Iranian Journal of Applied Animal Science

Estimation of Optimum Utilization of Ruminant Feed Resources on Tropical Dry-Land during Dry and Rainy Seasons

Research Article

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Received on: 21 Jan 2021
Revised on: 30 Jul 2021
Accepted on: 15 Aug 2021
Online Published on: Jun 2022

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Online version is available on: www.ijas.ir

ABSTRACT

This study aimed to estimate the optimum utilization of ruminant feed resources in tropical dry-land during dry and rainy seasons. Data concerning feed availability and quality were collected from Gunungkidul Regency of Indonesia over two seasons: the dry and rainy seasons. The JAVA program, the model, was used to estimate the availability of feed for ruminants associated with mean live weight gain (MLWG) and total live weight production (TLWP). The results showed that the maximum production in the dry season was obtained when 18% dry matter (DM) was used (MLWG 0.33 kg/animal unit (AU)/day, herd size (HS) 197 AU, and TLWP 11.94 tons/season), or in the rainy season, when 46% DM was used (MLWG 0.18 kg/AU/day, HS 1116 AU, and TLWP 37.22 tons/season). Furthermore, when only 100% was used, it could feed a maximum of 1500 AU and 2968 AU in the dry and rainy seasons, respectively. Without the transfer of feed from one season to another, a constant number, 350 AU, was obtained for HS, with a maximum TLWP of 19.16 tons/year. On the other hand, when the feed was kept constant at 34% dry matter (DM), a maximum TLWP obtained was 32.32 tons/year which is enough 420 and 820 animal units in the dry and rainy season, respectively. It was concluded that to obtain maximum TLWP in each season, only 14.5% to 46% of available DM feed should be used, as most of the available feed was of very low quality.

KEY WORDS animal production, dry-land farming, dry season, rainy season, ruminant feed.

INTRODUCTION

Animal production is a key aspect of the food security and development of any country (Bamaiyi, 2013). It provides foreign exchange for the economy, employment for people, a protein source for human nutrition, and also provides raw materials for industries (Ibrahim and Jayatileka, 2000). Animal production can be defined as the conversion of feed into animal products, such as meat and milk, which provides an opportunity for the use of surplus labor between sowing and crop harvesting. One of the factors that influences development and animal productivity is the nutrition of animal feed. Without enough supply of feed and nutrition, the availability of livestock supply will be significantly reduced (Parmawati *et al.* 2018). The animal's nutritional balance plays an important role in animal productivity. Manipulation of better nutrition can increase animal production of crude protein (CP) and total digestible nutrients (TDN) by up to 50% (Sarwar *et al.* 2012).

In some areas, feed is not readily available and not easily affordable for certain farmers, especially in dry-farming areas (Bamaiyi, 2013). Dry-farming areas are defined as regions used for crop production which receive less than 500 mm of annual precipitation (Peterson, 2005). Gunungkidul Regency in Daerah Istimewa Yogyakarta is well known as the district most used for livestock farming, especially cattle. The population of cattle in Gunungkidul in 2016 reached 150,331 individuals (Disperta Gunung Kidul, 2017). A previous study reported that Gunungkidul is a very good region for developing livestock, with the total area available for forage reaching 315,218.90 tons in a year (Triyanto and Purnomo, 2018). The feed resources for ruminants in this district are dominated by agricultural waste and availability is highly dependent on rainfall and crop planting patterns. During the rainy season, there may be an excess of feed, leading to some parts not being used. On the other hand, during the dry season, feeding difficulties often occur due to low availability of feeds (Mekuanint and Girma, 2017).

In dry-land farming systems, the availability of forage depends on the season and crop planting patterns. Fluctuation in the availability of feed requires farmers to balance feed availability with the number of animals that can be supported, rather than maintaining a constant number of livestock. Under practical conditions, it may be difficult to synchronize the number of animals with the quantity and quality of available feed, since maintaining a constant herd size throughout the year may lead to a shortage of feed in the dry season and excess feed in the rainy season. In this condition, it would be difficult to estimate the number of animals, the level of livestock production, and feed availability in an area to obtain optimal livestock productivity (FAO, 2018). Therefore, information on the availability, quantity, and quality of feed is very important to estimate livestock production capabilities. A previous study reported by Zemmelink *et al.* (1991) estimates maximum animal production reached when 35% of the available dry-matter (DM) feed was used. Moreover, Zemmelink *et al.* (2003) reported that seasonal distribution and selective use of feeds are important factors to be considered in ruminant production systems in tropical limestone area. Reports regarding estimation of optimum feed resources for ruminants in Gunungkidul regency as beef cattle producing district, a dry land area of Indonesia, is not found yet. Therefore, this study aimed to estimate the optimum utilization of ruminant feed resources in the rainfed farming area during dry and rainy seasons.

MATERIALS AND METHODS

Study area and farming systems

The village of Kemejing in Semin, a sub-district of the Gunungkidul regency in the province of Daerah Istimewa Yogyakarta, Indonesia (DIY), was selected for data collection as cattle production in this village was considered to be representative of rainfed agriculture in Java. This village is located on relatively flat terrain at altitudes varying from 200 m to 700 m above sea level (coordinates 7˚51'58.2"S 110˚42'49.5"E). This region has a tropical monsoon climate; the dry season ranges from April to September, and the rainy season ranges from October to March. The annual rainfall average over the last 5 years was 2.633 mm.

