Developing a strategy for improved crop and animal production in the semi-arid tropics of West Timor

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Abstract

Subsistence farmers in West Timor rely on the production of maize and rice for food security. Cattle constitute an individual's wealth and status and are sold for live export to the more affluent Indonesian islands. The semi-arid environment is highly variable with annual rainfall of over 1000 mm common. The resilience of the farming system is low, with food deficits an issue in the late dry season (September-November). Consequently there is a need to improve production, specifically the farming systems' capacity to increase both food security and disposable income.

The combination of heavy clay soils with high water holding capacity (160-180 mm) and the introduction of forage legumes including *Clitoria ternatea, Centrosema pascuorum, Lablab purpureus, Stylosanthes seabrana* and *Stylosanthes guianensis* provide an opportunity to contribute to both cattle forage and maize nitrogen supply. In trials, *C. ternatea,* grown into the dry season on stored soil water produced 2.3-3.8 t DM/ha over 200 days. *S. seabrana* was still actively growing at the start of the subsequent wet season and produced between 5 and 9 t DM/ha. Preliminary evaluation of the potential for the forages to contribute to subsequent maize crop nitrogen supply indicate a positive response to fixed legume nitrogen when compared to a sole maize control although this is yet to be confirmed and will be comprehensively tested during the 2008/09 season.

From the biological perspective the building blocks of potential farming system change are in place, however it remains to be seen whether farmers perceive sufficient value in the proposed changes. The use of on-farm participatory research is forging a link between the biophysical research and local social systems. It is the ability of local researchers and farmers to actively contribute to shaping this research intervention which will ultimately decide the research outcomes.

Key Words

Forage legumes, stored soil water, maize systems, nitrogen fixation, on-farm research, subsistence farmers

Introduction

Although the average rainfall for West Timor is between 1000 and 2000 mm per annum (Table 1), farmers have difficulty in sustaining food supply throughout the year with food shortages common in the late dry season (September to November). Food security relies primarily upon cereal production. Rice is grown in the more fertile lowlands under supplemental irrigation with scarce financial resources directed towards production inputs including inorganic fertilisers, pesticides and farm mechanisation. In contrast, maize is grown in the higher lands under rain fed conditions, often as a component of an intercropping system in which annual grain legumes and other crops form an understorey. Whilst yield potential for maize in West Timor is >4 t/ha, the average yield is around 2 tonnes (Faesal et al 2006), a result of factors including the variable climate, the use of low yielding local varieties, poor agronomic management, and the farmers' preference to direct financial and labour resources to rice production.

Over 330,000 head of cattle are farmed in West Timor (Statistical Livestock Handbook 2003). Cattle are seen as constituting an individual's wealth and provide social status to the owner. Whilst traditionally cattle have been allowed to roam free or been tethered for grazing, there has been a recent move to develop communal village feed lots to fatten bulls for sale. This has resulted from increased demand for beef in the more affluent western Indonesian islands, which has led to the development of a lucrative live export market with more than 40,000 head shipped per annum (Statistical Livestock Handbook 2003). While farmers are keen to tap into this market they are hampered by low and variable cattle live weight gains, a result of erratic, low quality forage supply. Research indicates that improved forage supply could double daily live weight gain from around 200 g/day to 450 g/day (Budisantoso, unpublished data).

In the traditional farming system maize is sown on the third rainfall event after the commencement of the wet season in November-December. After harvest in March, the land is fallowed until the following wet season with crop stover and weeds used to feed cattle, either via tethered grazing or cut and carry. It was evident that soil water remaining at maize harvest, supplemented by late wet season rainfall was being underutilised. This raised the question - would it be possible to relay crop forage legumes into the maize sward around crop maturity and utilise existing water resources to produce forage legumes into the dry season? This paper describes the opportunities provided by the introduction of forage legumes into the existing farming systems of West Timor. It focuses on the identification of a set of legumes with the ability to utilise currently unused water resources and the contribution of these forages to improved animal and cereal production.

