Integration of Small Holder Crop-Forage-Livestock Systems in South East Asia--an Eastern Indonesian Case Study

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Key points: Materials and practices for integrating forage-based livestock activities into smallholder farming systems in South East Asia are readily available, but have a poor adoption record. A 5 step participatory technology development approach has been successfully trialled in 3 regional sites in eastern Indonesia to integrate Bali cattle raising activities based on planted forages into traditional food and cash cropping systems. The approach is underpinned with simulation modelling applied within a farming systems research framework. The 5 steps are described and their application illustrated for a smallholder household located in South Sulawesi. The resulting forage and cattle management technologies and practices are being extended over a large area of eastern Indonesia.

Key words: farming systems, modelling, forages, Bali cattle

Introduction

The rapidly expanding demand for livestock products, particularly beef, over recent decades in tropical regions throughout the world has the prospect of making a major impact on both smallholder agricultural production systems and regional economies (e.g. Delgado et al. 1999). As is the case for many South East Asian countries, this development has had a profound impact on the cattle industry of eastern Indonesia. Historically high beef prices, beginning in the early 1990s, particularly fuelled by increased demand in urban centres in Java, have led to a rapid decline in Bali cattle numbers, 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. However, while the strong growth in demand for beef 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 still need to be addressed. These constraints particularly include an array of animal feeding, animal management and animal health issues, which persist despite a considerable investment of research, development and extension (R, D&E) over many years in the region (Horne and Stür 1977). The strategic planting and feeding of improved forages has been well-recognised to provide the capacity to address these constraints for smallholder households (Horne and Stür 1997), but may also introduce some conflicts with resource demands (esp. working capital and seasonal 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. Pengelly and Lisson 2001) and have the potential to substantively lift animal productivity, their adoption has generally been quite limited, even where participatory R, D&E has suggested a good fit with smallholder household needs (Cramb 2000).

A major part of the reluctance of many smallholders to embrace new forage-based livestock activities may simply be that they are as yet not convinced that the advantages will outweigh the costs and effort of their employment; that more attractive options exist for investment of their scarce resources both within and beyond their farming activities; or they may perceive the risk associated with changing their household activity portfolio to be unacceptably high. It is also posited that part of the limited adoption is because in most cases the smallholders have had little input to the development of the farming practices that employ them (Horne and Stür 1977). As the cost of lost welfare opportunities that stem from this continuing failure to more tightly integrate forage-based livestock activities into smallholder farming systems is high, and these constraints are principally systemic, their address is best effected through a participatory farming systems research approach. As the complexities of interactions between farm, non-farm and household activities in South East Asian smallholder farming systems are well-recognised (MacLeod et al. 2007), and impossible to comprehensively study in a formal field setting, simulation modelling and active smallholder participation has been increasingly employed to support forage-livestock systems development, adaptation and diffusion (Lisson et al. 2008). This paper describes one such approach, using a case example drawn from an ongoing program of research supported by the Australian Centre for International Agricultural Research (ACIAR) that is investigating the benefits in bio-physical, economic and social terms, of integrating new forage activities to improve Bali cattle production within the mixed crop-livestock systems of eastern Indonesia (The research program collectively comprises ACIAR projects AS2/2000/124, AS2/2000/125 and AS2/2004/005).

Method

The opportunity for improving smallholder household production and welfare from the integration of improved forages and Bali cattle management into traditional cropping systems was explored using a participatory technology development approach involving a joint Australian-Indonesian multi-disciplinary R , D&E team interacting with targeted smallholder communities in three regional locations in eastern Indonesia (South Sulawesi , Central Lombok and Central Sumbawa) . The approach which involves close and regular interaction between the R ,D&E team and smallholder communities and is strongly supported by a series of simulation models that are embodied within an integrating computer package , employs the following five major steps :

Step 1 -The existing farming systems in the targeted communities are defined from biophysical , economic , social and cultural perspectives (benchmarking) .

Step 2- Appropriate biophysical and economic simulation models that seek to mimic the behaviour of these systems are developed and validated with smallholder groups and local agencies that service them (model assembly) .

Step 3- The component models are linked within a computer-based framework (interfaced) to enable the team and partner smallholders to jointly explore the prospective impacts of alternative forage and livestock options that might be incorporated within the existing smallholder farming and trading system on production , income and consumption opportunities (Integrated Analysis Tool) .

Step 4-Specific options for profitably integrating new crop , forage and livestock activities into existing smallholder farming systems are examined with the IAT and canvassed with smallholder households (Best-bet identification) .

Step 5- Options that are attractive to smallholders are field evaluated by selected households (Field proving) .

