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Sustainability of Timor Deer in Captivity: Captive Breeding Systems in West Java, Indonesia

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Abstract

The population of Timor deer (*Rusa timorensis*), an Indonesian endemic, continues to decline in its natural habitat, so captive breeding could become a source of individuals to bolster wild population. Support for captive breeding programs may be stronger if captive breeding also provided meat for human consumption. Thus, sustainable captive yields could be expected to support both conservation interests and food needs. The aim of this research is to evaluate the environmental impact, based on global warming potential (GWP), of two Timor deer breeding systems, that is, a farming system and a ranching system, in West Java, Indonesia. Life cycle assessment methodology was used for the evaluation to gain a cradle-to-gate perspective. The functional unit used was 1 kg of Timor deer live weight in captivity. The main result of the study indicated that the GWP per kg of Timor deer was estimated at 17.30 kgCO_2eq (farming system) and 17.60 kgCO_2eq (ranching system). The largest GWP in both systems was derived from cultivation activities and infrastructure development. In general, there is no significant difference in the GWP of the two breeding systems studied. This was due to the similar overall management adopted by the two breeding systems, especially the use of food types and infrastructure materials. Currently, the environmental dimension, especially the emissions from Timor deer breeding activities, is not a major concern, but in the future, breeding management should pay attention to the efficient use of the food and infrastructure to make it more environmentally friendly.

Keywords

life cycle assessment, Timor deer, captivity, conservation, Indonesia, global warming, farming system, ranching system

Conservation and sustainability are intercorrelated (Jervis, 2000). Natural resource conservation activities are an integral part of improving human welfare (Kirkpatrick & Emerton, 2010). The utilization of natural resources must be carried out within sustainable biological boundaries so that management strategies can be used to create positive incentives for biodiversity protection practices (Hutton & Leader-Williams, 2003). Wildlife is one of the resources that can be sustainably utilized. Sustainable utilization of wildlife would be achieved if its exploitation for economic, health, social, and cultural purposes did not affect population size, habitat, ecological functions (United Nations Environment Programme, 2010), or the surrounding environment.

Overexploitation of hunted mammals, including Timor deer (*Rusa timorensis*), is common in tropical forests (Bennett & Robinson, 2000). The Timor deer is one of Indonesia's endemic species, included in the order Artiodactyla, class Ruminantia, and family Cervidae (International Union for Conservation of Nature

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[IUCN], 2018). The natural distribution of Timor deer is only in Java and Bali (Heinsohn, 2003; IUCN, 2018). Therefore, it is often referred to as the Javanese deer (Pairah et al., 2014). However, eight subspecies of Timor deer are now recognized, with very diverse local names because of its very widespread distribution that is, *R.t. russa* Muller and Schlegel, 1844 (Java and South Borneo), *R.t. floresiensis* Heude, 1896 (Lombok and Flores), *R.t. timorensis* Blainville, 1822 (Timor Island), *R.t. djonga* Bummel, 1949 (Southeast Sulawesi), *R. t. moluccensis* Q & G, 1830/Muller, 1836 (Maluku), *R. t. renschi* Sody, 1933 (Bali), and *R.t. laronesiotes* Bummel, 1949 (Peucang Island, West Java; IUCN, 2018; Semiadi, 1998; Semiadi & Nugraha, 2004; Takandjandji, 2009).

Various types of ungulates, including Timor deer, are key species in many ecosystems, and changes in their abundance will affect adjacent trophic levels (Karanth et al., 2004; Sinclair et al., 2003). The carrying capacity, human activity, number and type of predator species, and habitat changes all influence the predator–prey relationship (Ballard et al., 2001). For example, the Timor deer is one of the main prey items of Komodo dragons (*Varanus komodoensis*), Javan leopards (*Panthera pardus*), and Dholes (*Cuon alpinus*; Jessop et al., 2006; Nurvianto et al., 2016; Santosa et al., 2008). However, poaching, conversion of forestland into agricultural land, and the pressure of human population growth have led to a decrease in the natural populations of Timor deer (Santosa et al., 2008). Decreasing Timor deer populations in their natural habitat can lead to a decline in the populations of their predators (Ariefiandy et al., 2016). Thus, the presence of the Timor deer is very important in the efforts to conserve their predators.

The Timor deer is protected by Indonesian law, and IUCN has designated the Timor deer as Vulnerable (IUCN, 2018). Therefore, in Indonesia, the use of Timor deer is only for conservation purposes, and other uses outside of that are only permitted from the yield of captive breeding. In general, there are two captive deer breeding systems in Indonesia: a ranching system and a farming system. In the ranching system, management is carried out in a large area, deer graze or browse vegetation that is available in the extensive captivity area. In the farming system, management is carried out more intensively. The area needed is not as large, and all food and water needs are provided from outside the fenced paddocks that the deer are kept in. Actions included in extensive management are shepherding, controlled burning, weed control, and selection of feeding plants (Gee et al., 2011).