Farming activity in this dry-farming region comprises mostly mixed crop-livestock farming, where livestock (mainly cattle with some goats and sheep) are kept by smallholder farmers undercut and carry systems. The main feedstuffs were king grass (a hybrid of *Pennisetum purpureum* and *Pennisetum typhoides*), rice and maize straw, and a small amount of leave from trees, such as acacia, mahogany, jack fruit, mango, and banana.

Farmer sampling procedure

The population in this region at the time of the study consisted of 700 households; of these, 200 were livestock farmers. A total of 17 households was selected as the respondents. They raised cattle for at least 10 years to investigate the feeding management of experienced farmers. In addition, the selected households were cattle farmers with Ongole, Limousine Ongole Cross (LIMPO), and Simmental Ongole Cross (SIMPO).

Data collection

The data were collected from the dry season and rainy season. Cattle were counted and weighed with an electric scale with a maximum capacity of 1000 ± 1 kg. Bodyweight data and cattle identity records were collected on days 1, 67, 148, 247, and 302 of the study. Farmer profile including age, education level, occupation, cultivation area, cattle breed was also recorded. The feeding practices were then observed, including the main feedstuff provided, frequency of feeds, and feed amount. The availability of the main feedstuff was estimated for the whole village by multiplying the village acreage by the average amount of feed per acreage of the selected farms (data obtained from the Bureau of Agriculture, with the average yield of the feed per unit acreage). Samples were taken when the king grass, rice, maize, peanut, soybean, mung bean, and cassava crops were harvested. This was performed in both the dry season and the rainy season to estimate the yield for each. Each feedstuff was collected from three different locations in the village. Within each location, 3 squares were randomly assigned by throwing a stick, the sample areas of one m^2 of king grass and 6.25 m^2 of food crops were fully harvested. Crop residues (the feed part) were separated from the feed part and weighed. After weighing, the harvest of all three repeat squares was then pooled and thoroughly mixed. A subset of the samples was then taken for further analysis.

Samples were analyzed for DM, organic matter (OM), and crude protein (CP) according to the standard proximate analysis. In addition, *in vitro* organic matter digestibility (OMD) was measured according to Tilley and Terry (1963).

Feed resource simulation using the JAVA program

The JAVA feed animal performance simulation model developed by Brouwer (1991) simulates the production performance of ruminants given an animal's live weight, maintenance requirements, and ration inputs for feeding practices during different seasons. The output is the value of surplus or deficit energy available for each animal in the herd at the end of a defined period (Thornton *et al.* 2003). All animals were standardized into an animal unit (AU) of 325 kg per animal (Dinas PKH, 2015) and included in the JAVA program according to their metabolic weight (liveweight$^{0.75}$) without consideration of other factors affecting the animals. The major feature of the JAVA program is that voluntary feed intake is related to the quality of feed (Zemmelink *et al.* 1991; Zemmelink *et al.* 2003) and the quantity and quality of feeds were therefore required for data input.

There were two main steps in analysis using the JAVA program. First, the feedstuffs were ranked based on the intake of metabolizable energy (IME). This value is calculated from the intake of organic matter (IOM) using the following equation for sheep reported by Tolkamp and Ketelaars (1992).

$$IOM= -42.78 + 2.3039 \times OMD - 0.0175 \times OMD^2 - 1.8872 \times N^2 + 0.2242 \times OMD \times N$$

Where:

IOM: expressed in g/kg$^{0.75}$/d^{-1}.

OMD and N (Nitrogen): concentrations in organic matter are expressed in % (g/100 g).

The IOM for sheep is multiplied by an intake factor of 1.333 for conversion to the value for cattle. Then, IOM is multiplied by OMD to obtain the value for the intake of digestible organic matter (IDOM), and this is converted into IME, assuming that 1 g IDOM is equivalent to 15.8 kJ ME.

Secondly, the JAVA program was run to start a stepwise procedure. Steps included taking the proportion of feed available (e.g. 1% determined, the next 1% was added) until all feedstuffs were included and started with the feed with the highest IME. In every step, the following values were calculated:

(1) the total amount of DM feed included.

(2) the mean of weighed OMD and N.

(3) IOM.

(4) IDOM and IME.

Based on those mentioned values above, the following parameters could be calculated:

(5) The number of AU that can be fed *ad libitum*.

(6) Production, measured in MLWG per AU per day.

(7) Total live weight production (TLWP): (5) × (6).

The MLWG was calculated using the formula:

$$MLWG= (IME-ME_M) / b$$

Where:

ME_M: maintenance requirements.

b: amount of ME needed per unit live weight gain.

The values for ME_M and b were set at 512 kJ/kg$^{0.75}$/d and 38.1 kJ/g, respectively. One AU is defined as a cow with a body weight of 325 kg.

