises. Those fattening animals for sale and having difficulty in sourcing consistent feed of high quality are the most likely to commit. As the number of animals being fattened increases, so too does the demand for quality feed and the potential for forage legumes to form part of the mix. The farmer with a small number of cattle (~1-3) and access to browse legumes and communal grazing is unlikely to be interested in using high demand family labour to produce forage legumes. These farmers are also more likely to be animal 'keepers' rather than 'producers' and as a consequence less oriented to animal fattening and sale.

Evaluation suggested that while farmers understood the potential for legumes to contribute to crop nitrogen supply and had experienced small increases in maize grain and stover yield as a result, there was no indication that better crop yields would be the primary reason for growing legumes, given the small yield increases being observed. It is therefore unlikely, that the 30% of farmers in participating West Timor farmer groups (Table 29) who did not own cattle in 2006, would invest in forage legumes unless improvements were made to the nodulation and fixation ability of the legumes or markets develop for the sale of animal feed or seed. Contract forage production could be driven by either local demand or by demand from the live export trade.

Future structures to encourage adoption

Agency personnel were interviewed individually to ascertain their attitudes and aspirations for forage legumes to be part of cereal-based farming systems. Discussion focussed on the future direction of agriculture and its governance with the general view of senior government and NGO extension staff, being that agricultural intensification was both necessary and inevitable because shifting agriculture was becoming increasingly dysfunctional, and because of pressures for agriculture to continue to provide food security to an increasing population. Agricultural intensification was viewed as requiring attention to both cash and subsistence crops in a diversified farming system with the increasing integration of crops and livestock via legume forages viewed as a useful step towards a more intensified, diverse, balanced and productive farming system.

Agency representatives considered that in promoting farming system change to address the historical decline of traditional practices, the project was also advocating social change (changes in farming community attitudes and behaviour). The experience of the village of Usapinonot is instructive regarding the *management* of social change. This village enjoys a simultaneously modern (Kepala Desa and Farmer Group Leader) and traditional (clan) leader. This well organised and dynamic leader views the problem of change management as a problem of increasing human resources:

> *"The motivation for establishing the farmer groups was to increase the members' welfare by increasing the human resources (knowledge and expertise) so as to change the working pattern from traditional production methods to those introduced by outside so as to increase production and income … The legume forages are viewed as especially helpful for increasing farmer knowledge. Early weaning is a new idea and we now have enough forage fodder to support early weaning and fattening despite the long dry season. We can use the manure (from cattle fattening stalls) for fertiliser and biogas. We can use the by-products of other crops (maize husks, banana trucks, gliricidia leaf, mungbean pods and cassava) to feed cattle with chaff mixes … The grazing lands have been reduced because of (weed) infestation … this has driven the interest in intensification of cattle production".*

Despite varying levels of optimism about the prospects of generalising this progressive attitude, many of the agency interviewees agreed that social change management is assisted by support from traditional leaders interested in change and agricultural extension that respects tradition in its pursuit of change. The interviewees indicated that social change is facilitated by clearer, more transparent rules agreed upon and enforced at the local level. These rules function to stabilise social expectations that support changes in farming practises by reducing free riding behaviour. Examples of rules that have been formulated and are in use by village level interviewees included:

- Fines for grazing cattle that damage crops (general rule);
- Fines for non-attendance of a farmer group meeting (Lapeom)
- The dedication of particular days for farmer group activities (Usapinonot).

At the district, subdistrict and villages levels, extension agencies have a role in designing and enforcing rules supporting farming practice change. For example, Dinas Livestock in Belu, TTS and TTU Districts has renovated its rules regarding cattle redistribution by making cattle provision conditional upon minimum levels of farmer group professionalism. Such professionalism includes ensuring that sufficient forage is available *before* cattle can be received. However, simply imposing a rule will not ensure farming practice change occurs. Agricultural extension also needs to respect and dovetails with tradition in its pursuit of change. Most interviewees at the agency and local levels advocate the provision of 'continuous technical support'. Continuous technical support *"does not imply a specific method, rather, it means learning more about their culture, being friendly, not forcing them to plant, explaining the benefits of the forages so that later on they will try and adopt them"* (BPTP researcher).

Farmer ideas for expediting the use of forage legumes

Relay vs. rotation

While the original project hypothesis was to grow legumes in relay with maize, longitudinal feedback in 2007 suggested that the rotation of legumes may be an alternate option. Farmers argued that the logistics of relay cropping were quite difficult given that the legume was required to be planted into the maize inter-row space at crop anthesis. This was considered to be of most concern when growing the tall (>3 m in height) landrace maize lines which are prone to lodging and difficult to physically access. This is a significant issue given that these types comprise ~50% of the maize grown in West Timor. Farmer recommendation was that where labour and land were not constraining, to consider growing forage legumes in annual rotation with maize. This was a good suggestion given that later research showed biomass yields from legumes grown in rotation were much higher than those grown in relay (Figures 27 and 33).

Fresh vs. dry feeding

In the semi-arid tropics it is common for cattle to lose weight in the late dry and early wet seasons due to a lack of sufficient high quality feed. Browse legumes are often in short supply by this time, or at a prohibitive distance from the feedlot making it more difficult to supply sufficient feed to meet animal demand. The research solution was to harvest the forage legume in the early dry season and to store the material as hay for later dry and early wet season use. While this is a logical solution, the farmers identified an alternative option. Instead of investing scarce labour and resources into harvesting and storing the dried legume material, it was suggested that the legume be harvested and the fresh material fed directly to cattle in the late wet and early dry seasons, with browse legumes material retained for later dry season use. This was an elegant solution given that there was no requirement to dry and store biomass and the labour required to harvest the browse legumes later in the season was reduced because the feed source was located closer to the feedlot (Figure 51). However, the cattle feeding information from the Usapinonot trial (Figure 42 and Table 25) suggests that the quality of native feed available in the late wet and early dry seasons is sufficient to fatten animals and that it is unnecessary to provide legume supplementation at this particular time of year. Therefore, the feeding of legume material is likely to be wasteful of the resource compared to feeding in the late dry and early wet seasons.

Figure 51: Clitoria ternatea *being grown in relay with maize and sequentially harvested for direct feeding to cattle.*

Figure 52: *Leo Leau standing in what was the best maize crop ever grown on this field. Regenerating Clitoria ternatea can be seen below the maize.*

Examples of successful forage legume adoption

While a number of examples are provided of where farmers utilised forage legumes as part of a cereal-based cropping system, it should be noted that the project was not tasked with the broad scale extension of a technology, but rather, understanding the potential of such a technology. As a consequence, the experiences described are the result of engagement over a prolonged period with a small number of farmer groups, at an intensity that would be difficult to replicate into the future without high levels of extension agency support.

Usapinonot – a case study of successful village application of forage legumes
Increased maize production: Between 2007 and 2009, Leo Leau, the village and farmer group leader was exposed to the potential of forage legumes when he hosted 1 of 2 local on-farm trials. Based on this experience, he grew hybrid maize in 2010 that was grown after relay cropped *Clitoria ternatea*. The maize yield was the highest ever achieved from the particular field. This was attributed to nitrogen contribution by the relay crop (Figure 52). In addition, the forage legume regenerated on stored soil water with the biomass harvested 4 times and used to fatten cattle during the early 2010 dry season.

Improved access to credit: Normally ~20 animals were housed in the communal feedlot at Usapinonot with animals owned by individual group members who either sourced replacement stock from their own breeding herd (free/ tether grazed animals) or accessed animals through donor schemes. As with most farmers in ENT, private funds for the purchase of animals were limited. However, a government initiative in 2009/10 had a dramatic impact on animal ownership. The government supported, Farmer Group Union was tasked with providing loans to farmer groups to develop the capacity of agricultural enterprises across Indonesia. In Usapinonot, funds were used to purchase cattle with profits retained by the individual farmer. This free enterprise system was attractive to farmers because they were able to source animals on the open market. Forty cattle were purchased by the farmer group with 21 of those fattened and sold by early 2010. As a result of better access to credit, overall village cattle numbers increased by 17. Recognising the need to provide high quality feed for their cattle, and having had experience growing the forage legumes, village leaders developed the aspirational goal of establishing 5 ha of *Clitoria ternatea* over a 5 year period.

The tangible benefits of cattle ownership in this village were very obvious. Community development programs (curbing and channelling of the streets and reticulation of water), private investment in housing and the increased standards of education of the children were all cited as examples of the benefits of a stable, sustainable animal production system.

Nagekeo district (Flores) – Agency interest in developing a systems role for forage legumes
The Director of the Agency for Food Security and Agricultural Extension in Nagekeo, Flores has a long-term goal to establish a vertically integrated regional livestock enterprise supplying the live cattle export market in Sulawesi. The aim is to breed cattle in the regional uplands utilising native grasses and browse and forage legumes and to fatten in the lowlands using forage legumes integrated into the irrigated rice based cropping system. Whilst the system is still in its infancy, various aspects have been trialled in collaboration with the project.

The focus of research has been the fattening of animals and forage seed increase. The Tunas Baru Farmer Group at Marapokot has provided a case study of the integration of forage legumes into an irrigated rice-based system. In collaboration with DINAS and the farmer group, a trellised seed increase area was established in February 2010. This was designed to supply the seed requirements of group members for the most popular legumes (*Centrosema pascuorum*, *Clitoria ternatea* and *Lablab purpureus*). Five individual farmers collected seed and established fodder banks (~200 m^2) on their own land. Forage from these areas commenced to flow back into the feedlot by mid-2010 (Figure 53). Information on the resulting animal live weight gains are provided in section 7.4.1 (Trial 3) (Figures 43, 44).