Wildlife domestication through a captive breeding program can be carried out with the aim of making wildlife, including deer species, a domestic commodity that is useful for human needs (Snyder et al., 1996). Domestication of captive wildlife can reduce hunting pressure in wild populations, and even if the population is excessive, it can be used as a stock of hunting animals (Bulte & Damania, 2005). Commercial use of domesticated species can help meet the demand for wildlife products, especially meat (Brooks et al., 2010; Hoffman & Wiklund, 2006). According to Zeder (2008), deer are both one of the most endangered and the most domesticated wildlife species in the 20th century. Globally, some of the most common domesticated deer species are red deer (*Cervus elaphus*), fallow deer (*Dama dama*), and sika deer (*C. nippon*) from the temperate regions and Timor deer (*Rusa timorensis*), sambar deer (*Rusa unicolor*), and chital or spotted deer (*Axis axis*) from the tropical region. Other common domesticated species are wapiti or elk (*C. elaphus canadensis*), hog deer (*Axis porcinus*), reindeer/caribou (*Rangifer tarandus*), musk deer (*Moschus moschiferus*), Père David's deer (*Elaphurus davidianus*), and moose (*Alce salces*; Food and Agriculture Organization, 2018; Kayat & Hidayatullah, 2010; Scherf, 2000).

New Zealand has been one of the pioneers in the development of the deer livestock industry since 1950 (Couchman, 1980). The high demand for venison and its competitive price makes deer husbandry profitable, and it has become an important export commodity for some countries (Fennessy & Taylor, 1989; Hoffman & Wiklund, 2006). Moreover, New Caledonia, Mauritius, and Australia have long used Indonesian deer, especially Timor deer and sambar deer, as one of the backbones of the local livestock industry (Anonim, 2018; Drew et al., 1989; Fennessy & Taylor, 1989; Woodford & Dunning, 1992). In Mexico, white-tailed deer (*Odocoileus virginianus*) has become one of the major deer species that is widely consumed by local people, and it is an important trophy in sport hunting (Mandujano & González-Zamora, 2009).

The breeding of Timor deer in captivity outside its natural habitat will have an impact on the surrounding environment. Since the publication of *Livestock's Long Shadow: Environmental Issues and Options* (Steinfeld et al., 2006), public awareness of the environmental impact of animal production has increased (Ripoll-Bosch et al., 2011). Livestock is a major contributor to environmental problems (Winkler et al., 2016). Moreover, greenhouse gas (GHG) emissions from animal products differ from other sectors because they are dominated by methane (CH_4) and nitrous oxide (N_2O; Reckmann, 2013). Methane produced from ruminant manure contributes 23 times more to global warming than CO_2 (Broucek, 2014a; Intergovernmental Panel on Climate Change, 2001). Over the past few years, the livestock sector has been considered to be responsible for 18% of anthropogenic GHG emissions (Broucek, 2014a, 2014b; Steinfeld et al., 2006).

Many methods have been developed to assess sustainability, one of which is life cycle assessment (LCA) analysis (Schau et al., 2012). The LCA method is suitable for environmental evaluation (International Organization for Standardization (ISO), 2006a), especially for estimating the environmental burden of a particular product, process, or activity (Boguski et al., 1996). LCA covers the entire product life cycle, starting from raw material extraction, material processing, product use, to disposal at the end of product life, often called *cradle to grave* (Finkbeiner et al., 2010; ISO, 2006b). LCA also allows for the quantification of emissions from a product's life cycle and comparison with other systems, as well as identification of hotspots to maximize efficiency and/or minimize environmental impacts (Dudley et al., 2014; Huerta et al., 2016). Therefore, the life cycle approach can provide valuable support in evaluating sustainability (Zamagni, 2012). The LCA method has been widely used to evaluate the environmental impacts of livestock activities especially from ruminant species (Asem-Hiablie et al., 2019; Rabier et al., 2015; Ripoll-Bosch et al., 2011; Rotz et al., 2015). This study aimed to identify the potential contribution to global warming of the life cycle of Timor deer in two different captivity management systems in Indonesia, a farming system and a ranching system.

Methods

Research Location

This study was conducted from July to December 2017. The deer farming system was located in the Dramaga Research Forest (Figure 1; 6°32′59.04″–6°33′13,98″ SL and 106°44′0.06″–106°44′59.64″ EL) at 244 m above sea level, which represents a lowland ecosystem. Administratively, this area is located in West Bogor District, Bogor City, West Java Province. The average rainfall is 3,552 mm/year with air temperature of 22.4°C to 32.80°C and an average humidity of 84.17% ± 4.32%. The deer captivity area is approximately 2.5 ha, of which approximately 0.5 ha is physical buildings (cages, warehouses, waste management installation, and other installations) and approximately 2 ha is forage garden. There were several different captive breeding enclosures used in the area: yards, breeding cages, and individual cages.

The deer ranching system was located in Ranca Upas Timor deer captivity. Administratively, this area belongs to Rancabali District, Bandung Regency. The captivity location is between Mount Patuha, Mount Tikukur, and Mount Cadas Panjang (107°23′30.34″–107°23′30.39″ EL and 7°8′5.8″–7°8′16.48″ SL). The area has flat to hilly topography at an altitude of 1,550 m asl. The air temperature is between 15°C and 17°C with rainfall of 2,400 to 3,000 mm/year. Initially, this was a swamp area that dries naturally, of which 3 ha is now used as Timor deer captive breeding areas (Figure 1).

