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9.2 An optimization model for a sustainable agro-livestock industry

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Abstract
This paper deals with an optimization model for a sustainable agro-livestock industry. In this case, the agro industry established a subsidy program for the farmers in terms of utilizing pineapple skin waste generated from its production activities as the main cattle feed as a grass substitute. The policy is desired to increase welfare of farmers as well as minimize welfare deviation among farmers. The problem faced by the agro industry is to determine the cattle which will be fattened using the subsidized feed with regards to waste availability. The result of the study shows that the subsidy policy could improve welfare of the farmers and minimize welfare deviation among farmers. This indicates that such kind of subsidy policy can be use to promote sustainable development.
Keywords:
Agro-Livestock Industry, Optimization, Subsidy Policy, Sustainable Development

1 INTRODUCTION

Sustainable development has gained increasing awareness in recent years. The concept of sustainable development is widely used to assess the impacts of human activities on nature, environment, and resource base. The interdependent and mutually reinforcing pillars of sustainable development include economic development, social development, and environmental protection [1].

There have been literatures discussed about strategies to achieve the goal of sustainable development. On the manufacturing side, strategies have been developed to achieve sustainable manufacturing. One of the main focuses of sustainable manufacturing is showing a higher level of regard for the impact on the environment by minimizing water use, greenhouse gas emissions, waste generation, and energy requirements. In addition to protecting the environment, sustainable manufacturing further aims to improve the welfare of people, nature, and life in the future.

With regards to supply chain of manufacturing industries, the concept of sustainable manufacturing should be implemented along the supply chains. For example, a sustainable food manufacturing that uses agricultural material as an input should develop an approach which improves the economic, social, and environmental protection both for the manufacturing company and the agricultural industry as a supplier. On the downstream side, an industry should develop strategies that can reduce waste and pollution generated from distribution and after use activities. Thus, an integrated approach along the supply chain such as developing industrial park is necessary to develop to achieve the aim of sustainable manufacturing.

Government usually uses a range of policies to promote sustainable development. Literatures in economics provide extensive discussions and mentioned that economic instruments such as tax and subsidy provide one of the most effective public policy tools. The quality of life should be further increased by way of the environmental and economic benefits accruing from the implementation of the policy.

An integrated approach has been done by an agricultural industry called PT GGP. The company was established in 1979 in Lampung, South Sumatra, Indonesia and has evolved to be fully integrated pineapple plantation and processing facility to produce canned pineapple products and pineapple juice concentrate. PT GGP is now the third largest producer of canned pineapple products and pineapple juice concentrate in the world. The plantation currently consists of 33,000 hectares of land with production capacity of 500,000 tons of Cayenne pineapples annually [2]. In order to utilize pineapple skin waste produced by production activities, PT GGP established PT GGL as their subsidiary.

PT GGL is an agro industry in Terbanggi District, the province of Lampung, Indonesia. PT GGL is a company engaged in breeding cattle and began operations in 1987. The company utilizes PT GGP's pineapple skin waste as the main feed for cows as a grass substitute.

PT GGL has an area of 50 acres. Fifteen acres of the land is used for cowshed. In addition to breed local cattle, PT GGL imports Brahman Cross cattle types from Australia. PT GGL also processes pineapple peel, an abundant waste product that is difficult to dispose of, into pinemeal for internal use and for export to overseas markets, mainly Japan [3]

As an agro-based industry, besides having economic mission PT GGL has a social mission. This can be seen from the company's strategy in achieving its vision, such as establishing a close cooperation with the local communities in implementing community development.

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PT GGL has developed a partnership to more than 2,000 farms covering an area of plasma 6 districts with 48 villages in 17 districts. One of the types of the partnership is cooperation in cattle fattening. This partnership aims to provide knowledge and opportunity to the people to be able to maintain the cattle farming systems better than traditional systems, so that the income can be increased. This partnership will also facilitate the public in terms of feed that is in accordance to the standard owned by the company.

This study focuses on GGL's cooperation in cattle fattening, especially cow fattening. In this case, breeders or stock farmers prepare livestock production facilities such as bred cows and stables. The company gives subsidy to the farmers in terms of cattle feed with lower price than market price. At the end of the subsidy program, the farmers have to sell their subsidized cows to the company. The farmers do not pay the subsidized feed at the time they take the feed from the company, instead of paying the cost of the feed at the end of the program. So when the farmers sell the subsidized cows to the company, the farmers receive money from the company as the price of the cows minus cost of the subsidized feed. The feed has standard nutrition and cheaper than the normal market price.