Figure 53: *The* Centrosema pascuorum *fodder bank of Edmundus Bata, the leader of the Tunas Baru Farmer Group.*

Figure 54: Clitoria ternatea *being grown in an irrigation area at Mbay. The area yielded >7 t DM/ha from 2 harvests during the 2010 dry season (with 2 supplementary irrigations)*

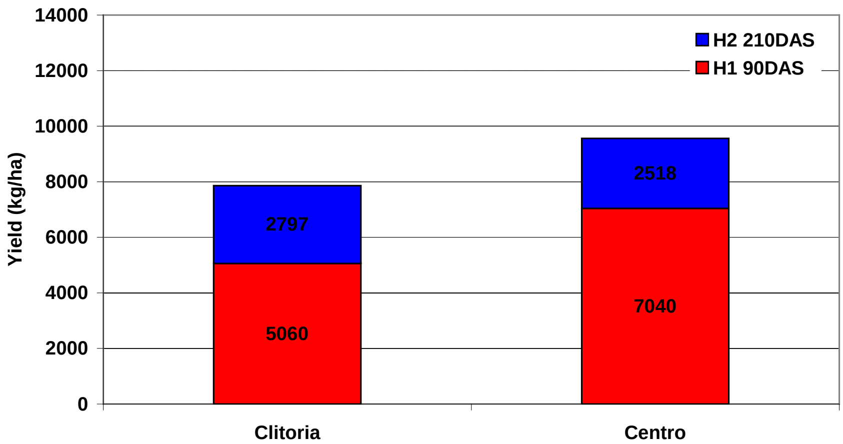

Figure 55: *2010 dry season legume biomass production (kg/ha DM) from 2 harvests of Centrosema pascuorum and Clitoria ternatea grown in Nagekeo District, Flores. A supplementary irrigation was provided to the crop after each harvest.*

In addition, an area of approx 6000 m^2 was established during the 2010 dry season to trial the larger scale production of *Centrosema pascuorum* and *Clitoria ternatea* (Figure 54) in irrigated rice-based systems. Levels of biomass production (grown with 2 supplementary irrigations over the dry season) exceeded expectations (>7 t DM/ha *Clitoria ternatea* and >9 t DM/ha *Centrosema pascuorum*) (Figure 55). The legume material was dried and baled and used in feeding trials at Marapokot (cattle) and Ulupulu (goats) (Figure 45 and 46).

To enable future expansion of forage legume use in Nagekeo, local seed production expertise was strengthened in 2011 through the project initiated (Crawford Fund) training of a Dinas extension officer (see 7.5.4.). This led to expansion of seed production at 2 SMK (Aeramo; Boawe) and a local mission.

7.6.4 Summarising the key considerations for integrating forage legumes into farming systems

During the 7 years of research there are many examples of successful use of forage legumes. There are also, as should be expected, examples of where farmers have not seen the need for change or have been constrained in their longer-term adoption. Longitudinal evaluation and *ad hoc* discussion between researchers and farmers provides insight into where the constraints to future expansion of the technology lie. These can be grouped into 4 main areas.

Availability of animals

A major constraint to future technology adoption and to moving towards the long-term Indonesian government goal of a self sustaining cattle industry is the availability of animals. As a result of high and increasing domestic demand for beef, breeding males and females are being sold at a younger age, resulting in an overall decline in animal numbers in Eastern Indonesia. Farmers source the majority of their store cattle and goats through provisioning schemes run by government and non-government donor agencies. However, with the high demand for live export, and competition for store animals, farmers often wait long periods before being provided with an animal and then after fattening, have to wait prolonged periods for its replacement. Project experience shows that while farmers see benefits in feeding forage legumes, there is little incentive to invest in the prolonged production of forages when there are no guarantees of consistent animal supply. The more market driven credit model discussed above, where the Usapinonot farmer group was able access credit to purchase cattle in their own right, holds promise for the future, allowing farmers to approach cattle ownership as a business knowing the potential risks and rewards.

Availability of legume seed

A lack of seed has been regularly mentioned by both farmers and extension staff as being the major constraint to the future expansion of the technology. While initial seed supplies were sourced overseas to meet early project demand, the longer-term goal was always to develop local capacity to ensure long-term sustainability of supply. While it was anticipated that the involvement of commercial seed production partners would be the logical means of ensuring future seed supply, this has not eventuated due to the market being too small to attract commercial interest. Consequently, a two tier approach has been taken to supply seed, a) the promotion of simple production technologies for use by farmers at the village level, and b) larger scale on-farm and on-station production. The village system (commonly 2-300 m^2) uses trellising to support the legumes. This configuration exposes more of the plants to light and encourages increased flowering and seed set. It is also easier for the farmers to collect seed. Commercial areas of up to 2 ha have been grown successfully at a number of locations by project and government agencies although there are challenges associated with the management of such large areas. To meet the growing demand for seed, research and extension agency staff have been trained in seed production techniques (Section 7.6.4.).

Availability of land and labour

It is a common misconception that the availability of land and land ownership are the major constraints to increased production in eastern Indonesia. While these issues are important in some areas and will become more generally important as the population increases, they were not considered as major limiting factors by collaborating farmers. Overall availability of labour, and conflicts for seasonal labour were more important issues in relation to the adoption of forage legumes. Land preparation and planting of food security crops were seen as the priorities prior to and during the early wet season. Once crops were established, weeding then became the priority. Attempting to integrate another crop into the system, such as a forage legume, was thought to place further pressure on seasonal labour availability. Consequently, system flexibility was required. Where land was not constraining, farmers considered planting legumes as a rotation crop in January or February after food security crops had been successfully established and labour demands reduced. Using a zero-till system and herbicides to control weeds was seen as an expedient means of reducing labour requirements at this time. Alternately, where land was not constraining, farmers considered that legumes could be grown in relay with maize or rice, with planting undertaken at around the time of cereal crop anthesis, when labour demands were lower.

The use of herbicides for the control of weeds has begun to revolutionise crop production in the more advanced farming communities of ENT. In benchmarking interviews in 2006, it was commonly stated that herbicides were too expensive for general use. It was not until farmers gained experience growing high value crops such as mungbean, where they could afford to use herbicides, that experience was gained and the technology flowed to the lower value, labour constrained crops such as maize. Traditionally, labour intensive hand tilling to a depth of 20-30 cm was the only means of controlling the grass, *Imperata cylindrica* prior to the planting of a wet season crop (Figure 49). However this is now often replaced by the use of herbicides and zero-tillage. Labour reductions are further enhanced by the use of herbicides to control weeds in-crop, freeing up labour for the production of alternate crops including forage legumes, the growing of larger areas of staple crops and the diversification of livelihood into fish farming, cattle production or off-farm enterprises.

Availability of expertise

Evaluation undertaken with farmers and extension agencies suggests that development of extension expertise has to be a priority if the potential for forage legumes is to be realised. Priority in this project has been to provide underpinning research and regional examples of how forage legumes may be used in cropping systems. Future activity needs to focus on increasing the collaboration between researchers and extension agencies to ensure broader adoption of the technology. This has commenced through collaboration with Dinas, BAPPEDA and some NGOs but needs to be increased for maximum impact.

Collaboration with the Agricultural High School at Soe (Soe SMK) in West Timor was commenced in 2008 and later extended to high schools at Aeramo and Boawe in Flores. These relationships aimed to expose staff and students to the potential for forage legumes through training in forage legume production and seed increase. It is anticipated that there will be longer-term impact from these activities as many students become farmers or extension officers after graduation.

8 Impacts

While project research has shown the potential benefits of integrating forage legumes into crop and animal systems, one of the most satisfying outcomes of the work has been the development of capacity in collaborating organisations and the moves to integrate project outcomes into regional research and extension activities, necessary to ensure longer term impact of the research. In line with the Indonesian Central Government's aim of achieving national beef self sufficiency by 2014, government development and extension agencies, including Dinas and BAPPEDA, see the role of improving animal feed supply as critical to the meeting of this goal and to broader regional development. Consequently, there has been increased investment in regional capacity and infrastructure development and in support of farmers through provision of credit and the education of the next generation. The project has supported these efforts on a number of fronts including the continuation of targeted on-farm research, direct training and mentoring of project staff and collaborators and through communication of outcomes at all levels of regional government and the farming community.

8.1 Scientific impacts – now and in 5 years

The project was tasked with the role of exploring the opportunities to improve crop and animal production through the introduction of forage legumes to the upland, rainfed maize- and rice-based production systems prevalent in ENT. A participatory on-farm engagement process was considered appropriate, understanding that the level of scientific rigor able to be brought to such research was likely to be lower than from more highly controlled research station experimentation. As a consequence scientific impact has been at the applied end of the spectrum and includes the following:

8.1.1 Identification of suitable legumes

Early project emphasis focussed on the identification of legume species which were not only well adapted to the environments of West Timor but were suitable for use in maize-based cropping systems i.e. smaller stature plants, limited twining, easy to establish and control in a cereal crop and palatable to animals. This led to the selection of *Centrosema pascuorum*, *Clitoria ternatea* and *Lablab purpureus*. Subsequent legume evaluation in 2009-12 in West Timor and Flores confirmed these selections and identified additional species with potential for future detailed evaluation. The testing of tropical legumes and the development of knowledge and information about their suitability and performance has relevance not only for ENT but also in other regions of Indonesia and northern Australia where the soils and climate are similar and demand for similar legumes is present.

An ENT example of the expansion of the use and understanding of forage legumes occurs in the district of Nagekeo, Flores where Dinas and the Agency for Food Security and Agricultural Extension have embraced the use of quality forages in the development of cattle breeding and fattening systems aimed at supplying the Indonesian live export market. Forage legumes are seen as being pivotal to the success of the enterprise, with agencies supporting project research whilst developing their own understanding of legume production and capacity to undertake extension.

Knowledge developed within the project has also allowed a more rapid identification and roll-out of appropriate forage legume species for the feeding of Bali cattle in Timor Leste as part of the ACIAR Project, LPS/2009/036: *Enhancing smallholder cattle production in East Timor*. Having access to relevant information, on which to build the research program in this project has saved significant time in species identification.

Provided that continuing support is available for regional initiatives such as the one at Nagekeo, and national priorities continue to support self sufficiency in cattle production, it is envisaged that in 5 years there will be a reliable supply of seed to drive the expansion of forage legumes and the regional expertise available to advise farmers on legume production and use in improving animal productivity. Engagement with the agricultural high school (SMK) network is seen as a long term strategy to develop capacity, with plans in place to move to the collaborative development of an SMK curriculum in forage and cattle production for use on the islands of West Timor, Flores and Sumba.

8.1.2 Optimising crop production through improved systems knowledge

Intensification through dry-season cropping

Traditional farmer practice in ENT is to grow rainfed upland crops during the annual wet season and to allow the land to remain fallow, with some grazing, during the remainder of the year. Project research has shown that there is a means of intensifying overall systems productivity, through the utilisation of late wet season rainfall and stored soil water, without exposing the farmer to increased risk. Contrary to common thinking, many of the agricultural soils of ENT are relatively fertile and have the ability to store large quantities of water for later crop use. Consequently, this resource is available to grow a crop into the dry season after the harvest of the annual cereal crop, thus increasing overall land productivity without jeopardising food security.