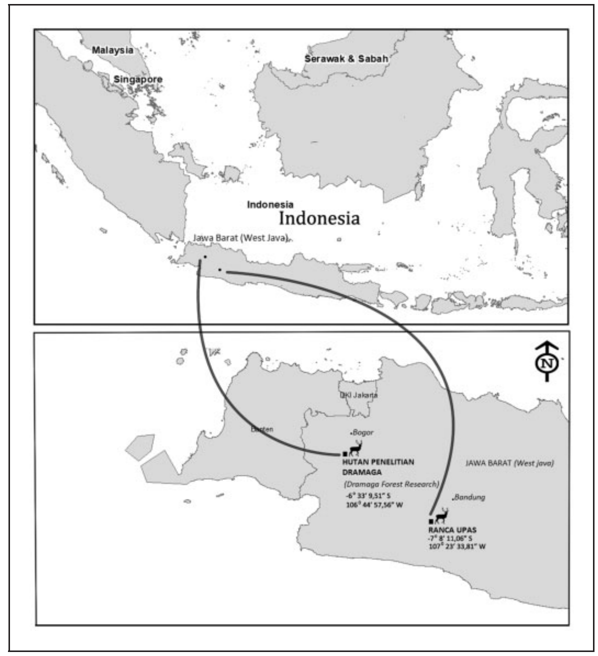

Figure 1. Locations of Timor Deer Captive Breeding in Dramaga Research Forest Bogor and Ranca Upas Bandung.

LCA Analysis

The LCA method has obtained international standards of ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b) and consists of four phases of analysis. In this study, the four phases are as follows:

Objective and Scope. The objective of this study was to evaluate the environmental impacts of two different systems of Timor deer captive breeding, a ranching and a farming system. The scope of the study is shown in Figure 2. The system study scope was a cradle-to-farm gate, which is the assessment of the deer life cycle from "cradle" to the age of 18 months until it is ready to be harvested (farm gate). The study scope includes the construction of cage infrastructure, the use of inorganic fertilizers and seeds for forage gardens (in the farming system), consumption of fresh grass, rice bran, mineral salts, and water resources. In both farming and ranching systems, fuel is needed for transporting building materials and deer feed. Electricity is needed for cages lighting and running water pumps (in the farming system). The functional unit used in this research was 1 kg of deer live weight in captivity.

Life Cycle Inventory. The second stage in the LCA analysis was to conduct an inventory of all resources used as

