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Input parameters for LiGAPS-beef mechanistic model: an attempt to study Bali cattle production under oil-palm plantation systems

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Abstract. In Indonesia, integrated oil-palm plantation (OPP) and cattle production systems has been widely practiced in outside Java Island, as an efficient strategy to meet the demand of meat. A dynamic model, called LiGAPS-beef is then needed to simulate the potential and feed-limited production of Bali cattle. This pre-liminary study was aimed to identify and determine the input parameters of Bali cattle production under oil-palm plantation systems for LiGAPS-beef. Literature review and survey on intensive and semi-intensive OPP-cattle integrated systems (I-OPP and SI-OPP), were done, to identify the parameters which define (potential) and limit (actual) the production of Bali cattle. The general parameters were calf crop (%), weaning age (month), culling rate (%year^{-1}), heat increment of feeding; ME content undergrowth plants, grass, legumes, oil palm by products and, concentrates (MJkg^{-1} DM); potential production of undergrowth plants, grass, legumes, and oil palm by products (kgDMha^{-1}year^{-1}); percentage of carcass (%) and percentage of beef meat (%).The difference between the potential and actual production then will be simulated using LiGAPS- beef to assess the yield gap of Bali cattle production under OPP systems.

1. Introduction

The demand for animal sources food in developing countries is predicted to double by 2050. In Indonesia, there has always been a gap between supply and demand of beef with national beef production only satisfying about 45% of demand [1]. To satisfy the demand of red meat, government has been attempting to increase cattle population and productivity on smallholder farming systems, due to the fact that > 90% of cattle population are hold by smallholder farmers [2]. Productivity of beef cattle is determined by genetics and environment, including keeping management, in particular feed sufficiency. Bali cattle (variously named *Bos sondaicus*, *Bos javanicus*, *Bos/Bibos banteng*) is indigenous cattle in Indonesia, well-adapted genotype form basis for smallholder farming systems [3].

The amount of animal products among different farming systems is varied which caused by complex biophysical factors [4]. Due to various ecological zones and production systems in Indonesia, potential genetic of Bali cattle should be adjusted with existing agroecology and production systems. To obtain standardized procedure of production systems in various situation, a mechanistic model should be developed. This model is built with an objective of assessing the potential growth and production of cattle in different beef production systems [5].

A mechanistic model, called Livestock simulator for Generic analysis of Animal Production Systems – Beef cattle (LiGAPS-Beef) was developed by a group of researchers [6]. It can identify the defining factors (genotype and climate) and limiting factors (feed quality and available feed quantity) for cattle growth by integrating sub-models on thermoregulation, feed intake and digestion, and energy and protein utilisation [6]. Moreover, the LiGAPS-Beef outputs contained necessary information for simulating beef production in a broad range of systems with different climates and feeding strategies. This initial study was aimed to identify the input parameters which define (potential) and limit (actual) the production of Bali cattle production under oil-palm plantation systems for LiGAPS-beef.

2. Materials and methods

Referring a conceptual framework, developed by [4], the combined crop–livestock system includes livestock production and all corresponding feed crop production, and in this study included livestock production and all corresponding of production of undergrowth OPP and oil palm by products. Hence, all livestock systems are part of OPP–livestock system [4].

2.1. Units for palm oil production

Beside main products for foods, biofuel and energy, personal care and cosmetic, and pharmaceutical, palm oil also provides the main livestock feed sources, i.e., by-products from the palm oil production, like palm kernel cake (PKC) and palm fronds, made up of leaves and midribs that may be processed [7]. Other feed sources are plantation undergrowth. Livestock feed sources production from oil palm plantation is expressed in kg DM ha^{-1} year^{-1}.

2.2. Units for livestock production

Cattle production can be expressed in three different measures: 1) state-based per animal per year, this parameter is obtained by dividing total herd production per year with the total number of animals in a herd; 2) state-based per productive animal per year, which is similar to the first method but excluding reproductive individuals [4]; and 3) kg animal product per kg body weight per year; which is calculated by dividing total herd production per year by the total cattle weight of all animals present in the herd or flock. Most common approach in tropical region, production is expressed in tropical livestock unit (TLU) per year [2].

2.3. Units for OPP-cattle system

To calculate integrated OPP-cattle production, input-based production of the OPP system and the livestock system are multiplied, as presented in an equation below:

$$\underbrace{\frac{\text{kg DM OPP source feeds}}{\text{ha x year}}}_{\text{OPP production}} \times \underbrace{\frac{\text{kg animal product}}{\text{kg DM feed}}}_{\text{Livestock production}} = \underbrace{\frac{\text{kg animal product}}{\text{ha x year}}}_{\text{OPP-livestock system production}} \quad [4]$$

Production for OPP-cattle system therefore is expressed in kg animal product ha^{-1} year^{-1}.

2.4. Application to Bali cattle production in Indonesia

The theoretical framework, presented in 2.1 – 2.3 was applied to two Bali cattle systems under OPP. Estimation of potential and also actual production for Bali cattle and OPP system production and for integrated OPP-cattle production were made. This enables to compute relative yield-gaps for cattle, OPP and integrated OPP-livestock production.