The new knowledge that soils in ENT have the capacity to hold between 150 and 250 mm of plant available water (equivalent to 500 – 800 mm of rainfall at a storage efficiency of 30%) and are commonly full at the end of the wet season, has resulted in the realisation by both local and international researchers that there is considerable opportunity to exploit this resource in the production of additional crops such as short duration pulses, green maize, forages or vegetables.

In 5 years it is anticipated that the value of stored soil water and its use in crop production will be commonly understood by extension agencies and some farmers. A range of crops including forage legumes will have been investigated for use in relay or rotation with cereal crops using this water resource.

Effective N fixation by forage legumes

It has been impractical to promote forage legume inoculation as a means of improving N fixation and cereal crop N supply due to the lack of understanding of legume requirements, the level of presence of appropriate endemic strains of rhizobium and the practicalities of supply and distribution of inoculums in ENT. The comparison of the inoculation of the 2 most successful legumes species with endemic and introduced rhizobial strains shows that *Centrosema pascuorum* fixed the most N when an endemic strain of rhizobia was used, while *Clitoria ternatea* fixed 50% less N when inoculated with an endemic strain compared to an introduced species. While inoculation appears promising, there are continuing questions about the feasibility of utilising endemic root nodule bacteria to avoid the necessity for other methods of inoculation. Preliminary research is showing that this is feasible, but further validation of N fixation efficiency of native strains vs. commercial strains is required. Future research should include investigation of the potential for particular legume species to contribute to N supply under field conditions with the aim being to develop rules of thumb for use by farmers when making decisions on sources of N supply. If it is shown that there is significant benefit to inoculation, then it would be the responsibility of national research and extension agencies to develop the capacity to produce and distribute product and to communicate the benefits of inoculation.

Farming systems simulation

This project has significantly advanced the ability to utilise the APSIM farming systems model to simulate production of a range of forage legumes and regional maize varieties, which has been vital in developing an understanding of the production risks farmers deal with on a daily and seasonal basis (Fig 39 and 40). The development of this regional capability has resulted from project research in both Australia and Indonesia which developed the necessary crop and soil parameters, collected and collated the long-term daily climate data for a range of ENT environments and trained Indonesian staff in the basics of model use. Development of model parameters for 3 legumes species formed the basis of post-graduate (Masters) degrees for 2 BPTP researchers. The APSIM model, and locally derived crop and soil parameters, have recently been used to investigate maize production for a range of West Timor environments as part of the PhD thesis of the John Alwright Fellowship recipient, Evert Hosang, BPTP.

In the next 5 years the developed systems modelling capability will be utilised in ongoing ACIAR projects involving farming systems research and will be vital to provide input data to investigate whole-farm implications of farming system changes in ENT and possibly other regions of Indonesia and south Asia. This type of analysis uses crop production output derived from the APSIM model as input to the IAT whole farm model (Integrated Assessment Tool) (McDonald *et. al.* 2004[23]) to investigate farmer trade-offs between enterprises and enterprise mixes and has been successfully used by farmers in other Indonesian provinces to optimise their production systems. In a similar way, there are several projects in Australia that may call upon the science underpinning APSIM's simulation of tropical forage legume production e.g. project examining irrigation and development opportunities in Northern Australia, projects examining the integration of forage legumes into Australian cropping systems.

[23] McDonald, C.K., MacLeod, N., Lisson, S., Ash, A., Pengelly, B., Brennan, L., Corfield, J., Wirajaswadi, L., Panjaitan, T., Saenong, S., Sutaryono, Y., Padjung, R., Rahman, R., Bahar, S., 2004. Improving Bali cattle production in mixed crop–livestock systems in eastern Indonesia using an integrated modelling approach. In: Wong, H.K., et al. (Eds.), New Dimensions and Challenges for Sustainable Livestock Farming, Proceedings of the 11th Animal Science Congress, Kuala Lumpur, 2004, vol. II, pp. 116–119.

8.2 Capacity impacts – now and in 5 years

As would be expected, the continuing development of knowledge and skills within participating farmer groups and research and extension organisations has been evident over the 7 years of project activity. Impact has been a result of collaborative effort between the project and other agencies and through the coincidental alignment of project priorities with Indonesian government rural sector development initiatives.

8.2.1 Legumes for cereal based cropping systems

This project was tasked with researching the potential for forage legumes to contribute to cereal based farming systems. This resulted in a suite of legumes being identified and recommendations for use communicated to stakeholders. As a result, government extension agencies in Kupang, TTS, TTU, Belu, Nagekeo and Ende districts now consider that forage legumes are a feasible option in the region and have knowledge about the role, benefits and challenges of their introduction and the skills necessary to conduct further research and extension.

In 5 years time it is expected that in districts where animals (particularly cattle) are a significant component of the farming system and forages in short supply, that those legumes identified early in the project (*Clitoria ternatea*, *Centrosema pascuorum* and *Lablab purpureus*) will be considered as important feed resources for animal fattening whilst suitable legumes identified during the later round of evaluation will be at a stage of seed increase if deemed to be appropriate.

8.2.2 Seed increase capacity

Seed supply was identified early on as being one of the potential stumbling blocks to long term sustainable use of forage legumes in ENT. The issue has been addressed by increasing project capacity in forage evaluation and seed increase and investment in the training of local staff in seed production. The provision of Crawford Fund training support to 6 research and extension officers from 3 organisations (BPTP, Dinas, BAPPEDA) in 2011 increased the capacity to produce seed for research purposes and for use by the trainees' home organisations. Project engagement with Soe, Aeramo and Boawe SMKs has provided a catalyst for the training of high school students in seed increase, and at the same time provided small, but valuable quantities of seed for research and development purposes. In Kupang, West Timor, there is a similar example of how project activity, in conjunction with targeted Crawford funding has allowed another of the seed specialists to develop areas of *Clitoria ternatea* and *Leucaena leucocephala* with the aim of supporting local entrepreneurs establishing a cattle fattening enterprise in the area. To meet organisational demand and requests from the provinces, BPTP and Dinas are producing forage legume seed for a range of species at their Research Stations at Lili in Kupang.

Seed from the various seed production sites on West Timor and Flores (2010 to 2012) has mostly been used for village demonstration trials and the establishment of village based seed production areas. The volumes of seed produced of *Centrosema pascuorum, Clitoria ternatea* and *Lablab purpureus* generally increased over the project life as crops became larger, more expertise was gained and seed production began on Flores. Volumes were highest in 2012 for *Clitoria ternatea* (192 kg) and *Lablab purpureus* (221 kg), which were easier to harvest than *Centrosema pascuorum* (98 kg).

Seed increase is pivotal to the long term adoption of legumes by ENT farmers. In 5 years time there have to be farmers, entrepreneurs or agencies (government or non-government) that have created a viable business from seed production. It is likely that demand will be met initially through increased production by agencies and as demand builds, will also be seen by private enterprise as an attractive investment. Given the experience of Thailand and

Australia, it is likely that specialist growers will emerge who may not have the resources to own animals but do see seed production as a business opportunity.

8.2.3 Impacts of government policy on animal access and ownership

This project has provided examples of how effective government policy can enhance technology use. In the village of Usapinonot the push for national self sufficiency in cattle production has enabled the establishment of a profitable village enterprise. This has occurred because farmer groups gained access to government supported loans which enabled them to purchase agricultural requirements including cattle. In 2009 this resulted in the purchase of more than 40 cattle, an increase of 17 in the number managed by the farmer group. Twenty one were fattened and sold over the first few months. A stable, high quality source of forage was recognised by the farmers as being critical to the longer term sustainability of such a system and was the catalyst for expansion of their legume production. The tangible benefits of cattle ownership are now evident in this village with community development programs (curbing and channelling of the streets and reticulation of water), private investment in housing and the increased standards of education of the children (including 1-3 villagers graduating from university each year), all examples of the benefits of a stable, sustainable animal production system. This has resulted from skilled community and farmer leadership going hand in hand with farmers who see themselves as cattle ‘producers’ and good extension support.

Whilst Usapinonot provides an example of enlightened policy relating to the provision of credit, there are many examples where erratic supply or lack of availability of animals is to the detriment of the introduction of forage technologies. Currently the majority of farmers access cattle and goats through government or NGO donor schemes in which animals are fattened and profits shared between the donor and the farmer. The problem arises when demand for animals exceeds supply and farmers are unable to consistently source animals. Consequently, while farmers see the potential for forages, and have grown them successfully, they lose interest. This occurred at Tobu where farmers were provided with pregnant cows which were returned, as agreed, to the owner of the scheme after the birth of a calf. The calf was fattened and sold by the farmer with the profit split 70/30 with the scheme. On completion of a cycle, farmers were required to await their turn before repeating the process. This often resulted in farmers gaining access to a cow every three or more years, no basis on which to develop animal or legume production capacity. Therefore, despite Tobu farmers being highly successful at growing legumes their interest waned. They did however, continue to grow legume seed for sale to Dinas and BPTP.

These examples highlight the need for the development of policy and infrastructure that meets the requirements of farmers for stable and consistent animal breeding and procurement systems, underpinned by access to credit.

8.2.4 Short term training

A major aim of the project has been to improve the capacity of research and extension staff through short-term training. Table 8 provides a summary of training activities undertaken through work based and more formalised training programs. Nine training activities were undertaken, 3 in Australia and Thailand and the remainder in Indonesia. Around 30 staff members were involved. The Crawford Fund supported 3 activities undertaken in Australia and in West Timor. While all of the training was valuable, some activities in particular have had a major ongoing impact on research and development capacity in the region.

Soil sampling

At the commencement of the project, none of the local research or technical staff had experience in the characterisation or sampling of soils for water and nutrients. Training was provided in equipment fabrication and the field techniques required for the collection and processing of soil samples. As a result, BPTP now has the expertise to fabricate and maintain equipment and the necessary field sampling skills. In addition 7 soils in West Timor were characterised for plant available water capacity, a first for eastern Indonesia and critical to the interpretation of project data.

Soil analysis capability

While Naibonat Research Station had a well established analytical laboratory, staff were inexperienced in soil nitrate analyses. Training was provided to laboratory staff through the Crawford Fund and new equipment purchased to improve the quality of water supply and nutrient analysis. A work manual "*Analysis protocols for the measurement of soil nitrate using an Merk RQeasy Nitrate meter"* was developed to assist in staff training and as an analytical reference.

The development of field sampling and laboratory analytical skills has improved the ability of BPTP to do science in eastern Indonesia. The skills, tools and infrastructure are now available for use by other projects and have already been utilised by a PhD student undertaking research on maize production. Over the coming years it is expected that the capability will be utilised by other projects including an upcoming ACIAR project which will be investigating the economics of farming systems design and will require soil information as input data to simulation.