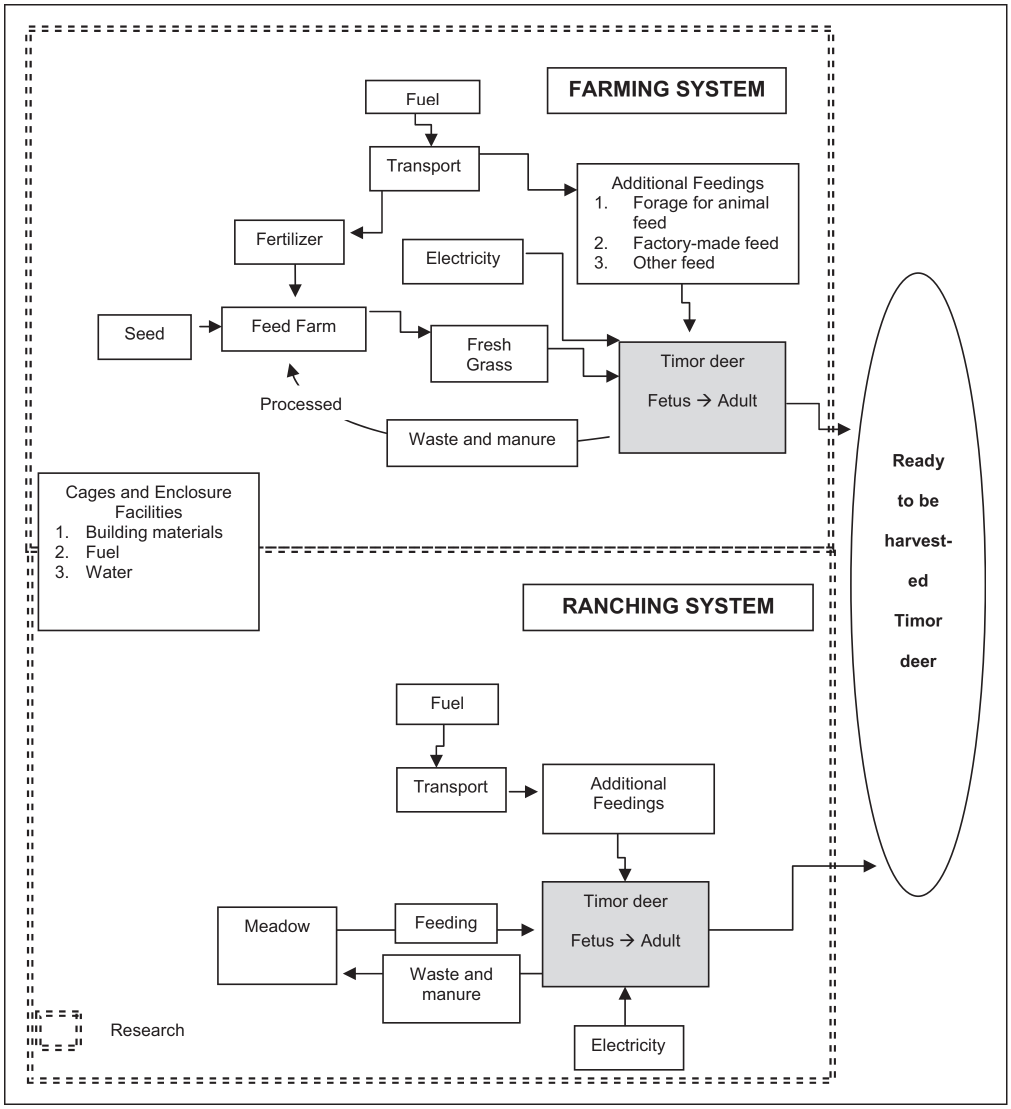

Figure 2. Boundaries and Scope of Timor Deer Breeding.

inputs for captive deer breeding activities and the outputs generated from these activities that affected the surrounding environment. The data were collected from a number of studies, interviews, and direct observations in the field. The input variable used in the LCA analysis was grouped into two stages: infrastructure development and captive breeding or cultivation activities. All inputs, in the form of materials and energy needed during all processes in the two stages, were inventoried. One cycle of deer cultivation used in this analysis comprised several stages of individual deer development, starting from the fetus (250 days of pregnancy), to fawn (120 days), to subadult (240 days), up to the adult stage (180 days), thus taking a total of 790 days. The main characteristics of both systems are described in Table 1.

In the LCA analysis, inputs were infrastructure, feed, water, electricity, fuel, and output waste. The details for each input and its calculation results per kg of Timor deer live weight are presented in Table 2.

Infrastructure inputs were calculated based on the Indonesian National Standard year 2008 (Badan Standardisasi Nasional, 2008). The most dominant materials used in the infrastructure construction were iron, cement, and wood. Especially for the farming system, in addition to physical buildings, another infrastructure built was 2 ha forage garden. At the beginning of the forage garden construction, inorganic fertilizer (urea) was needed, which as amounted to 0.049 kg/kg of live weight. This amount was greater than that of the ranching system where the provision of additional fertilizer for pasture in the captivity area was only 0.031 kg/kg of live weight.

Feed input is one of the important factors for analyzing the environmental impacts of captive breeding

Table 1. Main Characteristics of Deer Captive Breeding in the Farming System and Ranching System at the Two Research Sites.

No.	Description	Farming system	Ranching system
1.	The number of Timor deer in captivity (heads)	48 (21 hinds and 27 stags) (5 calves and 43 adults)	26 (12 hinds and 14 stags) (9 calves and 17 adults)
2.	Deer weight		
	Calves deer (kg)	20.91	18.33
	Adult deer (kg)	49.38	71.76
	Average (kg)	46.08	53.27
3.	Land area (ha)	2.5	3
4.	Infrastructure	Open and closed cages, water installations, inspection roads, and forage gardens	Wire fences and deer observation buildings
5.	Feeding method	Food from outside the cage (cut and carry)	Grazing, food from outside the cage (cut and carry)
6.	Types of feed	Grass, corn, sweet potatoes, cassava, rice bran	Grass, corn, cassava, carrots, kale, rice bran
7.	Water source	Wells	Water from natural swamps
8.	Electricity	Grid electricity (Perusahaan Listrik Negara (PLN) or State Electricity Company)	Grid electricity (PLN)
9.	Fuel	Gasoline and diesel use for all transportation in captivity activities	Gasoline and diesel use for all transportation in captivity activities
10.	Waste management	The manure is used as fertilizer	Directly into the ground

activities. In the farming system, starting from the cradle to 1.5 years old, each kg of deer live weight was given 58.249 kg of fresh food and 1.174 kg of rice bran, on average. Meanwhile, in the ranching system, every 1 kg of deer weight was provided with 71.588 of fresh food and 7.410 kg of rice bran, on average. In addition to food, the deer in captivity were also given powdered salt and minerals to maintain their health. The amount of salt given to each kg of live weight in the farming system was 0.117 kg while that in the ranching system was 0.375 kg.

The use of water in the farming system was very high compared with that in the ranching system. On average, one deer life cycle in the farming system needed 535.71 L of water per kg live weight. This amount included the use of water for cleaning the cage. Meanwhile, in the ranching system, if it was assumed that each deer consumed up to 6.4 L of water per day (Kii & Dryden, 2005), the amount of water required was only 3.87 L/kg of live weight.

