Life cycle assessment of local and crossbred cattle production systems in Central Java, Indonesia

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ABSTRACT

Indonesia is a prominent example where crossbreeding with European breeds has been promoted to intensify beef production. It is implemented throughout the country regardless of the different agro-ecological conditions, of which the available feed resources are the main element. Crossbreeding at farm level in Central Java showed that crossbreeding has not changed the farming systems or motivations for keeping cattle. These results lead to our hypothesis that we expect no differences in global warming potential (GWP) of local and crossbred cattle production systems in Central Java. Life Cycle Assessment (LCA) is acknowledged method to assess the contribution of livestock production to GWP. Expressed per kg live weight, GWP of local and crossbred cattle was 29.1 kg CO_2 and 32.1 kg CO_2. These results were higher compared to the GWP of beef cattle production systems in European countries. Future LCA's of smallholder systems should pay more attention to the multi-functional aspects of a production system, because the GWP's mitigation depending on the multi-functions included.

Keywords: Local cattle, Crossbred cattle, Life Cycle Assessment, Global Warming Potential, Indonesia

INTRODUCTION

In resource-poor environments, crossbreeding with breeds selected for a high production has become the standard intensification approach for cattle husbandry. Indonesia is a prominent example where crossbreeding with European breeds has been promoted to intensify beef production (Widi et al., submitted).

Pilot studies, indicate, however, that the impact of intensification on e.g. the global warming potential (GWP) of dairying is not straight forward leading to less emissions. Little is known about greenhouse gas emissions of beef cattle systems in smallholder settings. Studies on greenhouse gas emissions from beef cattle production invariably analyzed systems under intensive conditions in Europe or America (Casey and Holden, 2006; de Vries and de Boer, 2010; Nguyen et al., 2010). Wall et al. (2010) and Scholtz et al (2012) claim that genetic improvement and crossbreeding may be permanent ways of reducing the carbon footprint of beef cattle, but no results from field studies support such hypothesis.

The objective of this study was to assess the environmental impact, in terms of GWP of Ongole and crossbred beef cattle production systems in different agro-ecological zones, in Central Java, using LCA methodology.

MATERIALS AND METHODS

The study areas were situated in the southern part of Central Java. Wet lowlands, wet uplands and dry uplands could be distinguished. Each area has different topography, soil types, soil fertility and agro-climatic conditions.

We sampled 146 farms for monitoring inputs, outputs, and on-farm resource flows. The first author recorded, by monthly visiting farms, farmers' inputs and outputs of their cattle keeping over a period of one year (January 2011 – January 2012). Feed inputs were calculated based on farmers' estimates and direct observation on kind and amounts of feeds offered, in one year. These estimates were translated into kg dry matter (DM) applying the literature of Hartadi et al. (2005).

The first step of LCA includes definition of system boundary, the 'Functional Unit' (FU), the method of allocation, and the impact categories to be analysed. Based on the system boundary, we computed the main greenhouse gases (GHGs): carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). We assessed all processes up to the farm-gate, including the cattle (enteric fermentation), feed production and transportation of feeds. The method used to calculate GHG-emissions from the enteric fermentation was based on the intergovernmental panel on climate change (IPCC) good practice guidance, Tier 2 approach (IPPC, 2006). To assess GWP at Ongole and crossbred cattle farms, emissions of CO_2, CH_4 and N_2O were summed up based on their equivalence factors in terms of kg CO_2-eq. One for CO_2, 25 for CH_4 and 298 for N_2O (IPCC, 2006). Interpretation of the results is based on the FU live weight of sold cattle.

Analysis of variance by one-way ANOVA was performed to analyse the variation in GWP per kg product among areas, with breed nested within areas (Ott and Longnecker, 2001). The model was simplified to compare breeds within areas, because for most parameters no interaction was found between breed and area.

RESULTS AND DISCUSSION

Table 1 shows the total GWP for the cattle component of the two farm types for the four areas. Overall, Ongole farms had, on average, a significantly lower GWP than crossbred cattle farms: 4,100 vs 6,010 kg CO_2-eq per year, of which about 75% was methane emissions from enteric fermentation. The remaining 25% were from feeds and forage transport. Use of forages in crossbred farms resulted in significantly higher GWP per farm compared to Ongole farms. Expressed per kg live weight, GWP of local and crossbred cattle was 29.1 kg CO_2 and 32.1 kg CO_2.