Seed increase

While sufficient seed has been produced to support project research and extension requirements it was recognised that increased capacity was necessary to meet longer term demands. An Australian seed specialist, appointed to the project in 2009, has introduced new methodologies to village and broader scale seed production which have been adopted by farmer groups and agencies. It was also understood that local technical expertise in seed increase capacity had to be developed. Six research and extension staff from BPTP, BAPPEDA and Dinas in Flores and West Timor undertook intensive training in 2011 with the Department of Agriculture and Fisheries at Walkamin, Queensland. Graduates have since been instrumental in increasing the area under seed production with yields improving as experience develops (Figure 56 and 57).

Figure 56: *Trellised* Clitoria ternatea *being grown for seed at Naibonat, Kupang by a BPTP seed production course graduate.*

Figure 57: Lablab purpureus *being grown for seed at the Nagekeo mission, a site established by the Dinas seed officer in 2012.*

8.2.5 Formal capacity building

Post-graduate training

A very positive impact of the project has been the development of the individual capacity of Indonesian collaborators through formal studies. Four BPTP researchers have been supported in post-graduate study. Sophia Ratnawarty and Alex Leki Serin were both awarded their Masters Degree in Agriculture in 2008 from the University of Nusa Cendana for work on the development of simulation parameters for maize and legumes. Ms Ratnawarty has continued on to undertake her PhD in Jogjakarta on the feeding of forage legumes to cattle while Leki Serin has taken on a project management role in BPTP. Two BPTP staff members were awarded John Alwright Fellowships by ACIAR for post-graduate study in Australia. Yohanis Ngongo completed his research in 2012 and was awarded his Doctorate in Social Science from the University of Queensland for his work on the impacts of ethnicity on farmer innovation. Evert Hosang has completed his Doctoral studies at the University of Southern Queensland and has submitted his thesis on maize seed quality. He is expected to graduate in mid-2013.

Volunteer placement
In late 2010, Skye Gabb (a graduate of the University of New England) accepted a project position as a Volunteer for International Development from Australia (VIDA). She worked with BPTP in West Timor for 10 months as a Research Officer in Tropical Forage and Crop Production. This placement was tasked with supporting and mentoring local technical staff, developing appropriate communication materials and being involved with farmer interactions alongside her BPTP colleagues. This was a highly successful placement with outputs including the training and mentoring of BPTP Naibonat Analytical Laboratory staff in the analysis of soil nitrate nitrogen. Skye was also involved in on-farm research and legume evaluation and was an editor of the forage production manual '*Integrating herbaceous legumes into crop and livestock systems in eastern Indonesia*' which will be released in July 2013.

All 4 post-graduate students and the VIDA volunteer have contributed significantly to the project and in the next 5 years it is anticipated that the 4 Indonesian graduates will take on more responsible roles within their organisation. In particular, Evert Hosang will commence in a new role as deputy project leader on an ACIAR project and Skye Gabb will return to eastern Indonesia to undertake her Doctorate on issues relating to animal and crop production in 2013.

8.2.6 Developing capacity in agricultural high schools (SMK)

A prolonged association with the Soe Agricultural High School (SMK) has resulted in the development of a relationship which involves both the mentoring of staff and students in the practical production of legumes and seed. The school has invested in the development of a seed increase area (~1ha) where a range of species are grown for school use and for sale. The engagement in 2011-12 by the Dinas seed production specialist with the SMKs at Aeramo and Boawe, Nagekeo has enabled large areas of three important legumes to be grown by the staff and students (*Centrosema pascuorum* - 5000 m^2, *Clitoria ternatea* - 1500 m^2 and *Lablab purpureus* - 1 ha) with the aim being to provide training for students, to develop local seed increase capability and to supply local Dinas requirements.

As a result of the successful interaction with the 3 SMKs during this project, plans are in place, as a part of a subsequent ACIAR project, to increase engagement with SMKs in ENT in 2013. Five SMKs in West Timor, Flores and Sumba have expressed interest in the development of a common high school curriculum for the teaching of legume and animal production in ENT. In the coming years it is expected that this will result in the high school students graduating with a better understanding of animal and crop production which is expected to lead to a more broadly educated farming community.

8.2.7 Developing capacity in non-government organisations

In the first phase of the project, little interaction occurred with NGOs in West Timor, however on expansion to Nagekeo and Ende districts in Flores in 2009, linkages were developed with community and church groups interested in animal and legume production. In 2009-11 the farmer group at Ulupulu, managed by the NGO MTM, hosted a number of on-farm legume and animal (goat) production trials. This group was also involved in the production of seed for village use and for sale to Dinas. In 2011-12, the Nagekeo Mission, in collaboration with Dinas, developed a legume seed production area of ~2500 m^2 (Fig 57). The main short-term impact of engagement with these groups has been to expand their knowledge of the potential for forage legumes in animal feeding and to develop their capacity in forage and seed increase. In the longer term, the common organisational emphasis of many of these groups on animal 'keeping' and subsistence agriculture makes it unclear whether their goals align with the pathway to impact anticipated from forage legume use. If the non-government sector were to become a major emphasis of future work, investment would be required to identify organisations with the capacity and philosophical interest in being involved in animal 'production'.

8.2.8 Economic impacts

Animal production

Positive economic impacts resulting from an increase in animal numbers and faster turn-off of fattened animals have been experienced by farmers growing forage legumes. Research indicates that by supplementing young cattle with forage legume at a rate of 40% of diet results in a 1.7 fold increase in live weight gain compared to those fed local forages. Farmers in Marapokot and Usapinonot have experienced these impacts with cattle able to be fattened more quickly with the overall number and turn-off increasing as a result of improved credit systems and fodder supply. Trialling of the feeding of goats at Ulupulu on 100% legume also showed improved live weight gains over a 2 month period. The impacts of improved income from animal production are exemplified by the benefits to farming families in Usapinonot where public facilities and sanitation have been improved and there has been increased private investment in housing and education.

However, there are also examples where farmers, whilst seeing the potential for forage legumes, have not invested, and for very good reasons. In the village of Oebola, research was unable to show improved growth rates for cattle fed forage legumes. Further investigation showed that an endemic legume (thought to be *Macrotyloma uniflorum*) was providing similar benefits to the newly introduced species. From the farmers perspective it was a logical choice to continue feeding the local plant which was less labour intensive than farming an introduced species, freeing up labour for the growing of food security crops and other enterprises.

Crop production

In some cases, research and anecdotal experience showed increased yield and profit from the growing of cereal crops following legumes. At Wolomasi in 2010 farmer maize yields increased by 400 kg/ha (from 3.04 to 3.44 t/ha) when the crop was grown in rotation with *Clitoria ternatea*. With maize grain prices of Rp3000/kg, this equated to an increase in income of Rp1 200 000/ha. However, contribution to cereal crop yield through nitrogen fixation should not be assumed with research showing highly variable responses to the inclusion of legumes into the system. The reality is that the more legume biomass removed to feed animals, the less that will be available to support subsequent cereal crops. Consequently, the primary purpose for growing legumes should be to feed animals with any subsequent benefit to crops a positive outcome, but not to be assumed.

Seed production

In the 2011/12 wet season ~4 ha was sown to the 3 most popular legumes in West Timor and Flores. This increase can be partially attributed to the increased availability of seed production expertise but there was also a heightened interest in seed production amongst farmers, SMK and NGOs due to the potential for higher returns than in the past. This resulted from the recognition by research and extension organisations that the extra labour required to produce legume seed crops (particularly *Centrosema pascuorum* and to a lesser degree, *Clitoria ternatea*) was not being reflected in the prices being offered to farmers which were originally based on returns from mungbean (approximately Rp7000/kg). During 2011, *Clitoria ternatea* and *Centrosema pascuorum* seed was sold by BPTP to Dinas-Nagekeo for Rp50 000/kg and *Lablab purpureus* for Rp30 000/kg. Small amounts of *Stylosanthes guianensis* were sold for Rp75 000/kg. This represents a doubling of prices in two years. These prices were for government sales and it seems that a more realistic purchase price from farmers is now in the order of Rp30 000/kg for *Clitoria ternatea* and *Centrosema pascuorum* and Rp20 000 – Rp25 000/kg for *Lablab purpureus*. Assuming the yield of 250 kg/ha for *Lablab purpureus* which was achieved at Nagekeo Mission in 2012, a total income of Rp6 250 000 /ha would be achieved at the realistic farmer prices. While this income would be lower than a well grown mungbean crop, it is still significant income and could probably be increased with continuing production experience.

8.2.9 Social impacts

Engagement with farmers

Social research shows that there is little farmer interest in increasing the complexity of the farming system through the introduction of forage legumes, unless animal ownership is a significant component of the income stream. Research also shows that it is not sufficient to just own animals but to have the interest and resources to transition from a subsistence economy into the cash economy where animals are considered a commodity to be traded i.e. moving from a 'keeper' of animals to a 'producer' of animals. The villages of Usapinonot and Marapokot are good examples of those transitioning to 'producer' mode. In Usapinonot, this has been achieved through improved access to credit in the presence of good village leadership and farmer group structure. The result of this has been community benefits in education and infrastructure. In Marapokot, success has resulted from a strong Dinas regional animal production vision and farmer group mentoring, including the development of infrastructure and provision of credit. This approach has also engaged the wider community with relationships developing between the extension agency and the local agricultural high schools (Aeramo and Boawe) in the education of the next generation and in contract seed increase. Again, this is an example of the importance of good leadership.

The village of Tobu in West Timor could be seen as a village transitioning from ‘keeper’ to ‘producer’ mode; it had the land and labour and had successfully grown legumes for cattle feeding and produced seed over a number of years as part of the Dinas “Primatani” animal production program. However, social evaluation indicated that while this was a highly motivated farmer group, the system failed due to a lack of predicable animal supply and access to credit. These are the two biggest challenges facing farmers who see animals as being the pathway to the cash economy but do not have access to the resources to become involved. Both of these issues need to be addressed at the policy level to facilitate greater impact of new forage technologies.

Engaging with collaborators, partners and stakeholders

While the project has addressed the technical and social aspects of the integration of forage legumes into the local farming systems of ENT, it has not been done in isolation from regional and district organisations. An important project role has been to develop organisational research and extension capacity to ensure longer term sustainability of the technology and to foster relationships between Indonesian provincial and district organisations and their Australian counterparts. This has seen excellent engagement with organisations including provincial and regional Dinas and BAPPEDA. The project has also had a role in the development of farmer/extension/ researcher networks through a program of regular meetings, research updates and cross-group visits which is expected to have longer-term benefits on the skills of individuals and the way in which research and extension is done in ENT.