The farming system required greater energy resources than the ranching system, both for electricity and fuel (gasoline or diesel). The use of electricity in the farming system reached 3.201 kWh/kg of live weight while that in the ranching system reached only 0.616 kWh/kg of live weight. In the farming system, in addition to lighting, electricity was also used to turn on the water pump to meet the water needs in all breeding activities. In the ranching system, the use of electricity was minimal because, at night, the lights were turned off to avoid interference with deer activities.

Premium fuel was used to transport food. The amount of premium fuel needed in the farming system was 1.08 L or 0.867 kg/kg of live weight while that needed in the ranching system was 0.04 L or 0.032 kg/kg of live weight (1 L premium = 0.8 kg). Diesel fuel was used for the trucks transporting building materials during the construction of the captivity infrastructure. In the farming system, diesel fuel was also used for the excavators during land preparation for the construction of the forage garden. It was assumed that the total distance travelled from the location of material purchase to the farming system-captive breeding area was up to 50 km while that to the ranching system-captive breeding area was 130 km. Thus, the use of diesel fuel in the farming system was 0.003 L/kg of live weight while that in the ranching system was 0.009 L/kg of live weight.

Life Cycle Impact Assessment. The life cycle impact assessment stage was conducted to evaluate the impact of Timor deer captive breeding activities on the environment based on the use of inputs (Table 2) and outputs. The data of inputs and outputs from the captive breeding activities were then converted into a functional unit of global warming impact ($kgCO_2eq$) using SimaPro Software (PRé Consultants, LE Amersfoort, the Netherlands; Goedkoop et al., 2016).

Interpretation. In the fourth and final stage, the results of the LCA were interpreted in accordance with the study objective and scope previously determined in Stage 1.

Results

The results showed that the environmental impacts of farming and ranching systems were only slightly different. Table 3 shows that for each kg of live deer body weight, the highest emissions were produced by the farming system. The largest contribution came from cultivation activities, followed by infrastructure construction and construction of the forage gardens. For the ranching system, more than half of the total emissions were generated from the construction of infrastructure, followed by cultivation activities.

Table 2. Inventory Data From Deer Production Process in Captive Breeding With Farming System and Ranching System per Functional Unit (1 kg of Live Weight).

Input	Measurement	Farming system	Ranching system
Infrastructure			
Steel	kg	0.5787	0.945
Wood	m^3	0.0006	0.0037
Cement	kg	0.7958	0.8835
Sand	kg	5.1582	2.1097
Gravel	kg	1.0356	2.9514
Wood oil	kg	0.0009	0.0033
Water	L	10.7156	0.5036
Diesel	kg	0.0032	0.0086
Plastic	kg	0.005	–
Brick	kg	4.4066	–
Paving block	kg	2.0078	–
Inorganic fertilizer (urea)	kg	0.0489	0.0312
Cultivation			
Feed			
Fresh grass	kg	54.7261	55.5736
Corn	kg	1.1742	0.3123
Cassava	kg	1.1742	0.3123
Sweet potatoes	kg	1.1742	–
Carrot	kg	–	7.6948
Kale	kg	–	7.6948
Rice bran	kg	1.1742	7.4098
Salt and minerals		–	–
Salt	kg	0.1174	0.3748
Energy		–	–
Gasoline	kg	0.8671	0.0315
Electricity	kW/h	3.2009	0.6156
Water	L	535.7143	3.8759

The LCA analysis shown in Figure 3 shows that to produce 1 kg of deer body weight in the farming system, inputs that produced the most emissions were from infrastructure of 0.586 m^2 with a total emission of 7.47 $kgCO_2eq$, followed by electricity of 11.5 MJ with a total emission of 3.80 $kgCO_2eq$. Among the variety of foods, grass and rice bran produced the most emissions. The 25.3 kg of grass obtained from the forage garden had a total emission of 2.25 $kgCO_2eq$, and the 1.17 kg of rice bran had a total emission of 2.57 $kgCO_2eq$. Several other inputs produced a total emission of 1.51 $kgCO_2eq$.

Figure 4 shows that to produce 1 kg of deer body weight in the ranching system, inputs that produced the most emissions were from infrastructure of 21.6 m^2 with a total emission of 10.10 $kgCO_2eq$, followed by the variety of food, including 55.6 kg of grass with a total emission of 2.90 $kgCO_2eq$, 0.74 kg of rice bran with a total emission of 1.62 $kgCO_2eq$, and 7.69 kg of kale with a total emission of 1.11 $kgCO_2eq$. Several other inputs produced a total emission of 1.57 $kgCO_2eq$. Therefore, the total emission generated for each kg of Timor deer live weight in the ranching system was 17.30 $kgCO_2eq$.

