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Improving the reproductive performance of cows and performance of fattening cattle in low input systems of Indonesia and northern Australia

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List of abbreviations and commonly used Indonesian words

BCRI	Beef Cattle Research Institute
BCS	Body condition score (1-5 scale)
BPTP Lampung	Assessment Institute for Agricultural Technology, Lampung
BPTB NTB	Assessment Institute for Agricultural Technology, Nusa Tenggara Barat
BPTB Sultra	Assessment Institute for Agricultural Technology, Sulawesi Tenggara
CP	Crude protein
DM	Dry matter
GAPPSI	Indonesian feed-lotters association
ICARD	Indonesian Centre for Animal Research and Development
IGF-1	Insulin-like growth factor 1
IOFC	Income over feed cost
IVMS	Integrated village management system
Kandang	Animal barn/shed
ME	Metabolisable energy
ME_m	Metabolisable energy required for maintenance of liveweight
N	Nitrogen
Onggok	By-product from cassava processing used as cattle feed
PPAI	Post-partum anoestrus interval (days)
SRW	Standard reference weight (kg)
UNHALU	University of Haluoleo
UNRAM	University of Mataram
UNTAD	University of Tadulako
UQ	University of Queensland
W	Liveweight (kg)

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2 Executive summary

Increasing beef supply in Indonesia will require an increase in the number of breeding cows, improvement in the reproductive performance of these cows, and increased productivity of smallholder fattening operations. The high rural population and intensity of land use for food crops mean there are limited opportunities to increase the feed available for livestock. Increasing cattle numbers and improving the productivity and profitability of smallholder cattle enterprises will therefore require greater and more efficient utilisation of underutilised feed resources such as rice straw and crop by-products.

The aim of the project was to develop and evaluate a beef cattle production system based on crop residues. We proposed that untreated low-quality feeds (rice straw and other crop residues) would be directed towards the cow, while higher quality feeds would be saved for growing and fattening cattle. Initially, the project focused on Ongole (*Bos indicus*) and Bali (*Bos javanicus*) cattle, which are the two most common breeds in Indonesia. In 2010, the scope of the project was expanded to include Brahman (*Bos indicus*) cattle.

The project was led by The University of Queensland (UQ; Gatton, Australia) and the Indonesian Centre for Animal Research and Development (ICARD; Bogor, Indonesia). Collaboratating institutions responsible for implementing project activities in Indonesia and Australia were the Beef Cattle Research Institute (BCRI; East Java, Indonesia), the Assessment Institute for Agricultural Technology (BPTP; Lampung, Nusa Tenggara Barat and South East Sulawesi), the University of Mataram (Lombok, Indonesia), the University of Haluoleo (UNHALU; Kendari, Indonesia), the University of Tadulako (UNTAD; Palu, Indonesia) and the Northern Territory Department of Primary Industries and Fisheries (NT DPIF; Katherine, Australia).

The following project objectives were designed to develop the 'Straw Cow' system and evaluate the use of Brahman cattle in smallholder production systems;

Original 'Straw Cow' Project

1. Characterise the current feeding systems and resources in East Java
2. Develop and implement more productive cow-calf systems based on low quality feeds
3. Develop and promote promising options for growth and fattening of Ongole and Bali cattle
4. Socio-economic analysis of new cow-calf and fattening systems

Brahman variation

5. Develop and implement a productive Brahman cow-calf system at village sites in Lampung and Java
6. Quantify options for growth and fattening of Brahman progeny in villages
7. Socio-economic analysis of Brahman cow-calf and fattening systems
8. Disseminate information on successful cow-calf and fattening enterprises

This project combined on-station feeding trials and on-farm evaluations of the new cattle management system. Controlled on-station experiments were conducted in Indonesia (BCRI, UNRAM and UNHALU) and Australia (NT DPIF) to determine the nutrient requirements of different cattle breeds, test supplementation strategies for cows fed rice straw, and evaluate least-cost fattening rations for bulls. The on-station work was complemented by intensive village monitoring of cattle growth and reproduction at seven sites in Indonesia (3 in East Java, 2 in Lampung, 1 in Lombok and 1 in South East Sulawesi). In addition to feeding rice straw based diets to cows, farmers were encouraged to adopt the Integrated Village Management System (IVMS) developed in previous ACIAR projects (AS2/2000/103). The main feature of the IVMS is weaning calves at or before 6 months of age to reduce energy requirements of cows and increase conception rates. Surveys and focus group discussions with farmers and traders were used to characterise the current production system, assess the availability and use of current feed resources and to identify factors influencing cattle prices.

This project successfully demonstrated a model for increasing Indonesian beef production through greater and more efficient use of crop residues (such as rice straw) and improved animal management. Bali (*Bos javanicus*), Ongole and Brahman (both *Bos indicus*) cows can maintain liveweight and a moderate body condition score (BCS) on a rice straw-based diet if they are provided with a small amount of green feed at approximately 3 g DM/kg cow liveweight.day. Purchased supplements such as rice bran, onggok and urea provided no advantage over using tree legumes, which can be planted around the kandang (cattle shed) or on paddy bunds for little or no cost.

Reproduction rates of cows in villages increased during the project, and reproductive success was related to cow breed, age and BCS. Bali cows were significantly more likely to be pregnant within 100 days of calving compared to *Bos indicus* breeds, but also had higher rates of calf mortality. Cows with BCS ≥ 2.5 at calving and more than 4 years old were more likely to conceive within 100 days of calving and more likely to successfully rear a calf than heifers and cows with a BCS ≤ 2. However, even at high levels of supplementation, cows were unable to reach and maintain a BCS greater than 3 on a 1-5 scale when fed rice straw as a basal diet. This has implications for reproduction and demonstrates that management practices such as weaning are essential to increase BCS and reproductive rates of cows in low-input systems of Indonesia and northern Australia. More research is required to identify low cost and easily available diets that provide enough metabolisable energy and crude protein to increase cow BCS within a short period of time, and we recommend that farmers maintain good cow BCS throughout the year.

The project also established that small-scale Brahman producers can be viable, given adequate feed supplies in the system and appropriate management. The larger mature size and higher maintenance energy requirements of Brahman cows compared to local Ongole and Bali breeds mean that farmers require access to larger quantities of feed resources to support a Brahman cow-calf or fattening enterprise.

The popularity of artificial insemination in East Java has seen an increase in the number of European and Brahman cross bulls in small and medium scale fattening operations. These fattening operations can be profitable, but profit is made from small increases in animal liveweight resulting from minimal inputs. Growth rates of cattle in both small and medium scale fattening operations are low, and below the genetic potential of the breeds monitored. Growing bulls were generally fed diets similar to the cows, with large amounts of poor quality crop residues forming the bulk of their diets. On-station and in-village experiments demonstrated that strategic use of purchased high energy and high protein feeds can increase the liveweight gain and income from fattening cattle.

3 Background

Indonesia has a long-running program to develop the domestic beef industry (Program Swasembada Daging Sapi Kerbau). The aim is to increase the numbers and productivity of the domestic cattle herd, whilst also reducing imports of beef and cattle to less than 10% of consumption. However, demand for beef in Indonesia is increasing, and current domestic supply is unable to meet local demand (Subagyo 2009).

Increasing beef supply in Indonesia will require an increase in the number of breeding cows, improvement in the reproductive performance of these cows, and increased productivity of smallholder fattening operations. The high rural population and intensity of land use for food crops mean there are limited opportunities to increase the feed available for livestock. Increasing cattle numbers and improving the productivity and profitability of smallholder cattle enterprises will therefore require greater and more efficient utilisation of feed resources such as rice straw and crop by-products.

Rice straw is currently underutilised in Indonesia. Rice straw contains low levels of crude protein [5% dry matter (DM)], high neutral detergent fibre (75% DM), high ash (20% DM) and has low organic matter digestibility (51%) (Bakrie 1996; Dahlanuddin *et al.* 2003). Rice straw alone does not provide sufficient nutrients for cattle to maintain liveweight (McLennan *et al.* 1981; Suriyajantratong and Wilaipon 1985). However, it is cheap, readily available, and can be stored for long periods of time to meet periods of feed shortages or reduce daily labour requirements for cutting feed for cattle.

Figure 1. Rice straw is underutilised in some areas of Indonesia. This photo shows farmers in Lombok burning rice straw that could be fed to cattle. (Photo: Di Mayberry)

Previous research has focused on improving the feeding value of rice straw through treatment with additives such as urea, ammonia and enzymes, but these treatments have not been widely adopted by smallholder farmers because they are considered costly, labour intensive, technically difficult or dangerous (Doyle *et al.* 1986; Van Soest 2006). The use of supplements to increase the energy and protein content of rice straw-based diets has also been investigated. Supplements need to be cost effective, easily accessible and practical to be adopted by farmers (Owen and Jayasuriya 1989). Concentrates, urea and molasses are of limited use to Indonesian smallholder farmers because they are expensive (Doyle *et al.* 1986). Tree legumes (e.g. *Gliricidia sepium, Sesbania grandiflora* or *Leucaena leucocephela*) are a viable alternative; they provide green feed throughout the year, contain high levels of crude protein [25-30% CP in DM, (Lowry *et al.* 1992)], and can be planted as living fences around the house and kandang, where they can be harvested with little labour cost. Feeding tree legumes as a supplement to untreated rice straw has been shown to increase total feed intake, energy intake and organic matter digestibility and reduce weight loss in cattle (Doyle *et al.* 1986; Moran *et al.* 1983; Seresinhe and Pathirana 2008).

Most research to date has been focused on the feeding value of rice straw for animals with high nutrient requirements, such as dairy cows and growing steers [for example, (Schiere *et al.* 1989; Wanapat *et al.* 2011)]. A more efficient system would be to feed untreated rice straw as a maintenance feed for cows with low energy requirements, for example, cows that are not pregnant or lactating, or cows in the early stages of pregnancy. Tree legumes could be used to meet any shortfall in protein and energy requirements, but the majority of high quality forages and agro-industrial by-products would be redirected towards cows in late pregnancy (7-9 months gestation), lactating cows, weaned calves and fattening cattle.

This project used a systems approach, combining on-station feeding trials and on-farm evaluations, to develop and test systems where untreated low-quality feeds (rice straw and other crop residues) are directed towards the cow, while higher quality feeds are directed towards growth and fattening of other cattle. In addition to the rice straw feeding strategy, the village work included dissemination of an improved cattle management system (the Integrated Village Management System, IVMS) developed and tested in previous ACIAR projects. The key feature of the IVMS is early weaning of calves (at or before 6 months of age) to reduce the energy requirements of the cow and increase conception rates.

The initial focus of this project was Bali (*Bos javanicus*) and Ongole (*Bos indicus*) cattle, which are the two most common cattle breeds in Indonesia, and comprise 32 and 29% of the national beef herd, respectively (Kementan–BPS 2012). The remainder of the beef herd is Madura cattle (9%) and imported breeds such as Brahman, Simmental, Limousin and their crosses. Bali cattle are most common in the eastern islands of Bali, Nusa Tenggara Timur, Nusa Tenggara Barat (NTB), Maluku, Papua, Sulawesi and Kalimantan, while Ongole cattle are the dominant breed in Java. Based on this geographical distribution we selected two village sites with Ongole cattle in East Java, and two sites with Bali cattle in Lombok (NTB), and south east Sulawesi (Table 1, Figure 2).

Table 1. Distribution of Indonesian project activities in relation to the national beef herd

Region	Number of beef cattle[1]	% of national beef cattle population[1]	Breed focus	Project activities
East Java	4,727,298	32	Ongole and Brahman	3 village sites On-station Socio-economic
Lampung	742,776	5	Brahman	2 village sites Socio-economic
Nusa Tenggara Barat	685,810	5	Bali	1 village site On-station
Sulawesi Tenggara	213,736	1	Bali	1 village site On-station

[1] Cattle population data is taken from the 2011 cattle census (Kementan–BPS 2012).

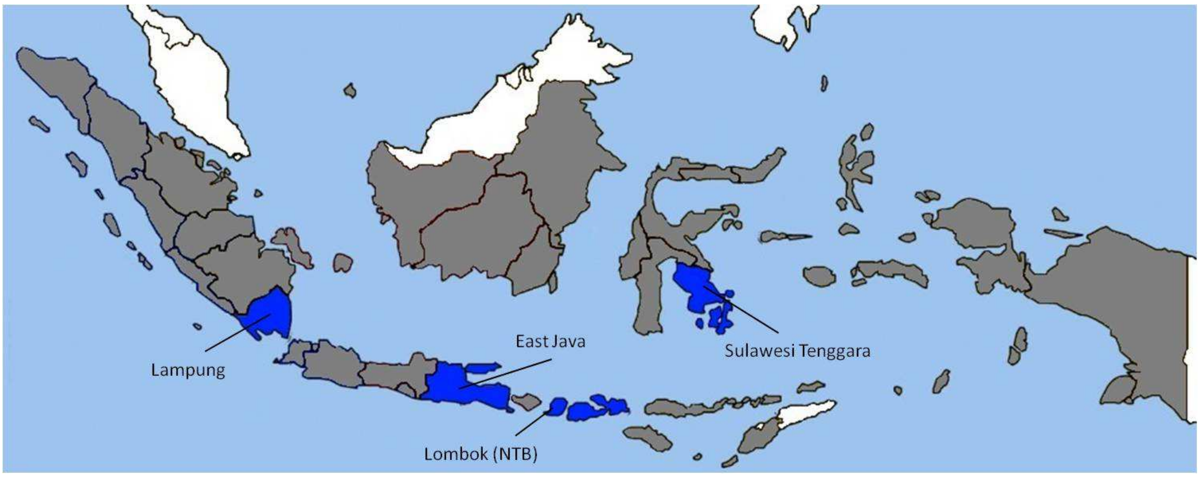

Figure 2. Location of project activities in Indonesia

In 2010, the Indonesia-Australia Economic Partnership Agreement (IA-CEPA) provided an opportunity to extend the scope of the existing ACIAR project. As part of the Indonesian government program to increase domestic beef production, imported Australian Brahman cattle have been placed in Indonesian village systems through loan and credit schemes. Brahman cattle have been targeted through this scheme because compared to local Indonesian breeds they have a faster growth rate and higher feed conversion ratio. However, the success of Brahman cattle in Indonesian village systems has been mixed. Some enterprises have been profitable, but most smallholder farmers are yet to see a return on their investment. Brahman cows in village-based systems struggle to conceive a second (or even first) pregnancy. The mortality rate of calves in the villages is high, and growth of young cattle is low.

A variation to the original ACIAR project was created to determine the viability of village-based Brahman cow-calf systems in Indonesia and provide recommendations on management options. Three additional village sites were established in Lampung and

East Java, supported by on-station and socio-economic research activities (Table 1, Figure 2).

The project also included an Australian research component. Similar to cattle in Indonesia, Brahman cows in northern Australia face significant periods of under-nutrition, where they lose, and then regain, liveweight and body condition. This has consequences for reproduction, since cows of low BCS are less likely to conceive and raise a calf. We were able to link with researchers from the MLA-funded ‘Cash Cow’ project to conduct detailed physiological examination of cows undergoing tissue mobilisation and accumulation. This included identifying key genes and metabolic hormones in control of the animal response. Understanding the process by which cows cope with low protein diets is important in maintaining reproductive performance of cows in both northern Australia and Indonesia.

4 Objectives

4.1 Original Straw Cow

1. Characterise the current feeding systems and resources in East Java
2. Develop and implement more productive cow-calf systems based on low quality feeds
3. Develop and promote promising options for growth and fattening of Ongole and Bali cattle
4. Socio-economic analysis of new cow-calf and fattening systems

4.2 Brahman variation

5. Develop and implement a productive Brahman cow-calf system at village sites in Lampung and Java
6. Quantify options for growth and fattening of Brahman progeny in villages
7. Socio-economic analysis of Brahman cow-calf and fattening systems
8. Disseminate information on successful cow-calf and fattening enterprises

5 Methodology

This project combined village monitoring and extension activities, on-station experiments and socio-economic surveys in Indonesia and Australia. All activities involving animals were reviewed and approved by the University of Queensland Animal Ethics Committee.

A brief overview of project methodology is provided below, with more detailed descriptions of project activities provided in associated publications cited in the text and listed at the end of the report.

5.1 Village cow-calf

The main focus of the project activities was the Indonesian village work. The primary objective of the village activities was to develop and implement more productive cow-calf systems based on low quality feeds. Seven village sites were established across four regions in Indonesia (Table 2). Sites were chosen by the local site coordinators based on cattle numbers, feed resources (access to rice straw) and location. In three cases the original village was abandoned within the first year and a new site was established. This was due to a combination of low animal numbers, low farmer participation rates and staffing issues.

Each village site was managed by a local village coordinator and a junior scientist. The junior scientists were recent graduates employed by the project so that there was a dedicated person responsible for the management of project activities at each site. These young scientists were supported by more experienced staff at BCRI, BPTP NTB, BPTP Lampung and BPTP Sultra. Junior scientists were locally based, and lived in or near the villages. They were provided with a laptop, modem, printer, motorbike, cattle scales, girth tape and feed scales.

When cows were enrolled in the project the junior scientist collected information such as cow breed, age, reproductive history, kandang type, if they were used for draught, and farmer name. At the time of enrolment all cows were given a unique identification number. We originally aimed to monitor 120 cows at each site, which often meant that cows were spread across multiple neighbouring villages. Many cows were sold during the project, and additional cows were enrolled whenever the number of cows at an individual site dropped below 100.

Data collected by the junior scientists during the project included;

- Cow liveweight – monthly for at least the first year, then every second month
- Girth and BCS – monthly
- Feed offered – monthly for a sub sample of cows at most sites
- Dates of oestrus, mating, calving and weaning
- Calf birth and weaning weights
- Dates and causes of cattle deaths
- Cattle sale date and price
- Rainfall, minimum and maximum temperature – daily

Figure 3. Project junior scientists and farmers measured the girth, liveweight and body condition score of cows on a regular basis. (Photo: Di Mayberry)

The junior scientists also helped to establish farmer groups, organised regular farmer meetings and arranged extension activities such as field days and cattle competitions.

At the Ongole and Bali cow sites, farmers were encouraged to feed untreated rice straw to their cows. The guidelines for supplementation were green feed or concentrate at 1% of liveweight for two months either side of calving, and 0.5% liveweight for the rest of the year (DM basis).

As part of the IVMS, weaning was encouraged at all sites when calves were 6 months of age or when cow BCS declined to 2 on a 1-5 scale. Green feed was targeted to weaned calves, and the village teams helped the farmers to plant tree legumes and grasses around the kandang and in the village.

Table 2. Overview of cow-calf village sites in Indonesia

Region	Site	Villages	Period of monitoring	Cattle breed	No. farmers	Institution	Production system
East Java	Probolinggo	Dadanggendis , Klampok	2010-2013	Ongole	92	BCRI	Individual kandangs Cut & carry
	Malang	Bantur	2010-2013	Ongole	114	BCRI	Individual kandangs Cut & carry
	Lamongan	Modo, Sambeng	2011-2013	Brahman	92	BCRI	Mostly individual kandangs Cut & carry
Lampung	Tulang Bawang Barat	Daya Asri, Murni Jaya, Pulung Kencana	2011-2013	Brahman	77	BPTP Lampung	Individual kandangs Cut & carry
	Seputih Banyak	-	2011-2013	Brahman Bali	1	BPTP Lampung	Feedlot style operation with cattle kept in group pens
Nusa Tenggara Barat	Lombok	Karang Kendal, Papak	2011-2013	Bali	96	BPTP NTB	Individual kandangs Cut & carry
Sulawesi Tenggara	Kolaka	Lapangisi	2010-2013	Bali	47	BPTP Sultra	Extensive grazing Semi-intensive & individual kandangs with cut & carry

5.2 Village fattening

Smallholder farmers in East Java keep many different breeds of cattle for growing and fattening prior to slaughter, but there is little published information available about how different breeds perform under village conditions. We compared the growth of common breeds of cattle during the dry and wet seasons at the smallholder farmer level.

The four breeds of cattle monitored were Ongole (37 in dry season, 49 in wet season), European-Ongole cross (50 in dry season, 51 in wet season), Brahman (19 in both dry and wet seasons) and European-Brahman cross (21 in dry season, 28 in wet season). Animals were bulls aged 1 to 2.5 years and kept by farmers in Pasuruan, Malang, and Lamongan districts of East Java. Liveweight, girth, BCS and feed offered to cattle were measured for 3 months in the dry and wet seasons. More detailed information is available in the series of papers by Pamungkas *et al* (2012; 2013a; 2013b).

Following the village monitoring we conducted a short village intervention. A concentrate mix was formulated from locally available ingredients to achieve high growth at minimum cost. The concentrate was provided to owners of fattening bulls in Pasuruan and Lamongan as a supplement to existing cattle diets. Liveweight gains and returns on feed costs from sales data were recorded and compared with a control group of farmers from the same districts.

5.3 On-station

On-station experiments in Indonesia were designed to complement the village work and provide answers to specific research questions:

- Can cows maintain liveweight on a rice straw based diet?
- How can we increase the liveweight and condition of cows in villages?
- How does nutrition affect the development of Bali heifers?
- How can we increase the growth of fattening bulls in villages?

Specific details regarding the methodology for each experiment can be found in the associated publications listed in Table 3 below. Diets fed to cattle are described in Table 4.