Step 1 -*Benchmarking the system* . Group meetings and individual interviews were held with smallholder households , community leaders and local extension staff in selected communities in South Sulawesi , Central Lombok and Central Sumbawa that were selected as pilot study areas for defining and trialling integrated crop-forage-livestock systems , and from which wider technology scale out extension programs are now being undertaken (Supported by ACIAR projects SMAR/2006/061 , SMAR/2006/096) . This local community data , including social and infrastructure maps , was augmented by secondary data drawn from local , community and regional government sources (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 . The benchmarks were discussed and confirmed at subsequent community meetings .

Step 2-*Model assembly* . A crop-farming systems model , APSIM (McCown *et al* . 1990) , simulates crop , forage and soil-related processes and the influence of climate and management activities 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 . As some of these crops (e .g . cowpea , mungbean) are dual purpose food and forage crops , yield estimates were derived for both roles . A second model was developed for predicting the 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 from collaborating households on animal body condition score , measured liveweight gain 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 that may be associated with exploiting any 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 animal draught . Data to calibrate this model for local conditions was sourced from the step 1 benchmarking activity , field monitoring , and projections from the biophysical models .

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 and captures significant flows of materials and effort between various farm , non-farm and off-farm activities . 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 that are based on locally available climate data . This scenario based data is 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 , while the simulated crop yield data is an input to the economic budgets within the IAT spreadsheets .

The IAT interface allows users to define and calibrate a baseline case for a given smallholder household against which to design and test alternative crop , forage and livestock management options that are described as scenarios . When a particular scenario has been configured , the component models are run and the output is presented in either graph or tabular form

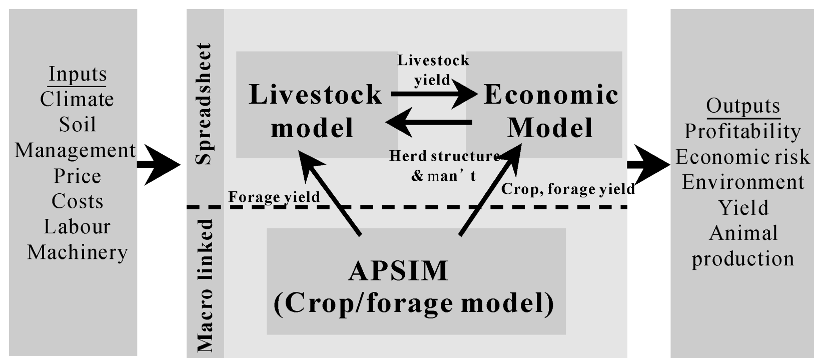

Figure 1 *Conceptual framework of the Integrated Analysis Tool .*

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 period whose limit is set by the availability of suitable climate data at the study sites (presently 5 years at the 3 Indonesian study sites) . The inter-temporal variability of the results can be easily read from the data output tables of graphs .

Step 4 -*Best bet identification* . A range of options (scenarios) for further integrating new crop , forage and livestock options into existing farming systems is canvassed with smallholders in the target communities . For the Indonesian project , the scenarios that were to be tested were identified at each study site through a multi-stage workshop process involving facilitated groups of smallholder household members , the R , D& E team and local extension specialists . The options were explored with the IAT and the projected results for each scenario were discussed and additional refinements made to the scenarios where this was judged to be appropriate by the participants .

Step 5 -*Field proving best-bet technologies and practices* . The more promising crop , forage and livestock management options identified in Step 4 ('best-bets) are adapted for field trialling under local conditions by selected smallholder households located across the target communities . In the Indonesian project , the selected households were identified by the workshop participants , and the options are adapted , monitored and evaluated by each of the best-bet households in partnership with the R , D& E team . Because the scenarios (baseline and alternative) that are canvassed at the workshops are necessarily generic in nature , the suite of best-bets that are trialled are customised to the specific conditions and preferences of each participant household . The process of customisation and field testing recognises the likelihood that the field yields will be lower than the potential simulation yields due to limited inputs and non-uniform management practices across households . The power of the simulation process generally lies in the relative differences between the scenarios , rather than the actual figures that are generated by the model ; and the fact that large numbers of options can be screened and manipulated quickly with the IAT .

An application of the procedure , using one of the case study communities in eastern Indonesia , is presented in summary form in the following section .