RESULTS AND DISCUSSION

Table 1 shows the social characteristics of the farmers. Most of the sample farmers were in the productive age category, between 15 and 64 years (76.47%), have a low education level (70.59%) (BPS, 2018) and their main occupation was farming (70.59%). The farmers have been raising cattle for an average of more than 25 years, assuming that they have been helping their parents raise cattle since they were teenagers (15 years of age), and that all practice animal husbandry as a side occupation. The area of land owned was ranged from 0.15 ha to 1.5 ha (Table 1), and nearly half of the farmers (47.06%) can be considered small farmers, with less than 0.5 ha land. Furthermore, their land could be divided into two types: horticulture (maize, soybean, groundnut, and green pea) fields and rice fields.

The available land was primarily used to cultivate food crops (both on the horticulture and rice fields). The rice cultivated was a local variety (go-go variety), which is harvested at 105 days of age, while plants such as maize, soybean, peanut, mung bean, pea, and cassava were grown in the horticulture fields. The garden, which is the land space around the house, was generally planted with crops such as spinach, chili, eggplant, banana, mango, coconut, and perennials plant (teak, mahogany, and acacia). The mahogany and acacia leaves can be used as animal feed. Therefore, livestock farmers can provide their animals with feed from their farming areas. However, the existing land was used mainly for crop cultivation, while less productive lands, such as the riverbank and the bunds of field, were used to cultivate animal feed (grasses). Thus, the role of crop residues as animal feed was highly prominent.

The main activity of the farmers was planting food crops; cattle rearing was a side occupation.

Table 1 Data of profile farmers respondent

Farmers	Age (year)	Education level	Main occupation	Rice Field (ha)	Horticulture (ha)	Cattle breed
Puryanto	57	ES	Farmer	0.45	0.33	S, PO
Suyatno P	58	SS	Retired	0	0.40	S, L, PO
Suharyanto	52	SS	Farmer	0.25	0.66	L, PO
A. Marsudi	49	B	Officer	0	0.26	S, PO
Sudaryono	71	ES	Farmer	0	0.66	L, PO
Suyanto	67	ES	Business	0	0.18	PO, PO
Darto	67	ES	Farmer	0	0.30	PO, PO
Ny. Suradi	70	ES	Farmer	0	1.50	PO, PO
Gimin	47	ES	Farmer	0.05	0.15	L, L, PO
Sugiyo	60	ES	Farmer	0	0.55	S, S, S
Pariman	52	SHS	Officer	0	0.41	S, PO
Purwanto	60	SS	Farmer	0.10	0.85	S, S, PO
Tarmaji	46	SHS	Farmer	0.15	0.63	S, S, S, L
Ny. Supadmi	47	SS	Farmer	0.05	0.68	S, S
Suyono	60	ES	Farmer	0.75	0.25	S, L
Pandi	44	SHS	Business	0.15	0.22	S, S
Tamin	45	SS	Farmer	0.05	0.10	L, L

ES: elementary school; SS: secondary school; B: bachelor; SHS: senior high school; S: Simmental PO cross (SIMPO); L: Limousin and PO cross (LIMPO) and PO: Pure Ongole (PO).

The number of cattle reared by the farmers were ranged from 1 to 4 heads per farmer, and the breeds were PO, SIMPO, and LIMPO (Table 1). Their reasons for raising cattle were to produce fertilizer and to use agricultural residues.

Farmers fed their cattle 3 times a day: in the morning, afternoon, and evening. The amount and type of feed given daily were highly dependent on the feed availability in the fields. The feed availability usually corresponded to crop harvesting time as the crop residues were the main feed for their animals, regardless of quantity and quality. As a consequence, the feed was varied and might not meet production requirements.

Rice straw and king grass were the dominant forages in both seasons, while rice was cultivated mainly in the rainy season (Tables 2 and 3). King grass was cultivated more intensively on land which could not be planted with food crops. King grass can be harvested starting from 30 days after the water supply was sufficient, and could thus be harvested three times in the dry season and four times in the rainy season.

Farmers cultivated horticulture crops such as maize, soybean, groundnut, and green pea on lands that are unsuitable for rice, in both the dry and rainy seasons. Furthermore, when the water was insufficient for rice cultivation in the dry season, farmers might plant more of the other crops. As a consequence, there was a higher availability of maize straw, groundnut, soybean and green pea in the dry season than in the rainy season.

Rice was harvested only twice a year in this region. The first round was planted after the beginning of the rainy season (November) and harvested at the end of the season in February.

A second round of rice was planted in February and harvested in May. The extending area for the second planting was reduced due to less rainfall. Therefore, the amount of rice straw produced in the dry season was lower than that produced in the rainy season. Overall, the total feed produced in the rainy season was higher than that produced in the dry season.

The nutritional value of individual feeds varied from season to season according to their availability. For example, cassava leaves were only available in the dry season because they were planted at the beginning of the rainy season and then harvested in July and August (the dry season). Furthermore, the estimated IME ranks of feeds were similar for both seasons, with groundnut straw and green pea straw ranking the highest and rice straw ranking the lowest. Results for king grass were not important in the dry season due to its limited availability and low quality.

The effect of increasing the use of all available feeds and using the best quality feeds first on feed intake and animal production, including MLWG and TLWP, in the dry season (Figure 1 A-F). When farmers fed their cattle 5% of the best feeds, the feeds they used consisted of groundnut straw only (Table 2). Consequently, the highest-quality feed (127 g/kg DM CP, 69.2 g/kg DM OMD, and 826 kJ IME) was obtained as indicated by the highest recorded values for both IME and MLWG. However, with this feeding method, only 50 AU could be fed *ad libitum* and resulting in a TLWP of only 6.24 ton/season.

