Modelling for scenario analysis for improved smallholder farming systems in Indonesia

MacLeod, N.D. [1], C.K. McDonald[1], S.N. Lisson[1,2] and R. Rahman[3]

[1] CSIRO Sustainable Ecosystems, St Lucia Q 4067, Australia
[2.] Tasmanian Institute for Agricultural Research, University of Tasmania, Hobart Tas 7001
[3.] Balai Pengkajian Teknologi Pertanian Sulsel, Makassar 1234, Indonesia
Email: neil.macleod@csiro.au

Keywords: *farming systems, modelling, forage, Bali cattle*

EXTENDED ABSTRACT

A rapid expansion in demand for livestock products is having a major impact on smallholder agricultural production systems throughout the tropical world. This development has had a particularly profound impact on cattle rearing opportunities in eastern Indonesia, where historically high beef prices in the past decade have contributed to a substantial decline in Bali cattle numbers. While the rising demand for beef cattle is providing opportunities for income security through cattle production, taking advantage of this potential has been constrained by limited resources and a difficult production environment.

Smallholder farming systems in eastern Indonesia typically involve sowing subsistence food crops in the relatively short rainy season, followed, where possible by cash crops (e.g. peanut, tobacco, maize) in the less reliable early dry season. Small numbers of cattle are kept (2-5), grazing in backyards, roadsides and local forests where access is available. The incorporation of improved forages for feeding cattle into local farming systems could address the prevailing resource constraints. To date, limited use has generally been made of new forage sources as these may be perceived to conflict with household resource demands (esp. working capital and rainy season labour), with traditional cropping systems, and potentially interfere with food security.

A whole-farm systems approach which includes both farm and non-farm production and consumption activities, can usefully address these issues. A crop simulation model (APSIM) and an animal production model have been linked with a smallholder household economic model to form an integrated analysis tool (IAT) to support a whole-of-system analysis of alternative forage and livestock options that may be integrated within existing smallholder farming systems. The IAT allows the production, economic and social benefits of such options to be explored concurrently. Preliminary analyses have identified the scope for substantial improvements for animal production, farm profitability and family welfare from within the resources and constraints of current farming practices. Selected crop, forage and livestock management options have been developed through smallholder participation and are now being successfully applied in the field.

This paper describes a farming systems research approach to develop an integrated analysis tool (IAT) to explore the opportunities and constraints to increasing the production of Bali cattle on smallholdings. The utility of the IAT is demonstrated with a synthetic case study farm, located in South Sulawesi, exploring 3 prospective forage and husbandry management options, and a change in livestock prices. The case study example results support the apparent opportunity for a farming systems change that favours forages and cattle raising activities to increase smallholder household welfare.

1. INTRODUCTION

The demand for livestock products, particularly beef, has expanded rapidly in tropical regions over recent decades (e.g. Delgado *et al.* 1999, Hadi *et al*. 2002), and is having a major impact on both smallholder agricultural production systems and regional economies. This development has had a profound impact on the cattle industry of eastern Indonesia. High beef prices, particularly fuelled by increased demand in urban centres in Java, have led to a rapid decline in Bali cattle numbers beginning in the early 1990's, including breeding cows. For example, cattle numbers in South Sulawesi declined from 1.23 million in 1991 to 841,000 in 1997 (FAO 1999) and are still declining in some regions despite the more recent introduction of controls on the slaughter of female animals. While the strong growth in beef demand is obviously creating opportunities for smallholder households to increase their income from cattle production activities and also to improve the economic sustainability of their farming enterprises, some major constraints (e.g. animal feed, management and health) need to be addressed. The strategic use of improved forages has the capacity to address these constraints but may also introduce some conflicts with resource demands (esp. working capital and rainy season labour) and with traditional subsistence and cash cropping systems. While previous research has identified many forage species that are well adapted to mixed crop-livestock farming systems (e.g. Horne and Stür 1997, Pengelly and Lisson 2001), their adoption has been limited even where participatory research has suggested a good fit with smallholder household's needs (Cramb 2000).