Table 3. Summary of on-station activities

Institution	No.	Experiment	Animals used	Diets	Length of experiment	Publications
BCRI	1	Maintenance requirements of Ongole cows fed rice straw based diets	32 Ongole cows	Rice straw *ad libitum* Rice straw + 3 levels of tree legumes	20 weeks	Mayberry *et al.* 2011, Syahniar *et al.* 2011, Syahniar *et al.* 2012
	2	Strategies for increasing the liveweight and BCS of Ongole and Bali cows	15 Ongole cows 15 Bali cows	Rice straw + tree legume or rice bran Elephant grass *ad libitum*	24 weeks	Antari *et al.* 2012, Antari *et al.* 2014b
	3	Strategies for increasing the liveweight and BCS of Brahman cows	30 Brahman cows	Rice straw + onggok (cassava by-product) + urea or tree legume	21 weeks	Antari *et al.* 2014a
	4	Crude protein requirements of young Ongole and Bali bulls and mature Ongole bulls (3 separate experiments)	25 young Ongole bulls 25 mature Ongole bulls 25 young Bali bulls	Elephant grass + concentrate containing different levels of crude protein	10 weeks for each experiment	Antari *et al*. 2014c
	5	Comparison of growth rates and feed conversion efficiency of Ongole, Brahman and Euro-Ongole cross bulls	10 Ongole bulls 10 Brahman bulls 10 Euro-OngoleX bulls	Elephant grass *ad libitum*	16 weeks	Appendix 2
	6	Comparison of growth rates and feed conversion ratio of Ongole bulls fed local forages or high quality, least-cost rations.	24 Ongole bulls	Elephant grass *ad libitum* Elephant grass + 2 different formulations of onggok, palm kernel cake and copra meal	12 weeks	Appendix 2

UNRAM	7	Growth and reproductive physiology of Bali heifers fed medium and high quality diets	28 Bali heifers	King grass *ad libitum* or king grass + concentrate *ad libitum* (in crossover design)	25 months	Irawan *et al.* 2014
UNHALU	8	Liveweight gain and BCS of Bali cows fed rice straw-based diets	30 Bali cows	Rice straw *ad libitum* Rice straw + 4 levels of tree legumes	12 weeks	Appendix 2
	9	Use of local feed resources to increase the liveweight and BCS of Bali cows	20 Bali cows	Native grass *ad libitum* Native grass *ad libitum* + 2 levels rice bran Rice straw *ad libitum* + rice bran	15 weeks	Appendix 2

Table 4. Average chemical composition of feeds offered to cattle during on-station experiments.

	Dry matter (g/kg)	Organic matter (g/kg DM)	Crude protein (g/kg DM)	Neutral detergent fibre[1] (g/kg DM)	Acid detergent fibre[1] (g/kg DM)
Copra meal	913	921	241	-	-
Concentrate (Exp 7)	-	902	178	82	-
Cracked maize	901	979	89	-	-
Elephant grass	187	882	86	723	429
Gliricidia	249	905	214	420	341
King grass	175	865	109	602	-
Leucaena	330	926	245	446	334
Native grass	231	888	100	618	407
Onggok	899	766	30	-	-
Palm kernel cake	946	952	174	-	-
Rice bran	926	860	105	-	-
Rice straw	761	763	60	629	409
Soybean meal	906	914	476	-	-

[1]NDF and ADF analysis was conducted without amylase, which is not readily available in Indonesia. This would not affect the results for feed types containing low levels of starch. However, since NDF and ADF content would be overestimated for feed types high in starch, results for these feeds are not presented in this table. The exception is the concentrate used in Experiment 7, which was analysed in Australia.

5.4 Socio-economic

Alongside the village work described above, a series of socio-economic surveys and economic analyses were undertaken, focusing on the Ongole and Brahman cow-calf and fattening sites. Specific details regarding these activities are described in the associated papers listed in Table 5.

All participating smallholder farmers in the East Java and Lampung sites were surveyed using a structured questionnaire. This enabled us to establish the initial characteristics, farming practices, outputs, and income of cattle-farming households in each site. An additional survey and group discussion were used to explore the role of women in cattle farming in East Java. The household surveys, in combination with surveys of traders, butchers, and end-users, enabled us to trace and partly quantify the beef marketing chain from smallholder cow-calf producers to beef consumers. As the provision of rice straw and other feeds involved both cattle farmers using their own crop by-products and (in East Java) a developed feed supply market, a questionnaire survey was undertaken of various actors in the feed supply chain, including small-, medium, and large-scale feed traders. Group interviews and secondary data were used to assess the overall availability of crop by-products in the East Java and Lampung sites and hence the existing degree of utilisation.

The monthly data available from the village sites in East Java were used to conduct an inventory analysis of the notional “village herd” for the first 12 months of recording (during which participant numbers were stable). Opening and closing inventories were used to assess the underlying herd dynamics in terms of age, sex, and breed. These village data were also used to conduct regression analyses of the factors affecting the farm-gate price of cattle sold, including measured and reported data for age, liveweight, BCS, breed, sex, time of sale, and reason for sale. To establish the net income to smallholder cow-calf operators in different settings (Ongole and Brahman, intensive and semi-intensive, lowland and upland) and following existing and recommended practices, a spreadsheet budget model was developed based on survey, village-monitoring, and experimental data, enabling us to explore different scenarios.

Small- and medium-scale fattening operations involving Ongole, Brahman, and European-cross breeds in East Java were also surveyed to establish the characteristics and performance of these types of farmer. In conjunction with the physical monitoring of and experimental intervention in these operations described above, financial analysis was undertaken of Income Over Feed Cost (IOFC) to assess the comparative profitability (gross margins) of the different operational scales and breed types.

Table 5. Summary of socio-economic activities

Objective	Method	Respondents	Location	Reference
Establish characteristics, practices and outputs of small-scale cattle farmers	Single-visit questionnaire survey of cattle farming households	184 farmers	East Java	Hanifah *et al.* 2010
Establish marketing practices of small-scale cattle farmers	Single-visit questionnaire survey of cattle farming households	184 farmers	East Java	Mahendri *et al.* 2010
Conduct inventory analysis of aggregate herds in the two East Java research sites	Monthly recording of cattle numbers by class Recording of cattle births, deaths, purchases and sales	184 farmers	East Java	Cahyadi *et al.* 2012
Establish characteristics, practices and outputs of small-scale Brahman cattle farmers	Single-visit questionnaire survey of cattle farming households	197 farmers in East Java, 61 farmers in Lampung	East Java, Lampung	Jasila *et al.* 2012
Describe the feed supply market in East Java	Single-visit questionnaire survey of feed traders, using snowball technique to identify respondents Focus group discussion with feed traders	40 feed traders	East Java	Priyanti *et al.* 2012a
Establish characteristics, practices and outputs of cattle growers/fatteners	Single-visit questionnaire survey of cattle growers/fatteners Focus group discussion	52 farmers	East Java	
Quantify cropping patterns and availability of feeds	Focus group discussion	15 farmers	East Java	

Trace and quantify beef marketing chain from producer to consumer	Single-visit questionnaire survey of actors along market chain Focus group discussion	113 small-scale cattle producers 52 cattle growers 78 cattle traders 7 market places 35 butchers 3 large slaughter houses 5 wet market sellers 7 supermarkets 65 end-consumers	East Java	Mahendri *et al.* 2012
Quantify the factors affecting farm-gate pricing of cattle	Monthly monitoring of cattle sale price, liveweight, BCS, and other traits of cattle sold by participating farmers Multiple regression analysis	184 farmers and 353 cattle	East Java	Priyanti *et al.* 2012b
Explore the role of women in small-scale cattle farming	Single-visit questionnaire survey of female cattle farmers Focus group discussion	60 female farmers	East Java	
Quantify the income over feed cost for growing/fattening Ongole and European cross bulls	Direct measurement of feed intake and growth rates Focus group discussion Single-visit questionnaire survey of farmers	42 small-scale farmers 18 medium-scale farmers	East Java	Priyanti *et al.* 2012c

Quantify the income over feed cost for growing/fattening Brahman bulls vs local breed	Direct measurement of feed intake and growth rates	39 farmers with Brahman bulls 29 farmers with Ongole bulls	East Java	
Establish extent of and reasons for selling cows	Focus group discussion Monthly monitoring	30 cattle traders in sub-district marketplace 42 farmers 6 key informants (officials from Livestock Office)	East Java	
Identify the potential of crop by-products for cattle feed	Secondary data (Village and district statistics on crop areas and yields)	-	East Java, Lampung	Haryanto *et al.* 2013
Quantify the net income from the small-scale cow-calf system	Baseline survey and monthly monitoring of project participants Budget models of cow-calf system	All farmer participants	East Java, Lampung	

5.5 Australian experiments

The reproductive efficiency of a beef cattle herd is largely determined by the duration of post-partum anoestrus, which is influenced by the energy balance of the cow. This is indicated by adipose and protein stored in the soft tissue pool, which is measured as BCS. Mobilisation and deposition of adipose tissue and protein is influenced by the physiological status of the cow and diet quality. It is regulated at the tissue level by the co-ordinated expression of various genes in response to nutrient and hormonal signalling. An understanding of nutritional, hormonal and gene regulation of the mobilisation and accretion of these reserves is required to develop nutritional strategies to more efficiently manage body condition of cows to improve reproduction rates under low crude protein diets.

Two experiments were conducted to determine:

1. Relationships between cow liveweight, BCS, metabolic hormone profile and reproductive performance in *Bos indicus* cattle raised under extensive conditions
2. Liveweight and BCS response of lactating and dry cows grazing low crude protein pastures and re-alimented on wet season pastures

Relationships between cow liveweight, BCS, metabolic hormone profile and reproductive performance in Bos indicus cattle raised under extensive conditions

A mob of 241 *Bos indicus* cows was managed under commercial conditions at Manbulloo Station (14°35’ S, 132°09’ E), NT, over two years. The cattle were managed as a single mob and grazed a *Heteropogon contortus*-dominant pasture in a paddock that was 34 km^2 in area. During the wet season, a phosphorus based supplement was offered at 120 g/head.day (distributed weekly). Musters were conducted in April and September each year. At each muster, BCS, lactation status and fetal age were assessed. Blood samples were collected from a sub-sample of approximately 100 cows at three of the four musters and these were analysed for IGF-1, leptin, insulin and progesterone. A negative binomial regression analysis using StataIC 13.1 (Stata Corporation, Texas, USA) was employed to determine the effects of BCS change on risk of non-pregnancy. Differences between incidence rates across levels of BCS change were estimated and statistically compared using pairwise comparisons.

Liveweight and BCS response of lactating and dry cows grazing low CP pastures and re-alimented on wet season pastures

At the commencement of the dry season, 37 mature, non-pregnant, lactating *Bos indicus* cows (449 ± 8 kg liveweight; 3.0 ± 0.05 BCS) were allocated to treatment groups that either lactated (*L*; n=18) or did not lactate (*NL*; n=19) throughout the dry season. Calves (126 ± 2.7 kg liveweight at commencement) were then weaned depending on the allocation of their dams in either June (*NL*) or October (*L*). The cows grazed *Heteropogon contortus*-dominant pastures as a single mob at the Katherine Research Station (14°28’ S, 132°18’ E), NT. Supplement was distributed weekly, with a urea-based supplement offered at 120 g/head.day in the dry season and a phosphorus based supplement offered at 120 g/head.day during the wet season. Liveweight was recorded in most months over the dry season (June to October 2012; 132 days) and subsequent wet season (October 2012 to April 2013; 175 days) after a 12 hour curfew. BCS, eye muscle area and blood samples were collected at liveweight measurements. Blood samples were collected from the jugular vein of cows into SST vacutainers and analysed for IGF-1, leptin and insulin by radio-immunoassays. Biopsies were collected from the *semitendinosus* muscle of cows at the start of the experiment (June), at weaning at the end of the dry season (October) and near the end of the subsequent wet season (April). Biospies were placed in RNAlater and stored at -80°C prior to extraction in Trizol followed by RNeasy column treatment with an on-column DNAse treatment. RNA extracted from six biopsies from *L* and *NL* cows at the end of the dry season and end of the wet season was submitted for Next Generation Sequencing (RNA-seq) on the Illumina Hi-Seq 2000 platform. This gave six replicates, with 2 (time points) x 2 (lactation status) conditions for comparisons.

6 Achievements against activities and outputs/milestones

Objective 1: Characterise the current feeding systems and resources in East Java

no.	activity	outputs/ milestones	completion date	comments
1.1	Understand the current system of cow-calf and fattening operation	Survey across the region wider than just feed survey villages	10/10	A questionnaire survey was conducted of 184 cattle producers in lowland and upland sites in East Java. The survey provided an understanding of the circumstances of different types of farm-household and the characteristics and constraints, and productivity of their cow-calf operations. The farmers in the survey appeared to be efficiently utilising their limited resources (including available crop by-products) to produce calves (lowland site) and both calves and adult cattle (upland site) for local markets. An additional questionnaire survey was conducted of 52 small- and medium-scale growing/fattening operations in East Java to provide an understanding of their characteristics, practices and outputs. This was supplemented with a focus group discussion to get qualitative insights into the situation and potential for expansion of these operations. Small-scale operations were really “growers”, holding bulls for 1-2 years, while medium-scale operations were genuine “fatteners”, holding bulls for 6-8 months. Both types had more resources (land, capital) than most of the cow-calf farmers surveyed.
		Monitor villages used in feed survey	6/10	The feeding practices of 58 cow-calf farmers who were participating in the village monitoring sites in East Java were recorded for 6 months in 2010 and 2011, capturing data on the types and quantities of different feeds made available to the cattle. A wide range of crop by-products (especially rice straw and maize stover), native grasses, and planted forage grasses were recorded, with seasonal variation. The use of legumes was less apparent.
1.2	Identify the feed resources and opportunities which are available	Survey across the region and from villages monitored in cow-calf and fattening systems	10/10	Local government statistical data was collected and research literature reviewed to assess feed availability from agricultural by-products. Type of crops planted, time of harvest, area of

		Retrieve Government statistical data	10/12	crop production, and nutritive value of crop by-products were used to calculate the available feed potential of lowland and upland villages included in the questionnaire survey of cow-calf producers mentioned in 1.1. The current level of utilisation appeared to be close to the estimated potential.
1.3	Quantify socio-economic factors in operation in current systems	Data obtained from villages in 1.1 and 1.2 to evaluate system and obtain social and market information within those activities	10/12	A focus group discussion and a questionnaire survey of 40 feed traders were undertaken to describe the feed market in East Java. An efficient market has evolved to distribute crop by-products from crop producers with surplus feed to cattle producers with no or insufficient feed. A survey was undertaken of actors along the beef supply chain to trace and partly quantify the chain from producers to consumers. Producers mainly sold to local traders who on-sold to regional traders and butchers at abattoirs, who in turn supplied fresh meat to traditional markets. Most beef was consumed as meatballs in street stalls and restaurants. The evidence points to a reasonably efficient supply chain that is focused on price and quantity of beef. Monthly monitoring was undertaken of cattle sale price, liveweight, BCS, and other traits of 353 cattle sold by participating farmers in the village monitoring sites in East Java. Regression analysis was used to quantify the factors affecting farm-gate price. The price was significantly related to liveweight, age, BCS, breed, and sex, indicating an efficient transmission of market information through pricing.
1.1-1.3	Assess implications of survey data for future directions of village and on research station experiments	Data obtained from surveys and recommendations made	10/10	The data in 1.1 to 1.3 were analysed to assess implications for experimental work. Existing farmer practice in East Java already makes good use of rice straw (and maize stover), but farmers could grow and feed more legumes. The East Java farmers' and traders' preference for crossbred cattle and the resultant decline in pure Ongole herds suggests a shift in focus of research away from Ongole only.

Objective 2: To develop and implement more productive cow-calf systems based on low quality feeds.

no.	activity	outputs/ milestones	completion date	comments
2.1	Review and document existing information on body condition score and reproduction rates of cattle breeds in Indonesia	Data collated within 4 months of start. Journal publications (ICARD) and national seminar	11/09	A review of existing literature and data was conducted. Unfortunately, there was not enough good quality data available to make recommendations or publish a paper. Data collected during the current project will provide a lot of missing information.
2.2	Develop and evaluate a low input based system to maintain reproduction rate and increase cattle numbers at sites in East Java, South East Sulawesi and Nusa Tenggara Barat	4 sites identified and established	12/09	Four village sites were established in East Java (2), South East Sulawesi (1) and Lombok in Nusa Tenggara Barat (1). Ongole cattle were monitored at both sites in East Java and Bali cattle were monitored at the sites in Sulawesi and Lombok. A junior scientist was employed at each site to work with the farmers and record animal data. The junior scientist had the responsibility of encouraging farmers to adopt the rice straw feeding regime and improve their animal management (through practices such as early weaning). The junior scientists also recorded reproduction data (dates of oestrus, mating, calving and weaning), cattle growth (liveweight, girth, body condition score), climate data, feed offered and cattle sales.
		4 sites monitored and adapted	12/13	
2.3	Determine body composition and reproductive physiological and functional changes in response to nutrition so as to improve wet and dry season nutritional management	Cash Cow indigenous property identified and blood samples taken	9/11	Reproductive performance, liveweight, and body condition score was monitored and linked to the profile of circulating metabolic hormones in a commercial *Bos indicus* beef cattle herd near Katherine in the Northern Territory of Australia.
		Cows transferred to Katherine Research Station for study, samples taken	4/13	An experiment was conducted to investigate the effect of dry season lactation on physiology and body composition of *Bos indicus* cows in northern Australia. Significant differences in skeletal muscle gene expression and circulating metabolic hormone profiles were measured between cows that did or did not lactate in the dry season.

2.4	Investigate supplementation strategies to maintain body condition score and reproduction rate of the cow	BCRI conduct feeding experiment with Ongole cows for maintenance	7/10	A feeding experiment was conducted at the BCRI. Cows were fed rice straw plus different amounts of tree legumes. In this experiment we were able to demonstrate that it is possible for a non-pregnant, non-lactating Ongole cow to maintain liveweight on a rice straw based diet with the addition of a small amount of tree legumes (2.8 g DM/kg W/d).
		BCRI conduct comparative feeding experiment with Ongole and Bali cows for body composition changes	7/11	A feeding experiment was conducted at the BCRI. Ongole and Bali cows were fed the same diets. We aimed to measure the maintenance requirements of both cattle breeds and also identify a suitable diet for increasing condition of cows in the villages. Increasing the body condition score of cows is difficult when using feed commonly available in villages, and the diets tested were only suitable for maintenance. We were able to demonstrate that Ongole cows have higher energy requirements for maintenance compared to Bali cows.
		UNHALU conduct feeding experiment with Bali cows for maintenance	7/11	An experiment was conducted with Bali cows at the University of Haluoleo. Bali cows maintained liveweight on rice straw basal diets. Supplementation with Gliricidia resulted in a modest increase in liveweight gain. Feeding native grass supplemented with rice bran resulted in the highest liveweight gain during a re-alimentation period.
2.5	Determine comparative growth and development of Ongole and Bali heifers	NTB heifer growth (Ongole and Bali) over 2.5 years	5/13	Due to changes in local regulations the experiment could not be conducted with Ongole heifers. A revised experiment was designed to examine the effect of diet pre- and post-puberty on liveweight gain and age/liveweight at puberty of Bali heifers. In this experiment Bali heifers reached puberty at ~19 months and this was independent of diet/liveweight.

Objective 3: To develop and promote promising options for growth and fattening of Ongole and Bali cattle

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Review existing information on feeding strategies for Ongole cattle and present review paper at National seminar	Data collated within 4 months of start. Journal publications (ICARD) and national seminar	11/09	Existing literature was reviewed and a paper was presented at the 2010 International Seminar on Tropical Animal Production in Yogyakarta (Haryanto & Pamungkas 2010).
3.2	Evaluate existing feeding systems of cattle fattening enterprises in East Java and test new feed combinations in village	Survey village feed for fattening systems	3/11	We monitored the growth rates and feed offered to Ongole, Limousin-Ongole and Simmental-Ongole bulls kept by smallholder and medium-scale farmers in East Java for 4 months in the wet season and 4 months in the dry season. Growth rates of crossbred cattle are higher than Ongole cattle. Growth rates of all breeds were lower than expected due to the high proportion of low quality feeds in the diets. There was no difference in average growth rates between seasons or between small and medium-scale fattening operations.
		Monitor liveweight gain in village fattening systems		
		Best Bet diets evaluated in village	11/13	The best diet from the 4th feeding experiment in Objective 3.3 was evaluated with fattening bulls in villages. Liveweight gains and sale results from bulls fed this diet as well as a control group of bulls showed that there was a greater financial return despite the greater feed costs outlaid with the 'best-bet' diet.
3.3	Determine crude protein requirements for growth and fattening of Ongole and Bali cattle and develop some Best Bet feeding options on Grati research station	Conduct 4 feeding experiments at Grati	7/13	Three experiments investigating the crude protein requirements of young Ongole bulls, young Bali bulls and mature Ongole bulls were conducted at the BCRI. Bulls were fed diets containing different levels of crude protein to determine the amount required for growth. A fourth feeding experiment at the BCRI investigated three 'best-bet' diets for growing Ongole bulls. The best diet was the one that resulted in the highest average daily liveweight gain of cattle for the lowest cost. This diet was then evaluated in villages in objective 3.2.