Methods

Process and design

In order to explore the potential for forage legumes to contribute to farming system change, it was considered important that farmers be an integral component of the research process. A participatory research approach was initiated that involved on-farm research in collaboration with existing village farmer groups. Groups consisted of between 20 and 100 members supported in their activity by government extension and research personnel. Surveying of farmers, extension staff and researchers has been undertaken to gain an understanding of farmer group functions, the socio-economic position of farmer group members, and to benchmark the agronomic knowledge underpinning the existing farming systems. Six villages located in Kupang, Timor Tengah Selatan (TTS), Timor Tengah Utara (TTU) and Belu regencies were selected to represent the agro-climatic variability of West Timor (Table 1). All regencies, with the exception of Belu, experience a unimodal rainfall pattern with the majority of rain occurring between December and April. In Belu regency a second rainfall period occurs during May and June.

Table 1. On-farm research sites representing the agro-climatic variability of West Timor.

Regency	Village	Latitude, Longitude	Elevation (m ASL)	Annual Rainfall (mm) and Rainfall pattern	Soil Type
Kupang	Sillu	-10.053, 123.960	440	1000 - unimodal	Alfisol
TTS	Biloto	-9.873, 124.222	560	1500-2000 - unimodal	Vertisol
TTU	Usapinonot	-9.452, 124.544	360	1500-2000 - unimodal	Vertisol

	Lapeom	-9.497, 124.576	360	1500-2000 - unimodal	Vertisol
Belu	Kakaniuk	-9.538, 124.827	70	1200+800 - bimodal	Vertisol
	Kletek	-9.588, 124.933	70	1200+800 - bimodal	Vertisol

Legume selection

Eight forage legumes species *Centrosema pascuorum, Clitoria ternatea, Dolichos lablab, Desmanthus pernambucanus, Desmanthus virgatus, Macroptilium bracteatum, Stylosanthes guianensis* and *Stylosanthes seabrana* were evaluated for species adaptation, systems 'fit' and biomass production during the 2006/07 season. Legume trials were sown using a randomised plot design (3 reps) in late February 2007 as rainfall started to decline towards the end of the wet season. Phosphorus was applied at 10 kg/ha. Legumes were not inoculated with specific rhizobia at sowing. Species selection was based on trials undertaken at Naibonat Research Station during 2005/06, with selection for each location further dependant on soil type and farmer preference. Biomass cuts were undertaken every 14 days from sowing until crop maturity for annual species and for 266 days after sowing (DAS) (7^{th} November) for semi- and perennial species.

Bioassay of legume contribution

At Kakaniuk during the 2007/08 wet season maize was opportunistically sown as a bioassay over existing legume plots to gain insight into the potential for the forage legumes to contribute to crop N supply. Maize was sown in 80 cm rows at an average plant population of 53,000 plants/ha with no additional nitrogen applied. This on-farm observation trial should only be considered as a preliminary evaluation of the legumes' ability to fix N and not an assessment of the proposed system (as the legumes were not established as intercrops, nor all legume biomass removed during the dry season) which will be fully tested during the 2008/09 season.

Determination of Plant available water capacity (PAWC) and monitoring of plant available water (PAW)

PAWC was determined at five of the research locations. Techniques modified from Dalgliesh and Foale (1998) were used to determine the drained upper limit (DUL) and crop lower limit (CLL) of the soil. DUL was measured at the end of the wet season after the profile had been naturally recharged by rainfall. The crop lower limit (CLL) was estimated for each legume species based on the water remaining at crop senescence or, in the case of the semi- and perennial species, late in the dry season. Soil parameters were measured in 7 layers to a depth of 180 cm (0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm). Plant available water was measured at legume establishment (February), 50% flowering (early May) and 200 DAS (3^{rd} September) to determine seasonal crop use.

Results

Legume biomass production

Of the eight legumes evaluated six produced biomass of significant quantities (Centrosema pascuorum, Clitoria ternatea, Lablab purpureus, Macroptilium bracteatum, Stylosanthes guianensis and Stylosanthes seabrana) when sown in mid February at the four unimodal rainfall locations. At Biloto (unimodal rainfall) (Figure 1 and 2) mean maximum biomass production for the annual species, Lablab purpureus (4300 kg DM/ha), Centrosema pascourum (3600 kg DM/ha) and Clitoria ternatea (3300 kg DM/ha) was achieved in 94 days when the Lablab purpureus and Centrosema pascourum senesced. Clitoria ternatea, however, continued to grow through to 197 DAS (3800 kg DM/ha). The perennial species Stylosanthes guianensis and Stylosanthes seabrana were slow to establish and did not commence producing significant biomass until around 94 DAS, however by 197 DAS (3^{rd} September) these species had produced 6400 kg and

9700 kg DM/ha respectively and continued to grow into the following wet season (Figure 2). Whilst Macroptilium bracteatum produced significant biomass (5200 kg DM/ha after 197 days) it was not favoured by the farmers due to its erratic establishment and variable sward and was subsequently dropped from evaluation.