Discussion

Our LCA analysis of both the farming and ranching systems showed that the farming system produced a 1.7% higher environmental impact, measured as global warming potential, than the ranching system. Different inputs in the process of infrastructure development and cultivation activities carried out in both systems, and the construction of the forage gardens in farming system, make the total GHG emissions per kg of deer live weight from the farming system (17.60 $kgCO_2eq$) slightly higher than from the ranching system (17.30 $kgCO_2eq$). Both systems were still within the range of 9.88 to 44.8 $kgCO_2eq$ resulting from an LCA analysis of venison production from red deer, roe deer, and fallow deer in Denmark, which also included several infrastructure

Table 3. Comparison of Global Warming Potential Between a Farming System and a Ranching System for Captive Deer Breeding (per 1 kg of Live Weight).

		Farm breeding system		Ranch breeding system	
No.	Category	$kgCO_2eq$	%	$kgCO_2eq$	%
1.	Captive infrastructure	7.47	42.44	10.10	58.38
2.	Feed meadow	2.25	12.58	0	0
3.	Cultivation	7.88	44.77	7.20	41.62
	Total	17.60	100.00	17.30	100.00

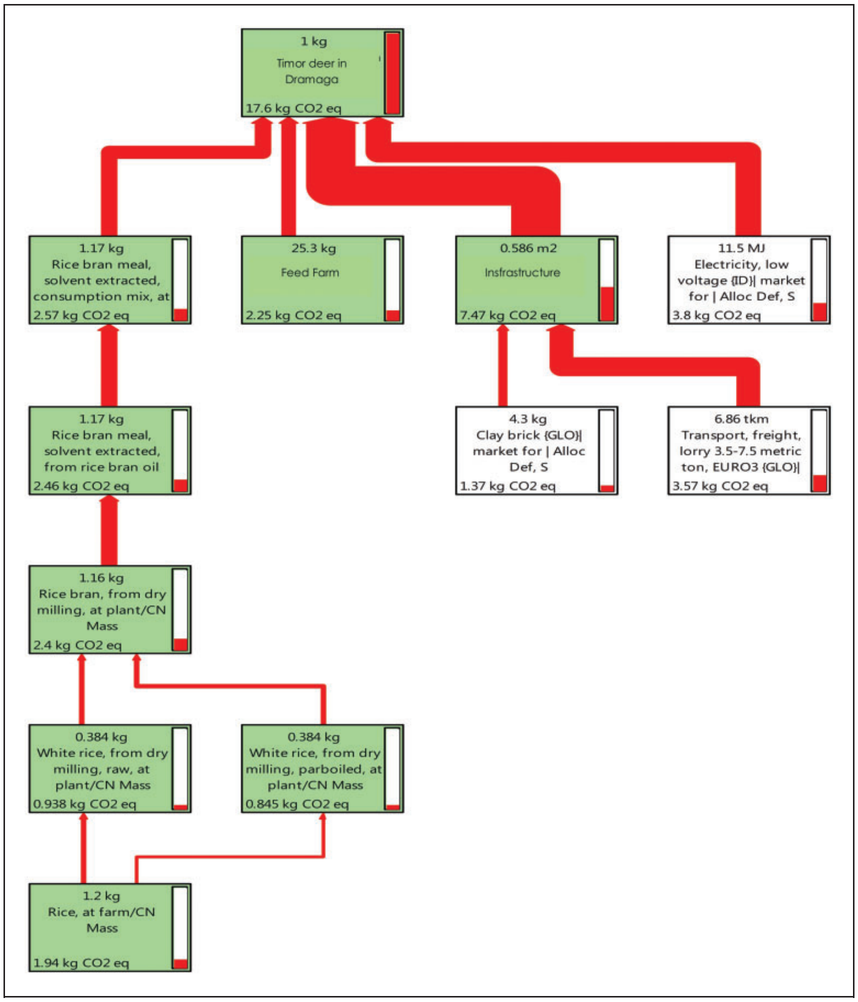

Figure 3. LCA Analysis of Timor Deer in the Farming System (Dramaga Research Forest Bogor).

inputs such as cages, slaughtering process, and transportation to consumers (Saxe, 2015).

The results of other deer LCA analyses indicated smaller values, including 12.532 $kgCO_2eq$ (Natural Capital Ltd, 2009) and 0.188 $kgCO_2eq$ (Rebecca et al., 2013). Variations in the values generated from these deer LCA analyses, apart from the different functional units used, are also caused by the unequal LCA analysis scope. The wider the scope set in the LCA calculation, the greater the value generated due to the increased number of resource inputs. The variety of methods in breeding systems and the scope of analysis make it difficult to compare the results of different studies (Florindo et al., 2017). Nevertheless, the range of impacts resulting from the various production processes can be shown in Table 4.

Table 4 shows the emissions produce from conventional livestock production. The least emissions are produced from pig breeding, ranging from 0.959 to 6.90 $kgCO_2eq$ (González-García et al., 2015; Nguyen et al., 2011; Rebecca et al., 2013; Reckmann, 2013; Reckmann et al., 2012; Roy et al., 2012; Winkler et al., 2016). For sheep breeding, the GHG impact generated ranges from 19.0 to 28.4 $kgCO_2eq$ (Ledgard et al., 2010; Ripoll-Bosch et al., 2011). The greatest emissions are produced from cattle breeding, ranging between 13.78 to 35.6 $kgCO_2eq$ (Florindo et al., 2017; Huerta et al., 2016; Ogino et al., 2016; Pelletier et al., 2010; Rebecca et al., 2013; Roop et al., 2013; Roy et al., 2012). Thus, from the studies that are available, emissions from deer production in Indonesia are only bettered, on average, by pig production in other parts of the world.