8.2.10 Environmental impacts

One unforseen potential environmental impact of the project was observed during on-farm research in West Timor. *Striga sp*., a parasitic weed hosted by cereals, including maize, is a major pest for production and the environment. This was the case in Usapinonot where the crop of a farmer group member regularly failed due to severe *Striga* infestation. The situation changed when a maize crop, grown after 1 year of forage legume, achieved a yield of 2.5 t/ha, the highest ever achieved on this particular land. According to reports in the literature, reductions in *Striga sp*. attack are associated with higher levels of nutrition and allelopathic affects associated with the growing of particular legumes species (Khan *et al.* 2002[24]). This effect has important implications for the rejuvenation of impacted lands which in turn impacts on farmer livelihoods.

[24] Z. R. Khan, A. Hassanali, W Ovweholt, T.S. Khamis, A. M. Hooper, J.A. Pickett, L. J. Wadhams and C. M. Woodcock (2002). Control of Witchweed Striga hermonthica by intercropping with Desmodium spp., and the mechanism defined as allelopathic. Journal of Chemical Ecology, Vol. 28, No. 9, September 2002 (2002).

8.3 Communication and dissemination activities

Dissemination of information and engagement with agency and farmer communities were critical components of the project and occurred throughout its life. Examples of communication are provided through the report but some of the highlights follow.

Conferences and seminars

The project was represented at a range of conferences and workshops including:

- 2008: International Grasslands Congress, Inner Mongolia: Esnawan Budisantoso presented a paper related to project activity (see 10.1).
- 2008: AAPN Conference, Hanoi: Neal Dalgliesh and Esnawan Budisantoso presented 2 papers related to project activity (see 10.1).
- 2008:14th Australian Agronomy Conference, Adelaide. Jeremy Whish presented a paper related to project activity (see 10.1).
- 2010: 15th Australian Agronomy Conference, Christchurch. Jacob Nulik presented a paper related to project activity (see 10.1).

Project Coordination Meetings

- 2007: Operational and strategic planning meeting for 2007/08 (Naibonat Research Station). Involved the Australian project leader and BPTP staff. Resulted in the development of an experimental program of ~15 on-farm trials focusing on forage legumes as relay and rotation crops within the maize system.
- 2008: Operational planning meeting for 2008/09 season (Naibonat RS) involving BPTP researchers and Australian collaborators.
- 2010: Operational planning meeting for 2010/11 (Naibonat RS). Resulted in the development of plans for activities in West Timor and Flores
- 2011: Operational planning (Naibonat RS) undertaken to finalise on-farm, on-station, seed increase and evaluation activities for the 2011/12 season.
- 2012: Operational planning (Naibonat RS) for the 2012 dry season. Management of seed increase and the development of a long term research site planned.

Institutional stakeholder engagement

- 2007: Annual project workshop (Kupang)-informed collaborating farmers and government and non-government stakeholders (~40-50 people) on project progress.
- 2007: ACIAR Livestock Program meeting, Brisbane convened by Bill Winter. Neal Dalgliesh presented overview of the project to program managers and project leaders.
- 2009: Annual project workshop (Kupang): 30 stakeholders and collaborators from BPTP, DINAS, BKP2, CSIRO and NGOs (Care, MTM and TLM) updated on project progress and contributed to project direction setting.
- 2009: ACIAR program meeting, Brisbane, convened by Peter Horne to discuss progress and directions of beef cattle research in eastern Indonesia. Jacob Nulik, Neal Dalgliesh and Kendrick Cox attended.
- 2009: Annual project workshop (Kupang): 30 stakeholders and collaborators from BPTP, DINAS, BKP2, CSIRO and NGOs (Care, MTM and TLM) involved in project reporting and direction setting.
- 2009: Meeting of senior project staff with the regional office of BAPEEDA (Ende, Flores) to enlist support for the expansion of the project into Flores.
- 2010: Annual project updates conducted in Nagekeo (~60 attendees) and Ende (~40) and Kupang (~40).
- 2010: DINAS Peternakan (Belu Regency)-meeting with the Director and staff of the research station to inspect seed increase and to discuss plans for legume Belu expansion.
- 2011: Seed increase site inspections and operational planning undertaken in West Timor and Flores with Australian researchers and Dinas, BAPPEDA and BPTP partners.

- 2011: Project external review-collaborator and stakeholder meetings were conducted in Nagekeo, Ende and Kupang and visits made to farmer groups and to Soe SMK.
- 2012: Strategic direction setting was undertaken in Flores and West Timor involving a broad range of stakeholders (district and provincial Dinas, BPTP, BAPPEDA, the Agency for Food Security and Agricultural Extension, the University of Flores and the University of Nusa Cendana and NGOs) to communicate the potential for future collaborative research in forage and animal production.

Farmer engagement

Farmer engagement by Indonesian researchers occurred on a regular basis with many visits not recorded. The following are an example of activities undertaken during visits by Australian researchers.

- 2007: Farmer group meetings in Oebola, Biloto, Sillu, Usapinonot, Lapeom, Kletek and Kakaniuk. Research results from the 06/07 season were presented and plans discussed for the 07/08 season.
- 2008: Visits to all West Timor collaborating villages by project staff and the Australian project leader to participate in establishment of experiments.
- 2008: Social surveys undertaken in West Timor villages to determine the prospects for adoption of forages. 39 interviews (99 participants) undertaken representing researchers, government services, farmer group leaders and farmers.
- 2008: Field walk (Belu)-the Director of Livestock Services, extension officers, sub-district chief's and representatives of around 40 farmer groups (~50 people) inspected research at the legume forage and seed production site in Belu Regency.
- 2009: Farm Walk (Usapinonot)-10 farmers visited the local relay and rotation trials to discuss results with Indonesian and Australian project researchers.
- 2009: Farm walks (Oebola)-the farmer group hosted 4 farmer groups (29 farmers and 4 extension staff) from surrounding villages and 3 cross-visits from project villages to inspect and discuss the on-farm research.
- 2009: Field walk (Oebola)-the Director of BPTP, Naibonat hosted a visit to the village by senior representatives of provincial agricultural bodies to promote the work being undertaken in ACIAR, SMAR and DINAS projects.
- 2009: Farmer group meetings (Flores) in Ulupulu, Nakuramba and Wolomasi to discuss potential for collaboration as part of a project extension.
- 2010: Soe Agricultural High School (Soe, West Timor)-meeting with the principal and senior agriculture and animal production staff to formalise plans for the 2009/10 season.
- 2010: Farmer group meetings (Flores)-informal meetings in Ulupulu, Nakuramba, Wolomasi and Marapokot to communicate project plans and to operationalise local research for the 2010 season.
- 2010: Farmer group meetings (West Timor) conducted with farmer groups in Tobu (TTS), Usapinonot (TTU), Betun (Belu) and Oebola (Kupang) to gauge farmer use of forage legumes.
- 2010: Farmer group meetings (Flores) in Nagekeo and Ende regarding opportunities for collaboration.
- 2010: Cross visit to Marapokot, Flores by ~15 farmers from the villages of Nakuramba, Ulupulu and Wolomasi and accompanied by Debbie Kana-Hau and Skye Gabb. Visited the Tunas Baru farmer group at Marapokot to discuss cattle production and the contribution of forage legumes.
- 2011: Farmer group meetings (Flores) were conducted at Ulupulu, Nakuramba, Wolomasi and Marapokot. Meetings were attended by local NGO and DINAS extension officers.
- 2011: Farmer group meeting (West Timor) conducted with the farmer group in Oebola. Included the inspection of a maize agronomy trial and seed production.
- 2011: Soe Agricultural High School (West Timor)-meeting with staff to inspect wet season seed increase and legume evaluation activity.

Promotional activities

- 2007: A series of 6 posters was developed and distributed to collaborating villages to provide information on the aims of the project and the science underpinning the research.
- 2007: The Australia Network (Jakarta) interviewed project staff for a report on food security. The program was screened on Asia Network and the ABC.
- 2009: Australian radio journalist, Sarina Locke interviewed project staff for stories to air on Radio Australia, Radio National, ABC rural programs and the ABC website.
- 2010: Interviews conducted with Jacob Nulik, Kendrick Cox and Neal Dalgliesh by media representatives from the Flores regional newspaper, a national radio station and the Java Post. Articles on the use of forage legumes in eastern Indonesia subsequently appeared in all 3 outlets.
- 2013: Publication in the ACIAR Monograph Series of the manual, '*Integrating Herbaceous Legumes into crop and livestock systems in eastern Indonesia*', in English and Bahasa Indonesia (planned for publication in July 2013)

9 Conclusions and recommendations

9.1 Conclusions

This project has successfully established a case for forage legumes in eastern Indonesian cropping systems. Biophysical and social research have both contributed to major leanings about the potential systems applications and likely changes to animal and crop productivity including key socio-economic constraints and drivers that will influence use in ENT farming systems.

Identification of forage legumes

The success of the project centred on the identification of legumes appropriate to eastern Indonesian environments (from the coastal plains to the higher rainfall and cooler mountain areas) and suitable for use in cereal-based systems. *Clitoria ternatea*, *Centrosema pascuorum* and *Lablab purpureus* were identified by farmers as being the most appropriate plants because they produced large quantities of biomass and seed, were easy to harvest, palatable to animals, of relatively short stature and did not constitute a weed risk. Other legumes also grew successfully but were seen as less suitable for use in cereal systems although may be useful in grazing systems or for erosion control. A second round of evaluation identified other species which show promise but are yet to be tested within cereal systems.

Utilising a wasted resource

The project has shown there is significant opportunity to utilise currently unused soil water reserves in the late wet and early dry seasons to grow forage crops, or potentially, pulses or vegetables, without detriment to the main food security crops. The understanding that the main agricultural soils of ENT have high water holding capacities, and often contain significant quantities of stored water after wet season cereal crop production is an important learning. This makes the growing of a forage legume during this period a feasible addition to the current cropping system. The legumes may be grown in relay with cereal crops, if land is constrained, or as an annual rotation where land and labour are not limiting.