When more of the feedstuffs with lower-ranking IME, such as green pea straw, cassava leaves, and soybean straw, were used, accounting for up to 18% of the total available DM feed, the CP increased (Table 2), while OMD, IME, and MLWG all decreased (Figure 1B-D).

Table 2 Amount of forage, composition and rank of IME in dry season

Name of feed	Harvest Acreage (ha)	Available DM (ton)	CP (g/kg DM)	OM (g/kg DM)	OMD (g/kg DM)	IME (kJ)
Groundnut straw	45	61 (5)	127	903	692	826
Green pea straw	20	19 (2)	112	900	648	724
Cassava leaves	282	106 (9)	181	918	548	585
Soybean straw	73	37 (3)	106	938	522	487
Maize straw	81	188 (16)	72	899	486	388
King grass	29	477 (39)	96	836	426	304
Rice straw	68	324 (27)	58	779	345	157
Total	598	1212 (100)				

DM: dry matter; CP: crude protein; OM: organic matter in dry matter; OMD: organic matter digestibility and IME: intake of metabolizable energy.

Table 3 Amount of forage, composition and rank of IME in rainy season

Name of forage	Harvest acreage (Ha)	Available DM (t; % of total)	CP (g/kg DM)	OM (g/kg DM)	OMD (g/kg DM)	IME (kJ)
Green pea straw	2	2 (0.1)	112	900	648	724
King grass	29	1198 (46.0)	102	863	577	583
Soybean straw	2	3 (0.1)	101	938	522	482
Groundnut straw	10	19 (0.7)	87	867	514	452
Maize straw	14	31 (1.2)	58	890	405	245
Rice straw	250	1351 (51.9)	49	802	399	229
Total	307	2604 (100)				

DM: dry matter; CP: crude protein; OM: organic matter in dry matter; OMD: organic matter digestibility and IME: intake of metabolizable energy.

Nevertheless, the number of animals increased to 200 AU and a maximum TLWP of 11.94 ton/season was achieved (Figure 1 E-F).

When the lower-quality feeds accounted for 39% of DM, the quality of the feed decreased (11.1 g/kg DM CP, 52.8 g/kg DM OMD, and 512 kJ IME). With this feeding method, the energy intake of IME was sufficient only to maintain the herd size. Thus, MLWG was zero, but the number of animals increased to 490 AU (Figure 1 D).

The use of more than 39% DM feed, which was accomplished by including low-quality feedstuffs such as king grass, maize straw, and rice straw, led to a decrease in both the MLWG and the TLWP. King grass and maize straw were estimated to provide only enough energy for maintenance, while rice straw was considered to be a sub-maintenance feed. However, more animals could be kept, which compensated for the lack of growth. Furthermore, if only 100% of DM feed was used, 1500 AU can be fed *ad libitum* (Figure 1E), although this would result in decreases in both the MLWG and the TLWP (Figure 1D and Figure 1F).

The effects of using different percentages of DM feed on the composition of feeds and animal production (MLWG and TLWP) in the rainy season (Figure 2 A-F). The use of up to 46% of the available DM feed resulted in a relatively flat graph (Figure 2 A-D) due to the similar quality levels of the feeds, including both IME and MLWG, consisting of groundnut straw and king grass.

Consequently, 1116 AU could be fed *ad libitum* and a maximum TLWP was achieved. When feedstuffs producing lower levels of IME were used, the quality of the feed decreased and, consequently, so did the OMD and MLWG. In addition, TLWP decreased sharply (Figures 2 D and 2 F).

The use of 61% of the available DM feed was sufficient only for maintenance. Due to the inclusion of rice straw in the feed, the nutritional value of the feed was 892 g/kg DM CP, 53.5 g/kg DM OMD, and 510 kJ IME (Table 2), and the feed decreased in quality, providing energy levels (IME) sufficient only for maintenance. The MLWG was at the zero position, meaning there was no growth, but more animals could be fed *ad libitum*, allowing farmers to have up to 1600 AU.

Furthermore, when all the available DM feed (100%) was used, the nutritional value of the feed was much lower (7.3 g/kg DM CP, 48.2 g/kg DM OMD, and 397 kJ IME), becoming insufficient even for maintenance purposes. Consequently, negative MLWG (-0.23 kg/AU/day) and TLWP (-125.73 ton/season) values were obtained. This occurred because more than 50% of the feed consisted of rice straw (Table 2), which is below the requirement for maintenance. However, the increased number of animals that could be kept *ad libitum*, amounting to 2968 AU, compensated for these values (Figure 2 E).

The amount and proportion of individual feedstuffs largely varied between seasons depending on the distribution of rainfall and crop patterns.