Deer cultivation practices in Indonesia have relatively low GHG emissions, with little difference between the farming and ranching systems. Deer cultivation has high potential in Indonesia, with a majority Muslim people, for whom pig cultivation is not an option. The small differences between farming and ranching systems are due to the similar forms of management applied, especially the use of similar feed types and the construction

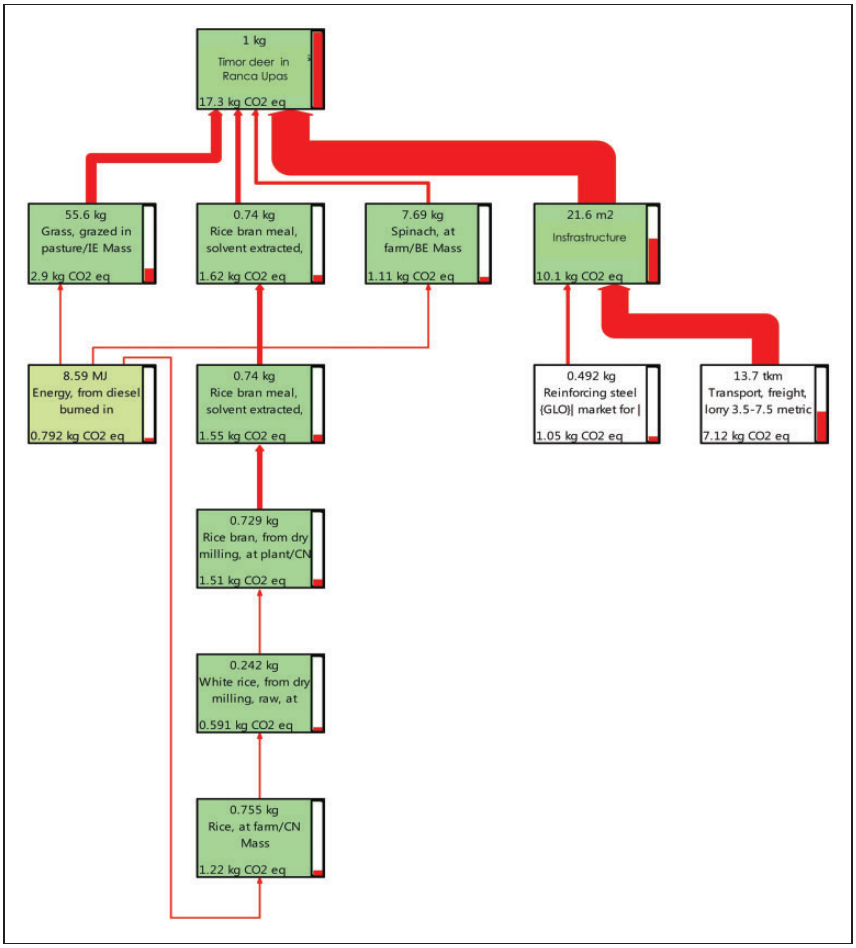

Figure 4. LCA Analysis of Timor Deer in the Ranching System (Ranca Upas Bandung).

Table 4. Comparison of Life Cycle Assessment (LCA) Analysis Results Between Deer and Other Livestock.

Type of livestock	Environmental impact (kg CO2eq)	Functional units	Boundaries	Sources
Deer	9.88–44.8	1 kg of deer meat	From farm to consumers	Saxe (2015)
	12.532	1 kg of carcass weight	From the farm to consumers	Natural Capital Ltd. (2009)
	0.188	1 kg of deer meat	Deer from hunting to slaughtering	Rebecca et al. (2013)
Cow	20.60–21.73	1 kg of boneless and nonfat meat	From the farm to slaughter	Huerta et al. (2016)
	14.8–19.2	1 kg of live weight	From the farm to slaughter	Pelletier et al. (2010)
	13.78	1 kg of live weight	From the farm to slaughter	Roop et al. (2013)
	30.00	1 kg of meat	From farms to supermarkets	Rebecca et al. (2013)
	10.6–14.00	1 kg of live weight	From the farm to slaughter	Ogino et al. (2016)
	35.6	1 kg of meat	From the farm until cooked	Roy et al. (2012)
Sheep	19.5–28.40	1 kg of live weight	From farms to consumers	Ripoll-Bosch et al. (2011)
	19.0	1 kg of sheep meat	From farms to consumers	Ledgard et al. (2010)
Pig	2.6–6.3	1 kg of pork meat	From the farm to slaughter	Reckmann et al. (2012)
	3.22	1 kg of pork meat	From the farm to slaughter	Reckmann (2013)
	6.90	1 kg of meat	From the farm until cooked	Roy et al. (2012)
	0.959	1 kg of meat	From farms to supermarkets	Rebecca et al. (2013)
	2.2–3.7	1 kg of live weight	From the farm to slaughter	González-García et al. (2015)
	4.751	1 kg of carcass weight	From farms to consumers	Winkler et al. (2016)

of captive breeding infrastructure. The use of iron material for cage construction and the use of fuel for transportation is quite large during infrastructure development, so the GHG emission contribution at this stage is quite high, reaching 42.44% of the total emission (in the farming system) and 58.38% of the total emission (in the ranching system). Moreover, metals used in construction usually experience a number of different processing techniques, such as heating, coating with nonmetallic substances, mixing with other metals, and reaction with certain chemicals. The whole process requires high fuel consumption and produces CO_2 emissions and other pollutants that can affect the environment (Yahya et al., 2016).