It may be the case that many smallholders are yet to be convinced that the advantages of adopting the new forages can outweigh the costs of their employment; that more attractive options for investment of their scarce resources exist; or there may be a perception that the risk associated with the change is unacceptably high. This paper describes a farming systems research approach that has been employed within the context of a current program of research supported by the Australian Centre for International Agricultural Research (ACIAR). It aims to investigate the benefits of new forages to improve Bali cattle production in the mixed crop-livestock systems of eastern Indonesia, in bio-physical, economic and social terms[1].

2. METHOD

A participatory technology development approach has been employed that centred on a joint Australian-Indonesian multi-disciplinary team interacting with targeted smallholder communities at 3 regional locations in eastern Indonesia (South Sulawesi, Central Lombok and Central Sumbawa) to investigate prospective improvements to smallholder household production and welfare from the trialling and introduction of improved forages and Bali cattle management. The approach is strongly supported by simulation modelling and has employed the following 3 major steps:

Step 1 - The existing farming systems have been defined from biophysical, economic, social and cultural perspectives (benchmarking).

Step 2 - Appropriate biophysical and economic models of these systems have been developed and validated (model assembly).

Step 3 - The component models have been linked within a framework (interfaced) that enables a whole-of-system analysis of the production, income and consumption impacts of alternative forage and livestock options that might be incorporated within the existing smallholder farming and trading system (Integrated Analysis Tool).

2.1 **Step 1** - Benchmarking the system.

Interviews were held with individual smallholder households, village heads and local extension staff in selected villages in South Sulawesi (Barru, Pattalikang), Central Lombok (Mertak) and Central Sumbawa (Lanci) that were selected as case studies from which wider extension programs are now being rolled out[2]. This local community data was augmented by secondary data sources drawn from local and regional government offices (e.g. Kepala desa, Kecamatan and Kabupaten). The key features of the farm-household system included: resource endowments (land, machinery, labour inputs), crop and livestock activities (area/quantity, material production inputs, field commitments, husbandry and marketing), income (input costs, output prices, household expenses, non farm income, credit) and constraints to increasing crop and livestock yields, prices and market access.

2.2 **Step 2** - Model assembly.

The APSIM crop-farming systems model (McCown *et al.* 1990) simulates crop, forage and soil-related processes and the influence of climate and management factors on these processes using local climate and soil characterization data. New growth models were developed for rice and Napier grass (Pennisetum purpureum) to complement existing APSIM models for other locally grown crops including maize, peanuts, and forage legumes (e.g. stylosanthes, mucuna, lablab, cowpea and mungbean) which were recalibrated for local application. Some of these crops (e.g. cowpea, mungbean) are dual purpose food and forage crops requiring yield estimates in both roles. A second model was developed for predicting annual liveweight gain and reproduction cycles for Bali cattle under local feeding and husbandry practices; including grazing and cut and carry systems for feeding forages and crop residues. The model used both published data and data from animal and forage monitoring records that were collected each 2-3 months on animal body condition score, measured liveweight gain

[1] Collectively comprising ACIAR projects AS2/2000/124, AS2/2000/125 and AS2/2004/005.

[2] Supported by ACIAR projects SMAR/2006/061, SMAR/2006/096.

and stage of pregnancy, as well as the quality, composition and quantity of various feed sources. A third model of a smallholder household was custom developed to identify production, consumption and economic returns and resource constraints associated with exploiting new forage-livestock opportunities identified by the projects. This model accounted for the key resource pools of labour, finance, land, household consumption needs and opportunities, forage and draught. Input data was sourced from the step 1 benchmarking activity, field monitoring, and projections from the biophysical models.

2.3 **Step 3** – Integrated Analysis Tool.

A user-friendly interface employing both English and Bahasa Indonesia language options was incorporated within the smallholder household economic model to form the working 'hub' of the IAT, with links to the livestock and crop simulation models (Figure 1). The household model is built on an Excel ® spreadsheet platform.