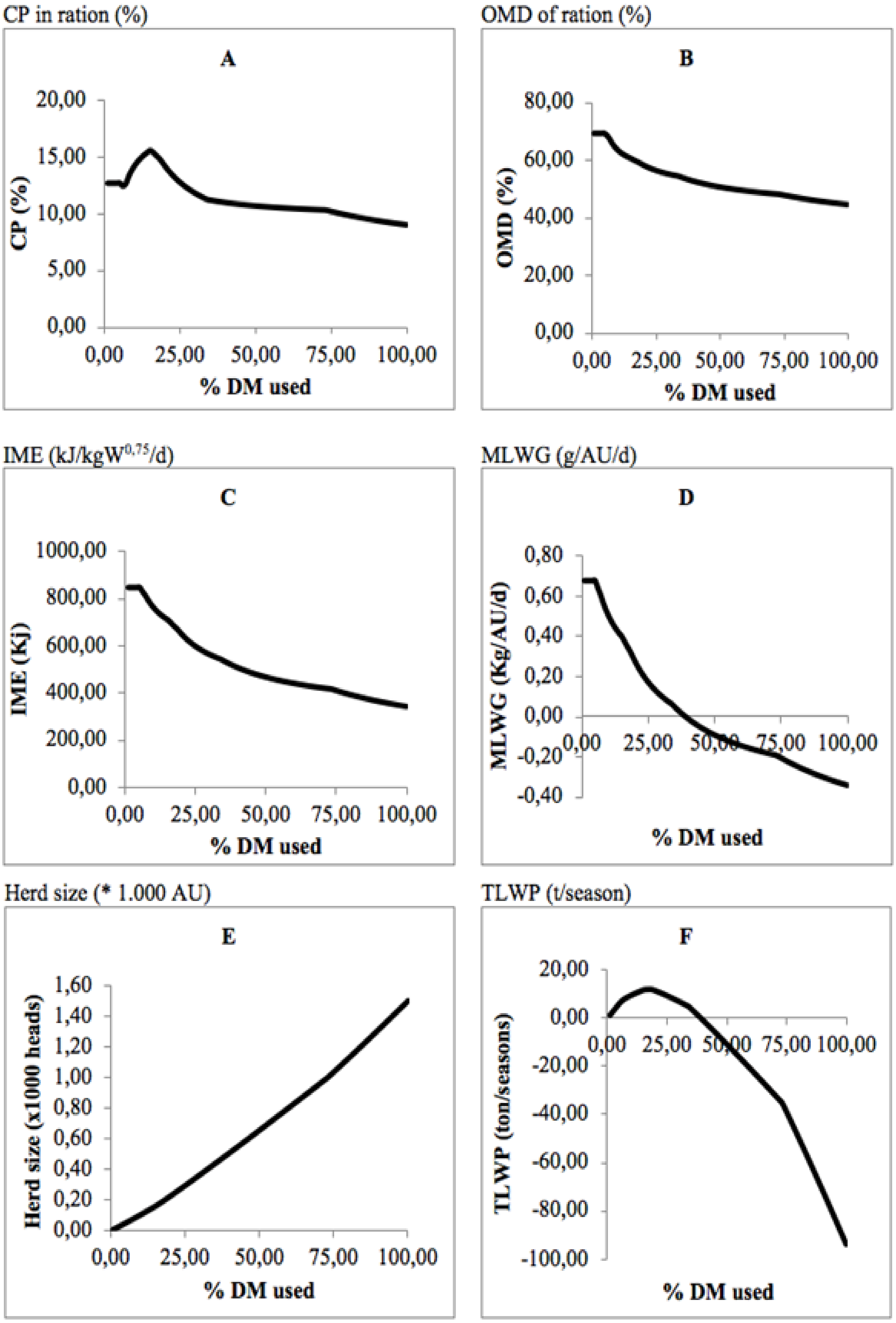

Figure 1 Effect of increasing proportions of total feed dry matter in the dry season (starts with the best feed) on CP content (A), OMD (B), IME (C), MLWG (D), Herd size (E) and TLWP (F)