The above description illustrates that PT GGL cares about the quality of life of surrounding communities. The company voluntarily operates subsidy policy without government intervention. This can be one example of industry's commitment to support the achievement of sustainable development. The social mission of PT GGL is intended to an increase in social welfare or poverty reduction, which is one of the challenges of sustainable development.

The utilization of pineapple skin waste for cattle feed is a practice of industrial ecosystem. The principle underlying 'industrial ecosystem' or 'industrial symbiosis' or 'eco-industrial parks' is that an industrial estate operates as an ecosystem, with wastes, by-products, production aids and energy being exchanged among closely situated firms [4 & 5].

The objective of this paper is to model the problem faced by PT GGL. The problem here is how to determine the optimal distribution of the subsidized waste cattle feed to the farmers with regards to waste availability and both for economic and social objectives of the company. We examine the model with a case study. It is then followed by a discussion about the benefit of a cooperation strategy as done by PT GGL to help promote the concept of sustainability.

There have been studies on the utilization of agro-waste. However, the studies concerned with different objects and objectives. A study on the optimization of the biogas yield from anaerobic co-digestion of manures and energy crops was done by Guilano *et al.* [6]. By applying the principles of Industrial Ecology and Ecological Modernization, Anh *et al*. [7] studied on the possibility and feasibility to develop an eco-agro industrial cluster including agriculture, fishery processing company, by-product pants, and waste water treatment units in Vietnam. Using dynamic model, Parsons *et al*. [8] developed an integrated crop-livestock model of farming practices exhibited in sheep system of Yucatan state. The study was to assess biophysical and economic consequences resulted by the interactions between farmer, crops, and livestock. Another study was done by Lin et al. [9]. The study aimed to propose a strategy for sustainable treatment of the livestock husbandry wastewater, which was to recycle anaerobic treatment effluent as irrigation water. It is clear that this study is different from previous studies.

2 SUSTAINABLE AGRO-LIVESTOCK INDUSTRY

Agro industry is an industry that adds value to agricultural products in the widest sense, including marine products, forest products, livestock, and fisheries [10]. Agro-industrial development will be very strategic when done in an integrated and sustainable. A synergistic and productive agro industry is one done by the application of agro-livestock industry [11]. Agro-livestock industry can be regarded as an attempt to integrate the agriculture and livestock industry. It is carried out in synergy where each business are integrated with each other "mutual support", "strengthening mutual" and "interdependence" by optimally making use of all potential resources owned by zero waste principle. There are some objectives of livestock integration such as to increase the use of local resources, resulting in zero waste and to improve the independence of the farmers [12].

Agro-livestock industry which is conducted through collaboration between the company and the surrounding community has the advantages for the farmers such as providing opportunity trying to farm livestock, additional revenues, ability to raise the technical and organizational, and togetherness among farmers and between farmers and companies. As for the company, such industry has the advantage of utilizing company's waste, increasing revenues from byproduct and marketing services livestock production, and a sense of belonging within the company [13].

3 A MODEL FOR SUSTAINABLE WASTE-BASED AGRO-LIVESTOCK INDUSTRY

The cooperation with stock farmers established by PT GGL described in Section one can be categorized as sustainable waste-based agro-livestock industry. In this case, the company try to optimally making use of pineapple waste to substitute main cattle feed resulting in zero waste. Moreover, in addition to reduce environmental impact, the program is desired to improve the welfare of the farmers.

The problem of the cooperation between PT GGL and stock farmers is illustrated in Figure 1. The figure shows that there are I farmers who want to participate in the subsidy program. Each farmer has g cattle that are categorized into local cow (l=1) and imported cow (l=2). The problem needs to be solved by the company is to decide which cow that will be subsidized in term of feed with special price (Cp_s). The objective of the subsidy program is to minimize the deviation of welfare among farmers (*DevH)* with regards to feed availability per period (A_t). When selling their subsidized cows, the farmers receive over the selling price of the cattle cut by the cost of the subsidized feed. The subsidy program is scheduled for fattening period of T. Unsubsidized cow is fattened with feed from outside the company with the price of Cp_b per kilogram, which is more expensive that the subsidized feed from the company.