Biomass production

Research has shown that forage legumes have the ability to produce high levels of biomass under rainfed conditions in the late wet and dry seasons. Yields of up to 11000 kg/ha DM are possible when grown in annual rotation with a cereal although 3-5000 t/ha is more common. Yields tend to be higher in bi-modal rainfall regions due to the longer rainy period, although seed increase is more difficult as a result of the wet conditions. Biomass production is generally lower in legume relays than rotations due to cereal crop competition for light and soil resources (yields of <1000-3000 kg/ha DW). *Clitoria ternatea* and *Centrosema pascuorum* are well suited to dry season, supplementary irrigated production with yields of 7.9 and 9.6 t/ha DW achieved over 210 days. Biomass may be fed as ‘cut and carry’ in the early to mid dry season or stored as hay for later dry season use when animal need is greater, and efficiency of use of the high nutritive value material, higher.

Seed increase

The capacity to grow key legumes for seed in ENT has been demonstrated in lowland and upland areas on Flores and West Timor and a range of management methods used to determine best practice. BPTP, Dinas and Bappeda staff have been trained in seed production methodology and instigated seed increase programs on Flores and West Timor, and there is momentum for seed increase of forage legumes as the price has become more attractive to growers. Recommended practices for seed increase have been included in the ACIAR technical manual '*Integrating Herbaceous Legumes into crop and livestock systems in eastern Indonesia*' which is expected to form the basis for future extension in the province and beyond.

Although there has been good progress, particularly for the three key legume varieties, seed production has been unreliable with some crops variously affected by water stress, disease, insect damage or accidental damage (livestock). More research is required on the interaction between photoperiod and temperature (elevation) on flowering consistency and intensity for some species. A better understanding of optimum sowing and cutting times for flowering and seed crop development, including disease and pest pressure, in differing areas of ENT would also help to minimise the risk of crop failure, optimise seed yields and help identify the best districts for seed production in ENT. Also, given the observed responses of some of the legumes seed crops to trellising and *Clitoria ternatea* to cutting, there is also merit in investigating the manipulation of plant architecture to maximise seed production and facilitate harvesting.

Animal feeding

The project provided preliminary data that supplementary feeding of livestock with forage legume results in higher live weight gains than where native forages are fed alone. Young cattle (~70 kg live weight) supplemented for 320 days gained weight at a rate 1.7 times higher than those fed native forages with the largest difference occurring in the late dry and early wet seasons when supplemented animals gained at a rate of 220 g/head.day compared to those fed native forages which lost 65 g/head.day. Larger bulls (200 kg live weight) also benefitted from legume supplementation with increased weight gains of between 46 and 125 g/head.day, compared to native forages. Goats also benefited with 40% higher growth rates when fed a 100% legume ration.

Cereal crop impacts

Legume nitrogen contribution to the yield of subsequent cereal crops varied considerably, which was likely associated with management of legume biomass and effective root nodule symbioses and N fixation inputs. The most positive impacts were found where legume plant material remained on the field, and the least where material was removed. This indicates that in a farming situation where legume material is removed to feed cattle, that there is unlikely to be large benefits to subsequent cereal crop yield. Research also indicated that N fixation efficiency for some species was lower using endemic rhizobial strains, compared to introduced species, leaving the opportunity for future investigation of improving fixation ability through inoculation.

9.1.1 Social impacts

A key learning of this project was that farmers are more likely to invest in forage legume production when a set of pre-existing conditions apply, including a 'producer' mentality and profit motivation, own cattle in their own right or are part of an efficient donor scheme, have the land and labour to support legume production, consider they have a shortage of animal feed and have an understanding of the value of feeding legumes in animal feeding. Local and regional governance that supports the farmer through provision of extension advice and the establishment of farmer groups and village feed lots are critical to success. Currently, it is unlikely that farmers would invest in legumes solely on the basis of their impact on subsequent cereal crop production, although this may change over time.

9.2 Recommendations

This project has been successful in showing that forage legumes can contribute to cereal based farming systems and that the capacity exists for technology expansion in ENT. However, there is also a need to undertake detailed component research which was not part of the original mandate. There is also the opportunity to further expand the geographic spread of forage legume use in ENT, including islands such as Sumba, where cattle play a major role in local farming systems. Consequently, the recommendation is for a two pronged approach to future activity.

Detailed component research

Detailed research is required to develop a deeper understanding of particular parts of the system. These include the nitrogen fixation ability of individual legumes and their potential to contribute to subsequent cereal crop yield, the potential to improve N fixation through rhizobial inoculation, the characterisation of legume species for agro ecological fit, the optimising of seed increase through better understanding of physiological response to environment, the feeding of legumes to a range of animal classes and the detailed mapping of legume physiology and phenology to continue to improve the capability to model legume yield across a range of environments. Improving the science behind components of the system results in the provision of more informed extension materials and allows for a more critical evaluation of the system to be made using whole of farm models such as the Integrated Assessment Tool (IAT) (McDonald *et. al, 2002*[25]). This tool has been successfully used in farmer engagement in other ACIAR projects with positive changes to farming system and livelihood resulting.

Capacity development and extension

Meaningful adoption of such technologies requires the development of skills within local extension and research agencies. This needs to be approached from a number of directions including the continuing mentoring of agency staff e.g. seed increase, the development of financial partnerships with agencies to engender project ‘buy-in’ and the longer-term development and mentoring of junior staff. Other projects have adopted the model of employing junior scientists in key technical roles to provide project capacity and to develop personal skills with flow-on benefits to future research careers. It is suggested that this model could be used in any new project. In addition, engagement with the SMK at Soe exposed >500 students to seed increase and legume biomass production. As these high schools are the training ground for next generation farmers and agency staff, it is suggested that engagement with a larger number of SMK be undertaken to provide staff mentoring, the development of legume and cattle production curriculum and the joint conduct of experiments.

Policy recommendations

While research of this nature can show the biophysical and economic reasons for the adoption of a technology, nothing will change unless it fits within existing social systems and is supported by policy. In terms of the adoption of forage legumes, this will require changes to the way in which animals (particularly cattle) are sourced by farmers including improved access to credit or to more reliable animal procurement schemes. Currently, live export of cattle from ENT to the main population centres of Indonesia is stymied by a poor supply chain in which live weight is lost or inefficiently gained during the animal production and

[25] McDonald, C.K., MacLeod, N., Lisson, S., Ash, A., Pengelly, B., Brennan, L., Corfield, J., Wirajaswadi, L., Panjaitan, T., Saenong, S., Sutaryono, Y., Padjung, R., Rahman, R., Bahar, S., 2004. Improving Bali cattle production in mixed crop–livestock systems in eastern Indonesia using an integrated modelling approach. In: Wong, H.K., et al. (Eds.), New Dimensions and Challenges for Sustainable Livestock Farming, Proceedings of the 11th Animal Science Congress, Kuala Lumpur, 2004, vol. II, pp. 116–119.

transport phases. Therefore, any new research should include work on improving the way in which farmers gain access to animals, their fattening in the village and purchase and during transport and shipping to market. As well as improving the efficiency of animal production, the increased use of forage legumes in animal feeding and transport also improves animal welfare and moves Indonesia further towards its goal of meeting cattle self sustainability.

10 References

10.1 List of project publications

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11 Appendixes

11.1 Appendix 1: Example of farmer interview protocol

Farmer response to village legume production during 2006/07 Rainy Season

The aim of this activity is to gain insights into farmer thinking about the legumes that have been grown in a number of villages across NTT during the 2006/07 season.

Who should be interviewed?

1) **Legume evaluation villages** (Biloto, Sillu, Usapinonot, Lapeom, Kakaniuk and Kletek

- Individual interviews of farmers who were initially interviewed in late 2006. This group provide a longitudinal perspective on project activity and learnings (around 5-7 per village)
- Individual interview of farmer on whose land the trial activity is talking place-this person then becomes part of the longitudinal group in later interview rounds (they may already be one of those being individually interviewed of course)
- Village farmers (as a group)-invite the farmers to visit the legume trial to provide their thinking on the value of the legumes in their system and their observations during the season

2) **Villages where animal forage is currently being produced (Oebola, Belu, Naibonat, Lille)**

- Farmer on whose land the trial activity is talking place
- Village farmers (as a group)-invite the farmers to visit the legume trial to provide their thinking on the value of the legumes in their system and their observations during the season

3) **Extension staff associated with the trials in each village**

- This could either be as a discussion with an individual or group of extension staff from both BPTP and Dinas

4) Outer villages and other change agents

- Village farmer group-invite the farmers from surrounding villages to inspect the legumes to:
  - Provide their thinking on the value of the legumes in their system
  - Promote the use of the legumes
  - Ascertain whether any diffusion of the technology has already taken place
- Invite local NGO's to visit sites to promote the research. This could be done in conjunction with the first dot point

Questionnaire

I suggest that we use a common protocol for the individuals, groups (with the exception of the outer villages and NGO's) and extension staff. I suggest that the facilitator uses the following protocol but sees it as a 'list of prompts' which will remind them to ensure that all points have been covered. I am not suggesting that each point be covered as an individual question or that they necessarily need to be asked in any given order. At the end of the interview we need to be confident that all of the main points have been covered, but we also want the flexibility to follow leads within the interview when something of interest comes up that will add to our learnings. Extension staff interviews can also be based on the following questions with some modification to fit their circumstances as observers of the farmers and their farming systems.

Who will do the interviews?

Esnawan is the logical facilitator for this activity; he will provide consistency of technique and questioning and is known in all of the villages. I suggest that we record the individual interviews for future reference and to provide Yohanis with material which may be of use in his PhD studies.