Objective 4: Socio-economic analysis of new cow-calf and fattening systems

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Monitor and analyse the range of socio-economic issues in the new cow-calf systems	Economic analysis of current and proposed cow-calf system completed	8/14	The survey of current cow-calf systems in 1.1 served as a baseline and the monthly monitoring of participants and their cattle provided data on changes in system performance. However, a conventional evaluation survey at the end of the project was not undertaken because (a) the cohort of participating farmers was continually changing and (b) the practices being implemented by farmers were also varied and changing, hence there was not a clear 'before and after' situation to evaluate. It was decided to develop activity budgets for the cow-calf enterprise, drawing on the survey, monitoring, and experimental data to model the economic performance of the system under different technical and market scenarios.
		Social structure of current and proposed cow-calf system evaluated	7/13	The survey in 1.1 identified four main classes of cow-calf producer in East Java based on access to crop land: (i) paddy only, (ii) paddy and dryland, (iii) dryland only, and (iv) landless. The incidence of cattle-keeping (on a share basis) was highest in the landless class and this class also relied more on off-farm income. The capacity to access crop by-products and to plant forages, hence to implement recommendations, varied between these classes. A questionnaire survey was undertaken with 60 female cattle farmers in East Java to explore the role of women in small-scale cattle farming. Focus group discussions were conducted with farmers in project villages in East Java to assess participants' responses to the practices promoted in the project.
4.2	Monitor and analyse the range of socio-economic issues in the new fattening diets	Economic analysis of current and proposed bull fattening system completed	7/13	The survey of fattening operations in 1.1 provided a baseline as well as data to model the fattening operation in East Java. Direct measurement of feed intake and growth rates was undertaken for 93 cattle belonging to 60 small- and medium-scale farmers. The income over feed cost (IOFC, i.e., the gross margin in rupiah/bull/day) was calculated for Ongole and European-cross cattle. Medium-scale fatteners used only European-cross bulls and spent more on feed, including concentrates. However, small-scale operations achieved similar IOFC.

		Social structure of current and proposed bull fattening system evaluated	7/13	The survey in 1.1 indicated that small-scale growers were no different from land-owning cow-calf operators. Medium-scale fatteners were better educated and had more resources (crop land, capital). Both types had emerged from the existing social structure in the cattle-producing villages.

Objective 5: Develop and implement a productive Brahman cow-calf system at village sites in Lampung and Java

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Develop and evaluate a Brahman cow-calf system to maintain reproduction rate and increase cattle numbers at sites in Lampung and Java	3 sites established	10/2011	Three village sites were established in Lampung (2) and East Java (1). A junior scientist was employed at each site to work with the farmers and record animal data. The junior scientist had the responsibility of encouraging farmers to improve their animal management (through practices such as early weaning) and record reproduction data (dates of oestrus, mating, calving and weaning), cattle growth (liveweight, girth, body condition score), climate data, feed offered and cattle sales.
		3 sites monitored and adopted	12/2013	
1.2	Investigate supplementation strategies to maintain body condition score and reproduction rate of the Brahman cow in Indonesia	Quantification of maintenance requirements of Brahman cows fed village-based diets	4/13	A feeding experiment with Brahman cows was conducted at the BCRI. Cows were fed rice straw plus onggok and urea or onggok and Gliricidia. Both diets provided enough energy and crude protein for maintenance of cow liveweight. Gliricidia was as effective as urea in providing N to the animal.

Objective 6: Quantify options for growth and fattening of Brahman progeny in villages

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Evaluate liveweight gain and feed conversion ratio of imported Brahman, Ongole and European X steers	Comparison of liveweight gain and feed conversion ratios of Brahman, Ongole and European X steers	10/12	A feeding experiment comparing the growth rates of Ongole, Brahman and Limousin-Ongole bulls was conducted at the BCRI. All bulls were offered elephant grass *ad libitum*. Growth of all three breeds was low. Under the conditions of this experiment, the Limousin-Ongole bulls had the highest growth rates and best feed conversion rates. However, the results were influenced by variation in the age and condition of bulls at the start of the experiment.

2.2	Monitor growth rates of Brahman progeny produced in villages and compare to Ongole and European X for liveweight gain	Comparison of liveweight gain of Brahman progeny with Ongole and European X on farm	6/12	We monitored the growth rates and feeding of Ongole, Brahman and European-Brahman cross bulls kept by smallholder farmers in East Java during the wet and dry seasons. Growth rates of Brahman and European-Brahman cross bulls were higher than Ongole bulls. There was no difference in growth rates between seasons. Growth rates of all breeds were lower than expected due to the poor quality of the diets offered.

Objective 7. Socio-economic analysis of Brahman cow-calf and fattening systems

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Determine profitability and constraints of a village-based Brahman cow-calf system	Compare profitability and resource implications of Brahman and Ongole cow-calf systems	12/13	Questionnaire surveys were undertaken of 258 Brahman cattle farming households in East Java and Lampung to establish the characteristics, practices, and outputs of small-scale Brahman cow-calf operations relative to Ongole operations.
3.2	Determine comparative profitability and resource implications of Brahman, European X and Ongole fattening systems	Compare profitability and resource implications of Brahman, Ongole and European X fattening systems	12/13	Direct measurement of feed intake and growth rates was undertaken with 39 farmers with Brahman bulls and 29 farmers with Ongole bulls in East Java. The IOFC was calculated to compare the performance of the two breeds in growing/fattening operations.

Objective 8. Disseminate information on successful cow-calf systems and fattening enterprises

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Farmer and extension personnel visits to on-station experiments and village sites	Field days targeted at extension and other government personnel, NGO staff, feedlot staff and farmers involving all village sites and research station experiments	12/2013	A variety of extension activities were conducted at each site. These included field days, cattle competitions and farmer visits (both collaborator & non-collaborator) to village sites and on-station experiments. The project also interacted with staff from other government institutions (e.g. Dinas Peternakan) and private industry (e.g. Feedlots).

7 Key results and discussion

7.1 Characterisation of smallholder cattle farmers

A total of 184 Ongole cow-calf farmers in lowland (Probolinggo-Pasuruan) and upland (Malang) sites in East Java were interviewed in March-May, 2010, focusing on farm-household characteristics, cropping patterns, cattle numbers and uses, and feeding practices, especially with regard to rice straw. The lowland and upland cattle production systems varied in some important ways, reflecting the different agro-ecological and socio-economic characteristics of the two study sites. Lowland farms averaged 0.38 ha, only half of which was paddy land, and upland farms averaged 0.65 ha of mostly dryland. The dominant annual cropping pattern in both sites was rice-maize-(maize/soybean). Nearly half the lowland cattle producers had no paddy land and over a quarter were landless, hence rice straw and other feedstuffs had to come from beyond the household's own production. In the more intensively-managed lowland site, farmers had more cattle (a mean of 3.8 compared with 2.9) and tended to specialize in calf production, whereas the upland farmers produced calves, young cattle, and adult cattle for sale. Use of cattle for draught power was less common than in the past, especially in the upland site. The high importance of rice straw as a source of feed was evident in both sites. Most of this feed was obtained from other farms, whether directly or by purchase. The greater scarcity of this resource in the upland site meant that farmers travelled greater distances but incurred a similar total cost (allowing for the opportunity cost of their labour) to obtain their supply. Rice straw was dried for 3-4 days and stored in the lofts of cattle sheds. Planted grasses and legumes were also fed to cattle, but there was potential to increase their production and utilization, especially shrub legumes in the upland site.

Beef cattle production at the two sites was mostly undertaken to generate household income to meet current farm and household needs, rather than for the traditional motivations of providing draught power and a store of wealth. Analysis was undertaken to understand the factors affecting the prices, and hence the incomes, received by cattle producers. Data were recorded for each of 353 cattle sold during 2010-11. Cattle were sold in the village to local or district traders, who then on-sold them to larger traders or butchers. The farm-gate price was regressed on six variables – liveweight, body condition score, cattle breed (local or crossbred), age, reason for selling, and site (lowland/upland). The age variable was omitted in the final model to avoid multi-collinearity. The estimated equation was significant and provided a good fit of the data ($R^2 = 0.77$). The coefficients for all variables were positive and significant at the 5% level (Table 6). These results imply that the preferences and requirements of cattle buyers (growers, fatteners, and butchers) for growth potential and carcass weight and quality are effectively transmitted through primary traders (i.e. village collectors) to small-scale cattle producers and expressed in a differential farm-gate price for animals with different attributes. The urgency of the sale and the proximity to markets can also affect the farm-gate price.

Table 6. Results of regression of farm-gate selling price (IDR x 10^3) on various factors at two sites in East Java

Variables	Coefficients	Standard error	t	*P*-value
(constant)	-3204.9	409.1	-7.83	0.000
Site	318.6	143.9	2.21	0.028
Breed	506.8	159.8	3.17	0.002
Sex	837.3	141.8	5.91	< 0.001
Liveweight	15.7	0.7	23.40	< 0.001
BCS	1040.6	160.4	6.50	< 0.001
Reason	598.7	156.6	3.82	< 0.001

Though all households in the East Java sites were cattle producers, sources of income were diversified, both within and beyond the farm. Net cash income from all sources was, on average, over 50% higher in the lowland site (IDR 9.5 million) than in the upland site (IDR 6.2 million). Cattle accounted for 61% of farm cash income and 32% of household cash income (including farm and non-farm sources) in the lowland site, and 84% of farm cash income and 55% of household cash income in the upland site. Hence upland cattle producers were more dependent on cattle for their livelihoods than lowland producers. However, the level and composition of household cash income was related to the size and type of landholding. Figure 4 shows the breakdown of net cash income at both sites, with farmers in the lowland site differentiated according to land-ownership category, that is, households with only paddy land (18%), both paddy land and dryland (34%), only dryland (21%), and no cropland at all (26%).

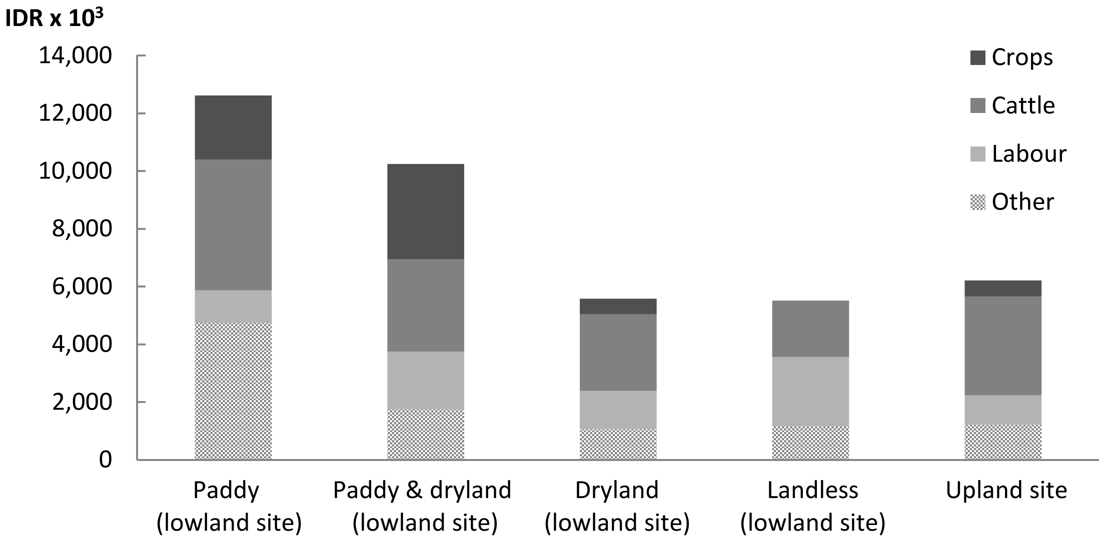

Figure 4. Household net cash income by source and land-ownership category in lowland and upland Ongole sites in East Java

A second questionnaire survey was undertaken of 61 smallholder Brahman producers in Tulangbawang Barat (Lampung) in July 2011 and 136 producers in Lamongan (East Java) in February-March 2012. The purpose of the survey was to describe and compare the production characteristics and constraints of cattle farmers in the two districts. The questionnaire focused on farm-household characteristics, cropping patterns, and cattle management practices, especially feeding. Farmers did not differ greatly in their age (40 years), education (6-8 years), family labour availability (4 persons), and farming experience (20-22 years). Farmers in Tulangbawang Barat had access to 1.8 ha on average and their cropping pattern included rice, maize, and cassava (sold to a local factory), whereas those in Lamongan averaged 0.4 ha and planted only rice and maize. This implied greater local availability of crop by-products that could be fed to cattle in Tulangbawang Barat, though farmers had to purchase and transport cassava by-products from the factory. Producers in Tulangbawang Barat owned more Brahman cattle on average (6.3 head) than in Lamongan (3.2 head). Rice straw was only used as cattle feed during the harvest season in Tulangbawang Barat, hence tended to be fresher, while it was fed all year round in Lamongan. The use of cassava by-products such as peelings and cassava starch residue (onggok) in Tulangbawang Barat was still not common (18% of farmers), perhaps due to the cost, which was IDR 300/kg and IDR 600/kg (as-fed basis), respectively.

7.2 Development and implementation of more productive Indonesian cow-calf systems based on low quality feeds

7.2.1 The beef herd

The majority of cows monitored in this project were between 4 and 8 years of age (Table 7). In East Java, a large proportion of the herd was 9 years or older. This was most pronounced in Malang, with 45% of the cows monitored being older animals. Anecdotal evidence suggests that farmers may be reluctant to sell 'good' cows to purchase younger replacements that may not have better reproductive performance. Socio-economic surveys found that older and female cattle received lower prices at sale, thus replacing an old cow with a younger animal could be an expensive activity (Priyanti *et al.* 2012b). In addition, limited feed resources might mean that farmers are unwilling to keep heifer calves as replacements when more economic gain can be made by feeding growing bull calves.

Sites with Brahman cows tended to have larger numbers of young cows, and this is probably related to the age of cattle distribution schemes. While there is much variation in how cattle distribution schemes work, many farmers involved in the project were provided with Brahman heifers within a few years of the commencement of our project. Poor reproductive performance of Brahman cows in villages prior to the start of the project meant that many farmers sold their Brahman cows as soon as they had met the obligations of the cattle loan scheme. Similarly, many farmers at the Lapangisi village site in Sulawesi Tenggara were new to cattle farming, and most cattle were heifers at the start of the project.

Table 7. Descriptive summary of the proportion of village cows in age groups observed across the entire project.

Note: this summary is not restricted to one value per animal if an animal contributed more than one production-year of data.

Region	Site	Number of animal years	≤ 3 years			4-8 years			≥ 9 years		
			% cows	95% confidence interval		% cows	95% confidence interval		% cows	95% confidence interval	
				Lower	Upper		Lower	Upper		Lower	Upper
East Java	Probolinggo	281	2.1	1.0	4.7	76.9	71.5	81.5	21.0	16.6	26.2
	Malang	246	1.6	0.6	4.3	53.7	47.4	59.8	44.7	38.6	51.0
	Lamongan	140	21.4	15.3	29.1	62.9	54.5	70.5	15.7	10.5	22.8
Lampung	Tulang Bawang Barat	120	17.5	11.6	25.5	77.5	69.0	84.2	5.0	2.2	10.8
	Seputih Banyak	246	15.0	11.1	20.1	85.0	79.9	88.9	0.0	-	-
Nusa Tenggara Barat	Lombok	327	26.6	22.1	31.7	66.7	61.3	71.6	6.7	4.5	10.0
Sulawesi Tenggara	Kolaka	215	19.1	14.3	24.9	68.8	62.3	74.7	12.1	8.3	17.2
Total		**1575**	**14.3**	**12.7**	**16.2**	**70.1**	**67.8**	**72.3**	**15.6**	**13.8**	**17.4**

Another window on the beef herd was given by an inventory analysis of all the cattle owned or kept by project participants in the Ongole sites in East Java. For each farmer, records were kept of the number of births, deaths, purchases, and sales, the number transferred from owners to keepers and vice versa, and the number moving between age-classes, by breed, sex, and age-class. The data for the first year of the project (2010) were aggregated to provide an inventory of the cattle herd in each site, enabling an analysis of herd dynamics over the year. The number of cattle increased by 7% in the lowland site and decreased by 2% in the upland site, so was probably fairly stable overall. The calf crop (calves born to females of reproductive age) was 62% and 54% in the lowland and upland sites, respectively, reflecting a generally low calving interval. Most of the cattle sold in the lowland site were calves (55%) due to insufficient feed for growing large numbers of cattle, while most sold in the upland site were adults (54%). European-cross calves dominated – 62% in the lowland site and 99% in the upland site – reflecting farmers' and traders' strong preference for the heavier calves resulting from these crosses. In addition, 37% of Ongole heifers and cows in the lowland site and 27% in the upland site were sold during the year, exceeding the likely replacement rate. Hence there was a trend away from Ongole breeders within the aggregate herd to European crosses, especially in the upland site.

As part of the village analyses, we were able to define the standard reference weight (SRW) of the three breeds of cattle monitored, and the liveweight of one BCS unit on the1-5 scale. SRW is the liveweight of a non-pregnant cow in moderate BCS (3 on 1-5 scale). The SRW of Bali, Ongole and Brahman cows was 220, 338 and 380 kg, respectively, with significant differences between all breeds ($P < 0.05$). As a comparison, average liveweight (corrected for pregnancy) of cows in the villages was 200 kg for Bali cows, 311 kg for Ongole cows and 329 kg for Brahman and Brahman-cross cows.

Average liveweight of one BCS unit (1-5 scale) was estimated to be 10, 31 and 59 kg for Bali, Ongole and Brahman cows, respectively. This equated to 5, 9 and 16% of SRW for each breed. The value for Brahman cows was similar to that reported by Fordyce *et al.* (2013) for Brahman and tropical composite cows in northern Australia, where one BCS unit was approximately 13% of liveweight. In comparison, the values we calculated for Ongole and Bali cows are quite different to those estimated by Winugroho and Teleni (1993), where 1 BCS of Ongole cows, converted to 1-5 scale, was 43 kg and 15% of SRW, while 1 BCS of Bali cows was 27 kg and 11% of SRW.

7.2.2 On-station experiments

Can cows maintain liveweight on a rice straw-based diet?

Answering this question was crucial to the success of the project. Across multiple on-station experiments, we fed Ongole, Bali and Brahman cows untreated rice straw with tree legumes, urea, rice bran or onggok as supplements to provide additional energy and protein. All breeds of cattle were able to maintain liveweight on a rice straw-based diet if they were provided with a small amount of supplement (Table 8). The amount of tree legumes required for cows fed rice straw to maintain liveweight was estimated to be 12 g DM/kg $W^{0.75}$.day, or ~ 0.3% of liveweight (Table 9). These results validated the feeding recommendations for farmers in the village component of the project. The amount of supplement offered to cows would need to be increased if cows were in the late stages of pregnancy, lactating, or used for draught. Cows offered water *ad libitum* drank 2.4 kg water per kg of feed DM intake.

Table 8. Feed intake and liveweight gain of Ongole, Bali and Brahman cows fed village-based diets in a series of on-station experiments.

RS: rice straw *ad lib*, RS+GL2.5: rice straw *ad lib* + tree legumes at 2.5 g DM/kg W.day, RS+GL5: rice straw *ad lib* + tree legumes at 5 g DM/kg W.day, RS+GL10: rice straw *ad lib* + tree legumes at 10 g DM/kg W.day, RS+G3: rice straw *ad lib* + Gliricidia at 3 g DM/kg W.day, RS10+G10: rice straw at 10 g DM/kg W.day + Gliricidia at 10 g DM/kg W.day, RS+B10: rice straw *ad lib* + rice bran at 10 g DM/kg W.day, EG: elephant grass *ad lib*, RS+G2.5: rice straw *ad lib* + Gliricidia at 2.5 g DM/kg W.day, RS+G5: rice straw *ad lib* + Gliricidia at 5 g DM/kg W.day, RS+G7.5: rice straw *ad lib* + Gliricidia at 7.5 g DM/kg W.day, RS+G10: rice straw *ad lib* + Gliricidia at 10 g DM/kg W.day, NG: native grass *ad lib*, NG+B5: native grass *ad lib* + rice bran at 5 g DM/kg W.day, NG+B10: native grass *ad lib* + rice bran at 10 g DM/kg W.day, RS+O+U: rice straw *ad lib* + onggok and urea at 10 g DM/kg W.day, RS+O+G: rice straw *ad lib* + onggok at 5 g DM/kg W.day + Gliricidia at 5 g DM/kg W.day.

Values are average ± standard error.