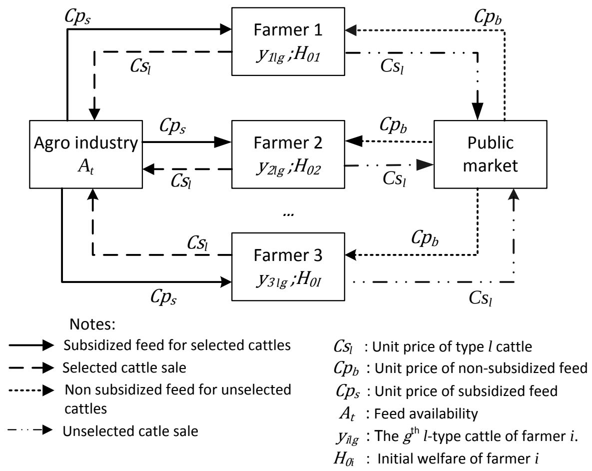

Figure 1: Sustainable agro-livestock industry

Welfare changes of farmer i during the subsidy period (σ_i) is represented by the difference between income (P_{Ti}) and family living cost of the farmer (D_{Ti}). The income can be from selling both subsidized and non subsidized cows and from outside livestock income. Thus, the welfare of each farmer at the end of the subsidy period (H_{Ti}) will be different. This difference is to be minimized by the company.

In developing the model of the case study, we used the following notations:

W_{0ilg}	:	Initial weight of the g^{th} type-l cow of farmer i at the end of the program (kg)
W_{Tilg}	:	The weight of the g^{th} type-l cow of farmer i at the end of the program (kg)
H_{0i}	:	Initial welfare of farmer i
H_{Ti}	:	Welfare of farmer i at the end of the program
P_{Ti}	:	Profit of farmer i at the end of the program
M_{Ti}	:	Total sales of farmer i at the end of the program
M_{0i}	:	Cows purchasing cost of farmer i
τ	:	A constant representing linearity of demand for cattle feed to cattle weight.
B_{Ti}	:	Total feed cost of farmer i at the end of the program
B_{Tsi}	:	Cost of subsidized feed of farmer i
B_{Tbi}	:	Cost of non-subsidized feed of farmer i
Q_{Ti}	:	Total demand for feed of farmer i for feed during the program
Cs_l	:	Unit price of type-l cow (Rp/kg)
Cp_s	:	Unit price of subsidized feed (Rp/kg)
Cp_b	:	Unit price of non-subsidized feed (Rp/kg)
Δw_l	:	The increase in weight of type-l cow (kg/day)
K	:	Number of days of the program (days)
k	:	The day of the subsidy period
t	:	Feed delivery period (t=1,2,…, T)
N	:	Number of days of feed delivery period (days)
n	:	The day of feed delivery
β_i	:	Net income of farmer i at the end of the program (Rp)
Δh_i	:	The changes of welfare index of farmer i
I	:	Number of farmers
A_t	:	Feed availability in each feed delivery period (kg)
D_{Ti}	:	Living cost of farmer i during fattening period (Rp)
y_{ilg}	:	Binary integer number, equal to 1 if the g^{th} type-l cow is selected for subsidy and 0 if otherwise
RT_i	:	Income outside cow fattening of farmer i

The model was developed based on the following conditions: (1) price of a cow is linear to his weight and the unit price is different for each type of cow; (2) feed price includes transportation costs; (3) welfare is linear to income and living cost; (4) cows are in a healthy or normal condition; (5) there is only a single market for cattle feed, so there is only one type of cattle price purchased from outside the company; (6) cow weight gained per day is constant and the same for the same type; and (7) subsidized feed meets the nutritional composition so that the changes in weight of the cow is assumed to be constant because the feeding is done on a regular basis.

The daily demand for cattle feed is linear to the weight of the cow. Based on the problem discussed earlier, the total requirement for feed of farmer i during the program can be formulated as follows:

$$Q_{Ti} = \sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}\, W_{0ilg} + \Delta w_l(k-1))\tau \quad (1)$$

$$\forall y_{ilg} = 1$$

Cattle feed requirement of each period is:

$$Q_{ti} = \sum_{n=1}^{N}\sum_{g=1}^{G}\sum_{l=1}^{l} y_{ilg}((W_{0ilg} + N\,(t-1)) + (n-1)\Delta w_l)\tau$$

$$\forall y_{ilg} = 1 \text{ and } t = 1, \ldots, T \quad (2)$$

Total feed cost of farmer i is:

$$B_{Ti} = B_{Tsi} + B_{Tbi} \quad (3)$$

where:

$$B_{Tsi} = \sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}((W_{0ilg} + \Delta w_l(k-1)\tau)Cp_s \quad \forall y_{ilg} = 1$$

and

$$B_{Tbi} = \sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}((W_{0ilg} + \Delta w_l(k-1)\tau)Cp_b \quad \forall y_{ilg} = 0$$