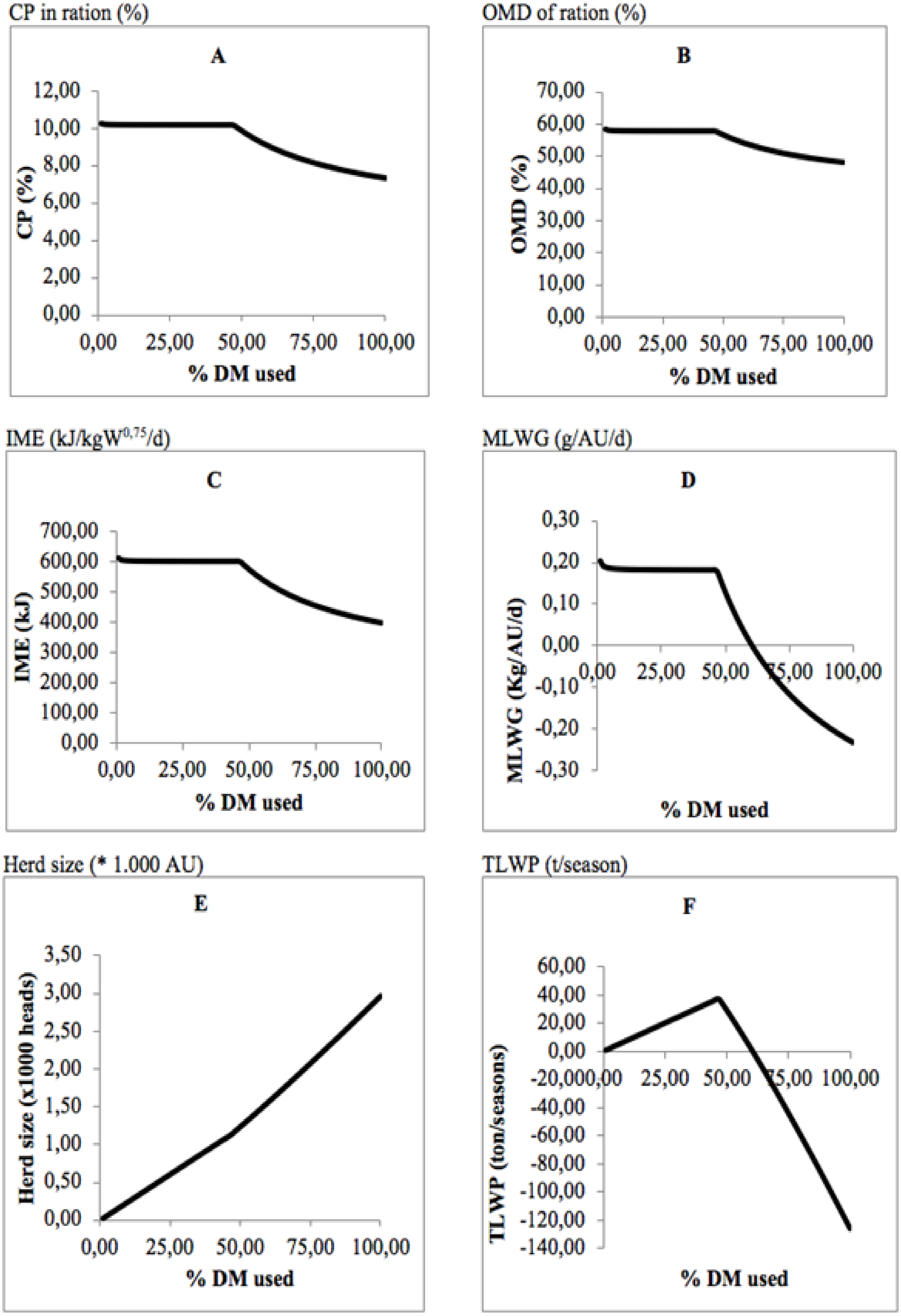

Figure 2 Effect of using increasing proportions of total seasonal amount of feed dry matter in rainy season (starts with the best feed) on CP content (A), OMD (B), IME (C), MLWG (D), Herd size (E) and TLWP (F)

It was difficult to adjust the herd size from one season to the next, as a fixed herd size can lead to a shortage of feed in one season or an excess of feed in another. Under the assumption that there would be no transfer of feeds between seasons, the optimum constant HS to obtain a maximum TLWP for the whole year was 350 AU (Figure 3). This can be obtained when the use of DM feeds in the dry season and the rainy season were 29% and 14.5%, respectively, resulting in TLWPs of 7.36 ton/season in the dry season and 11.80 ton/season in the rainy season. From this calculation, it was determined that the use of DM feed was remarkably different from total feed availability due to the large quantity of low-quality feeds resulting in negative MLWG and TLWP values.

Meanwhile, with a herd size of 900 AU, there was almost no yield of live weight gain with a TLWP of -28.02 ton/season in the dry season and 29.96 ton/season in the rainy season (Figure 4). This finding was in line with DM use; 66.5% in the dry season and only 37% in the rainy season.

There was a possibility to adjust the herd size to the availability of existing feeds for each season. For the portion of the study on the use of DM throughout the year, it was found that a maximum TLWP could be produced when 34% DM was used throughout the year, that is, in both the dry season and the rainy season (Figure 4).

Next, a maximum TLWP of 32.32 t was reached for the year (4.79 t in the dry season and 27.54 t in the rainy season) when cattle sizes were 420 AU in the dry season and 820 AU in the rainy season. The nutritional value of the feed in the dry season was measured at 11.2 g/kg DM CP, 54.3 g/kg DM OMD, and 543 kJ IME, while in the rainy season, it was 10.2 g/kg DM CP, 57.7 g/kg DM OMD, and 602 kJ IME.

This study estimated optimum utilization of ruminant feed resources during dry and rainy seasons in Gunungkidul Regency of DIY which is well known as one of beef cattle production areas. Integrated farming system is well-adopted in this area to increase overall agricultural productivity, optimize land use, reduce the risk of crop failure, and increase farmers' incomes and/or welfare (Devendra, 2012). Ruminants, especially cattle, are commonly raised in crop-livestock integrated systems due to the complementary effects between commodities. In this case, crop residues are used for feed, while livestock manure is used for fertilizer (Nayak *et al*. 2018). There are six dominant types of feedstuffs used for cattle feed in the dry and rainy seasons.

Common feedstuffs found in this area are agricultural waste such as rice straw (*Oryza sativa*), groundnut straw (*Arachis hypogaea*), green pea straw (*Pisum sativum*), soybean (*Glycine max*) straw, maize straw (*Zea mays*), and king grass (*Pennisetum hybrid*). In the rainy season, although there is a high availability of king grass, the use of rice straw remains dominant. Farmers were more likely to provide rice straw from storage than fresh feedstuff due to high availability of rice straw throughout the year (Jasmal and Syamsu, 2013). These findings are in accordance with a previous study stated that the dominant ruminant feed source is agricultural waste, which is influenced by rainfall and crop planting patterns (Yanti and Yayota, 2017).