Figure 1. Legume biomass production (kg/ha) (Biloto) for C*entrosema pascourum, Clitoria ternatea and Lablab purpureus* sown on the 18th Feb. 2007.

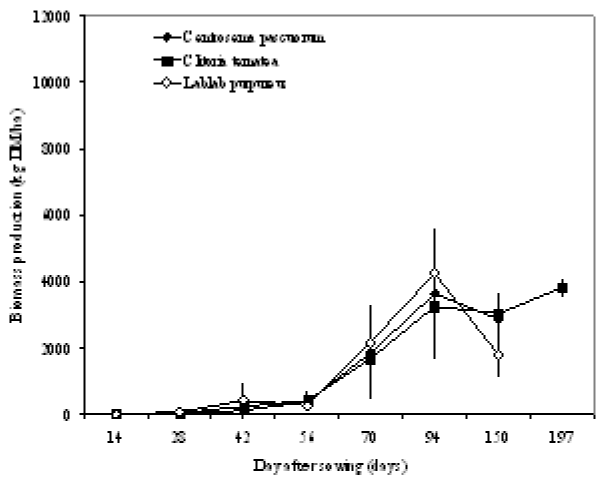
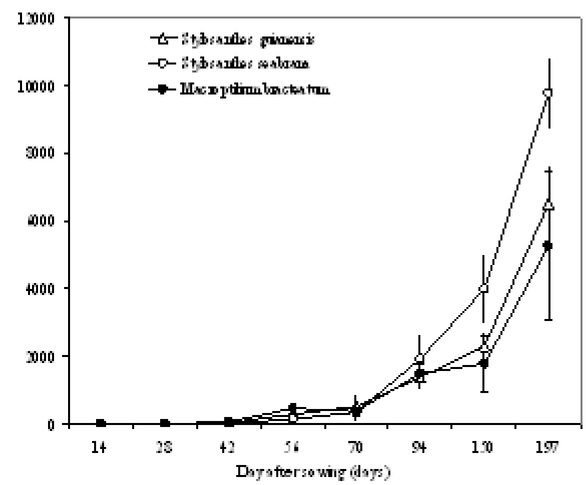


Figure 2. Legume biomass production (kg/ha) (Biloto)

for *Macroptilium bracteatum, Stylosanthes guianensis*

***and Stylosanthese seabrana* sown on the 18th Feb. 2007.**



At Kletek (bimodal rainfall) the same suite of legumes was sown on the 28th March as the monsoonal wet season drew to a close, but prior to the onset of the second rainy season in May. Biomass production of the annual legumes differed to Biloto and other unimodal rainfall sites. *Clitoria ternatea* and *Macroptilium bracteatum* produced 3500 kg and 3000 kg DM/ha respectively over 205 days, with *Centrosema pascuorum* and *Lablab purpureus* both producing approx 1500 kg DM/ha before onset of senescence at 155 DAS*.* Whilst less productive in this environment the perennial legumes *Stylosanthes guianensis* and *Stylosanthes seabrana* still produced 3200 kg and 5000 kg DM/ha biomass respectively over 205 days (19th October).