To compare our results with literature we converted the GWP estimates per kg product to per kg edible product using the conversion factor of 0.43 kg edible product in one kg beef (de Vries and de Boer, 2010). Our estimate of about 48.5 kg CO_2-eq per kg edible meat acknowledging various functions of cattle, was larger than the range of 14 – 43 kg CO_2-eq in beef systems in Europe (de Vries and de Boer, 2010; Nguyen et al., 2010), it was about comparable to suckler cow and fattening systems in Japan (52.5 kg CO_2–eq; Ogino et al., 2007), and slightly lower than the average value of 56.1 kg CO_2-eq per kg edible meat for SE Asia (Gerber et al., 2013). In Europe the GWP per kg beef is relatively low. This is due to the higher growth rates of beef animals and to the fact that 80% of the beef herd is produced by dairy animals (surplus calves and culled cows), resulting in lower emission intensities for beef.

Table 1. Global warming potential of Ongole and crossbred cattle production systems in four study areas

	Area /Breed								Average	
	Wet lowlands I (N=25)		Wet lowlands II (N=59)		Wet uplands (N=25)		Dry uplands (N=37)		Ongole	Crossbred
	Ongole (N=8)	Crossbred (N=17)	Ongole (N=28)	Crossbred (N=31)	Ongole (N=10)	Crossbred (N=15)	Ongole (N=14)	Crossbred (N=23)	(N=60)	(N=86)
	Mean ± s.d	Mean ± s.d	Mean ± s.d	Mean±s.d	Mean ± s.d	Mean ± s.d	Mean ± s.d	Mean±s.d	Mean±s.d	Mean±s.d
Total GWP (000 kg CO_2 –eq) in a year	4.82^{a} ± 1.81	5.91^{a} ± 2.0	3.46^{a} ± 1.53	5.29^{b} ± 3.05	5.32^{a} ± 2.34	5.54^{a} ± 1.70	4.08^{a} ± 1.17	7.35^{a} ± 7.81	4.10^{a} ± 1.76	6.01^{b} ± 4.58
• On farm cattle	3.77^{a} ± 1.3	4.67^{a} ± 1.5	2.76^{a} ± 1.2	4.16^{b} ± 2.4	3.92^{a} ± 1.6	4.34^{a} ± 1.22	2.78^{a}± 0.81	4.97^{a} ± 4.82	3.09^{a}± 1.30	4.51^{b} ± 2.98
• Forage	0.46^{a} ± 0.16	0.50^{a} ± 0.18	0.24^{a} ± 0.12	0.36^{b} ±0.21	0.46^{a} ± 0.17	0.48^{a} ± 0.16	0.65^{a} ± 0.20	1.10^{a} ± 1.00	0.40^{a} ± 0.22	0.60^{b} ± 0.60
• Supplementary feed	0.16^{a} ± 0.2	0.40^{b} ± 0.28	0.08^{a} ± 0.06	0.25^{b} ± 0.26	0.38^{a} ± 0.37	0.30^{a} ± 0.24	0.18^{a}± 0.11	0.48^{a} ± 1.21	0.16^{a} ± 2.02	0.35^{b} ± 0.66
• Rice straw^{ns}	0.44 ± 0.22	0.34 ± 0.20	0.38 ± 0.21	0.52 ± 0.37	0.57 ± 0.37	0.41 ± 0.22	0.34± 0.13	0.62 ± 0.70	0.41 ± 0.24	0.49 ± 0.45
• Transportation of forage (off farm)^{ns}	0.00 ± 0.00	0.00 ±0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ±0.00	0.00 ± 0.00	0.14 ± 0.04	0.22 ± 0.21	0.03 ± 0.06	0.06± 0.15
Without allocation GWP / FU (kg CO2 –eq / kg BW)^{ns}	33.9±10.8	33.1 ± 19.6	29.5 ± 21.1	32.3 ± 18.2	27.4 ± 12.7	29.9 ± 12.4	26.7 ± 10.2	32.7 ± 15.1	29.1 ± 16.4	32.1 ± 16.6