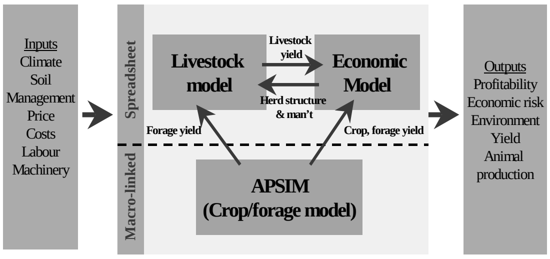

Figure 1. Conceptual framework of the Integrated Analysis Tool.

Livestock yield and other animal data (projected liveweight gain, calving dates, etc) are exchanged directly between the livestock and economic models within the same spreadsheet. The APSIM crop and forage models operate externally to generate temporal data for a wide range of scenarios (based on locally available climate data), and these are uploaded into the IAT spreadsheet model. APSIM forage (crop stover and/or forage crop) yield and quality data is an input to the livestock model, and the simulated crop yield data is also an input to the economic budgets within the IAT spreadsheets.

The IAT interface allows users to define and calibrate a baseline case against which to 'design' and test alternative crop, forage and livestock management options described as scenarios. Once a particular scenario has been configured, the model is run and the output presented in either graph or tabular form describing: (a) biophysical characteristics of the system (i.e. crop and forage yield/biomass and animal liveweight gain); (b) labour demand and supply details and; (c) economic performance (available cash balances, gross margins and net income) over a 5 year period (a limit set for this case by the availability of suitable climate data at the Indonesian sites). The inter-temporal variability of the results can be easily read from the data output tables of graphs.

For the work being conducted at each of the case study sites, the scenarios to be tested were identified through a multi-stage workshop process involving facilitated groups of smallholder household members and local extension officers. The projected results are discussed and additional refinements to the scenarios incorporated where this is judged to be appropriate. At each site, the more promising forage and livestock management options, `best-bets', are presently being field tested and monitored under local conditions by a number of the smallholder households. As the scenarios (baseline and alternative) canvassed at the workshops were necessarily generic in nature, the suite of 'best-bets' undergoing trial have been customised to the specific conditions and preferences of each participant household. This customisation and field testing is also based on the likelihood that the field yields will be lower than the potential simulation yields due to limited inputs and non-uniform (spatially) management practices across households. The real power of the simulation process lies in the relative differences between the scenarios, rather than the actual figures that are generated by the model.

3. EXAMPLE - BARRU CASE STUDY

To demonstrate the utility of the IAT, this section presents the outcomes from some of the scenario assessments in one of the projects' case study sites - Kading subvillage, Barru Regency, South Sulawesi (lat. -4.5^o S, long. 120.0^o E, average rainfall 2890mm). In the course of a series of smallholder workshops, participants were asked to identify the key constraints to increasing Bali cattle production and to nominate possible options for addressing these constraints. Several of these opportunities were subsequently analysed and the results are presented below:

3.1 **Option 1** - Increase conservation and quality of crop residues.

Under the present farming systems, smallholder households in Kading subvillage typically grow 2 rice crops (wet season, early dry season) and a

Table 1. Option 1 (Conservation of residues) - Selected baseline and alternative scenario 1 outputs from IAT

% Crop residue retention	Cut & carry (kg/day)	Cattle sold over 5 years	Fodder (Kg/year)	Labour balance	5 year cash balance Rp million
Baseline: Wet season: 0.54ha lowland rice, 0.3ha upland peanut, 2 cows					
80 peanut	30	6	-3000	deficit	14
Scenario 1: Baseline plus fermented 40% of rice straw					
80 peanut	30	7	-2000	deficit	22

small range of secondary cash crops including peanuts (early dry season). They conserve most of their peanut stover and a small percentage of their second (early dry season) rice crop for household and animal use. The remainder of the rice residue is either retained on the surface or burnt. There has previously been an effort made by local extension personnel (Dinas Perternakan) to increase smallholders' awareness of the potential value of rice straw for animal forage and to promote quality improvement via ensilage, fermentation and ammoniation.

Question for IAT: *'What is the impact of using fermented rice straw on feed and labour supply, cattle production and household income?'*

Baseline scenario: 0.54ha of rice on lowland during the wet season + 0.3ha of peanut on upland during wet season + maximum of 2 cows. 0% of rice residue + 80% of peanut residue are conserved. 30kg of cut and carry forage is collected per day.