Values within columns, within experiments, followed by different letters are significantly different at $P \leq 0.05$

Experiment x breed	Diet	Total intake (g DM/kg W.day)	Basal intake (g DM/kg W.day)	Green feed & concentrate intake (g DM/kg W.day)	Liveweight gain (kg/cow.day)
BCRI Exp 1. Maintenance requirements of Ongole cows fed rice straw-based diets					
Ongole	RS	18.0 ± 0.85	18.0 ± 0.85[a]	-	-0.11 ± 0.06
Ongole	RS+GL2.5	18.2 ± 1.25	16.0 ± 1.22[ab]	2.2 ± 0.10[a]	-0.07 ± 0.05
Ongole	RS+GL5	18.7 ± 1.19	15.3 ± 1.14[ab]	3.3 ± 0.17[b]	0.02 ± 0.05
Ongole	RS+GL10	19.1 ± 0.69	13.9 ± 0.70[ab]	5.2 ± 0.35[d]	-0.03 ± 0.05
BCRI Exp 2. Strategies for increasing liveweight and BCS of Ongole and Bali cows					
Ongole	RS+G3	16.5 ± 0.82[a]	13.6 ± 0.78[c]	2.9 ± 0.06[a]	-0.13 ± 0.04[a]
Ongole	RS10+G10	17.4 ± 0.48[ab]	8.80 ± 0.38[a]	8.5 ± 0.18[b]	0.03 ± 0.03[b]
Ongole	RS+B10	21.4 ± 0.41[cd]	12.2 ± 0.23[bc]	9.3 ± 0.29[b]	0.09 ± 0.08[b]

Ongole	EG	18.7 ± 0.21^{ab}	-	18.7 ± 0.21^{c}	0.28 ± 0.04^{cd}
Bali	RS+G3	21.4 ± 1.12^{cd}	18.4 ± 1.15^{d}	3.0 ± 0.04^{a}	0.14 ± 0.07^{bc}
Bali	RS10+G10	19.16 ± 0.56^{bc}	10.1 ± 0.33^{ab}	9.1 ± 0.43^{b}	0.03 ± 0.04^{b}
Bali	RS+B10	22.7 ± 1.77^{d}	13.2 ± 1.55^{c}	9.5 ± 0.24^{b}	0.14 ± 0.06^{bc}
Bali	EG	25.6 ± 0.97^{e}	-	25.6 ± 0.97^{d}	0.31 ± 0.04^{d}
UNHALU Exp 8. Liveweight gain and BCS of Bali cows fed rice straw-based diets					
Bali	RS	16.6 ± 0.88^{a}	16.6 ± 0.88	-	0.09 ± 0.066
Bali	RS+G2.5	18.7 ± 0.33^{ab}	16.3 ± 0.32	2.4 ± 0.03^{a}	0.23 ± 0.055
Bali	RS+G5	20.6 ± 0.53^{bc}	16.3 ± 0.42	4.3 ± 0.20^{b}	0.22 ± 0.024
Bali	RS+G7.5	20.8 ± 0.45^{bc}	15.6 ± 0.41	5.2 ± 0.42^{b}	0.09 ± 0.040
Bali	RS+G10	21.6 ± 0.84^{c}	15.3 ± 0.41	6.3 ± 0.54^{c}	0.15 ± 0.064
UNHALU Exp 9. Use of local feed resources to increase liveweight and BCS of Bali cows					
Bali	NG	19.4 ± 0.43^{a}	19.4 ± 0.43^{a}	-	0.12 ± 0.018^{a}
Bali	NG+B5	20.8 ± 1.65^{a}	15.7 ± 1.65^{ab}	5.1 ± 0.01^{a}	0.15 ± 0.053^{a}
Bali	NG+B10	26.5 ± 1.48^{b}	16.3 ± 1.49^{a}	10.1 ± 0.02^{b}	0.33 ± 0.043^{b}
Bali	RS+B10	22.1 ± 1.65^{a}	11.9 ± 1.65^{b}	10.2 ± 0.01^{b}	0.12 ± 0.044^{a}

BCRI Exp 3. Strategies for increasing liveweight and BCS of Brahman cows					
Brahman	RS+O+U	24.1 ± 0.81	16.2 ± 0.80	7.9 ± 0.06	0.13 ± 0.03
Brahman	RS+O+G	25.6 ± 0.73	17.9 ± 0.71	7.6 ± 0.14	0.15 ± 0.05

Table 9. Estimated minimum feed and water intake required for maintenance of liveweight in non-pregnant, non-lactating cows of standard reference weight fed rice straw *ad libitum*.

Feed values are kg fresh weight, assuming rice straw is 70% DM and tree legumes are 25% DM.

Breed	Cow weight (kg)	Rice straw (kg/cow.day)	Tree legumes (kg/cow.day)	Water (L/cow.day)
Bali	220	5	3	10
Ongole	338	7	4	14
Brahman	380	8	4	15

Although rice straw alone did not provide enough energy or crude protein for Ongole cows to maintain liveweight, average liveweight loss was only 0.11 kg/cow.day (Table 8). At this rate it would take almost a full year for cows to lose one BCS unit. In comparison, Bali cows were able to gain small amounts of liveweight when fed rice straw without supplementation, suggesting lower metabolisable energy (ME) requirements for maintenance of liveweight and growth.

An important result from our experiments was that there was no advantage in using urea instead of tree legumes as a source of N for the cows. Even at low levels of inclusion, both supplements comfortably met the daily rumen-degradable N requirements of cows. Tree legumes such as Gliricidia, Leucaena and Sesbania provide a cheap and locally available source of crude protein and ME for livestock throughout the year, including the dry season. They can be planted as living fences around the farmer's house or kandang where they can be harvested easily with little labour cost. In comparison, urea is expensive and farmers may consider it a risky supplementation option because the amount of urea fed needs to be carefully controlled or mortalities can occur.

Interestingly, cows of all breeds displayed a preference for rice straw over tree legumes, and did not consume all of the Gliricidia or Leucaena offered to them. This was especially noticeable at high levels of supplementation (≥ 5 g DM/kg W.day). By limiting rice straw offered to cows in Experiment 2 at BCRI (diet RS10G10), we were able to increase the intake of tree legumes. However, cows still did not eat all the green feed on offer, and we did not achieve a useful increase in liveweight gain (Table 8). Cows in Experiment 1 at BCRI increased their intake of Gliricidia during the experiment, suggesting that exposure may increase acceptability of tree legumes to livestock. Anecdotal evidence from the village work suggests that cultivars and cutting frequency may also affect palatability of Gliricidia, and this could be investigated further.

Cows must have adequate body reserves to maintain reproductive function, and a BCS of 3 or higher on the 1-5 scale is usually targeted in beef cattle (e.g. Short et al. 1990). Jenkins and Ferrell (2007) demonstrated that cows will reach a stable liveweight and BCS after a period of feeding a fixed dry matter or ME intake (g DM or MJ ME/day). A similar pattern was observed with Brahman cows in Experiment 3. Liveweight of cows increased for the first 15 weeks of the experiment, and then reached a plateau at 304 kg and a BCS of 2.2 (Figure 5). This means that while Brahman cows can maintain liveweight on a rice straw-based diet, they may not be able to maintain a BCS sufficient for good reproduction rates. This is also true for the Bali and Ongole cows fed rice straw-based diets. Across all experiments, cows fed elephant grass *ad libitum* were the only group to reach and maintain a BCS of 3. While the rice straw-based diets tested in our experiments were adequate for maintenance of liveweight in cows with BCS less than 3, cows may struggle to maintain a higher BCS without higher levels of supplementation.

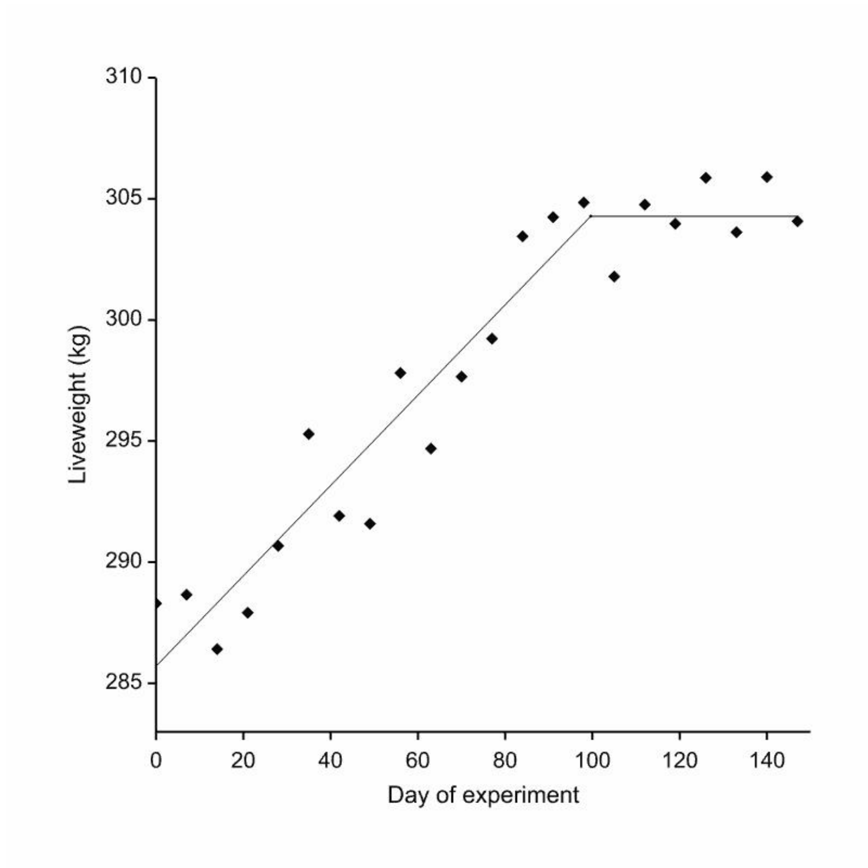

Figure 5. Split line regression of average daily liveweight gain of Brahman cows fed rice straw *ad libitum* plus onggok and urea or Gliricidia

Metabolisable energy required for maintenance of liveweight

The ME required for maintenance of liveweight (ME_m) was calculated for all breeds during the on-station experiments by regression of estimated ME intake against liveweight gain. Bali cows had the lowest ME_m of 0.49 MJ ME/kg $W^{0.75}$.day, followed by Ongole (0.60 MJ ME/kg $W^{0.75}$.day) and then Brahman cows (0.84 MJ ME/kg $W^{0/75}$.day). The low ME_m of Bali cows compared to Ongole and Brahman cows supports the widely held view that Bali cattle perform well under poor nutritional conditions compared to other breeds. Combined with their small body size, this makes Bali cattle the most appropriate breed for situations where feed quality and/or quantity are limiting.

The ME_m values for Bali cows were comparable to other published values. Yuliaty *et al.* (2013) reported ME_m of 0.42 MJ ME/kg $W^{0.75}$.day for young Bali bulls fed urea-treated rice straw and Leucaena, while Quigley *et al.* (2014) reported a value of 0.47 MJ/kg $W^{0.75}$.day based on a meta-analysis of young Bali bulls fed 36 diets of differing quality. Sukarini *et al.* (2000) reported a higher value of 0.53 MJ ME/kg $W^{0.75}$.day for lactating Bali cows fed rations based on elephant grass, tree legumes and mixed concentrates. Energy requirements for maintenance are influenced by many factors including animal age, liveweight, gender, physiological status, feed type and level of intake, previous level of nutrition, and environmental factors (NRC 2000). Differences in the types of animals used and diets fed between our experiments and those of Yuliaty *et al.* (2013), Quigley *et al.* (2014) and Sukarini *et al.* (2000) may help to explain the small differences in ME_m.

There are no published values for ME_m of Ongole cows in Indonesia. However, the value estimated from our experiments was higher than values published for genotypically similar Nellore cattle in Brazil, 0.47 MJ ME/kg $W^{0.75}$.day (Chizzotti *et al.* 2008). Estimated ME_m for Brahman cows was also substantially higher than expected. High ME_m could be due to the equations from Freer *et al.* (2007) overestimating the ME content of the diets, as is discussed in Antari *et al.* (2014a) and Mayberry *et al.* (2014). Alternatively, the maintenance energy requirements of cows in our experiments could have been increased due to the additional energy required to cope with high environmental temperatures and humidity, or consuming unchopped roughage feeds.

How can we increase the liveweight and body condition score of cows in villages?

Body condition score is a key driver of reproduction in cattle, and cows with low BCS tend to have extended periods of post-partum anoestrus and long inter-calving intervals (Montiel and Ahuja 2005). Given the low BCS of many cows in villages, it is necessary for us to develop strategies to increase the liveweight and condition of cows in a cost-effective and timely manner.

In the on-station experiments, we supplemented cows fed rice straw or native grass with different levels of tree legumes and concentrates such as rice bran and onggok (a cassava by-product). Liveweight gains of all breeds of cattle were low, even at high levels of supplementation (Table 8). The highest liveweight gains were for Bali cows fed native grass with high levels of supplementation, and both Bali and Ongole cows fed elephant grass *ad libitum* (liveweight gain of 0.3 kg/cow.day). However, even at these growth rates, it would take Ongole cows five months to gain one BCS unit.

In our experiments, feeding rice bran or onggok provided no advantage compared to feeding tree legumes, with no significant differences in liveweight gain at similar levels of supplementation (Antari *et al.* 2014a; Antari *et al.* 2014b). This suggests that the energy content of the concentrate feeds was lower than we anticipated, and similar to that of the tree legumes. The quality of the concentrates fed to cows in our experiments was highly variable, and the average ash content from our analysis (Table 4) was much higher than values previously reported in the literature [e.g. Aro and Aletor (2012)]. The high ash content of the onggok was attributed to contamination with soil, as some processors dry onggok by leaving it on the ground exposed to sunlight (Sari *et al.* 2013). The rice bran used in our experiments may have contained high levels of rice hulls if it was manufactured at the village level. In addition, it is possible that some traders dilute concentrates with sand or other material to take advantage of good feed prices. The concentrates used in our experiments were purchased from local feed traders, and can be assumed to be of similar quality to that available to smallholder farmers.

These results suggest that increasing BCS quickly to reduce the post-partum anoestrus interval, and hence calving intervals, is difficult within village-based systems. This is especially true for the larger, *Bos indicus* breeds of cattle. A more effective strategy would be to maintain the condition of cows throughout pregnancy and lactation.

How does nutrition affect the reproductive development of Bali heifers?

Lifetime productivity of female cattle is influenced by age at first calving. Managing pre- and post-pubertal growth of heifers is important in establishing this lifetime productivity. Heifers that are subjected to nutrient restriction after weaning are typically older at puberty and have lower pregnancy rates than those that are well grown over this period. The age at first calving in of Bali cattle villages across eastern Indonesia is typically 36 months of age, with lighter maiden heifers having low birth weight calves (Talib *et al.* 2003).

Over a 25-month feeding experiment, we were able to demonstrate the importance of a good diet between weaning and puberty on the longer-term growth and development of heifers. This may have implications for mature size, re-conception after first calving, and longer-term reproductive performance, and these impacts are currently being investigated in LPS/2013/017.

Weaned, 8-month-old Bali heifers were fed either a medium- [king grass (*Pennisetum purpureum* hybrid) *ad libitum,* R] or high-quality (maize and soybean meal concentrate *ad libitum* + king grass at 15-20% daily intake, C) diet in a cross-over design. The experiment consisted of two phases, with two pre-pubertal (C, R) and four post-pubertal (C-C, C-R, R-R, R-C) treatments.

Heifers fed the high quality concentrate diet had higher daily liveweight gain compared to heifers fed king grass only in both parts of the experiment, with no interaction between diet and phase (Table 10). Heifers fed the concentrate diet between 8 and 19 months of age were also heavier, and had a higher BCS, at the first detection of oestrus. At the end of the experiment, C-C heifers were 110 kg heavier than R-R heifers. They also had a higher BCS than all other heifers, and were higher at the hips than heifers that were offered the R treatment during Phase 1 (Figure 6).

Heifers that were subjected to a pre-pubertal restriction in growth were never able to fully compensate in terms of liveweight, fat cover and height when subsequently fed a high quality diet for an extended period of time. A significant reduction in the growth of heifers between 8 and 18 months of age also delayed the first detection of oestrus by one to two months.

Circulating IGF1 and leptin results and qPCR results are not presented within this report but are available as supplementary material upon request.

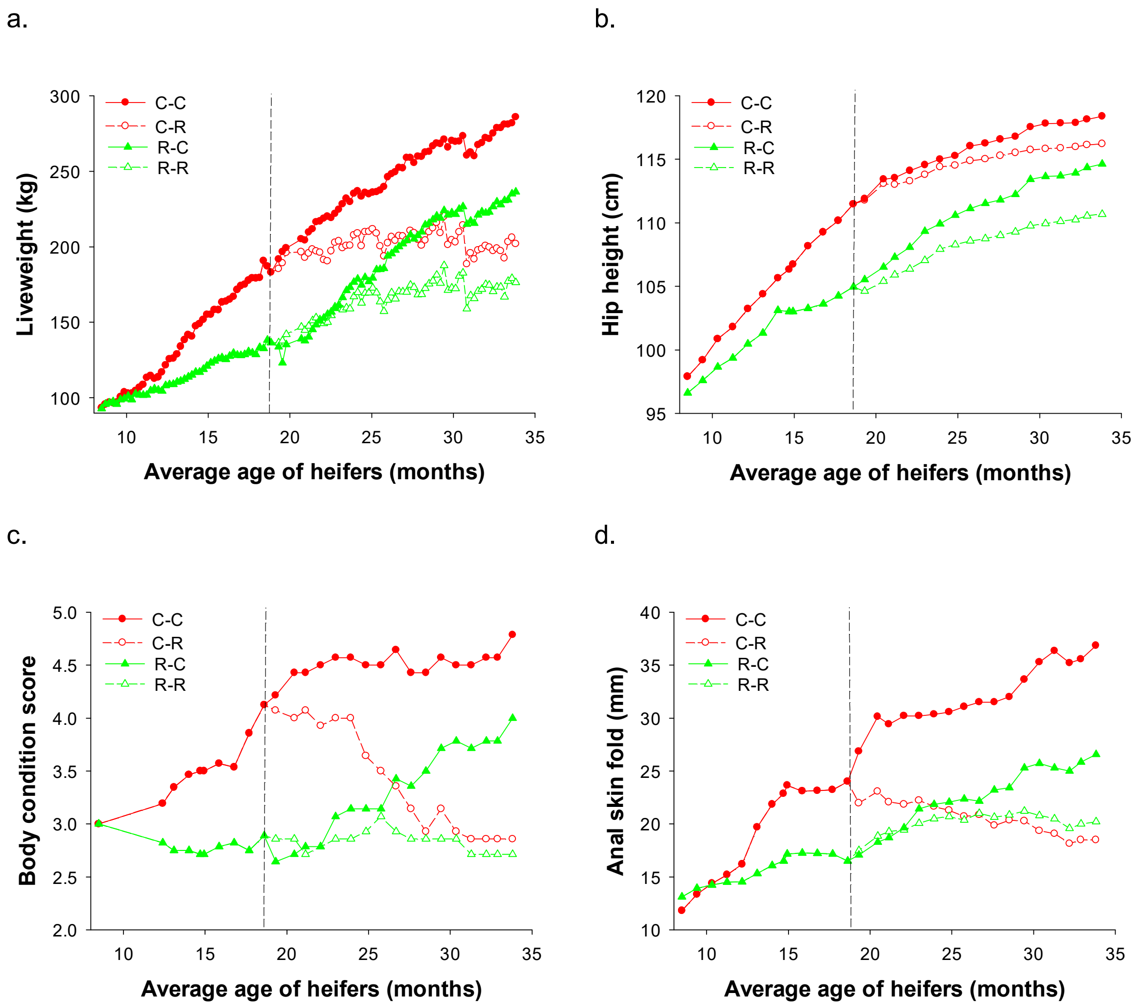

Figure 6. Change in (a) liveweight, (b) hip height, (c) body condition score (1-5 scale), and (d) anal skin fold thickness of Bali heifers fed a maize and soybean meal concentrate (C) or king grass (R) from 8 to 19 months (Phase 1, C- or R-) and 19 to 34 (Phase 2, -C or -R) of age. The vertical dashed line indicates change from Phase 1 to Phase 2.

Table 10. Liveweight gain, age, liveweight and body condition score (BCS) at first oestrus detection, length of oestrus cycle and final liveweight, BCS, girth and hip height of Bali heifers fed concentrate (C) or king grass (R) diets from 8 to 19 (Phase 1, C- or R-) and 19 to 34 months (Phase 2, -C or -R) of age

Values within rows followed by different letters are significantly different at $P \leq 0.05$

	C-C	C-R	R-C	R-R	SEM
Liveweight gain, 8-19 months of age (kg/heifer.day)	0.32^{a}		0.14^{b}		0.02
Liveweight gain, 19-34 months of age (kg/heifer.day)	0.18^{a}	0.03^{b}	0.24^{c}	0.07^{d}	0.01
Age at first oestrus detection (months)	19.9^{ab}	19.1^{a}	20.7^{ab}	21.6^{b}	0.8
Liveweight at first oestrus detection (kg)	195^{a}	177^{a}	141^{b}	155^{b}	7.3
BCS at first oestrus detection (1-5 scale)	4.2^{a}	3.8^{a}	2.8^{b}	2.9^{b}	0.1
Oestrus cycle length (days)	20	20	21	21	0.7
Final liveweight at 34 months of age (kg)	286^{a}	202^{b}	236^{c}	176^{d}	7.9
Final BCS at 34 months of age (1-5 scale)	4.8^{a}	2.9^{b}	4.0^{a}	2.7^{b}	0.1
Final girth at 34 months of age (cm)	168^{a}	146^{b}	157^{c}	138^{d}	2.1
Final hip height at 34 months of age (cm)	118^{a}	116^{a}	115^{b}	111^{c}	1.0

7.2.3 Village cow-calf systems

Feed

An assessment of potential feed availability from agricultural residues and by-products was carried out for the project villages in East Java and Lampung, including rice straw, maize stover and cobs, and cassava peelings. Based on the assumption of an annual feed dry matter (DM) requirement of 2.1 tonnes per animal unit, the estimated total availability of crop by-products was more than that required by the existing number of animals. In the lowland East Java site, existing requirements were 87% of potential capacity, in the upland East Java site they were 55%, while in the Lampung sites they were between 42 and 49%. Hence the lowland East Java site was probably very close to carrying capacity. However, the feed availability was not distributed evenly throughout the year; this was the case in all the villages studied. Therefore appropriate storage of crop residues and by-products is needed to carry over feed from surplus months to deficit months. Not only is there a time dimension to feed supply and demand but, as noted above, a spatial dimension, in that most cow-calf operators do not have the capacity to produce all their own feed requirements and need to collect or buy feed from others' farms (particularly in East Java). Only 18% of lowland farmers obtained all their rice straw and other crop by-products exclusively from their own land, while 25% bought some or all from traders or other farmers. Traders also faced the problem of high demand in the dry season when supplies were limited and low demand in the wet season when supplies were abundant, but there was no example traders carrying stocks of feed for more than 1-2 days.