Example -Barru household case study

The utility of the participatory technology approach employed in the Indonesian project , particularly the use of the IAT to explore prospective outcomes from some of the scenario assessments , is illustrated for Kading subvillage , Barru Regency , South Sulawesi (lat .-4 .5° S , long . 120 .0° E , average rainfall 2890mm) . Following a number of exploratory visits to the region and meetings with local , regional and provincial stakeholders , this community was selected as a pilot study for developing improved integrated crop-forage-livestock systems as a catalyst for future scale-out activities in the region . Benchmark surveys were conducted to identify the community structure , current farming systems , and scope for adopting forage-based livestock options to enhance community welfare . Through a series of smallholder workshops , key constraints to increasing Bali cattle production were identified , along with possible options for addressing these constraints , and their technical and social feasibility . The more promising of these options were analysed using the IAT and three examples of the results , which were then discussed and endorsed are presented below :

Option 1-*Increase conservation and quality of crop residues .*
Smallholder households in Kading typically grow 2 rice crops (wet season , early dry season) and a small range of secondary cash crops , including peanuts (early dry season) . Most of their peanut stover is conserved and a small percentage of their second (early dry season) rice crop is retained for household consumption and animal use . The remainder of the rice residue is

retained on the surface or burnt ; and local extension authorities had previously attempted to increase smallholder awareness of the potential forage value of rice straw when improved by 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 . Over 5 years (The 5 year period for this example is due to limited available climate data for Barru to calibrate the underlying simulation models . The models can generate much longer runs (eg . 100 years) when reliable data is available .) , cattle sales have increased by one animal and the cash balance increased from Rp14 million to Rp 22 million (At the time of writing AUD1 .00=Rp 7 ,900) (Table 1) .

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 years' 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

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

The main forages that are presently planted for animal forage in Kading are Napier Grass (*Pennisetum purpureum*) and Gliricidia (*Gliricidia sepium*) , a tree legume . Both are perennial species that are highly valued for their persistence into the dry season . Napier Grass is typically grown along riverbanks , in upland areas and on less productive lowland areas ; while 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 + 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 use of Napier grass and Gliricidia substantially reduces the annual forage deficit . Over 5 years , cattle sales increase by 1 additional animal , and the cash balance increases by Rp 8 million and Rp 4 million respectively (Table 2) . The deficit in available labour has been relieved in both scenarios ; and the extra available forage gives the potential to increase the number of cows that can be kept .

Option 3-*Change animal breeding .*

Smallholders in Kading generally prefer to breed their own cattle rather than buying in young animals for fattening and resale . A major constraint for the breeding option , however , is a shortage of local bulls and the poor strike rate of the artificial insemination services offered by the local livestock authorities . Under present farming systems , breeding cows are often pregnant or lactating at the time of peak demand for animal draught in the late dry and early wet seasons .

There is a growing interest in adjusting mating and calving schedules 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 . 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 (a 12 month cycle) . The cow is then being used for draught at a safe time of the pregnancy (avoiding the final 2 months of gestation) and is not raising a calf at the same time. The calf is born at the end of the wet season when forage availability is generally good 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.

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 years' 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

Baseline scenario: To utilise the increased forage availability (as per alternative Scenario 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).

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 years' 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

These are only three examples of options that can be explored through the IAT and smallholder discussion process that has been employed in the Kading case study. Many other options, including impacts of changing cattle prices, limited seasonal labour, varying crop and forage yields etc have been canvassed and explored as part of the discovery process.

Trialling the options

At the conclusion of the Kading workshops, an array of forage and livestock options were identified as potentially worth field trialling, and a number of smallholder households were nominated to explore these options in more detail. These included, use of new and improved forages (e.g. Paspalum, Brachiaria, Panicum, Arachis spp), better utilisation of existing forages (e.g. Napier grass, leucaena, gliricidea), conservation of crop residues (e.g. ammoniated rice straws, peanut stover), improved animal husbandry practices (seasonal mating, early weaning, preferential feeding) and improved animal housing and feed handling systems etc. Follow up meetings between the R, D&E team and five nominated households tailored these options for establishment and follow through, including two monthly visits to monitor both the forages and livestock outcomes. Impacts on the livelihoods of the best-bet households are also being monitored by social scientists working with the R, D&E team. The results to date, across all of the case study sites, have been sufficiently encouraging to support a successful scale out initiative in three regions of South Sulawesi and two regions in central Lombok, commencing in October 2007 under a joint Indonesia-Australia Governments agreement (Smallholder Agribusiness Development Initiative) with an expected 10 year duration.

Conclusions

The further integration of forages and livestock activities within contemporary smallholder farming systems in South East Asia does offer considerable scope for enhancing the material welfare and livelihood capacity of numerous smallholder households and supporting goals to enhance regional prosperity . However , the adoption record of forage technologies has not been particularly encouraging despite substantial investments in the same over several decades .

The application of a successful participatory technology development approach , central to which has been a partnership of stakeholder consultation and the development of systems-based analytical toolkits (IAT) , has allowed the prospective production , economic , and social impacts of alternative crop , forage and livestock production options for smallholder farming systems to be explored concurrently . Ongoing ACIAR projects are further testing and refining the approach and the various tools described in this paper and are striving to communicate the outputs of the project to a much wider range of smallholder households across eastern Indonesia (see footnote 2) ; and also to other providers of research and extension services .

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