Proposed questions

1) Location information
- Village name
- Farmer name (Individual)
- Number of villagers attending (in group situation)
- Ethnicity

2) Farmer group involvement
- Are you a member of a farmer group
- Have you been part of a farmer group involved in growing the legumes
- Are they on your land

3) Land preparation
- Were you involved in preparing the land and sowing the trial/experiment
  - What were the problems associated with sowing
  - Was any fertiliser used

4) Legume establishment
- How did the legumes establish?
  - Which ones established the best
- What were the problems with establishing and growing the legumes

5) Pests and diseases
- Were weeds an issue (whilst growing the legume)
  - If so how did you manage them
  - Did the legume cover the ground quickly
  - Were weeds such a problem that you would not consider growing the legumes
- Were pests a problem,
  - did you have to spray insects

6) Legume growth
- Which legume do you now think is your choice (near the end of the season)
  - Why
- Has you view on the best or worst legume changed as the season has progressed

7) Seed production
- Are the legumes setting seed,
  - how would you rank their ability to set seed
- Are there any that you think do not set enough seed and you would not grow them for that reason
- Do you anticipate any problems collecting the seed
- Would there be a market for the seed
- Have you or the village collected any seed for next year
- Do you plan to grow some of the legumes next year
  - Which ones

8) Legume use
- What would you use the legumes for
  - Do you have animals
  - When do you run short of feed for them
  - Would this material help address this shortage?
  - How would you store the legume until that time (hay, silage??)
- Our thinking is to sow the legumes as the maize matures and allow it to grow out into the dry season, we expect that it will be available for animal feeding.
  - What do you think of this idea
- How else do you see that the legume could be used e.g. grown as a sward crop purely for

animal feed and not grown as a relay crop but as a rotation crop (legume/maize/maize/legume etc)

- If your maize crops grew better after growing the legumes would this encourage you to grow the legumes

9) Weed Potential (of the legume)

- Do you have weeds in your maize at present
  - How do you handle them (what sort of control)
  - How much time does it take per season
  - Do you use the weeds for feeding your animals (either as cut and carry or tethered)
- Could the legumes become weeds in your maize area
  - Would this effect your thinking on growing the legumes
  - What if we could show that the legumes helped your animals to grow more quickly
  - Would the legumes increase your weeding time (or would the legumes replace other volunteer plants?)

10) The future

- You now have an area of legume that has been used for the experiments this year
  - What would you like to see happen to the area
  - Should it be used for seed production
  - Should an experiment be placed over the legume plots to see what impact the legume has on maize production
  - Should it be used by the owner for grazing or fodder

11.2 Appendix 2: Example of Communication strategy

Communications Strategy -Integrating legumes into the maize cropping systems of West Timor 2011

Skye Gabb, VIDA

Introduction

Integrating forage legumes into crop-livestock systems in Eastern Nusa Tenggara (ENT) can assist in reducing food deficits of both humans and animal. Whilst research results demonstrate the positive benefits of using forages legumes, broad uptake depends on the development of an effective communication strategy to enable farmers to make appropriate systems choices. This depends on effective training of extension staff and educators and a longer term commitment to the provision of technical support. Research to gauge the effectiveness of strategies used in the project so far, indicate there is a need for a range of activities and communication materials to cover the requirements of those with an interest in the technology. A factor currently limiting uptake of forage legumes is a scarcity of extension specialists with knowledge about forage legumes. To develop and expand this knowledge base, key findings demonstrate the importance of stakeholder participation in practical demonstrations however, in order to further motivate and educate, a broad range of materials and activities needs to be used. Thus, the aim of this communication strategy is to produce a range of communication and resource materials while also increasing the knowledge and extension skill base from which forage legume use can be expanded.

Communication Strategies

Objective	Activity	Person responsible	Comments
Gauge the effectiveness of communication strategies used in the project and identify additional materials and activities which interested parties find useful	Interview farmer groups, SMK Soe staff and extension specialist involved in the project on Timor and Flores. A paper summarising the findings to be submitted to the Conference on Sustainable Animal Agriculture for Developing Countries (SAADC)	Debbie Kana Hau, Skye Gabb & Johanna Suek	Presenting findings at the SAADC Conference will give this technology further exposure to an international audience. Conference attendance in Thailand may also include a visit to seed production sites in Thailand.
Produce a manual to provide introductory information and technical support for forage legume use in cropping livestock systems and also forage legume seed production	Project staff to write up their allocated sections of the forage legume production manual. To be collated by Skye Gabb. Distribution in NTT to be through BPTP NTT	Manager: Skye Gabb	Primarily aimed at extension specialists but also for farmers and school staff, this manual will cover; the potential of legumes in farming systems, species selection, legumes grown with crops, legumes as an animal feed, seed production, farmer experiences and recommended communication strategies extension officers can use.
Provide internet access to resources about forage legume use in cropping livestock systems and forage legume seed production	Produce a website that is potentially linked with BPTP NTT website with a PDF version of the forage legume production manual, posters and any other relevant material can be sourced.	Pak Musa	BPTP website management could be responsible for this, however, if the booklet is produced by ACIAR it is likely to be on the ACIAR site anyway. Is it also possible to put it on the BPTP website too?
Provide information about forage legume production in CD form	Convert the forage legume production manual to CD form		This was specifically requested by Soe SMK teachers as they regard it as the most useful class room resource we can provide. This could be expanded to include short videos of the experiences of particular farmers

Provide up to date information on legume species suitable to NTT	Update current legume species poster	Skye Gabb, Kendrick Cox & Claire Dalgliesh	
Produce visual educational aids that can be used at training days and be distributed to interested parties	Print additional copies of the 6 posters which have already been produced. Then use at training days and distribute to interested farmer groups, BAPPEDA, DINAS, Agricultural High Schools and NGO's	Skye Gabb & Debbie Kana Hau	
Increase the number of NGO's and NGO staff interested in and with a knowledge of forage legume production	Meet with local NGO's one on one and indentify if they are interested. If they are interested involve their staff in future training and distribute extension material to these NGO's	Debbie Kana Hau & Skye Gabb	It is important that each target NGO is involved in livestock production. Potential NGOs include NTA, MTM, CARE, PLAN, SVD (Pater) and Prodjo (Romo), Yayasaw. Additionally, Skye will spend a day with NTA at a Flores trial site as this NGO is already interested in the forage legume technology
To increase the number of extension specialists in Flores with knowledge of forage legume production	Training at Reworanga (Ende) for BAPEDA, DINAS and NGO staff	Debbie Kana Hau, Marsel & Skye Gabb	Depending on the school and class, students spend from 1 week up to 3 months with BPTP. Provides an opportunity for students to develop an interest in and learn about forage legumes
Initiate interest and increase awareness of forage legume production in Timor for DINAS staff	Present project findings and the future potential of forage legumes in NTT at a 3 monthly DINAS meeting	Jacob Nulik	
Engage and invite future interest in forage legumes production by extension staff in Timor	Cross visit for extension staff from DINAS and NGO's to Oebola to view seed production.	Debbie Kana Hau, Jacob Nulik & Skye Gabb	Pak Lao from Usapinonot to be invited to the cross visit to speak about using forage legumes as animal feed.
To increase teacher and student understanding of on farm use of forage legumes	Cross visit for staff and students from Soe SMK to Oebola and Naibonat to view seed production and legume evaluation sites as well as talk with local farmers about seed production	Debbie Kana Hau & Skye Gabb	
To educate agricultural high school students about forage legumes and their application in NTT production systems	School students who undertake practical experience with BPTP NTT based at Naibonat and at Lili will learn about forage legumes through involvement in planting, harvest and data collection	Marsel Meo, Dion Bria & Debbie Kana Hau	Depending on the school and class, students spend from 1 week up to 3 months with BPTP. Provides an opportunity for students to develop an interest in and learn about forage legumes.

Conclusion

Using this range of activities the aim is to increase interest in forage legumes while concurrently increasing the extension skill base. Initiating interest with a large number of extension specialists is an important precursor to the distribution of communication materials as it increases the relevance and likely hood of long term use these materials. Additionally, producing a range of communication materials will meet the requirements of a broad range of stake holders and future extension needs. Therefore, by implementing this combination of activities and distribution of communications materials the local knowledge and extension skill base will be increased, from which forage legume use can be expanded.

11.3 Appendix 3: Report on development of climate information for eastern Indonesia

Development of climate information for the ENT and Timor-Leste

Steven Crimp and Garry Hopwood, CSIRO Ecosystem Sciences

In order to examine the climate variation that has occurred over the case study region and the likely impacts on agricultural productivity, climate data was sourced from the National Oceanic and Atmospheric Administration data archive. In total data was extracted for eleven locations (Table 1).

Table 1: *Raw climate data extracted from the NOAA holdings database (*

	Station Number	Start of Record	End of Record	Latitude	Longitude
Alor/Mali Kalahahi	973200	1979	2013	-8.217	124.567
El Tari	973725	2008	2012	-10.167	123.667
Gewayentana	973785	2012	2013	-8.267	123
Kupang/Eltari	973720	1957	2013	-10.167	123.667
Larantuka/Gewayanta	973100	1983	2013	-8.267	122.967
Maumere/Wai Oti	973000	1975	2013	-8.633	122.25
Oe-Cussie	973850	1962	1999	-9.2	124.367
Rote/Lekunik Baa	973780	1979	2013	-10.733	123.067
Ruteng/Satar Tacik	972840	2005	2013	-8.633	120.45
Sabu/Tardamu	973800	1980	2013	-10.5	121.833
Waingapu/Mau Hau	973400	1959	2013	-9.667	120.333

After initial error checking, gap analysis and frequency distribution analyses the number of suitable sites for long term simulation studies was revised down to four. Missing data was a considerable challenge in the formulation of baseline and projection climate data. Sites with rainfall and temperature record consistency of greater than 60% were selected for the infilling process (Figure 1). These included:

1. 973200 (Alor) – 62% complete;
2. 973720 (Kupang) – 73% complete;
3. 973000 (Maumere) – 63% complete; and
4. 973400 (Waingapu) – 65% complete.

Daily data infilling and production of other climate variables was undertaken using a LMESS statistical modelling approach outlined in Kokic et al., 2011. The LMESS model combines output from global circulation models (GCMs) with small scale climate observations to produce statistically robust projections of climate for current and future time periods. The modelling approach allows location-specific weather predictions outside the historic data range and handles (some) missing data in the historic record. The LMESS model accounts both for serial correlation (e.g. the effect of temperature in the preceding time interval on temperature in the current interval) and for cross-correlations between variables. For historical climate information, climate data from two sources were used in the LMESS model: historical observations (point scale), and NCEP reanalysis data (NOAA, 2012). NCEP reanalysis data are of a high quality over long temporal intervals, but produced at a fairly coarse (250 km x 250 km grid) spatial scale.

There are four steps involved in using the LMESS model to create daily climate information. These are:

1. Checking the integrity of the historic climate data and revising them where required.
2. Choosing appropriate climate variables to model
3. Constructing appropriate covariates from the gridded data available for modelling and prediction.
4. Statistical modelling, validation and future climate prediction.

A total of eight present day and future APSIM ready climate files were produced as part of this project activity.

Observed historical data are available for fewer climate variables than the NCEP datasets and may be of a lower quality. These elements consist primarily of temperature and rainfall information.

Whilst a number of climate model projections exist for the South Asia region, including Indonesia, East and West Timor and Flores, only two GCMs, capture key climate interactions in south and south-east Asia well. These include GFDL 2.1 and ECHAM5. For the purposes of this analysis only one future projection produced by the ECHAM 5 model was chosen.