The types of feed offered to cattle tended to reflect what was available within each region. In East Java, both Ongole and Brahman cows were fed large amounts of rice straw and other crop residues (Table 11). This reflects the intensity of cropping in the area, and the scarcity of alternative feed resources. Despite this, green feed was provided above the minimum levels of supplementation required for maintenance of liveweight in Table 9. In Probolinggo, green feed and concentrate were provided at approximately 0.5% of liveweight (DM basis) as per the project recommendations. The amount of supplement offered in Malang was slightly higher, at approximately 1% of liveweight. Similar to the on-station experiments, cows fed large amounts of rice straw were able to maintain liveweight, but did not achieve an average BCS greater than 3 (Table 12). That we were able to achieve an increase in cattle reproduction at these sites, whilst feeding high levels of rice straw with limited supplementation, helps to validate the concept of the 'straw cow' model and highlights the importance of good animal management, as well as nutrition, for reproductive success.

Figure 7. Ongole and crossbred cows consuming fresh rice straw at the Malang village site. (Photo: Di Mayberry)

Despite encouragement from project staff, limited amounts of rice straw were fed in Lombok (Table 11) and Sulawesi (not presented). This was primarily because farmers in these areas had easy access to higher quality feed resources for their cattle, and this was reflected in the average cow BCS (Table 12). The reliance on crop residues and by-products in East Java supports the idea that the local cattle herd is close to carrying capacity. In comparison, underutilisation of crop residues in Lombok and Sulawesi indicates that there are enough feed resources to support a larger cattle population.

The total amount of feed offered was highest for Brahman cows in Tulang Bawang Barat and Lamongan, with high proportions of green feed and concentrate (Table 11). Farmers at these sites responded positively to messages regarding the importance of cow BCS for reproductive success, and by the end of the project, average cow BCS was above 3 at both sites. Farmers with Brahman cows also fed higher levels of concentrate-type feeds.

The total amount of tree legumes offered to cattle increased at all sites where feed offered was monitored during the project. This was due to the efforts of junior scientists and village teams who worked hard to promote the benefits of tree legumes, and helped farmers to plant them around the villages and on paddy bunds. The village teams also showed farmers how to harvest seeds and make cuttings so that farmers can continue to increase the number of tree legumes planted after the project finishes.

Table 11. Feed (fresh weight) and water offered to cows in villages.

Values are average ± standard error.

Values within columns followed by different letters are significantly different at $P \leq 0.05$.

Breed x Site	Total (kg/cow.day)	Basal diet[1] (kg/cow.day)	Grasses (kg/cow.day)	Tree legumes (kg/cow.day)	Concentrate (kg/cow.day)	Water (kg/cow.day)
Ongole						
Probolinggo, East Java	21.0 ± 0.64[a]	12.9 ± 0.33[a]	6.2 ± 0.47[a]	1.6 ± 0.10[a]	0.4 ± 0.04[a]	18.6 ± 0.10[a]
Malang, East Java	27.7 ± 0.65[b]	14.1 ± 0.65[a]	10.3 ± 0.60[b]	3.1 ± 0.22[b]	0.4 ± 0.08[a]	18.0 ± 0.12[b]
Brahman						
Lamongan, East Java	40.4 ± 0.94[c]	12.8 ± 0.73[a]	22.9 ± 0.92[c]	2.7 ± 0.32[b]	2.8 ± 0.19[b]	40.4 ± 0.31[c]
Tulang Bawang Barat, Lampung	34.5 ± 0.85[d]	6.0 ± 1.02[b]	25.5 ± 1.08[c]	0.3 ± 0.08[c]	2.7 ± 0.27[b]	-
Bali						
Lombok[2]	12.3 ± 0.98[e]	4.1 ± 0.81[bc]	6. 9 ± 0.67[ba]	1.2 ± 0.20[ad]	0.1 ± 0.02[c]	-

[1] Basal diet is primarily low quality crop residues such as rice straw and corn stover.

[2] Cattle in Lombok grazed for part of the day

Table 12. Body condition score (1-5 scale) of cows in villages

Region	Site	Number of observations	Mean	95% confidence interval	
				Lower	Upper
East Java	Probolinggo	4,434	2.7	2.6	2.8
	Malang	4,461	2.8	2.8	2.9
	Lamongan	2,705	3.0	2.9	3.0
Lampung	Tulang Bawang Barat	1,952	2.9	2.8	2.9
	Seputih Banyak	2,705	2.9	2.9	3.0
Nusa Tenggara Barat	Lombok	3,627	3.0	2.9	3.1
Sulawesi Tenggara	Kolaka	3,840	3.2	3.2	3.3

Figure 8. Sesbania trees and grasses planted on paddy bunds in Lombok; successful Gliricidia cuttings in Tulang Bawang Barat, Lampung (Photos: Di Mayberry)

Reproduction rates

The catch-phrase of many cattle projects in Indonesia is “satu induk, satu anak, satu tahun” (one cow, one calf, one year). Given the large number of cows entering and leaving the project, and the long gestation period of cattle, we used the proportion of cows pregnant within 100 days of calving as a means of estimating the proportion of the beef herd that were able to achieve a 12-month inter-calving interval.

Across the project, the average likelihood of cows conceiving within 100 days of parturition was 25% (Table 13). The likelihood of pregnancy within 100 days of calving varied between sites, and ranged from 8% in Malang to 51% in Lombok. There were also large variations between villages within sites. For example, in Lombok, 59% of cows at Karang Kendal became pregnant within 100 days of calving, compared to just 27% at Papak. At Tulang Bawang Barat in Lampung, pregnancy rates within 100 days of calving were 0, 9 and 43% for cattle in Murni Jaya, Daya Asri and Pulung Kencana, respectively. In East Java, proportions were similar for cows at Modo (17%) and Sambeng (14%) in Lamongan, and at Dadanggendis (24%) and Klampok (20%) in Probolinggo.

Table 13. Summary statistics of percentage of cattle pregnant within 100 days of calving by village.

Region	Site	n	Cow pregnant within 100 days of calving (%)	95% Confidence interval	
				Lower	Upper
East Java	Probolinggo	132	22	15.7	29.9
	Malang	104	8	3.9	14.7
	Lamongan	81	16	9.5	25.8
Lampung	Tulang Bawang Barat	35	14	6.0	30.4
	Seputih Banyak	52	44	31.3	58.0
Nusa Tenggara Barat	Lombok	144	51	43.2	59.5
Sulawesi Tenggara	Kolaka	71	38	27.5	49.9
Total		**619**	**25**	**12.8**	**37.1**

The likelihood of cows becoming pregnant within 100 days of calving was significantly influenced by cow breed, BCS at calving, age and month of calving (Table 14). Bali cows were significantly more likely to conceive within 100 days of calving compared to Ongole and Brahman cows, but there was no significant difference between the two *Bos indicus* breeds. BCS at calving and cow age were positively associated with likelihood of pregnancy, with cows in BCS ≥ 2.5 and aged ≥ 4 years more likely to be pregnant within 100 days of calving. Cows that calved during the dry season (June to October) were also more likely to be pregnant within 100 days of calving compared to cows that calved during the wet season (November to May). It is worth noting that this result was driven by data from the Lombok, Sulawesi Tenggara and Seputih Banyak villages, and may be related to timing of farm activities or availability of higher quality feeds that can be fed to cattle (e.g. rice bran).

Research with tropically-adapted beef cattle in northern Australia suggests that a realistic target for annual calving rates is 70-90% (McGowan *et al.* 2014). The proportion of cows pregnant within 100 days of calving increased during the project, from 22% of cows in 2010 to 42% of cows in 2013 (Table 14). While this is a substantial achievement for a relatively short project, there is still room for improvement. For cows to conceive within 100 days of calving, the combined duration of post-partum anoestrus interval (PPAI) and time from first oestrus to conception must be less than 100 days. In this project, we found that extended PPAI (as recorded by farmers and junior scientists) was the primary driver of long inter-calving intervals, but there was much variation between sites and breeds. Overall, the median duration of PPAI was significantly shorter in Bali cows (82 days) compared to either Ongole (111 days) or Brahman cows (105 days). Bali cattle are often reported to be more fertile than *Bos indicus* cattle breeds, but in this project, Bali cows also tended to be in better BCS, which is associated with shorter PPAI (Montiel and Ahuja 2005).

Cattle management was identified as a key issue influencing differences in PPAI between sites (Table 15). For example, Ongole cows at the Probolinggo and Malang sites in East Java had similar average BCS (Table 12), but median PPAI was two months shorter in Probolinggo. On average, calves in Probolinggo were weaned three months earlier than calves in Malang (Table 19), and this may help to explain the difference between sites. It is also possible that cows resume cycling before farmers detect oestrus. Many farmers reported that they looked for behavioural (e.g. cow bellowing, loss of appetite) rather than physical signs to determine when cows were ready for mating. This was more common in areas where kandang design made it difficult for farmers to access the rear end of cattle to check for physical signs (Figure 9).

Table 14. Results of univariate associations between known determinants of efficiency of reconception and likelihood of lactating cows becoming pregnant within 100 days of calving. Analyses using random effects logistic regression model with clustering at the village level were applied.

Variable	Raw observations		Odds ratio	95% Confidence interval of odds ratio		Cows pregnant (%)	95% Confidence interval		*P*-value
	Empty (n)	Pregnant (n)		Lower	Upper		Lower	Upper	
Breed									***<0.001***
Bali	123	119	Referent[2]			49.2	38.4	60.0	
Ongole	199	37	0.18	0.09	0.36	14.6	7.6	21.6	
Brahman[1]	115	17	0.15	0.07	0.30	12.4	5.6	19.2	
BCS at calving									***0.05***
≤2	29	12	Referent			14.6	2.3	26.9	
2.5	81	35	2.13	0.91	5.00	26.7	11.2	42.3	
3	177	53	1.69	0.74	3.88	22.5	10.0	35.0	
3.5	94	31	1.89	0.80	4.47	24.5	10.2	38.7	
≥4	52	46	3.25	1.42	7.44	35.7	17.4	54.1	

Month of calving									***0.04***
Jan	27	4	Referent			11.8	-1.0	24.6	
Feb	34	6	1.43	0.35	5.85	16.1	1.7	30.5	
Mar	33	9	1.96	0.52	7.40	20.8	4.9	36.7	
Apr	38	8	1.57	0.41	6.05	17.4	3.2	31.6	
May	55	14	1.37	0.39	4.80	15.5	4.2	26.8	
Jun	45	31	3.70	1.12	12.25	33.2	16.0	50.3	
Jul	48	28	3.03	0.91	10.05	28.9	12.9	44.9	
Aug	35	30	4.41	1.32	14.70	37.1	18.7	55.6	
Sep	32	20	4.27	1.23	14.75	36.4	17.0	55.8	
Oct	33	14	3.00	0.85	10.67	28.7	10.6	46.8	
Nov	37	9	1.92	0.51	7.21	20.5	5.0	36.0	
Dec	23	6	2.32	0.55	9.78	23.7	3.7	43.7	

Cow age group									***<0.001***
≤3	71	28	Referent			16.2	4.3	28.0	
4 to 8	295	126	1.67	0.98	2.85	24.4	10.5	38.3	
≥9	58	18	2.34	1.05	5.23	31.1	11.0	51.2	
Year									***0.01***
2010	90	21	Referent			22.2	8.1	36.3	
2011	145	49	0.90	0.47	1.72	20.5	9.1	31.9	
2012	166	68	1.16	0.61	2.23	24.9	12.3	37.5	
2013	39	41	2.51	1.12	5.64	41.7	22.4	61.1	

[1] Includes Brahman-cross cows

[2] Group to which other groups within the same explanatory variable are compared

Figure 9. Cattle in East Java are often housed in kandangs where farmers cannot easily check for physical signs of oestrus (Photo: Di Mayberry).

Table 15. Summary of post-partum anoestrus interval (days) by village

Values in same column followed by different letters are significantly different at $P \leq 0.05$

Region	Site	n	Median (days)	Inter-quartile range	
				Lower	Upper
East Java	Probolinggo	194	97[a]	64	121
	Malang	171	151[b]	97	211
	Lamongan	96	120[cd]	81	169
Lampung	Tulang Bawang Barat	50	92[a]	53	139
	Seputih Banyak	93	75[e]	40	106
Nusa Tenggara Barat	Lombok	138	83[a]	63	121
Sulawesi Tenggara	Kolaka	43	94[acde]	61	158

Mating management was also identified as a contributing factor to long inter-calving intervals at some sites. This was primarily an issue at sites where farmers did not have easy access to a bull or artificial insemination (AI) services. In Lombok, which had the shortest period from mating to conception, cows were housed in a communal kandang where there was always a bull available. At the more remote sites in East Java and Lampung, farmers had to arrange for an AI technician to visit their cow or walk the cow across the village to a bull. At some sites, especially Malang, the AI technicians were not always available when the farmers contacted them, so cows were not mated on time, or at all. In comparison, the village at Probolinggo in East Java was very well serviced by the local AI technician, and most cows became pregnant on the first or second mating.

Additionally, farmers did not always arrange for their cows to be mated when oestrus was observed. This was more common in instances where cows were kept by farmers who didn't own the cattle, and needed to arrange permission or payment for mating with the cattle owner. Anecdotally, these farmers were also less motivated to check for oestrus and arrange mating when the calf would go to the cow owner not the keeper.

The improvements in reproduction measured during the project were driven by a combination of increased cow BCS (Table 12, Table 17), weaning of calves, and improved oestrus detection and mating management. While messages regarding cow BCS and weaning of calves have been well-adopted, oestrus detection and mating management remain key issues for gaining further increases in reproductive performance. This is particularly important in the high-density areas of East Java where few farmers have access to bulls and >80% of calves are produced using artificial insemination (Table 18).

Table 16. Summary of first mating to conception interval (days) by village

Values in same column followed by different letters are significantly different at $P \leq 0.05$

Region	Site	n	Median (days)	Inter-quartile range	
				Lower	Upper
East Java	Probolinggo	130	4^{ab}	0	29
	Malang	105	4^{ac}	0	81
	Lamongan	84	8^{ade}	0	74
Lampung	Tulang Bawang Barat	29	60^{e}	0	143
	Seputih Banyak	75	15^{af}	0	55
Nusa Tenggara Barat	Lombok	138	0^{cg}	0	6
Sulawesi Tenggara	Kolaka	50	1^{bdfg}	0	23

Table 17. Proportion of cows with body condition score (BCS) greater than or equal to 3.5 on 1-5 scale at calving.

Values within columns followed by different letters are significantly different at $P \le 0.05$.

Year	Cows in BCS ≥ 3.5 (%)	95% Confidence interval	
		Lower	Upper
2010	23.0[a]	7.7	38.3
2011	16.5[a]	5.4	27.6
2012	36.6[b]	18.6	54.5
2013	46.3[b]	27.2	65.5

Table 18. Descriptive summary of the proportion of calves born to artificial insemination (AI) for each village

Region	Site	n	Calves born to AI (%)	95 % Confidence interval	
				Lower	Upper
East Java	Probolinggo	196	82	75.6	86.5
	Malang	175	94	89.0	96.5
	Lamongan	94	87	78.8	92.6
Lampung	Tulang Bawang Barat	65	43	31.6	55.4
	Seputih Banyak	92	42	32.7	52.7
Nusa Tenggara Barat	Lombok	117	7	3.4	13.1
Sulawesi Tenggara	Kolaka	53	0	-	-

Weaning

Suckling by calves can impact the reproductive performance of cows in two ways. Firstly, lactating cows must consume enough energy to maintain their own liveweight as well as produce milk for their calf, and it is common for cows to lose liveweight and BCS during lactation. As discussed previously, cows in poor BCS have prolonged PPAI, and poor BCS was associated with low proportions of cows pregnant within 100 days of calving in our village monitoring. Secondly, particularly in *Bos indicus* cattle, suckling suppresses the release of hormones involved in ovulation. For these reasons, we placed a strong emphasis on weaning calves within the project. Farmers were encouraged to wean their calves at 6 months of age (180 days), or when cow BCS reached 2 on the 1-5 scale.

After some initial hesitation, most farmers weaned their calves, and average age of calves at weaning was close to 6 months at all sites (Table 19). The two notable exceptions to this were the Probolinggo and Seputih Banyak sites, where most calves were weaned at approximately 3 months of age. In Probolinggo, calves were already being weaned prior to the start of this project, following the previous ACIAR Draught Animal Projects in the 1980s (Teleni *et al.* 1993). Cattle farmers in the Probolinggo villages are primarily calf producers and calves are usually sold at time of weaning. This has the dual benefits of risk minimisation (selling calf before it dies, not spending money on feed for growing animals) and reducing the nutritional demands of the cow. In Seputih Banyak, all the cattle were owned by a single, commercially-orientated, farmer.

Table 19. Descriptive summary of age at weaning (days).

Region	Site	n	Mean	Standard deviation	95% confidence interval	
					Lower	Upper
East Java	Probolinggo	240	98	21.4	56.0	139.7
	Malang	200	169	22.2	125.8	212.7
	Lamongan	100	165	25.8	114.8	215.7
Lampung	Tulang Bawang Barat	71	133	41.0	52.3	212.9
	Seputih Banyak	93	104	35.0	35.3	172.5
Nusa Tenggara Barat	Lombok	152	171	39.7	92.7	248.5
Sulawesi Tenggara	Kolaka	7	200	12.7	174.7	224.5

Calf growth rates and mortality

Average daily pre-weaning liveweight gain of suckling calves was affected by cow breed, calf birth weight, age of calf at weaning, and month of birth (Table 20). There was no difference in pre-weaning growth rates between male and female calves. Calves born to Brahman cows had significantly higher liveweight gains whilst suckling (0.63 kg/calf.day) compared to those born to Ongole (0.55 kg/calf.day) or Bali (0.31 kg/calf.day) cows. There were also significant differences in growth between Ongole and Bali calves. Generally, pre-weaning average daily gain within breeds increased incrementally with increases in calf birth weight. Associations between birth weight and pre-weaning average daily gain have previously been established. Age at weaning was negatively associated with liveweight gain of suckling calves, which is a new result. Calves born between October and December (early wet season) had higher liveweight gain if they were weaned by five months. We have hypothesised that cows may start to wean their calves around this time, and if additional feed is not provided specifically for the calves, their growth rates will decrease.

Table 20. Results of unconditional associations between explanatory variables and pre-weaning average daily gain (kg/calf.day) using generalised linear regression model with clustering at the village level.

Variable	n	Estimate	Standard Error	95% Confidence interval		*P*-value
				Lower	Upper	
Birth weight (kg)	817	0.015	0.001	0.012	0.018	<0.001
Age at weaning (months)	817	-0.064	0.007	-0.077	-0.050	<0.001
Breed						***<0.001***
Bali	192	Referent				
Brahman	189	0.389	0.028	0.334	0.444	<0.01
Ongole	428	0.302	0.042	0.220	0.385	<0.01
Month of Birth						***<0.001***
January	47	Referent				
February	59	-0.009	0.034	-0.075	0.057	0.79
March	79	-0.108	0.032	-0.170	-0.046	<0.01
April	76	-0.111	0.032	-0.173	-0.048	<0.01
May	106	-0.076	0.030	-0.136	-0.017	0.01
June	80	-0.037	0.032	-0.099	0.026	0.25
July	94	-0.030	0.031	-0.091	0.030	0.33
August	65	-0.059	0.033	-0.125	0.006	0.08
September	59	-0.044	0.034	-0.110	0.022	0.19
October	62	-0.036	0.033	-0.101	0.029	0.28
November	48	-0.044	0.035	-0.113	0.025	0.21
December	42	0.063	0.036	-0.009	0.134	0.09

Average birth weights of calves from Bali, Ongole and Brahman cows were 14, 26 and 30 kg, respectively, with no differences between sites. These birth weights are within the published normal liveweight range for each breed.

Calf mortality varied greatly between sites (Table 21). Calf losses were highest for Bali cattle at Seputih Banyak, where the herd suffered from a pestivirus infection that killed 58% of Bali calves born over the project. This infection did not affect the Brahman cattle population at the same site. When the Bali calves from Seputih Banyak were removed from the analysis, cow breed and BCS had the biggest effects on calf loss (Table 22). Calf losses for Bali and Brahman cows were similar, and significantly higher than for Ongole cattle. Incidences of calf loss tended to be higher for those calves of lower than average birth weight for Bali and Brahman cows, but this trend was not observed in Ongole cows.