In general, the ruminant carrying capacity of an area was calculated based on nutrient adequacy, including dry matter, crude protein, and total digestible energy (Alfian *et al.* 2012; Hermansyah, 2012), but the results of these studies were insufficient to describe the optimum livestock production in relation to the availability of feed. In general, the results were overestimated. In this study, we tried to overcome this obstacle by using the JAVA computational package to estimate the real conditions in the field. This model can calculate the average daily gain per animal unit and the total live weight production of a herd that can be achieved based on the available feed resources in an area. Previously, the simulation using JAVA program has been reported in intensive agricultural areas in East Java.

A balance between the availability of feed resources in the region with the existing livestock productivity was precisely estimated (Ifar, 1986; Zemmelink *et al.* 1991; Zemmelink *et al.* 2003). The calculation in their studies assumed that the feed given were arranged from best to lowest quality. For the area in which the composition of feedstuffs is dominated by agricultural waste indicates that using a small amount of available dry matter generated a high average daily gain per animal unit (ADG per AU).

However, it decreases with the increased use of available dry matter feed. This happens because the combination of more feed types decreases the quality of feed. On the other hand, herd sizes that can be maintained increase linearly with the increase in the use of the available dry matter feed. This interaction between herd size and ADG per AU indicates the optimal production results that can be achieved in this area.

In this study, the types of forages given to cattle in the dry season are more variable than those given in the rainy season, i.e. 35 *vs*. 15 types, respectively (data not shown). This indicates that it is difficult to provide forages during the dry season. Thus, farmers instead provide unusual forages for animal feed, such as tree leaves. However, tree leaves can be an alternative feed resource in the dry season to provide proteins, minerals, and vitamins for livestock breeds (Simbaya, 2002). Under this condition, farmers must adapt their feeding practices and herd management to the available resources which has implications for low animal production due to the lack of quality feed resources availability (Priyanti *et al.* 2012).

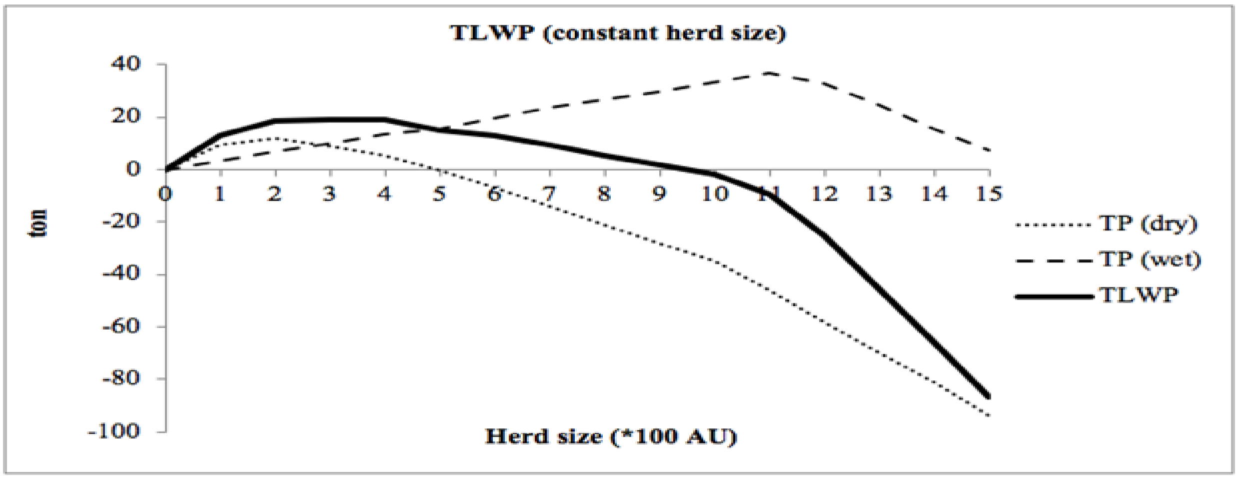

Figure 3 Effect of constant herd size on the total live weight production (TLWP) for whole year without transfer of feed