Alternative scenario 1 (Option 1): As for the baseline scenario + retention of 40% of rice straw and fermentation to improve quality.

Results: Increased rice straw retention and fermentation lowered the annual (purchased) fodder deficit, and, over 5 years, increased cattle sales by one animal and the cash balance from Rp14 million to Rp 22 million[3] (Table 1).

Table 2. Option 2 (Planting forages) - Selected baseline and alternative scenarios 2 & 3 outputs from IAT

% Crop residue retention	Cut & carry (kg/day)	Cattle sold over 5 years	Fodder (Kg/year)	Labour balance	5 year cash balance Rp million
Baseline: Wet season: 0.54ha lowland rice, 0.3ha upland peanut, 2 cows					
80 peanut	30	6	-3000	deficit	14
Scenario 2: Plus 0.3ha of Napier grass on upland					
80 peanut	30	7	-600	surplus	22
Scenario 3: Plus +200m of Gliricidia on upland					
80 peanut	30	7	-1000	surplus	18

3.2 **Option 2** - Increase the area of (existing) planted forages.

The primary planted forages that are presently grown at Kading subvillage are Napier Grass (*Pennisetum purpureum*) and Gliricidia (*Gliricidia sepium*), a tree legume. Both species are perennials and are highly valued for their persistence into the dry season. Napier Grass is typically grown along riverbanks, in upland areas and on less productive

[3] At the time of writing AUD1.00=Rp 7,900

lowland areas. Gliricidia is usually grown as a living fence in upland areas.

Question for IAT: *'What is the impact of increased upland Napier Grass and tree legume production on feed and labour supply, cattle production and household income?'*

Baseline scenario: As for baseline 3.1 above.

Alternative scenario 2 (Option 2): As for baseline 3.1 above + 0.3ha of Napier Grass on under-used upland, including field edges and bunds.

Alternative scenario 3 (Option 2): As for baseline 3.1 above + 200m of Gliricidia around the perimeter of upland fields.

Results: Increased Napier grass and Gliricidia production potentially reduces the annual forage deficit substantially, and, over 5 years, increases cattle sales by 1 additional animal, and has increased the cash balance by Rp 8 million and Rp 4 million respectively (Table 2). The deficit in available labour has been relieved in both scenarios. The extra forage available gives the potential to increase the number of cows kept.

3.3 **Option 3** - Change animal breeding.

Where circumstances allow it, Kading subvillage smallholders generally prefer to breed their own cattle rather than buy in young animals for finishing and resale. A major constraint for the breeding option, however, is a shortage of local bulls and the poor 'strike rate' of artificial insemination services offered by the local livestock services.

To lessen the stress associated with the synchronization of draught activity, calf raising and the dietary shift from dry to wet feed late in the year, there is now interest in adjusting the mating and calving schedule. For example, instead of mating in November-December, when cows are heavily engaged in draught activities, consideration might be given to calving in the March-April period and then mating 2-3 months later in June-July (to make it a 12 month cycle). With this schedule, the cow is being used for draught at a safe time of the pregnancy (avoid final 2 months of gestation) and is not raising a calf at the same time. Furthermore, the calf is born at the end of the wet season when there is good availability of forages and the cow is in good condition. Such modifications to reproduction management may also result in improved growth rates for cattle and faster turnaround times from birth to sale.

Question for IAT: *'What is the impact of adjusting to a 12 month cycle with calving in March/April and mating in June /July?'*

Baseline scenario: To utilise the increased forage availability (as per Scenario 3.2 in the previous section), cow numbers are increased from 2 to 4, and daily cut and carry increases from 30kg to 50kg.

Alternative scenario 4 (Option 3): As for baseline + seasonal mating of cows.

Results: The utilisation of the additional forages by keeping 4 cows increases cattle sales from 7 to 14, while seasonal mating increases cattle sales by a further 3 animals over 5 years and the cash balance over this same period from Rp 38 million to Rp 43 million (Table 3).

3.4 **Option 4** - Change cattle prices.