Table 21. Summary of observed calf loss by site

Region	Site	n	Calf loss (%)	95% confidence interval	
				Lower	Upper
East Java	Probolinggo	279	2.5	1.2	5.2
	Malang	217	1.4	0.4	4.2
	Lamongan	138	5.8	2.9	11.2
Lampung	Tulang Bawang Barat	83	9.6	4.9	18.2
	Seputih Banyak	181	49.7	42.5	57.0
Nusa Tenggara Barat	Lombok	228	8.8	5.7	13.2
Sulawesi Tenggara	Kolaka	179	15.1	10.5	21.1
Total		**1,305**	**8.1**	**0.9**	**15.4**

Cows in BCS ≤ 2 at calving were significantly more likely to lose a calf compared to cows in BCS 3. The impact of cow BCS on calf mortality was consistent across breeds. Cow age also had an effect on calf mortality, and young cows (≤ 3 years), especially those in poor BCS, were more likely to lose a calf.

Overall calf mortality, excluding Bali calves at Seputih Banyak, was 6.4% (2.6 – 10.1 95% confidence interval).

Table 22. Results of unconditional associations between putative risk factors for risk of calf loss using random effects of logistic regression model with clustering at the village level.

Note: Bali cows from Seputih Banyak are omitted from this analysis as they were considered to be influenced by pestivirus infection

Variable	Raw observations		Odds ratio	95% confidence interval of odds ratio		Calf loss (%)	95% confidence interval		*P*-value
	Reared (n)	Died (n)		Lower	Upper		Lower	Upper	
Breed									***<0.001***
Bali	349	44	6.19	2.83	13.54	11.1	7.2	15.1	<0.01
Brahman[1]	230	22	4.84	2.09	11.20	8.9	4.9	12.9	<0.01
Ongole	486	10	Referent			2	0.7	3.3	
BCS at calving									***<0.001***
≤2	75	20	5.80	2.57	13.01	19	5.8	32.2	<0.01
2.5	217	24	2.30	1.01	5.18	8.5	1.8	15.2	0.05
3	441	67	Referent			3.9	0.9	6.9	
3.5	243	40	1.60	0.79	3.35	6.2	1.6	10.8	0.19
≥4	153	9	1.10	0.47	2.81	4.4	0.4	8.5	0.77

Cow age									***0.02***
≤3	138	23	2.14	1.22	3.76	10.7	3.3	18.1	<0.01
4 to 8	721	43	Referent			5.3	1.9	8.7	
≥9	180	11	1.75	0.82	3.72	8.9	1.7	16.1	0.15
Calf birth weight									***0.57***
Below average	515	44	1.16	0.71	1.89	6.8	2.6	10.9	0.57
Above average	550	32	Referent			5.9	2.2	9.7	

[1] includes Brahman cross

7.3 Reproductive physiology and metabolic changes in *Bos indicus* cows in response to nutrition during the dry and wet seasons

The experiments in northern Australia further highlighted the importance of BCS for reproductive success. The amount of BCS loss in lactating cows was significantly associated with risk of non-pregnancy within four months of calving, with cows that lost more condition less likely to become pregnant (P <0.01, Table 23). Managing breeders to maintain or minimise loss of BCS whilst lactating will reduce the risk of non-pregnancy within four months of calving and maximise breeder performance.

Table 23. Impact of change in body condition score (BCS, 1-5 scale) during the wet season on the risk on non-pregnancy within four months of calving in lactating *Bos indicus* cows

Values within columns followed by different letters are significantly different at $P \leq 0.05$

BCS loss (1-5 scale)	Raw observations		Non-pregnant cows (%)	95% confidence interval	
	Not pregnant (n)	Pregnant (n)		Lower	Upper
< -0.5	52	15	78[a]	67.6	87.6
-1.0 to -0.5	55	15	79[a]	68.9	88.2
-1.5 to -1.0	51	5	91[b]	83.6	98.6
-2.0 to -1.5	32	7	82[ab]	70.0	94.1
>= -2.0	9	0	100[c]	100	100

Weaning calves is a good strategy to minimise loss of liveweight and BCS in cows. In the second Australian experiment we found that cows that lactated during the dry season lost more liveweight than cows whose calves were weaned (Table 24). Lactating cows also lost BCS during the dry season, while non-lactating cows were able to maintain BCS. Both groups of cows gained liveweight at similar rates during the following wet season.

Non-pregnant *Bos indicus* cows of different physiological status underwent different rates of tissue catabolism and synthesis and adjusted energy metabolism to attain a similar liveweight over one year. Circulating IGF-1 and insulin appear to be key circulating factors that drive this response. The concentration of IGF-1 in the plasma of cows was low at the start of the experiment when all cows were lactating (Figure 10). The concentration of IGF-1 increased and was higher at the end of the dry season (November) in cows that did not lactate. The concentration of insulin in the plasma decreased in both groups of cows over the dry season.

In the transition from the dry to wet season, there were significant increases in the concentration of all metabolites in response to the rapid change in pasture crude protein content and digestibility after early wet season rain. The concentration of leptin in the plasma of cows changed in association with BCS, as expected, but appears to be less sensitive to changes in diet quality (i.e. at the start of the wet season) than IGF-1 and insulin. There were no significant differences in the concentration of IGF-1, insulin or leptin in the plasma of cows during the mid- (January) to late- (April) wet season.

Table 24. Change in liveweight and body condition score (BCS) of non-pregnant *Bos indicus* cows that did or did not lactate during the dry season in northern Australia

Values are least-square means ± standard error

Values within rows and liveweight or BCS, with different letters are significantly different at $P \leq 0.05$

Interval	Liveweight (kg)		BCS (1-5 scale)	
	Lactation	No lactation	Lactation	No lactation
WR1 to WR2[1]	-78 ± 4[a]	-57 ± 4[b]	-0.5 ± 0.1[a]	+0.1 ± 0.1[b]
Dry season[2]	-102 ± 5[a]	-80 ± 5[b]	-0.5 ± 0.1[a]	0.0 ± 0.1[b]
Wet season	+129 ± 6	+115 ± 5	+1.0 ± 0.1[a]	+0.7 ± 0.1[b]
Overall	+27 ± 8	+36 ± 4	+0.4 ± 0.1[a]	+0.7 ± 0.1[b]

[1] Weaning muster 1 (WR1, June 2012) to weaning muster 2 (WR2, October 2012)

[2] Dry season continued for an additional 30 days after WR2

Results from the RNA-seq analysis are not presented within this report due to the amount of data generated but are available as supplementary material upon request. A large number of differential expressed genes were detected by RNA-seq between the end of the dry and end of the wet season samples, and a lower number of differentially expressed genes were observed between the two groups of cows at either time of sampling.

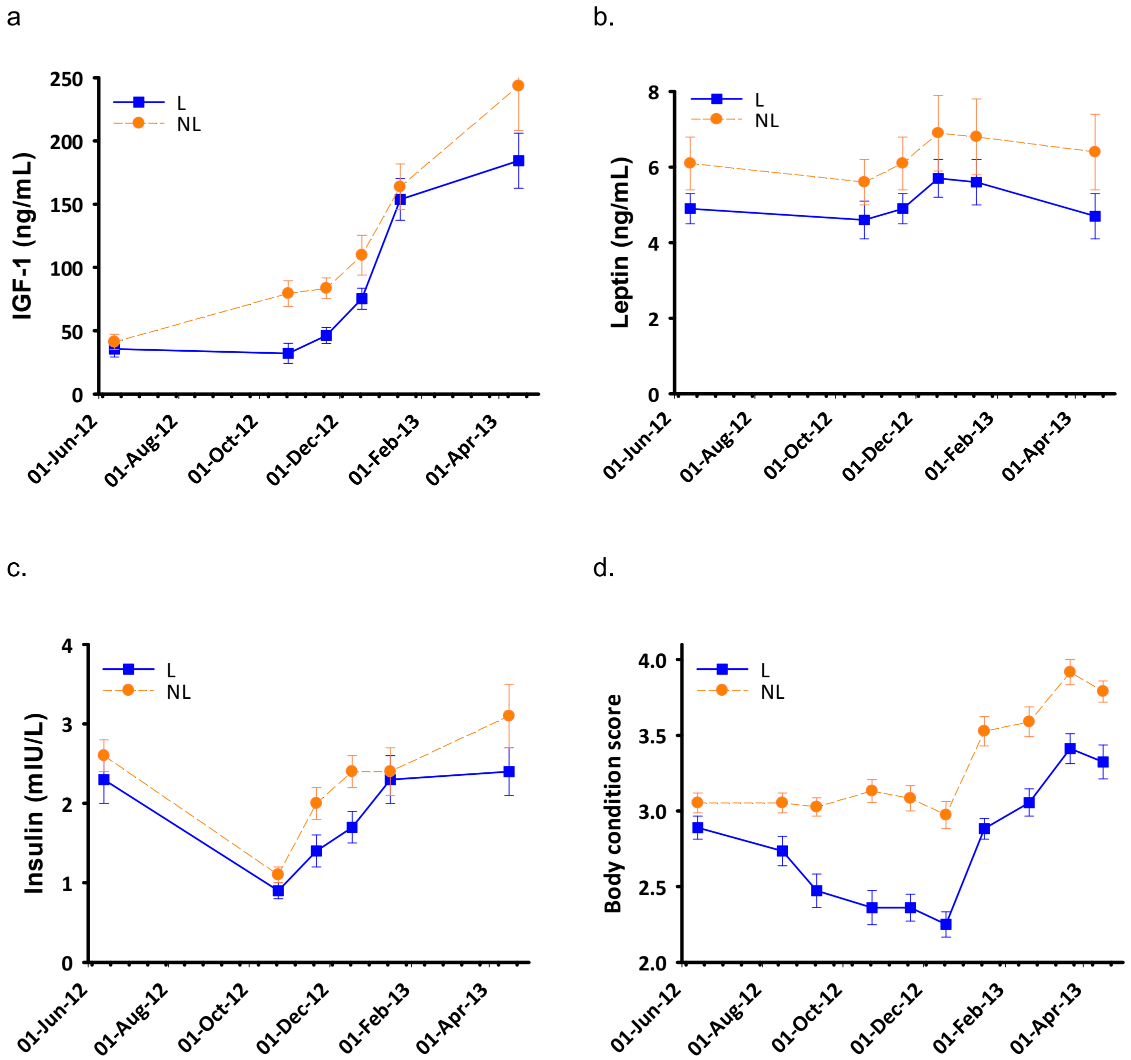

Figure 10. Change in plasma concentrations of (a) insulin-like growth factor 1 (IGF1), (b) leptin and (c) insulin, and (d) body condition score of cows that did (L) or did not (NL) lactate during the dry season. Dry season was June to November, wet season started in December.

7.4 Options for growth and fattening in villages

Current village fattening

A socio-economic survey was conducted of 60 small- and medium-scale cattle fatteners in lowland (Pasuruan-Probolinggo) and upland (Malang) districts in East Java, in conjunction with monitoring of 93 cattle during July-September 2010 (dry season) and January-March 2011 (wet season). Small-scale producers owned 1-2 bulls while medium-scale producers fattened 10-20 bulls in one period. The cattle breeds included local Ongole cattle and European crossbred cattle (Limousin-Ongole and Simmental-Ongole). There were 42 small-scale farmers and 18 medium-scale farmers; none of the medium-scale fatteners had Ongole cattle.

The characteristics of farmers running small-scale fattening operations were similar to those of beef cattle breeders and growers running cow-calf operations in the same districts. The distinguishing features of the farmers running medium-scale fattening operations were their higher level of education and the number of cattle owned. Medium-scale fatteners were more commercialized, buying in stock for fattening over 6-8 months, and buying most of their feed, including grasses, crop by-products, and concentrates. Small-scale fatteners were essentially growing their own bulls to 24 months, and relying more on cut-and-carry, using their own feed resources and/or labour, with little use of purchased concentrates.

Expenditure on feed by small-scale farmers was about 50% higher for European crosses than for Ongole bulls, and 50% higher for medium-scale operations than small-scale operations (Priyanti *et al.* 2012c). However, within each type of operation, there was no difference between wet and dry seasons. Overall, feed expenditure levels were lower than reported in other studies in Java. The daily growth rate of the crossbred bulls was 2-3 times higher than that of Ongole bulls, which were only fattened in small-scale operations. Growth rates for Limousin-Ongole and Simmental-Ongole bulls were similar, and there was no significant difference in growth rates between small and medium scale fattening operations, or between wet and dry seasons.

Using income over feed cost (IOFC) as the financial performance criterion, the results show that for small-scale operations, Simmental-Ongole bulls gave a significantly higher return than either Ongole or Limousin-Ongole bulls (4,700 IDR/day in the wet season and 6,000 IDR/day in the dry season). On the other hand, Limousin-Ongole bulls gave a higher IOFC than Simmental-Ongole bulls in medium-scale operations (2,700 IDR/day in the wet season and 2,500 IDR/day in dry season). Small-scale farmers achieved equal or higher IOFC for European-cross bulls than medium-scale farmers in both seasons. This reflects that their cash outlays for feed were about two-thirds that of medium-scale operations while the daily growth rates were similar. If the non-cash costs of acquiring feed were added to the budget for the small-scale operations, the difference in IOFC would be less. Nevertheless, the study shows that small-scale fattening operations, relying on family labour and local feed resources, can be financially competitive with medium-scale operations in both wet and dry seasons if fattening European-cross rather than Ongole bulls. However, overall the financial returns were very low, reflecting lower than potential growth rates.

The measured growth rate of all breeds of cattle (average 0.3 ± 0.02 kg/bull.day) kept by farmers in villages was lower than expected, and lower than the genetic potential of the breeds (Table 25). For example, Cruz de Carvalho *et al.* (2010) reported daily gains of 0.86 kg/day for Ongole cattle and 0.99 kg/day for Simmental-Ongole bulls fed a mixed diet of concentrate, elephant grass, soybean hulls and cassava. Brahman and Brahman cross bulls kept under feedlot conditions are also capable of gaining liveweight at ≥ 1 kg/day in large commercial feedlots. The low growth rates recorded in the village monitoring are most likely due to the poor quality of the feed fed to the bulls.

Table 25. Liveweight gains (kg/bull.day) of Ongole, European-Ongole cross (OngoleX), Brahman and European-Brahman cross (BrahmanX) bulls kept by farmers in East Java

Values are average ± standard error.

Values within the table followed by different letters are significantly different at $P \leq 0.05$

Breed	Dry season	Wet season
Ongole	0.20 ± 0.04^{a}	0.21 ± 0.03^{a}
OngoleX	0.34 ± 0.05^{ab}	0.39 ± 0.03^{b}
Brahman	0.41 ± 0.06^{ab}	0.26 ± 0.06^{ab}
BrahmanX	0.48 ± 1.0^{b}	0.39 ± 0.07^{ab}

The types of feed offered to cattle were grouped into low, medium and high quality based on nutritive value;

- Low quality: rice straw, corn stover & ears, sugarcane tops and peanut skins.
- Medium quality: native grass, elephant grass, rice bran
- High quality: concentrate, molasses, cassava, ketchup waste, tofu waste

Across all breeds and seasons, 86-100% of the diet was comprised of low and medium quality feed types (Table 26). On average, over half (55%) of feed fed to bulls was poor quality crop residues. Both crude protein and metabolisable energy would be limiting growth of bulls fed these diets.

Table 26. Total feed offered (average ± standard error) and proportion of low, medium and high quality feeds fed to Ongole, European-Ongole cross (OngoleX), Brahman and European-Brahman cross (BrahmanX) bulls kept by farmers in East Java

Values within the columns followed by different letters are significantly different at $P \leq 0.05$

Breed	Total feed offered (kg fresh weight)	Low quality (% total)	Medium quality (% total)	High quality (% total)
		Dry season		
Ongole	30.4 ± 1.17^{ab}	62^{a}	38^{ab}	0^{a}
OngoleX	26.8 ± 1.51^{acd}	41^{b}	45^{bc}	14^{b}
Brahman	26.2 ± 3.34^{ad}	62^{ac}	34^{a}	4^{c}
BrahmanX	27.5 ± 1.97^{abcd}	58^{ac}	38^{abc}	4^{c}
		Wet season		
Ongole	24.6 ± 0.88^{d}	52^{c}	48^{c}	0^{a}
OngoleX	27.7 ± 0.74^{abcd}	77^{d}	15^{d}	9^{d}
Brahman	25.0 ± 0.84^{d}	54^{ac}	44^{abc}	2^{ac}
BrahmanX	27 ± 0.83^{abcd}	36^{b}	64^{e}	0^{ac}

Ongole bulls had the lowest growth rates across all monitoring periods (Table 25). The superior performance of Brahman and crossbred cattle could be due to differences in animal management as well as genetics. Farmers with Brahman, European-Ongole cross and European-Brahman cross bulls were more likely to feed good quality feed to their cattle, especially during the dry season (Table 26). This is similar to what was observed within the cow-calf system, and may indicate that farmers understand that Brahman and crossbred cattle have higher energy and protein requirements compared to local Ongole cattle, or are feeding in response to higher market prices. Interestingly, farmers keeping European-Ongole cross bulls fed the largest amount of high quality feeds, and growth of European-Ongole cross bulls was similar to that of Brahman and European-Brahman cross bulls.

There was no significant difference in average daily liveweight gains between the wet and dry seasons for any of the breeds. Farmers tended to feed more green feed in the wet season, but more high quality supplements during the dry season (Table 26).

On-station breed comparison experiment

In order to gain a better understanding of the breed differences observed in village monitoring studies, we conducted an experiment where Ongole, Limousin-Ongole and Brahman bulls were all fed the same diet under controlled conditions (Experiment 5 in Table 3). Under the conditions of our experiment, Limousin-Ongole bulls performed better than Ongole or Brahman bulls. Limousin-Ongole bulls had the highest average daily liveweight gain (0.26 kg/day) and most efficient feed conversion (0.07 kg liveweight gain/kg DM intake) when fed elephant grass *ad libitum* (Table 27). All values were low in comparison to other published data.

Table 27. Dry matter intake, liveweight gain and feed conversion rate of Ongole, Limousin-Ongole (OngoleX) and Brahman bulls fed elephant grass *ad libitum*

Values are average ± standard error

Results within columns followed by different letters are significantly different at $P \leq 0.05$

Breed	Liveweight (kg)	Intake (g DM/kg W.day)	Liveweight gain (kg/bull.day)	Feed conversion (kg gain/kg DM intake)
Ongole	167 ± 1.2	21.2 ± 0.31[a]	0.18 ± 0.02[a]	0.05 ± 0.006[a]
OngoleX	188 ± 1.4	20.5 ± 0.32[a]	0.26 ± 0.02[b]	0.07 ± 0.006[b]
Brahman	192 ± 1.6	16.0 ± 1.67[b]	0.11 ± 0.01[c]	0.03 ± 0.003[c]

However, differences in growth and feed conversion between breeds appeared to be primarily related to differences in the age, liveweight and condition of bulls at the start of the experiment. Brahman bulls were significantly younger (0.8 years) than Ongole or Limousin-Ongole bulls (1.2 and 1.4 years), and had a higher initial liveweight and BCS (188 kg, BCS 3.6) than Limousin-Ongole bulls (171 kg, BCS 3). Limousin-Ongole bulls had higher liveweight and BCS than Ongole bulls (157 kg, BCS 2.4). When initial age, liveweight or BCS of bulls were used as covariates in the statistical analysis, there was no difference in average daily liveweight gain and feed conversion between breeds.

Differences between breeds at the start of the experiment occurred because bulls had to be purchased from local farmers, feedlots and markets prior to the start of the experiment. The absence of cattle scales at most cattle markets and farms in Indonesia meant that the bulls were purchased based on an estimated liveweight. In addition, the history of most animals prior to the experiment was not known, and factors such as previous nutrition or stress during transport to the market may have affected their performance during the experiment. While these factors may have affected our results, they also reflect the current conditions in Indonesia and what can be achieved in village based systems.

Growth of all cattle was lower than expected, and below the genetic potential of each breed. Average daily liveweight gains were also below the values recorded in the village monitoring activities (Table 25).The low growth rates of all breeds of cattle were most likely due to the low quality of the elephant grass, which was harvested at a mature stage and contained a high proportion of stem (31% of feed offered on a DM basis).

Crude protein requirements of growing bulls

Inadequate supply of energy and protein to village bulls was identified as a key constraint to increasing liveweight gains. Three experiments were conducted to estimate the minimum crude protein requirements for growth of young Ongole and Bali bulls and mature Ongole bulls (Table 3).

Crude protein requirements of young Ongole bulls were estimated to be ≥13%. Young Ongole bulls fed diets containing 11% crude protein had significantly lower ($P = 0.03$) average daily liveweight gains (0.34 kg/bull.day) compared to bulls fed diets containing between 13 and 19% crude protein (0.47 kg/bull.day, Figure 11). There was no significant difference in average daily liveweight gains between treatments for either the mature Ongole bulls or young Bali bulls. Based on this, it was suggested that mature Ongole bulls require diets containing at least 12% crude protein, while young Bali bulls require at least 10% crude protein.