Total cow purchasing cost of farmer i is a product of the initial weight of each cow and the unit price of cow, which depends on the type of cow:

$$M_{0i} = \sum_{l=1}^{2}\sum_{g=1}^{G} W_{0ilg}\; Cs_l \quad (4)$$

Final weight of the g^{th} type-l cow of farmer i can be calculated as follow:

$$W_{Tilg} = W_{0ilg} + (K-1)\Delta w_l \quad (5)$$

Total sales at the end of the fattening period of farmer i can be calculated as follows:

$$M_{Ti} = \sum_{l=1}^{2}\sum_{g=1}^{G} y_{ilg}\;(W_{Tilg}\, Cs_l)$$

$$M_{Ti} = \sum_{l=1}^{2}\sum_{g=1}^{G} y_{ilg}\;((W_{0ilg} + (k-1)\Delta w_l)Cs_l) \quad (6)$$

Total profit of farmer i is derived from the total cattle sales at the end of the program minus total cow purchasing cost at the beginning of the period and the total feed cost during the program. Equation (7) describe the profit of farmer i.

$$P_{Ti} = M_{Ti} - M_{0i} - B_{Ti}$$

$$= \sum_{l=1}^{2}\sum_{g=1}^{G} y_{ilg}\;((W_{0ilg} + (k-1)\Delta w_l)Cs_l - \sum_{l=1}^{2}\sum_{g=1}^{G} W_{0ilg}\; Cs_{l-}$$

$$(\sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}\,((W_{0ilg} + \Delta w_l(k-1)\tau\big)Cp_s +$$

$$\sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}\,((W_{0ilg} + \Delta w_l(k-1)\tau)Cpb) \quad (7)$$

Net income of farmer i is calculated based on his profit from the subsidy program and other incomes reduced by his family living cost during the program:

$$\beta_i = P_{Ti} + R_{Ti} - D_{Ti} \quad (8)$$

Assuming that the unit of welfare index is equal to Rp100,000,-, then the increase of the welfare of farmer i can be calculated as follows:

$$\Delta h_i = \frac{\beta_i}{100000} \quad (9)$$

Thus, the final welfare of farmer i is:

$$H_{Ti} = H_{0i} + \Delta h_i \quad (10)$$

The objective function, that is minimizing welfare deviation among farmers, can be formulated as follows:

$$Min\ DevH = \sqrt{\frac{\sum_{i=1}^{I}(H_{Ti}-\overline{H})^2}{I-1}}$$

$$= \sqrt{\frac{\sum_{i=1}^{I}((H_{0i}+\Delta h_i)-((\overline{H_{0\iota}+\Delta h_\iota}))^2}{I-1}} \quad (11)$$

The constraints of feed availability can be written as follow:

$$\sum_{i=1}^{I} Q_{ti} \leq A_T$$

$$\sum_{i=1}^{I}\sum_{n=1}^{N}\sum_{g=1}^{G}\sum_{l=1}^{L} y_{ilg}((W_{0ilg} + N(t-1)) + (n-1)\,\Delta w_l)\,\tau \leq A_T$$

$$\forall \mathrm{y_{ilg}} = 1 \text{ and } \mathrm{t} = 1, \ldots., \mathrm{T} \quad (12)$$

In addition to feed availability, the company determines minimum income from selling the subsidized cows (Equation (13)) and the minimum welfare to be achieved by each farmer (Equation (14).

$$\sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}\,((W_{0ilg} + \Delta w_l(k-1)\tau)Cp_s \geq 3000000$$

$$y_{ilg} = 0 \text{ or } 1, \text{for } \forall t \in T, i \in I, n \in N \quad (13)$$

$$H_{Ti} \geq 30 \quad (14)$$

4 NUMERICAL ILLUSTRATION

4.1 Case study

The model presented in the previous section was then examined using a case study where there are three farmers who follow the subsidy program. Table 1 show the farmers and their cows proposed for the subsidy program provided by PT GGL.

Table 1: Farmers and their proposed cows

i	H_{0i}	DT_i (x1,000)	RT_i (x1,000)	l	g	W_{0i}
1	20	Rp7,500,-	Rp7,000,-	1	1	250
					2	270
				2	1	300
2	27	Rp8,000,-	Rp7,000,-	1	1	200
					2	240
				2	1	220
3	15	Rp5.000,-	Rp5.000,-	1	1	280
				2	1	300

Subsidized feed composed of pineapple skin and concentrate with the ratio of 89%:11%. The unit price of subsidized feed is the sum of the price of pineapple skin of Rp100,- per kg and concentrate of Rp1,600,- per kg. Non-subsidized feed uses the same composition but different price of pineapple skin, that is Rp150,- per kg.