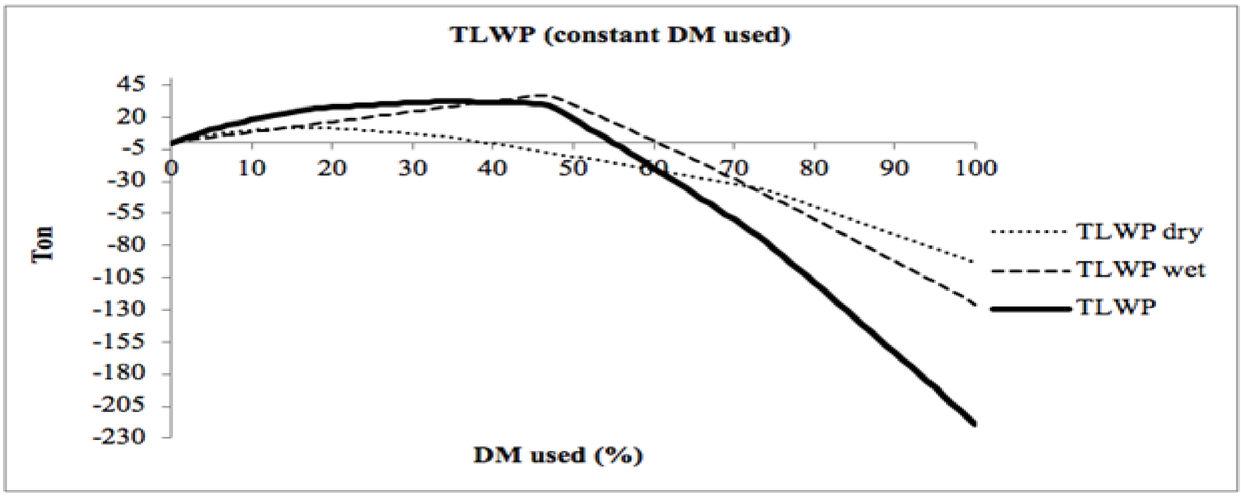

Figure 4 Effect of constant dry matter (DM) used on the total live weight production (TLWP) for whole year without transfer of feed

Actual ADG of the cattle in this study during season was positive, on the other hand, negative ADG was estimated using JAVA model. This difference might be caused by the use of tree leaves at 12% dry matter which is difficult to quantify and not able to be taken into account in the simulation program. Dutta *et al.* (1999) reported that leaves of *Prosopis* and *Leucaena* have higher crude protein levels compared to rice straw (15.5 and 29.6% *vs*. 6.0% DM, respectively).

In the rainy season, the actual ADG was almost similar to the JAVA model (0.21 kg/head/day *vs*. 0.18 kg/AU/day). These results are quite similar because the type of feedstuffs used in this study was similar to those used in the simulation program. This shows that the findings from the JAVA program can be applied to estimate the production rate of ruminants based on the availability of feed resources in a specific area.

Similarly, the findings of the JAVA program can be applied to estimate the level of use of feed resources that optimize the production of body weight in dry-land farming areas.

The ADG achieved both in the dry and rainy seasons ranged from 0.1 to 0.2 kg/head/day. Farmers raise beef cattle to accumulate savings, produce fertilizer, and provide a use for agricultural waste. Livestock farmers, therefore, prefer to raise big herd sizes, even though this resulted in low ADGs. This is because the farmers see more benefits when they raise more cattle. Livestock farmers feel more secure in their farming activities because they have more assets to hold as insurance against the risk of crop failure. Furthermore, higher cattle numbers lead to an increased production of organic fertilizers, which maintain soil quality. In an integration system, livestock and crops interact to create a synergy through the use of crop waste and the production of livestock manure (Gupta *et al.* 2012).

Under the condition of low feed availability and quality, SIMPO and LIMPO breeds did not show higher ADG than the PO breed. Therefore, the results of this study are not consistent with the objectives of crossing to obtain offspring with higher growth rates (Favero *et al.* 2019).

This is because farmers provide low-quality feeds, which are often the only feed available. In other words, the feed given was not adequate to support the genetic potential of SIMPO and LIMPO cattle.

The results of the computational simulation showed agreement with the farmers' practices in the field. The optimum total live weight production is achieved with the use of a total available 18% feed dry matter in the dry season and 46% feed dry matter in the rainy season. In the simulation with constant herd size and without transferring feeds between seasons, the highest total live weight production is achieved when the total available dry matter of feed used was 20%. This showed that the DM feed mostly originated from low-quality feedstuffs and that high use of these feeds leads to a decrease in total live weight production. However, larger herd sizes can be maintained with a higher use of total available dry matter of feed. As stated previously, livestock farmers prefer to keep a greater number of animals, even though it means they will achieve low ADGs. To optimize the use of available DM feed, high-quality feedstuffs must be added into feeds. For example, farmers could give legume leaves, such as *Gliricidia maculate*, *Sesbania grandiflora*, and *Leucaena leucocephala* in the dry season (Castro-Montoya and Dickhoefer, 2020). These plants can live and thrive in the dry season because they have deep roots (Sileshi *et al.* 2011).

CONCLUSION

Actual average daily gain of cattle was almost the same value compared to the estimation of average daily gain using Java Model. The optimum total live weight production was obtained when 14.5% and 46% of available dry matter of feed was used for dry and rainy seasons, respectively. Most of the available feed resources was of very low quality. Not all feed types and dry matter productions of feedstuffs could be identified due to difficulties in measurements. The primary disadvantage of the JAVA program simulation is that not all of the feedstuffs that were used can be included in the calculations. For example, forage production from trees, such as mahogany (*Swietenia mahagoni*), acacia (*Acacia sp*), guava (*Anacardium offinale*), and jackfruit leaves (*Artocarpus heterophyllus*), would not be useful for making estimations over the whole year, as these types of feedstuffs are mostly used in the dry season. To overcome this disadvantage, a methodology for the accurate estimation of dry matter forage production from tree crops should be developed.

ACKNOWLEDGEMENT

This study was partially funded by the Ministry of Education, Culture, Research, and Technology of Republic of Indonesia through sandwich program. The authors would also like to thank all those who helped during data collection in the field and writing this manuscript.

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