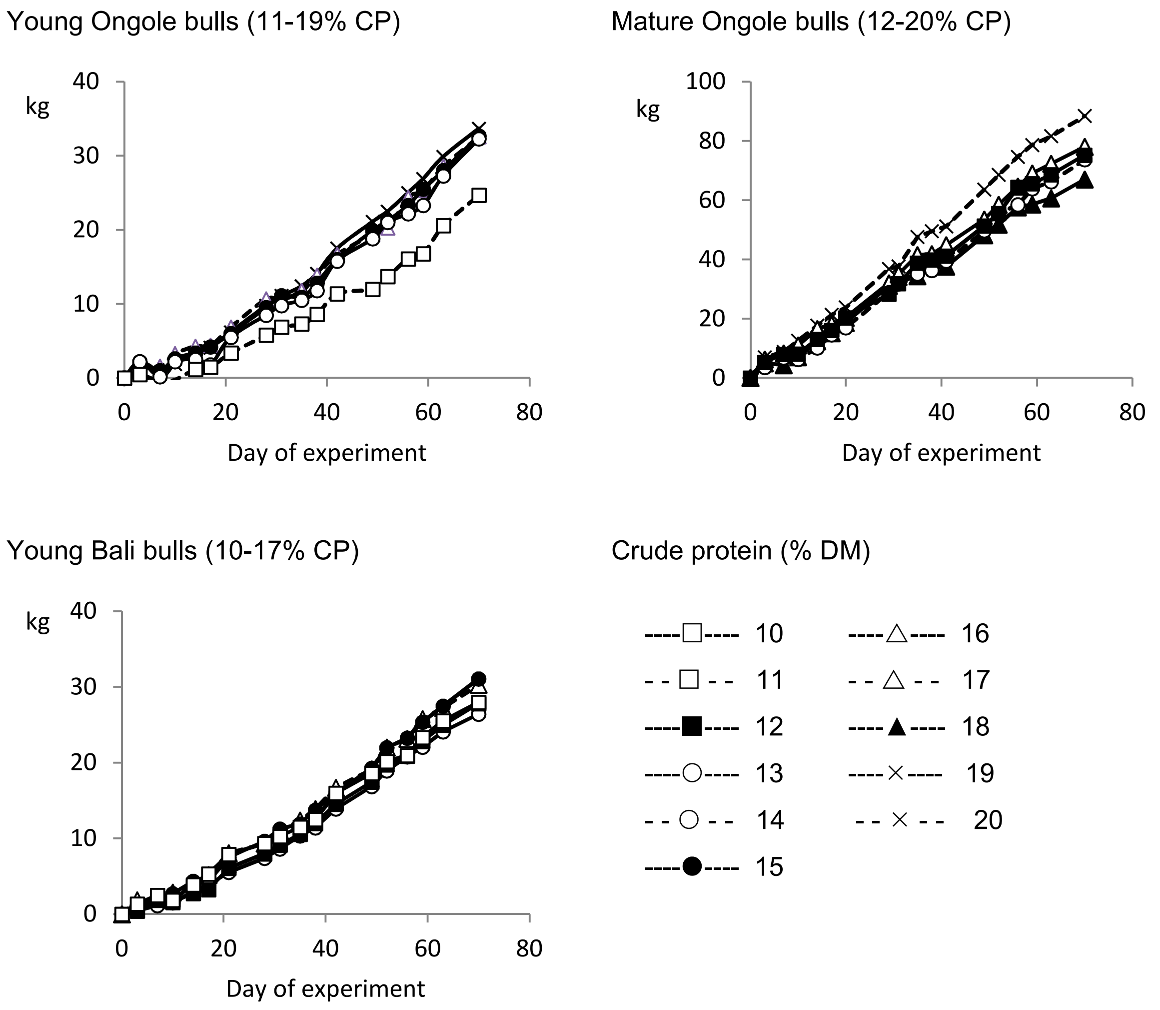

Figure 11. Cumulative liveweight gain of bulls fed diets containing different levels of crude protein

Interestingly, when diets were modelled (post-experiment) using the Large Ruminant Nutrition System, the diets fed to mature Ongole bulls were identified as lacking in ME content. While it is difficult to know if ME content did actually limit growth of bulls during the experiment, it is a possible confounding factor.

In the village monitoring of growing bulls, we found that the majority of bulls were fed diets based almost entirely on rice straw, corn stover, sugarcane tops, native grass, elephant grass and rice bran (Table 26). None of these feeds contain more than 10% crude protein, confirming that growth of all breeds of bulls in villages was limited by the level of crude protein in their diets. The level of crude protein in elephant grass is also likely to have limited the growth rates of bulls in the breed comparison experiment at BCRI (Table 27).

The potential growth rates of Ongole and Bali bulls when crude protein is not limiting are displayed in Table 28 below. When crude protein was not limiting, both young Ongole and young Bali bulls were able to gain 0.4 kg/day. Mature Ongole bulls were able to gain 1.12 kg/day.

Table 28. Intake and growth rates of Ongole and Bali bulls fed elephant grass and a maize and soybean meal concentrate containing sufficient crude protein for growth.

Values are average ± standard error

Results within columns followed by different letters are significantly different at $P \leq 0.05$

Breed	Liveweight (kg)	Total intake (g DM/kg W.day)	Liveweight gain (kg/bull.day)	Change in height (cm/bull)
Young Ongole	108 ± 1.0	22.6 ± 0.13^{a}	0.47 ± 0.021^{a}	8 ± 0.5^{a}
Young Bali	87 ± 0.6	22.1 ± 0.25^{b}	0.42 ± 0.011^{a}	8 ± 0.4^{a}
Mature Ongole	339 ± 2.1	20.8 ± 0.12^{c}	1.12 ± 0.043^{b}	4 ± 0.3^{b}

Options for increasing the liveweight gain of growing bulls kept by smallholder farmers

Information from the on-station bull experiments was used to design rations that could be used by farmers to increase the growth rates of their bulls. In a final on-station experiment (Experiment 6, Table 3), we compared the best quality local forage (elephant grass *ad libitum*), with two diets formulated from locally available feed resources. Diets were formulated to meet the crude protein and ME requirements for growth in a least-cost fashion, and included onggok, copra and palm kernel cake. Our results demonstrated that a modest, strategic increase in daily feed cost, using local feed resources, can have a much greater return in terms of average daily gain and cost-efficiency of growth (Table 29).

The highest average daily liveweight gains measured in this experiment were from bulls fed elephant grass and the balanced concentrate, which contained high levels of copra meal and palm kernel cake. These two ingredients increased the protein and ME content of the diet, resulting in an average daily gain of 1.00 kg/bull.day. Although the daily feed cost of this ration was the highest of the three tested, the high growth rate of bulls fed this diet meant it had the lowest cost of liveweight gain.

The liveweight gain of bulls fed the high onggok concentrate was below expectations at 0.24 kg/bull.day. Bulls offered the high onggok concentrate consumed less concentrate than bulls supplemented with mixed concentrate (3.43 kg DM/day and 5.78 kg DM/day, respectively), and it is possible that the high inclusion rate of the onggok reduced the palatability of the concentrate. Even though this diet had a moderate daily feed cost, the poor growth performance meant that the cost per kg of liveweight gain of this diet was very high.

Table 29. Growth and feed conversion efficiency of Ongole bulls (313 ± 1.9 kg) fed elephant grass *ad libitum* (EG) or elephant grass at 20% of *ad lib* intake plus one of two supplements formulated to meet energy and protein requirements for growth at least cost.

Balanced concentrate: 50% onggok, 25% copra, 25% palm kernel cake; high onggok concentrate: 85% onggok, 7.5% copra, 7.5% palm kernel cake.

Values within rows followed by different letters are significantly different at $P \leq 0.05$

	EG	EG + Balanced concentrate	EG + High onggok concentrate	SE
Dry matter intake (g/kg W.day)	16.7^a	21.8^b	17.2^a	0.09
Liveweight gain (kg/bull.day)	0.23^a	1.00^b	0.24^a	0.04
Feed conversion (kg liveweight gain/kg DM intake)	0.04^a	0.14^b	0.04^a	0.01
Feed cost (IDR/bull.day)	32,499^a	61,539^b	25,491^c	553
Cost of liveweight gain (IDR/kg)	26,378^a	11,761^b	32,465^c	365

Elephant grass is among the best quality of the local forages commonly fed to fattening bulls in East Java. However, its low ME and crude protein content limited the growth of fattening bulls in this experiment. Although the daily feed cost of the elephant grass diet was small, low liveweight gains meant that the cost per kg of liveweight gain for bulls fed this diet was very high. Elephant grass was purchased for this on-station experiment and costed at IDR 200/kg fresh weight. In a village situation, grass forages are generally not purchased, and only have a labour cost associated with them.

Based on the results from the on-station experiment, the balanced concentrate was fed to European-Ongole cross bulls as part of a village intervention at a rate of 4.4 kg DM/bull.day (approximately 12.5 g DM/kg W.day). Bulls fed the concentrate supplement gained liveweight nearly twice as fast as those in a control group that had no changes made to their feeding (Table 30). This additional liveweight gain increased the farmer's IOFC (Priyanti *et al.* 2012c) for the fattening period, making the intervention diet more profitable. The liveweight gain and the IOFC for the control were considerably higher than recorded for the earlier village monitoring study reported above.

Feeding a better quality diet can benefit the farmer in two ways: 1) for a given fattening period, a single bull will have a heavier sale liveweight, or 2) the farmer can fatten more bulls each year. The additional revenue from the increased liveweight of beef produced in that time exceeds the extra costs incurred from feeding the higher quality feed. This fattening strategy does have greater input costs, and requires that the farmer have adequate disposable income to purchase feed before the sale of the bull returns the profit to the enterprise.

Table 30. Growth, feeding costs and profitability of village European-Ongole cross bulls (341 ± 7.4 kg) in East Java.

Bulls in the intervention group were offered a concentrate supplement at 4.4 kg DM/bull.day. No changes were made to the farmers' feeding practice in the control group.

Values within rows followed by different letters are significantly different at $P \leq 0.05$

	Control	Intervention	SE
Liveweight gain (kg/bull.day)	0.52[a]	0.89[b]	0.06
Daily feed cost (IDR/bull.day)	2,606[a]	8,827[b]	589
Cost of liveweight gain (IDR/kg liveweight gain)	5,543 [a]	11,990[b]	1,159
Bull sale price (IDR/kg liveweight)	35,696	37,232	627
Income over feed cost (IDR/day)	15,774[a]	24,182[b]	1,936

The average daily feed cost of the intervention group (purchased feeds + value of intervention supplement) was significantly higher than the control group (purchased feeds only). The cost of liveweight gain was also higher for the intervention diet. However, once the limitation of time was introduced in IOFC, the intervention diet gave greater profit for the fattening period. The daily feed cost of village diets includes the purchase value of the supplied concentrate supplement as well as the actual cost of any feeds purchased by the farmer. It does not include the value of labour or transport used in obtaining feeds, nor the value of feeds obtained opportunistically or free of charge. Any estimate of those costs applied to this data would increase the daily feed costs.

Interestingly, the liveweight gain achieved by the control animals was much higher than other survey data measured in this project. Thus the costs of liveweight gain are very dependent on the feed quality. This also shows that growing high quality forages for bulls is a very profitable strategy.

Farmers in the intervention group fed the same amount of non-intervention feeds as did farmers in the control group (control 7.71 kg DM/bull.day, intervention 7.79 kg DM/bull.day). We know from the literature that there would have been a significant degree of feed substitution under supplementation at this high level. The opportunity thus exists for farmers to feed less forage under the supplement program, which did not appear to be realised here.

The feed costs used in the calculations for this analysis were the actual prices paid to local traders and to the research station for the feed ingredients. The price of high quality feed supplements will vary over time, between seasons and geographic locations within Indonesia. Therefore, this is not intended as a best-bet feed ration for all situations. However, it does demonstrate that by using locally available ingredients, farmers can easily increase the growth of their bulls and the profit of their fattening operations, echoing the findings of our earlier analyses of best bet feeding strategies for Bali calves (Priyanti *et al.* 2010). The relationship between nutritive value and price of concentrates and by-products in Indonesia requires further investigation.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Scientific impacts are in the form of new information gained from on-station experiments and village monitoring activities. This knowledge builds on lessons from previous ACIAR projects on beef cattle production in Indonesia. A large amount of high-quality scientific data was generated during the current project, as evidenced by the number of publications to date. These publications are detailed in section 10.2 below.

To our knowledge, the monitoring of cattle in villages is the largest and most rigorous survey of cow-calf production in Indonesia. Although this information has not yet been fully analysed and published, it is expected that results will contribute to the development of the Indonesian beef cattle industry.

Key scientific impacts to date include;

- Demonstration of the straw cow model on-station and in villages. Cows of all breeds were able to maintain liveweight on a rice straw-based diet if provided with small amounts of tree legumes (approximately 0.3% liveweight on a DM basis)
- Insights into the nature of smallholder cow-calf systems, demonstrating their importance to land-poor and landless households in the densely-populated lowlands of East Java.
- New insights into the structure and functioning of the market for cattle feed in East Java, whereby surplus crop by-products (especially rice straw and maize stover) are efficiently supplied to cattle producers, many of whom have no paddy land or indeed no crop land.
- Confirmation that Brahman cows can successfully reproduce within Indonesian smallholder farming systems if they are given proper nutrition to maintain good BCS, and there is good mating management. Reproduction rates of Brahman cows were similar to Ongole cows.
- Demonstration that smallholder Brahman operations can be economically successful, particularly when farmers have adequate land to produce feed.
- Identification of key issues limiting reproductive success of cattle kept by smallholder farmers in Indonesia. Calving intervals and successful rearing of calves were related to cow breed, BCS, length of lactation, and mating management.
- Identification of yield gaps in beef production by fattening cattle due to inadequate nutrition. We have demonstrated on-station and in villages that strategic use of high-energy by-products can increase cattle growth rates and farmer income.
- Demonstration that farm-gate prices of cattle are sensitive to key parameters including measured liveweight and BCS, implying the effective transmission of market signals to small-scale operators via local traders in the beef supply chain.
- Understanding of the factors affecting the profitability of small- and medium-scale fattening operations and the potential to increase growth rates and income.
- Comparison of metabolisable energy requirements for maintenance of liveweight in different breeds of cattle in Indonesia. Bali cows have smaller metabolisable energy requirements compared to Ongole cows. Brahman cows had the highest metabolisable energy requirements.
- Quantification of the impacts of nutrition on growth and development of puberty in Bali heifers. This has implications for lifetime productivity of Bali cows.
- Developed an understanding of the key hormonal and gene responses to diet and metabolic state of *Bos indicus* cows. This includes the use of RNA-seq analysis to develop an understanding of the gene pathways responsible for re-alimentation of muscle in cows managed under extensive conditions, typical of those found across northern Australia.

8.2 Capacity impacts – now and in 5 years

8.2.1 Staff capacity

A strong emphasis was placed on building the capacity of staff during the project. All staff were given the opportunity to develop their skills and experience through attendance at a wide range of workshops, training activities, meetings, conferences or postgraduate study.

The greatest achievements in capacity building were in the sharing of knowledge and experiences between scientists across the different sites in Indonesia and Australia, and the creation of networks that will outlast this project. For example, Professor Marsetyo (UNTAD) acted as a mentor for staff at BCRI involved in the on-station experiments, Dr Tanda Panjaitan (BPTP NTB) and Dr Dahlanuddin (UNRAM) provided advice to project staff and collaborating farmers in Lampung, and Tri Wahyudi (Junior Scientist at BCRI) worked with other project Junior Scientists employed through BPTP Lampung to enrol Brahman cattle at the start of that phase of the project. These networks have recently expanded into other countries, with Tanda Panjaitan visiting Myanmar to help with the establishment of a similar ACIAR project (AH/2011/054). Dahlanuddin has been involved with several ACIAR projects in Timor Leste (e.g. LPS/2011/004).

Scientists at all sites benefitted from interaction with experienced Australian and Indonesian scientists. The involvement of these senior scientists in all stages of experimental work on-station and in the villages has demonstrated the need for good scientists to be involved in the hands-on aspects of project research, rather than just delegating tasks and supervising technicians. It has also instilled in the junior scientists the need to pay attention to detail and keep good records in order to get good results. The Australian scientists have benefited by developing a greater understanding of the unique challenges faced when trying to run an experiment or fieldwork in a developing country.

One of the aims of the project was to develop the capacity of new scientists, and the project funded 12 full-time junior scientist positions. These scientists worked in the village sites in Lombok, Sulawesi Tenggara, East Java and Lampung (7), on on-station experiments at BCRI and UNRAM (3), and with the socio-economic team (2). Where possible, we also tried to involve junior researchers already employed by collaborating organisations in the project activities. These junior staff embraced the opportunity to work within the project, and took on greater levels of responsibility as the project progressed. At the conclusion of each project annual meeting we held a training day specifically targeted at the younger project staff. This has helped the junior staff to develop and maintain professional networks with their peers that will benefit them after the completion of the project. Within Australia, postdoctoral researchers were employed by the project and provided with the opportunity to continue their involvement in international agricultural research.

The career progression of more senior scientists has also been important to the project, and several project staff members were promoted or received awards during the project. Dr Dicky Pamungkas became the head of BCRI, and Takdir Saili was promoted to Professor and Dean of Animal Science at UNHALU. Atien Priyanti (ICARD) received a UQ-Indonesia award to visit UQ for several weeks during 2014, and Dahlanuddin (UNRAM) was elected to the international committee of the International Symposium on the Nutrition of Herbivores, and is also the inaugural director of the Large Ruminant Research Consortium.

Workshops and training

Informal training in scientific methodology, experimental design, data management, data analysis and presentation of results was conducted each time Australian scientists visited Indonesia. In addition, we provided formal training courses, which were also attended by non-project staff and students from collaborating institutions. These included;

- Laboratory training and ring test
- Writing scientific papers
- Preparation and presentation of scientific posters
- Preparation and presentation of PowerPoint presentations
- Data analysis and basic statistics

In 2010, we provided the opportunity for two mid-career Indonesian scientists to visit Australia. Dicky Dikman (BCRI) and Takdir Saili (UNHALU) received training in cattle reproduction and pregnancy testing, attended the Australian Society of Animal Production conference, engaged with Australian scientists external to our project, visited cattle stations in the NT and QLD, and developed a better understanding of how beef cattle are managed in Australia.

In 2011, Di Mayberry spent a week with Associate Professor Luis Tedeschi at Texas A&M University to learn about the Large Ruminant Nutrition System (a nutrition model). This model was subsequently used in designing rations for on-station experiments at BCRI, and a paper evaluating its use in Indonesia has been published in Animal Production Science (Mayberry *et al.* 2014).

Conferences and seminars

Training in presentation and communication of scientific results was a key focus of the project. As well as conducting training in scientific communication, we provided opportunities for project participants to attend and present at national and international seminars and conferences. A full list of conferences attended by project staff is outlined in section 8.4.

Seven Indonesian team members were funded through the project to attend international conferences outside of Indonesia:

- Takdir Saili (UNHALU) and Dicky Dikman (BCRI) attended the Australian Society of Animal Production Conference in Armidale, Australia, 2010
- Lukman Affandhy (BCRI) attended the Northern Beef Research Updates Conference in Darwin, Australia, 2011
- Tanda Panjaitan (BPTP NTB) attended the International Symposium on the Nutrition of Herbivores in Aberystwyth, Wales, 2011
- Atien Priyanti (ICARD) attended the Australian Agricultural and Resource Economics Society Conference in Fremantle, Australia, 2012
- Trie Mahendri (ICARD) and Dicky Pamungkas (BCRI) attended the 15th AAAP Animal Science Congress in Bangkok, Thailand, 2012

Five project junior scientists were also funded to attend local conferences:

- Theo Mahiseta Syahniar (BCRI), Ismi Jasila (ICARD), Fuad Cahyadi (ICARD) and Sahrul Gunadi (BPTP NTB) attended the Indonesian National Seminar in Bogor (2011, 2012) or Medan (2013)
- Giyar Prapti Ningrum (BCRI) attended the Animal Production International Seminar in Malang, 2013

In addition, several staff were funded by ACIAR to attend the following international conferences:

- Atien Priyanti attended the Global Conference on Women in Agriculture in New Delhi, India, 2012
- Dian Ratnawati (BCRI), Marsetyo (UNTAD) and Sahrul Gunadi (BPTP NTB) attended the 16th AAAP Animal Science Congress in Yogyakarta, November 2014

Australian scientists also had the opportunity to attend and present at international conferences. In particular, Dennis Poppi and Simon Quigley were invited to speak at the

Indonesian National Seminars in 2009 and 2013, respectively. Di Mayberry was invited to speak at the XXIV Brazilian Congress of Animal Science (Brazil, 2014).

Although we could not fund all project staff to attend conferences, all junior scientists gained experience in presenting oral and poster presentations at the project annual meetings. This provided a friendly environment for them to practice their presentation skills, and the presentations were generally of a very high standard.

Education

We recognised the importance of postgraduate education for young scientists, and have done our best to provide opportunities to those that were interested in continuing their education.

During the project, two of the junior scientists employed in Lombok used project work to contribute to their Masters degrees at UNRAM. Fahrul Irawan and Sahrul Gunadi graduated in 2013 and 2014, respectively. The project also helped another junior scientist, Theo Mahiseta Syahniar, to secure a scholarship to complete a Masters degree in animal production at IPB in Bogor.

Three young scientists from BCRI and ICARD were awarded John Allwright Fellowships to study at the University of Queensland; Risa Antari (PhD), Trie Mahendri (PhD) and Dicky Dikman (Masters). Another two young scientists (Vyta Hanifah and Reny Tambunan) received scholarships to study in the UK and New Zealand.

Multiple undergraduate students from local universities in East Java were involved in the on-station experiments at BCRI as part of their degree. Three students used results from experiments as part of their honours projects.