In subsequent sections the reader will be able to determine where the mean projections derived from the ECHAM 5 model reside within the range produced for this region (Figure 2).

Present day climate predictions

Comparisons between LMESS-NCEP present day and observed datasets show generally strong correlations (Table 2). In general, daily minimum temperature data were better correlated than daily maximum temperature data; this is likely to be because of greater day-to-day variability in observed maxima compared to minima, which is not well captured in the synthetic data, and also possibly larger errors in the synthetic maximum temperature data. Monthly, rather than daily, rainfall data are compared: day-to-day variability is such that any correlations at the daily scale are obscured by noise. At all sites there are strong correlations (≥69%) between the observed and nearby NCEP historic monthly rainfall data. The strong correlations between the small-scale observed historic data and the NCEP historic data created over a 250 km x 250 km grid provide confidence that the forecasts modelled using the NCEP data are appropriate for the study sites located in each grid cell.

Use of the LMESS derived baseline and future projection data enables the application of farming system prediction of future climate data at finer spatial scales.

Table 2: *Correlations between synthetic and observation*

Location	Daily TMAX	Daily TMIN	Monthly Rainfall
973200 (Alor)	0.80	0.81	0.72
973720 (Kupang)	0.83	0.84	0.77
973000 (Maumere)	0.83	0.91	0.69
973400 (Waingapu)	0.84	0.88	0.76

Future climate predictions

For each site the LMESS model has been used to generate one future climate forecasts for a 20 year time period centred around 2050 (2041-2060). Figure 2 illustrates the mean seasonal changes for 2050 produced by the ECHAM 5 model compared to four other climate projections available for this region (www.cru.uea.ac/uk/~timm).

For the most part the projections suggest slightly wetter future conditions by 2050 for both the December to February (DJF) and March to May (MAM) periods. During the DJF period four of the five models depict wetter conditions of the order of 1 to 3.5%, with projected temperature rises of 1 to 3^{o}C simulated (Figure 2). During the MAM period wetter conditions of between 0.5 and 4% were simulated with associated warming of between 1 and 3^{o}C (Figure 2). During the June to August (JJA) and September to November (SON) periods the spread of models across both wetter and drier outcomes suggest some uncertainty in terms of the direction of rainfall change (Figure 2). During the JJA period rainfall changes of between +or- 3% are simulated with associated warming of between 1 and 3^{o}C. In SON rainfall changes of between 3% and -4.5% were simulated (Figure2).

Over this region the ECHAM 5 model predicted mean seasonal rainfall and temperature changes of:

- +1.5% in rainfall and 2.5^{o}C warming in DJF;
- +1% in rainfall and 2.2^{o}C warming in MAM;
- -0.4% in rainfall and 2.5^{o}C warming in JJA; and
- -0.2% in rainfall and 2.1^{o}C warming in SON.

Through the LMESS approach future daily projections were produced for each of the four locations.

Changes in average temperatures and rainfall under 2030 future climates are modest and unlikely to have significant effects on most agricultural production.

References

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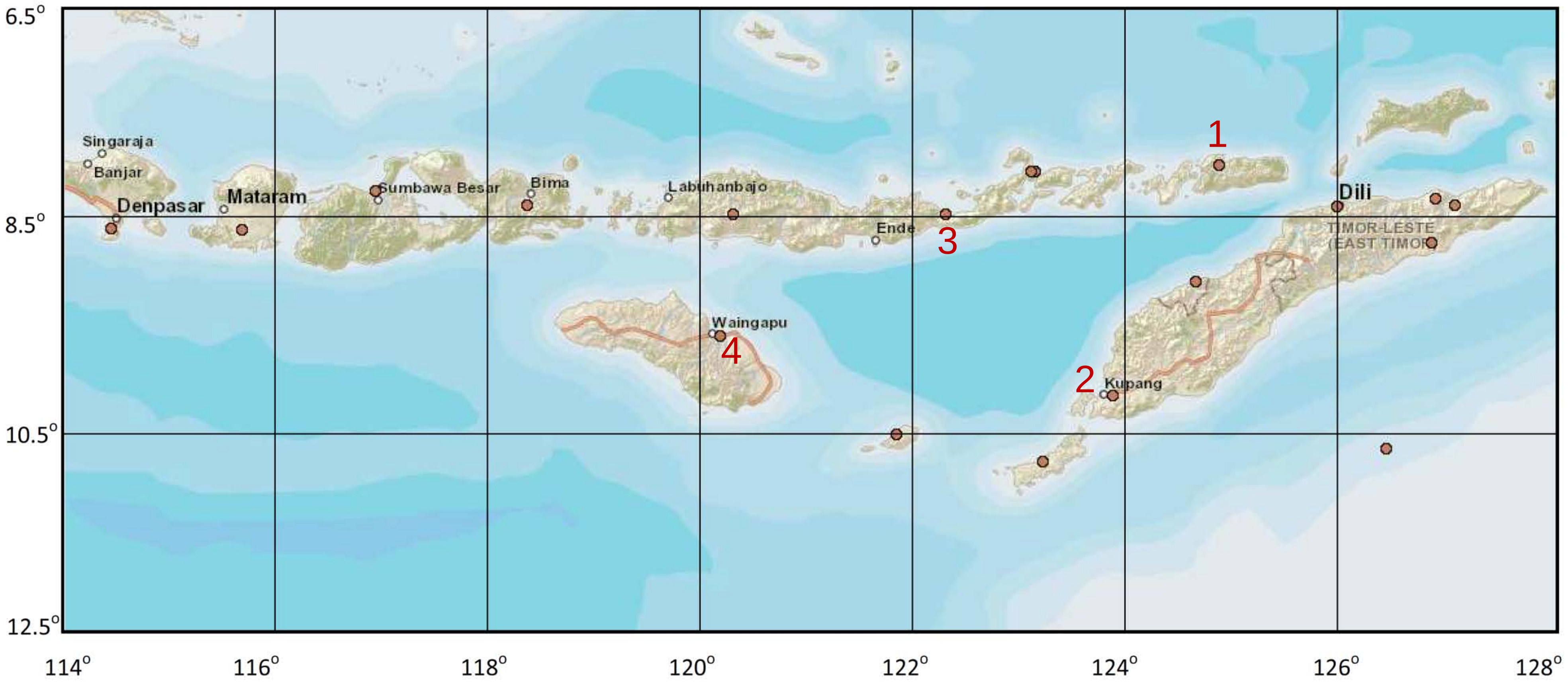

Figure 1: *Map indicating locations where it was possible to create daily climate baseline and projection data. The grids depicted on this map equate to the NCEP reanalysis data grids.*

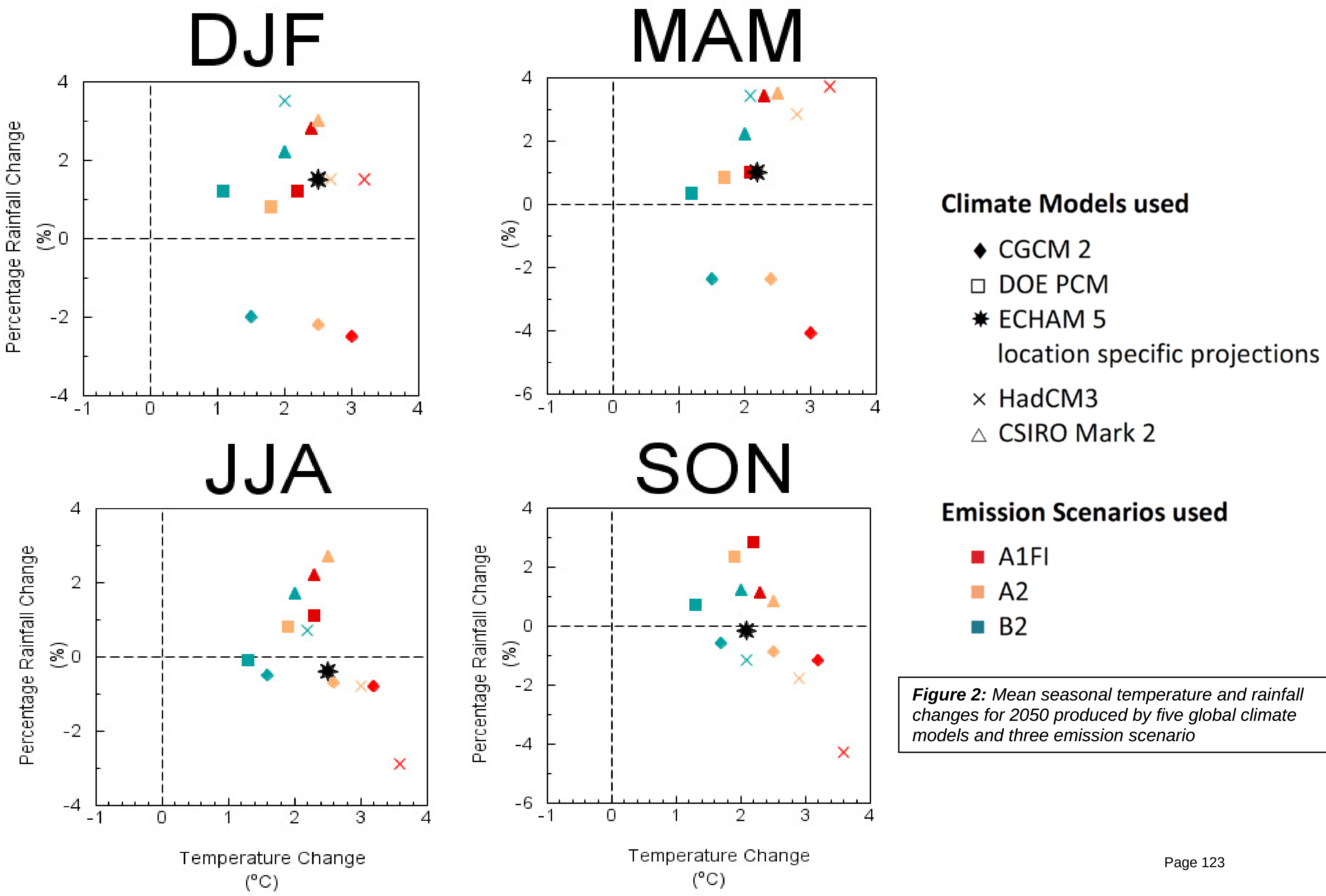

Figure 2: *Mean seasonal temperature and rainfall changes for 2050 produced by five global climate models and three emission scenario*