Soil water characterisation (PAWC) and monitoring (PAW)

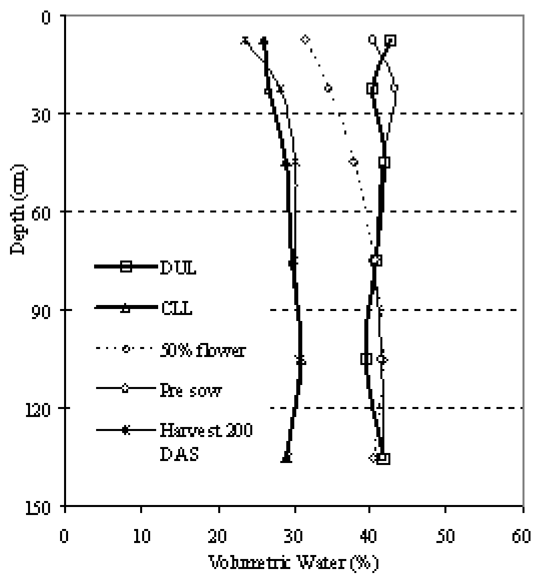
Measurement of PAWC at five of the research sites showed that the Vertisol soils had the potential to hold between 160 and 180 mm of plant available water to a depth of 150 cm (Figure 3), whilst the Alfisol soil held approximately 140 mm. There appeared to be little difference in extraction capacity between species to the measured depth of 150 cm, although the data indicated that it was likely that the perennial species extracted water from greater depths during their longer growing season. At legume sowing in mid-February (unimodal sites) soil profiles at all locations were at or near DUL. At Biloto this represented 185 mm of plant available water for *Clitoria ternatea* (Figure 3). By early May when 1700 kg DM/ha biomass had been produced and the wet season had ceased there was still 145 mm of water available for crop production. This water was subsequently used to produce a total biomass of 3800 kg DM/ha in 200 DAS.

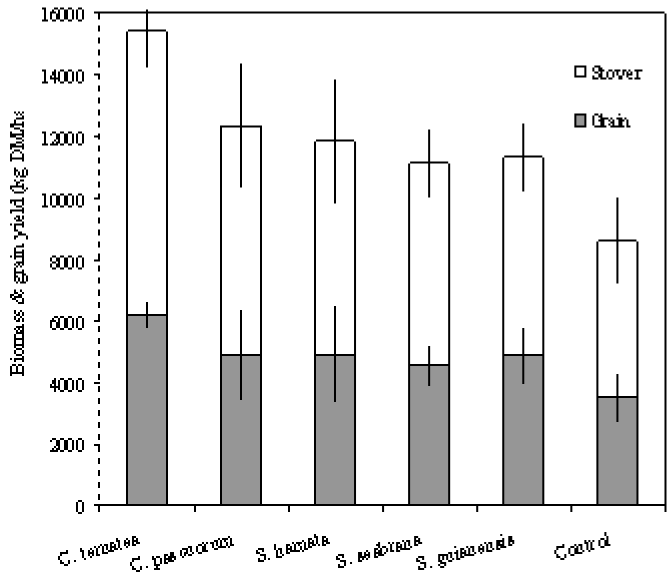
Legume contribution to N supply

The opportunistic use of a maize bioassay at Kakaniuk to determine N contribution from one season of legume growth indicated increased production of both grain and stover compared to a maize control (Figure 4). Whilst this preliminary assessment provides some optimism that the legumes will contribute to crop N supply this is yet to be fully tested as a component of the complete farming system where legumes are established as relay crops with maize and the majority of legume biomass removed for animal feeding during the dry season.

Figure 3. PAWC of 180 mm (to 150 cm depth) for a Vertisol soil (Biloto) represented by the Drained upper limit (_) and Crop lower limit (Δ). Soil water use during the season is shown for legume sowing (O), at 50% flowering (◊) and at 200 DAS (?).

Figure 4. Preliminary assessment of the potential for forage legumes to contribute to crop N supply through increased grain (shaded) and stover (open) production compared to a sole maize control (Kakaniuk, 2007/08 season).





Conclusion

Whilst the full farming system is yet to be tested (2008/09), research to date shows that dry season production of forage legumes is able to contribute to overall animal feed supply, and potentially to cereal production. The establishment of forage legumes prior to the end of the wet season which are able to rely on currently underutilised soil water resources for production has important consequences for the farming system. Not only can farmers improve supply and quality of animal feed but it is possible that more crop stover will also become available for animal feeding through improved cereal crop nutrition.

Whilst this research opens up opportunities for farmers, the future challenges include the development of a sustainable seed production industry, the continuing education of the farming community regarding the benefits of legumes within their system and the identification, in collaboration with the farmers, of the appropriate system ‘niches’ into which the individual legumes will fit in order to maximise impact.

Acknowledgements

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