While the various scenarios outlined before (Scenarios 1 to 4) appear to offer significant gains to smallholder household income, these were run using current cattle prices, which are buoyed by

Table 3. Option 3 (Changed calving management) - Selected baseline and alternative scenario 4 outputs from IAT.

% Crop residue retention	Cut & carry (kg/day)	Cattle sold over 5 years	Fodder (Kg/year)	Labour balance	5 year cash balance Rp million
Baseline: Wet season: 0.54ha lowland rice, 0.3ha upland peanut, 200m of tree legume, 0.3ha of Napier grass, 40% rice fermented, 4 cows					
80 peanut	50	14	0	surplus	38
Scenario 4: As for Scenario 3 plus seasonal mating of cows					
80 peanut	50	17	-2000	surplus	43

the relative shortage of Bali cattle in the eastern regions. To better understand any inherent risk to a change of management that is likely to significantly change cattle numbers and beef supplies in the region, it is important to test the better options for sensitivity to changes in cattle prices.

Question for IAT: *'What is the profit sensitivity of the Option 2 Scenario to a decline in cattle prices of 20%?'*

Baseline scenario: As for scenario 3.2 before.

Alternative scenario 5 (Option 4): As for scenario 4 (previous section 3.3), but with 20% lower cattle prices.

The effect of a 20% decline in the price of Bali cattle would be to reduce the 5 year accumulated cash balance from Rp 43 million to Rp 35 million. This still, however, would represent a considerable improvement over the original baseline scenario of only Rp14 million. As only the price variable is altered in this particular simulation scenario, all of the other impacts on the smallholder farming system are projected to remain the same as those shown in the last row of Table 3.

4. CONCLUSION

The development of the new systems-based analytical toolkit (IAT) has allowed the prospective production, economic, and social impacts of alternative crop and forage production options for smallholder farming systems to be explored concurrently. Preliminary applications of the IAT in conjunction with smallholder workshop analyses have identified the scope for substantial improvements to be gained to smallholder production profitability and household welfare from within the resources and constraints of their current farming systems. Ongoing ACIAR projects are further developing and testing the various tools and approaches described in this paper and to communicate the outputs of the project to a wider range of smallholder households across eastern Indonesia (see footnote 2); and also to other providers of research and extension services.

5. ACKNOWLEDGEMENTS

The work reported in this paper was funded by the Australian Centre for International Agricultural Research.

6. REFERENCES

Cramb R.A. (2000). Processes influencing the successful adoption of new technologies by smallholders. In. (W.W. Stür, P.M. Horne, J.B. Hacker, P.C. Kerridge Eds.) *Working with Farmers: The Key to Adoption of Forage Technologies. ACIAR Proceedings 95*, Australian Centre for International Agricultural Research, Canberra. pp. 11-22.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. (1999). *Livestock to 2020: The Next Food Revolution. Food, Agriculture and the Environment* Discussion Paper No. 28. International Food Policy Research Institute, Washington, D.C.

FAO (1999). *Livestock Industries of Indonesia prior to the Asian Financial Crisis.* FAO Regional Assessment Program publication 1999/37.

Hadi, P.U., Ilham, N., Thahar, A., Winarso, B., Vincent, D. and Quirke, D. (2002). *Improving Indonesia's Beef Industry*, ACIAR Monograph No. 95, Australian Centre for International Agricultural Research, Canberra.

Horne, P.M. and Stür, W.W. (1997). Current and future opportunities for forages in smallholder farming systems of south-east Asia. *Tropical Grasslands* 31,359-63.

McCown, R.L., Hammer, G.L., Hargreaves, J.N.G., Holzworth, D.P. and Freebairn, D.M. (1996). APSIM: A novel software system for model development, model testing, and simulation in agricultural systems research. *Agricultural Systems*, 50, 255-271.

Pengelly B.C. and Lisson S.N. (2001) Strategies for using improved forages to enhance production in Bali cattle. *In Strategies to Improve Bali Cattle in Indonesia. ACIAR Proceedings 110.* Australian Centre for International Agricultural Research, Canberra. pp. 29-33.