2.4.1. Calculation of potential Bali cattle production. Theoretically, to compute potential production of beef cattle, animals were assumed to be permanently in thermo-neutral zone [4]. However, in Indonesia, Bali cattle are mostly kept by smallholder farmers under traditional management practices. We only selected literatures of Bali cattle production under improved management systems.

2.4.2. Calculation of actual (feed-limited) Bali cattle production. Bali cattle production was investigated in two different systems, I-OPP in Province of Central Kalimantan and SI-OPP in Province of Riau. Bali cattle under I-OPP systems were daily housed and fed with forages, consisted of Taiwan grass and legume (*Indigofera sp.*); and concentrates, consisted of solid, palm kernel cake (PKC), rice bran, molasses and urea. In SI-OPP, Bali cattle were allowed to grazing undergrowth plantation during the day and kept in barns during the night without additional feeds.

3. Results and discussion

3.1. General parameters to calculate Bali cattle potential production

Literatures selected for potential Bali cattle production were assumed as the most ideal conditions (Table 1). Bali cattle have a high heat tolerance, are well adapted to the dry-land, efficiently utilize low quality feed, and is considered to have a high fertility in a harsh environment [8]. To assess the production potential, assumptions were made where all cows were on the first parity. This approach were made in order to reach a calving interval value of one year [4]. The cows in the simulations were assumed to have a maximum age until which production can be maintained. This assumption implied that the cows can have a maximum of eight calves; further, accounting for the calving interval and weaning age, cows ages were maximum of 11.3 years at culling.

Table 1. General parameters used to calculate potential production of Bali cattle

Parameter	Value	Unit	Reference
Age at first calving	2.67	Years	[3]
Calving interval	12.03	Month	[9]
Weaning age	205	Days	[10]
Reproduction index (calf crop)	90.1	%	[11]
Maximum calf number	8		
Maximum age at 8^{th} weaning	11.3	Years	
Heat increment of feeding	0.09	MJ MJ^{-1} ME	[12]
ME content undergrowth plants	4.6-7.0	MJ kg^{-1} DM	[13]
ME content (Taiwan) grass	8.5-9.2	MJ kg^{-1} DM	[14]
ME content legume	6.4-7.8	MJ kg^{-1} DM	[15]
ME content oil palm by products	5.8-6.5	MJ kg^{-1} DM	[16]
ME content concentrates	7.7-13.2	MJ kg^{-1} DM	[17]
Potential production of undergrowth plants	12,000-18,000	kg DM ha^{-1} $year^{-1}$	[18]
Potential production of (taiwan grass)	14,800	kg DM ha^{-1} $year^{-1}$	[19]
Potential production of legume	7,200-1,8150	kg DM ha^{-1} $year^{-1}$	[20]
Potential production of oil palm by products			
- Oil palm fronds	658	kg DM ha^{-1} $year^{-1}$	[21]
- Palm stem	5,214	kg DM ha^{-1} $year^{-1}$	[21]
- Empty bunches	3,386	kg DM ha^{-1} $year^{-1}$	[21]
- Fibers	2,681	kg DM ha^{-1} $year^{-1}$	[21]
- Solid	1,132	kg DM ha^{-1} $year^{-1}$	[21]
- Palm kernel cake	514	kg DM ha^{-1} $year^{-1}$	[21]
Percentage of carcass	55.61	%	[22]
Percentage of meat (of carcass)	67.18	%	[22]
Average daily gain (ADG)	0.7	kg / day	[23]

3.2. Actual production Bali cattle in two different systems

These two production systems were selected due to different management practices (Table 2). Intensive-OPP cattle system was owned and managed by a commercial palm oil company. Initially, the owner of OPP company was interested to integrate the OPP with cattle production and utilize the palm oil by products for feed sources. They also grow Taiwan grass and Indigofera sp. as forage feeds. In SI-OPP cattle system, the OPP was owned and managed by a company, but allowing smallholder farmers (who are also work for the company) to keep cattle and graze undergrowth plantation during the day.

Table 2. Farming system characteristics of I-OPP and SI-OPP cattle integrated systems

Characteristics	I-OPP cattle	SI-OPP cattle
Weaning weight (kg)	131.7	77.29
Reproduction index (calf crop) (%)	55.76	86.0
Forage production (kg DM year^{-1})		613.23
Dry matter (DM) of concentrates (%)	86.11	-
Dry matter (DM) of forages (%)	17.51	16.94
Average daily gain (kg/day)	0.37	0.27

Some assumptions and information were needed to calculate actual production of feeds (forages and concentrates stuffs), live weight and beef weight production. Yield gap for cattle and OPP cattle systems were estimated as the difference between potential and actual production [24]. The relative yield gap parameter was computed as the fraction potential production from the yield gap component.

4. Conclusion

This paper presents a pre-liminary study to quantify potential production of Bali cattle. Some assumptions are still needed to calculate actual or feed-limited production limited of Bali cattle production systems. The difference between the potential and actual production then are used to simulate by LiGAPS- beef to assess the yield gap of Bali cattle production under OPP systems.

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