8.2.2 Infrastructure & institution capacity

In order to complete project activities to an international standard, the capacity of institutions to conduct scientific research was improved. This included;

- Upgrades to existing kandang infrastructure at BCRI, UNRAM and UNHALU (e.g. improved flooring, better partitioning between individual animal pens, larger feed troughs)
- Construction of a new kandang with 30 individual cattle pens at BCRI
- Purchase of capital items including cattle scales, feed chopper, motorbikes
- Purchase of lab equipment required for accurate proximate analysis of feed
- Purchase of office and communication equipment (e.g. laptop computer, camera, modem, printer)
- Provision of printed resources (e.g. ACIAR publications on cattle production, MLA publications on cattle management)

Items purchased for use by project Junior Scientists were retained by the institutions at completion of the project. In many cases, items purchased using project funds differed to those specified in the original project budget. This was because the needs of each individual institution changed during the project.

8.3 Community impacts – now and in 5 years

This was primarily a research project to demonstrate the potential of a ‘straw cow’ system and to identify and solve potential problems associated with implementation at a village level. The villages were experimental units, and the focus of the project was on creating good quality data, rather than extension. Hence, there has been limited impact outside of households involved in the project at the current time.

Examples of problems identified during the project were (1) poor BCS of cows due to inadequate nutrition, with negative consequences for reproduction, and (2) poor mating management, which particularly with individually-penned *Bos indicus* cattle was driven by poor oestrus detection.

Due to the efforts of the village teams, some practice changes are apparent:

- An emphasis was placed on maintaining good cow condition, with a targeted BCS of 3 or higher at calving. Understanding by farmers of the importance of good cow condition has caused changes in feeding practices, and there has been an increase in average BCS of cows at calving at all sites.
- Emphasis was also placed on oestrus detection as some farmers were unsure of what to look for. Training has been put into farmers knowing the physical signs and timing of the oestrus cycle. Combined with better cow BCS, this has resulted in a decrease in observed post-partum anoestrus interval at many sites.

Long term, if a dedicated extension effort was implemented, the following are potential impacts from this project:

- More effective breeder management would significantly increase weaning percentage. More work needs to be done around the AI and mating system where bull access is difficult.
- Growth of bulls would increase markedly if simple least-cost rations were implemented at the village level. More work needs to be done to identify suitable rations for smallholder farmers, and ways to improve the economic access of smallholders to suitable feeds for fattening.

More specific examples of economic, social and environmental impacts are listed below.

8.3.1 Economic impacts

The research outcomes described above, such as improved reproduction and growth rates through better feeding and mating management, can increase farmer income. These improvements have the potential to make a significant economic impact in East Java. The growth in population and incomes in Indonesia has accelerated the demand for beef, generating increased process and creating improved livelihood options for a range of poor rural households in East Java, a province with over 6 million poor largely concentrated in rural areas. Nearly 2 million rural households pursue small-scale cattle production as one of their livelihood activities along with other farm and off-farm sources of income.

Small-scale cattle producers include some households in which the labour, livestock and feed resources are combined in one production entity, as well as others for whom the ownership and management of these production inputs is dispersed among several actors. Thus, even households with little or no cropland, nor even their own cattle, can benefit to a degree from the growth in the demand for beef by raising cattle on a share basis and collecting or buying feed from other people's cropland. Likewise, the need to link feed supply and demand beyond the farm boundary has created new livelihood options for other rural households in the feed supply chain.

Though all households surveyed in the East Java research sites were cattle producers, sources of income were diversified, both within and beyond the farm. Net cash income from all sources was, on average, over 50% higher in the lowland site (IDR 9.5 million) than in the upland site (IDR 6.2 million), but both were close to the poverty line. Cattle accounted for 61% of farm cash income and 32% of household cash income (i.e., including farm and non-farm sources) in the lowland site, and 84% of farm cash income and 55% of household cash income in the upland site. Hence, cattle production was a major source of income for these poor rural households. Farmers in the more densely populated lowland site kept cattle in intensive systems and focused on producing and selling calves. In the upland site, farmers tended to keep cattle longer and sell mature animals. However, in all sites, cash income was the primary motivation for cattle production.

Cattle were mostly sold at the farm gate to local or district traders, who then sold to the larger traders in the marketplace or directly to butchers. Hence the farm-gate price was a crucial determinant of the farmer's revenue. The study has shown that farm-gate prices were significantly influenced by cattle liveweight, breed, and BCS. The price increased by IDR 16,000 (USD 1.66) per kg liveweight. On average, a crossbred animal obtained a price IDR 510,000 (13%) higher than a local (PO) animal of the same weight. Likewise, an improvement in BCS from say 2.5 to 3.5 increased the price obtained by IDR 1,000,000. This suggests that buyers of young animals were anticipating a higher growth rate, and that buyers of mature animals were expecting a higher dressing percentage or carcass weight from crossbred animals or animals in better condition.

The improvements needed to increase reproduction and growth rates could be made with limited additional public investment in farmer training and support. Preliminary budgeting suggests that adopting these kinds of improvements could double the gross farm family income from cattle (i.e. the net returns to family resources of land, labour and capital). This would increase the net cash income of lowland households by 36% to around IDR 12.9 million and of upland households by 55% to IDR 9.8 million. While this would still leave most households just above the poverty line, they are substantial increases that could be expected to lead to the adoption of further improvements.

In this respect, our findings are consistent with those of McDermott *et al*. (2010: 96), who argue on the basis of a global review that 'an increase in public and private investments in smallholder livestock systems would help nearly one billion people use their livestock enterprises as pathways out of poverty . . . Public investment has a role in overcoming the constraints through knowledge and technologies that deliver quality feed, animal health, breeding, technical advice and other services' (2010: 99). McDermott *et al*. (2010) see more potential in extensive, rainfed areas than in the mixed intensive systems of Southeast Asia. However, this study has shown that, even in one of the most intensive farming systems in the world, support for smallholder cattle production can be a viable strategy for poverty reduction.

8.3.2 Social impacts

The potential economic impacts of improved livestock production are closely related to the social impacts. As noted, the incidence of rural poverty remains high in East Java, as well as in other crop-and-cattle provinces. Relatively small increases in household income can make a large difference to the capacity of poor households to remain in the village and to invest in other income sources (e.g., small rural business) and human capital (nutrition, education). These benefits extend to all household members – men, women, and children.

With regard to cattle-raising itself, both men and women participate in this activity, particularly as the cattle are raised in the house compound and sold in the village, making it easier to integrate cattle-related tasks with other domestic activities. Hence in both lowland and upland sites, it was found that women participated in decision-making (e.g., with regard to selling cattle to meet household needs) as well as in activities such as feeding and watering. The role of women cattle farmers needs to be recognized in planning approaches to improving cattle production.

8.3.3 Environmental impacts

Implementation of a more efficient cattle production system could reduce the need to use more land for cattle production. This would include better utilisation of existing feed resources such as crop residues and by-products, and better use of available land resources to grow additional feed (e.g. tree legumes on rice bunds or as living fences). Reduced burning of rice straw would improve local air quality and reduce carbon emissions.

Intensification of cattle feeding practices will result in the easier collection of organic materials that can be used for compost, fertiliser and biogas either within the household or sold to other users.

8.4 Communication and dissemination activities

Information from the project was shared with collaborator farmers and the wider farming, industry and scientific communities. Details of types of communication and dissemination activities are outlined below.

Project meetings

The whole team was invited to participate in the following project meetings;

- November 2009. Batu, East Java. Project initiation and planning meeting.
- October 2010. Sengiggi, Lombok. Annual meeting.
- May 2011. Malang, East Java. Brahman variation initiation and planning meeting.
- November 2011. Kendari, Southeast Sulawesi. Annual meeting.
- November 2012. Bandar Lampung, Lampung. Annual meeting.
- November 2013. Sanur, Bali. Final project meeting.

These meetings were also attended by heads of collaborating institutions, representatives from funding bodies (ACIAR, MLA, DFAT), Indonesian industry (GAPPSI) and government (Dinas Peternakan). The final meeting was also attended by representatives from other ACIAR projects in Myanmar, Timor Leste and Indonesia. The meetings included visits to project village sites, presentation and discussion of project results, monitoring and evaluation of project progress, and planning upcoming activities.

A project newsletter was established as a means of sharing information between sites between meetings.

Scientific publications and conferences

The project team have worked hard to publish results from on-station and village activities. A list of papers published during the project is available in section 10.2, and we expect more publications to follow.

Project members attended and presented results from project activities at the following conferences;

- The 5th International Seminar on Tropical Animal Production. Yogyakarta, Indonesia. October 2010.
- ICARD National Seminar. Bogor, Indonesia. June 2011.
- Northern Beef Research Updates Conference. Darwin, Australia. August 2011.
- International Symposium on the Nutrition of Herbivores. Aberystwyth, Wales. September 2011.
- Australian Agricultural and Resource Economics Society Conference. Fremantle, Australia. February 2012.
- 2nd Joint Conference of the New Zealand and Australian Societies of Animal Production. Lincoln, New Zealand. July 2012.
- ICARD National Seminar. Bogor, Indonesia. October 2012.
- The 15th AAAP Animal Science Congress. Bangkok, Thailand. November 2012.
- The 2nd Animal Production International Seminar on Sustainable Livestock Production Based on Local Resources in the Global Climate Changes Era: Prospects and Challenges. Malang, Indonesia. August 2013.
- Northern Beef Research Updates Conference. Cairns, Australia. August 2013.
- ICARD National Seminar. Medan, Indonesia. September 2013.
- XXIV Brazilian Congress of Animal Science. Vitoria, Brazil. May 2014.

- ICARD National Seminar. Malang, East Java, August 2014.
- Joint International Symposium on the Nutrition of Herbivores and International Ruminant Physiology Symposium. Canberra, Australia. September 2014.
- 8th International Workshop on Modelling Nutrient Digestion and Utilization in Farm Animals. Cairns, Australia. September 2014.
- The 16th AAAP Animal Science Congress. Yogyakarta, Indonesia. November 2014.
- Tropical Agriculture Conference 2015, Brisbane, Australia. November 2015.

Field days & farmer visits

The project village teams held regular group meetings with the 519 collaborator farmers. These meetings provided an opportunity for project staff to address problems faced by the farmers in regards to animal husbandry and management. Specific topics addressed through farmer meetings and monitoring visits included oestrus detection, mating management, weaning of calves, propagation of tree legumes, and preservation and storage of rice straw.

The village teams also organised public events such as field days and cattle competitions. For example, the Lampung village team held two field days and cattle competitions at Tulang Bawang Barat in September 2012 and 2013. These events attracted between 150-200 participants, and were sponsored by Dinas Peternakan. The Lombok team hosted around 250 participants at a field day in April 2012, with a focus on harvesting, storing and feeding of rice straw and tree legumes to cattle. In East Java, BCRI collaborated with the Department of Animal Husbandry and Animal Health in Lamongan to hold a Brahman cow competition as part of their cattle competition, which attracted over 300 participants in May 2013. Small-scale cattle competitions were also held at individual project sites, with prizes awarded based on cattle growth rates, BCS and inter-calving intervals.

Throughout the project, farmers and other people involved in the beef industry were invited to visit the village sites and research stations to view project activities. A summary of visitors to project sites is outlined in Table 31 below. These activities were complemented with a range of printed and visual materials such as leaflets and DVDs.

Table 31. Number of visitors to village sites and on-station experiments.

Number of visitors to UNHALU experiment was not recorded.

Region	Site	Visitors		
		Farmers	Other	Total
Villages				
East Java	Probolinggo	120	158	278
	Malang	30	24	54
	Lamongan	70	302	372
Lampung	Tulang Bawang Barat	209	39	248
	Seputih Banyak	47	67	114
Nusa Tenggara Barat	Lombok	365	100	465

Sulawesi Tenggara	Kolaka	213	285	498
On-station				
East Java	BCRI	190	58	248
Nusa Tenggara Barat	UNRAM	36	89	125

Figure 12. Farmer quiz on cattle management, Lampung. (Photo: Reny Tambunan)

Figure 13. Cattle competition and field day, Lampung. (Photo: Reny Tambunan)

Lampung farmer visit to Lombok

ACIAR provided additional funding for the project team in Lampung to visit Lombok, with the aim of sharing knowledge about cattle management and forage production between the sites. In April 2013, the site coordinator from BPTP Lampung and two project Junior Scientists accompanied two representatives from Dinas Peternakan and six collaborator farmers to Lombok. The group visited several village sites with cow-calf and fattening operations, as well as BPTP NTB and the UNRAM research station.

Figure 14. Farmers, project staff and representatives from Dinas Peternakan in Lampung visited village sites in Lombok. (Photo: Reny Tambunan)

9 Conclusions and recommendations

9.1 Conclusions

This project has successfully demonstrated a model for increasing Indonesian beef production through greater and more efficient use of crop residues (such as rice straw) and improved animal management. If these strategies are adopted, both the reproductive performance of cows and performance of fattening cattle could be increased. This would lead to an increase in income for smallholder farmers and the amount of beef available for domestic consumption.

Ongole, Bali and Brahman cows are all able to maintain liveweight and a moderate BCS on rice straw-based diets if they are supplemented with small amounts of tree legumes to provide additional energy and crude protein. Combined with the IVMS developed in previous projects (weaning of calves at or before 6 months of age and improved mating management), calving rates can be improved without increasing the need for additional feed resources. Between 2010 and 2013, the calving percentage of cows across project sites increased from 22 to 42%. Research from northern Australia suggests that there is potential to increase this even further to at least 70% if all practices were adopted (McGowan *et al.* 2014).

By redirecting resources so that cows are fed rice straw-based diets and the majority of green feed is fed to weaned calves and growing bulls, some broader regional improvements could be achieved. For example, a stocking rate of 1.7 cows/ha in single cropped or 3.3 cows/ha in double cropped areas could be maintained as a high reproduction (70% calving) unit on rice straw-based diets. In East Java, with approximately 2.8 million cows at present, this is an increase in the annual calf drop from 0.6 million to 1.96 million calves each year. The saving in green feed use by not feeding it to the cow would carry 1.5 fattening animals/ha, with a higher growth rate of an extra 0.37 kg/d or an extra 135 kg/animal/year. These potential increases from one region alone would go a long way to meeting the Indonesian Government desire to markedly increase cattle production.

The project also demonstrated that small-scale Brahman producers can be viable, given adequate feed supplies in the system and appropriate animal management. However, larger, faster-growing cattle breeds such as Brahmans may not be appropriate in all smallholder systems. In areas with low levels of feed resources, local cattle breeds may have the highest reproduction and growth rates.

9.2 Recommendations

The following recommendations are made from the project and end of project review:

1. A briefing paper is prepared for presentation to relevant Ministries, local government authorities and NGOs outlining the key findings of the project and how the Straw Cow and IVMS models can be implemented to assist the Indonesian government meet its objectives of increased beef production.
2. Training modules are prepared that facilitate the implementation of Straw Cow and IVMS models in smallholder cattle systems across Indonesia. Training modules could be linked with associated projects on cattle fattening systems based on forage tree legumes and strategies to reduce calf mortality. Train-the-trainer workshops are conducted with local extension agencies, DINAS, NGOs and farmers to facilitate the extension of project findings. This would include both cow-calf and small to medium fattening systems.
3. Strategies are developed to sustain the capacity building plan of future ACIAR projects. During this project we employed junior scientists to work in the villages or at research stations. These young graduates were trained in ruminant nutrition,

reproduction, scientific methodology and communication. However, at the end of the project, there was no clear career path, and many have now moved on to employment outside of the agricultural sector. It is recommended that initiatives are developed to retain these talented and hardworking scientists within the field of livestock research. Within this group of junior scientists we identified several individuals who were interested in pursuing postgraduate education. However, while the John Allwright Fellowships present a fantastic opportunity for young Indonesian scientists to study at Australian institutions, only permanent employees of Indonesian institutions in our project were eligible to apply. Closer collaboration of future projects with Indonesian universities would provide opportunities for junior scientists to complete masters or PhD degrees as part of ACIAR projects. In addition, access to English language training would increase the competitiveness of young Indonesian scientists for alternative scholarships to study overseas (e.g. Australia awards).

We have also identified the following production and socio-economic issues that require further research:

- What nutrition and management strategies result in the most rapid recovery of BCS by cows of different breeds within different farming/production systems?
- What systems/training are required to improve methods of oestrus detection and access to bulls/AI for cattle in smallholder systems?
- How can we better utilise locally available feed resources to further increase growth rates of fattening bulls? What combination of feedstuffs results in the highest (and/or least-cost) increases in liveweight production of fattening bulls? This would need to be tested within a number of agricultural systems and under different environmental conditions.
- What harvesting, processing and storage methods of crop residues are most suited to smallholder systems?
- How can we improve consumption (palatability) of Gliricidia and other tree legumes? This may include investigating pre-exposure, harvesting and feeding methods or examining different cultivars.
- Are the Straw Cow and IVMS models suitable for implementation into different farming systems (e.g. pulse cropping, plantations)?
- What are the most appropriate strategies for the sustainable scale-out of the Straw Cow and IVMS models?
- What scale of fattening operation is the most economically viable in Indonesia?
- What factors influence the decision making process of smallholder cattle producing households in regard to their cattle management and business practices?
- What impact does implementation of the Straw cow and IVMS models have on smallholder cattle producer livelihoods and on the whole-of-farm/household more broadly?
- What are the economics of associated products from the harvest and feeding of crop residues (crop residues, organic manure/compost)?

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10.2 List of publications produced by project

10.2.1 Published

Journal papers

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11 Appendixes

11.1 Appendix 1: Project team members

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11.2 Appendix 2: Brief methods for unpublished on-station experiments

BCRI Experiment 5. Comparison of growth rates and feed conversion efficiency of Ongole, Brahman and Euro-OngoleX bulls

Ten bulls of each breed were used in this experiment. The average liveweight (± standard error) of Ongole, Limousin-Ongole and Brahman bulls at the start of the experiment was 157 ± 4.5 kg, 171 ± 4.9 kg, 188 ± 6.9 kg, respectively. Average age of bulls was 1.2 ± 0.7 years. Bulls were allocated to blocks based on liveweight, with one bull from each breed in each block. Bulls were housed in individual pens and had free access to fresh drinking water at all times. The experiment consisted of a 2 week adaptation period where bulls were introduced to the pens and experimental diets, followed by a 16 week experimental period. All bulls were fed fresh chopped elephant grass (*Pennisetum purpureum*) *ad libitum*. Elephant grass is widely used in Indonesia, and is of similar quality to a typical village diet. Feed intake was measured daily. Liveweight and BCS were measured once each week before feeding.

BCRI Experiment 6. Comparison of growth rates and feed conversion ratio of Ongole bulls fed local forages or high quality, least-cost rations

Twenty-four Ongole bulls (292 ± 9.9 kg liveweight; BCS 2.5 ± 0.1; age 2.4 ± 0.1 years) were allocated to one of three treatment groups in a randomised block design, with 8 replicates per treatment. Bulls were housed in individual pens and had free access to fresh drinking water at all times. The experiment consisted of a 3 week adaptation period when bulls were introduced to the pens and experimental diets, followed by a 12 week experimental period. The three dietary treatments were;

1. Elephant grass *(Pennisetum purpureum) ad libitum* (EG)
2. Elephant grass *ad libitum* + onggok at 10 g DM/kg W.day + palm kernel cake at 5 g DM/kg W.day + copra meal at 5 g DM/kg W.day + limestone and mineral mix (Balanced concentrate)
3. Elephant grass *ad libitum* + onggok at 17 g DM/kg W.day + palm kernel cake at 1.5 g DM/kg W.day + copra meal at 1.5 g DM/kg W.day + limestone and mineral mix (High-onggok Concentrate)

Bulls were offered half of their forage ration at 1000 hours and again at 1400 hours. Half of the concentrate ration was offered one hour after each forage feeding.

Feed intake was measured daily for the duration of the experiment. Liveweight, BCS and girth were measured twice weekly, except for the weeks of digestibility trials. Height was measured at the beginning and end of the experimental period.

UNHALU Experiment 8. Liveweight gain and BCS of Bali cows fed rice straw-based diets

Thirty non-pregnant, non-lactating mature Bali cows (194 ± 2.7 kg liveweight and 1.9 ± 0.1 BCS at allocation) were ranked and blocked on liveweight then allocated to one of five treatment diets;

1. rice straw *ad libitum*
2. rice straw *ad libitum* + Gliricidia at 2.5 g DM/kg W.day
3. rice straw *ad libitum* + Gliricidia at 5.0 g DM/kg W.day
4. rice straw *ad libitum* + Gliricidia at 7.5 g DM/kg W.day
5. rice straw *ad libitum* + Gliricidia at 10.0 g DM/kg W.day

Cows were fed treatment diets for 12 weeks in individual pens with water available *ad libitum*. Gliricidia was harvested the evening prior to feeding and rice straw was harvested and sun-dried for approximately three days and stored and fed as a hay. Liveweight and

BCS were measured every two weeks and DM intake of rice straw and Gliricidia was determined daily.

UNHALU Experiment 9. Use of local feed resources to increase the liveweight and BCS of Bali cows

Twenty Bali cows (192 ± 3.6 kg and 2.2 ± 0.1 BCS at allocation) used in experiment 8 were used in this experiment. The cows were ranked and blocked on liveweight and allocated to one of four re-alimentation treatment diets;

1. native grass *ad libitum*
2. native grass *ad libitum* + rice bran at 5.0 g DM/kg W.day
3. native grass *ad libitum* + rice bran at 10.0 g DM/kg W.day
4. rice straw *ad libitum* + rice bran at 10.0 g DM/kg W.day

Cows were fed treatment diets for 15 weeks in individual pens with water available *ad libitum*. Liveweight and BCS were measured every two weeks and DM intake of basal diets and rice bran were measured every day.