^{a,b} different superscripts indicate significant differences between breeds within area and in all areas ($P<0.05$)

^{ns} non significant

The global call for intensification of livestock production to improve productivity of livestock production and so to reduce greenhouse gas emission intensities (Steinfeld et al., 2006; Herrero et al., 2010; Gerber et al., 2013) is not confirmed by our field research on the environmental impact of crossbreeding in mixed farming systems of Central Java. Systems should pay more attention to the multi-functional aspects of a production system, because the GWP's mitigation depending on the multi-functions The postulated paradigm that breeding strategies, such as crossbreeding, can reduce the carbon footprint of cattle production (Scholtz et al., 2012) is not that straight forward in complex mixed farming systems. Intensification through crossbreeding resulted in 25% higher body weights for crossbred cattle compared to local Ongole cattle (Widi et al., submitted). But, there were no differences in GWP per kg live weight sold between local Ongole and crossbred cattle production systems. Thus the reputation that local breeds in local production systems have much higher emissions per unit product than improved breeds or in this case crossbreds of Ongole and Simmental cattle is not justified.

IMPLICATIONS

Mitigation options coming from global studies focus on increasing individual animal production, reducing the number of unproductive animals, better feeding and manure management (Herrero et al., 2010; Gerber et al., 2013). Few studies show the environmental impacts of smallholder livestock systems in tropical countries where livestock is fed more forage and has various functions. Future LCA’s of smallholder should include multi-functional aspects of a production system, because the GWP’s mitigation depending on the multi-functions included.

REFERENCES

Casey, J.W. and N.M. Holden. 2006. Quantification of GHG emissions from sucker-beef production in Ireland. Agricultural Systems 90 (2006): 79 – 98.

de Boer. I.M.J. 2011. Environmental impact assessment of conventional and organic milk production. Livestock Production Science 80 : 69 – 77.

de Vries, M. and I.J.M de Boer. 2010. Comparing environmental impacts for livestock products: a review of life cycle assessments. Livestock Science 128: 1 – 11.

Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C, Dijkman J, Falcucci A, and Tempio G. 2013. Tackling climate change through livestock- A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization (FAO), Rome, Italy.

Hartadi, H., S. Reksohadiprodjo dan A.D. Tillman. 2005. Tabel Komposisi Pakan untuk Indonesia.Gadjah Mada Univ. Press, Yogyakarta.

Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Masangi, S., Freeman, H.A., Bossio, D., Dixon, J. Peters, M., van de Steeg, J., Lynam, J., Parthasarathy Rao, P., MacMillan, S., Gerard, B., McDermott, J., Sere, C., Rosegrant, M. 2010. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Science 327: 822-825.

IPPC. 2006. Intergovernmental Panel of Climate Change Vol. 4. Guidelines for National Greenhouse Gas Inventories Japan.

Nguyen, T.L.T., J.E.Hermansen and L.2010. Mogensen. Environmental concequences of different beef production system in the EU. J. Cleaner Production 18: 756 - 766.

Ogino, A., H. Orito, K. Shimada, and H. Hirooka. 2007. Evaluating environmental impacts of the Japanese beef cow-calf system by the life cycle assessment method. J. Anim. Sci. 78 : 424-432.

Ott, R. L. and M. Longnecker. 2001. An introduction to statistical methods and data analysis. Duxbury, Thomson Learning, Inc, United States of America.

Scholtz, M. M., Y. Steyn, E. v. Marle-Koster, and H.E.Theron. 2012. Improved production efficiency in cattle to reduse their carbon footprint for beef production. South African Journal of Animal Science 42(5).

Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales and C. de Haan. 2006. Livestock's long shadow: environmental issues and options. FAO.

Wall, E., G. Simm, and D. Moran. 2009. Developing breeding schemes to assist mitigation of greenhouse gas emissions. Animal 4(3):336 - 376.

Widi, T. S. M., H. M. J. Udo, K.Oldenbroek, I. G. S. Budisatria, E.Baliarti, and A. J. v. d. Zijpp. Submitted. Is crossbreeding benefecial for mixed farming systems in Central Java.