On the other hand, at the cultivation stage, each kg of deer live weight has a lower impact, which is 7.88 kgCO_2eq (farming system) and 7.20 kgCO_2eq (ranching system). That is, the environmental impact of producing 1 kg of deer is less than that of producing 1 kg of cattle (Cederberg et al., 2009). This is because cattle emit more methane, which is the main cause of GHGs, compared with deer both in total and per kg of meat (Swainson et al., 2008). Several factors influencing the production of methane from ruminants are intake levels; feed types and quality; energy consumption; animal sizes and types; growth rate; production levels; and environment temperatures (Broucek, 2014b). Swainson et al. (2008) stated that methane produced from each kg of dry feed intake consumed by cattle, sheep, and deer is different, reaching 20.6 g CH_4, 18.4 g CH_4, and 16.5 g CH_4, respectively. Highly nutritious types of feed tend to produce low amounts of methane and can increase livestock growth and reduce emissions in the life cycle of meat production (Cederberg et al., 2009; Pelletier et al., 2010; Peters et al., 2010; Rivera et al., 2014).

Feeding strategies not only have an impact on methane gas emissions resulting from impurities, which are by-products of digestion, but also impact other GHG emissions (Florindo et al., 2017; Nguyen et al., 2010; Van Middelaar et al., 2014a, 2014b). In this study, the contribution of feed to emissions reached 35.96% in both the farming system and ranching system. This number is lower than the one found by Saxe (2015) where the impact of feeding on emissions was 60% of the overall environmental impact of deer production. The more types of concentrated feed and other feeds purchased from outside the cage will lead to greater emissions (Ogino et al., 2016). Therefore, food becomes very noteworthy when breeding deer outside their natural habitats. Providing high-quality food for ruminants can produce lower methane levels and increase livestock growth rate, thereby reducing emissions in the life cycle of meat production (Cederberg et al., 2009; Pelletier et al., 2010; Peters et al., 2010).

Management intensification also affects the amount of methane produced. The effect of emissions resulting from differences in livestock breeding systems was also reported by a number of researchers. Rivera et al. (2014) conducted a study of cattle breeding in Veracruz, Mexico and concluded that GHG emissions produced by each kg of beef in an intensive system (adopting modern technology) are higher than that in an extensive system (more traditional). Meanwhile, Huerta et al. (2016) and Ogino et al. (2016) concluded that cattle breeding with an extensive system actually produced higher GHG emissions than the intensive system. This is due to the factors of feed and waste management. In this research, the difference in deer breeding between the farming system and the ranching system was not very influential on the amount of emission produced because the management of the systems was similar.

This study showed that LCA has the potential to support decision making from the perspective of the production chain. The breeding of Timor deer, as one type of ruminant, outside its habitat has impacts on the environment. Based on the research results, viewed from the environmental sustainability level, the farming system and ranching system applied in Timor deer captive breeding is almost the same because the management and use of resources applied are not very different. For each kg of Timor deer live weight in the farming system, the total emission produced (17.60 kgCO_2eq) was 1.7% greater than that in the ranching system (17.30 kgCO_2eq). In addition to infrastructure development, the use of food also significantly contributes to the increase in GHG emissions produced by these two deer breeding systems.

Implications for Conservation

The environmental dimensions of Timor deer breeding are not limited to the value of emissions produced. Conservation values currently become the dominant factor because the Timor deer in Indonesia is categorized as a rare species and protected by law, so the utilization of Timor deer in Indonesia is still limited. Therefore, efforts to increase the productivity and population of the deer outside their natural habitat are a priority, both through captive breeding carried out intensively in cages (farming system) and extensively in grasslands (ranching system). With the increasing population of Timor deer in captivity, it is expected that many will be released back to nature to stabilize the population of Timor deer in their natural habitat and to help conserve the wildlife that are predators of Timor deer such as Komodo dragons (*Varanus komodoensis*) and Javan leopards (*Panthera pardus*). Taking note of the development of Timor deer cultivation abroad and the low emissions produced from Timor deer production compared with those of other conventional livestock, there is a strong case for breeding Timor deer for human consumption while at the same time providing individuals for release into the wild to maintain the Timor deer population in nature. In addition, adequate protection effort is needed for wild deer in protected areas with an emphasis on protecting them from poacher so that the wild deer population in nature will be maintained.

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