The local cattle that traditionally fattened will increase by an average weight of 0.5 kg per day. While the weight gain for the imported cattle is equal to 1 kg per day. If the cows are fed better than traditionally fattening the increased weight can be more than 0.5 kg per day for local cattle and more than 1 kg for imported cattle [14]. Weight changes in this study was 0.8 kg per day for local cow (Δw_1) and 1.3 kg per day for imported cow (Δw_2) as the feed has better nutrition, in which there is additional forage and concentrates which serves to add weight.

Other data are as follows:

Cs_1 = Rp23.000,-/kg	C_{Pb} = Rp400,-/kg	x = 7 days
Cs_2 = Rp22.000,-/kg	A = 2500 kgs	T = 16 weeks
C_{Ps} = Rp300,-/ kg	K = 100 days	

Based on Table1 and Equation (11) the objective function of the problem can be formulated as follows:

Minimize

$$DevH = \sqrt{\frac{\sum_{i=1}^{I}\left(H_{Ti}-\overline{H}\right)^2}{I-1}} = \sqrt{\frac{\sum_{i=1}^{1}\left(\left(H_{0i}+\Delta h_i\right)-\left(\overline{H_{0i}+\Delta h_i}\right)\right)^2}{I-1}}$$

$$= \sqrt{\frac{\left(\left(H_{01}+\Delta h_1\right)-\left(\overline{H_{01}+\Delta h_1}\right)\right)^2+\left(\left(H_{02}+\Delta h_2\right)-\left(\overline{H_{02}+\Delta h_2}\right)\right)^2+\left(\left(H_{03}+\Delta h_3\right)-\left(\overline{H_{03}+\Delta h_3}\right)\right)^2}{I-1}}$$

$$= \sqrt{\frac{\left(\left(20+\Delta h_1\right)-\left(\overline{20+\Delta h_1}\right)\right)^2+\left(\left(27+\Delta h_2\right)-\left(\overline{27+\Delta h_2}\right)\right)^2+\left(\left(15+\Delta h_3\right)-\left(\overline{15+\Delta h_3}\right)\right)^2}{3-1}} \quad (15)$$

where:

$$\Delta h_i = \frac{P_{Ti}+R_{Ti}-D_{Ti}}{100000}$$

$$\Delta h_i = \frac{\left(M_{Ti}-M_{0i}-B_{Ti}\right)+R_{Ti}-D_{Ti}}{100000}$$

$$\Delta h_i = \frac{\left[\begin{array}{l}\sum_{\ell=1}^{2}\sum_{g=1}^{G} y_{i\ell g}\left(\left(W_{0i\ell g}+(K-1)\Delta w_\ell\right)\ \mathrm{Cs}_\ell\right)-\sum_{\ell=1}^{2}\sum_{g=1}^{G} W_{0i\ell g}Cs_\ell - \\ \left\{\sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{\ell=1}^{2} y_{i\ell g}\left(\left(W_{0i\ell g}+\Delta w_\ell(k-1)\right)\tau\right)C_{Ps}+\sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{\ell=1}^{2} y_{i\ell g}\left(\left(W_{0i\ell g}+\Delta w_\ell(k-1)\right)\tau\right)C_{Pb}\right\}\end{array}\right]+\mathrm{R_{Ti}}\ \text{-}\ D_{Ti}}{100000}$$

$$\Delta h_1 = 78.174y_{111} + 82.794y_{112} + 90.721y_{121} - 185.6$$

$$\Delta h_2 = 66.624y_{111} + 75.864y_{112} + 73.041y_{121} - 139.6$$

$$\Delta h_3 = 85.104y_{111} + 90.721y_{121} - 130.4$$

The Constraint of feed availability can be formulated as follows:

$$\sum_{i=1}^{I}\sum_{n=1}^{N}\sum_{g=1}^{G}\sum_{l=1}^{L} y_{ilg}((W_{0ilg} + N(t-1)) + (n-1)\,\Delta w_l)\,\tau \leq 2500$$

$$\boldsymbol{y_{ilg} = 0 \text{ or } 1, \text{for } \forall t \in T} \quad (16)$$

In addition to feed availability, the company has a target to achieve at least 30 of welfare for each farmer. It can be written as follows:

$$H_{Ti} \geq 30 \quad (17)$$

The company target on minimum farmer's income received from cow sales is described as follows:

$$\sum_{k=1}^{K}\sum_{g=1}^{G}\sum_{l=1}^{2} y_{ilg}\,((W_{0ilg}+\Delta w_l(k-1)\tau)Cp_s \geq 3000000 \quad (18)$$

4.2 Optimal solution

The problem was integer linear programming. We solved the problem with the help of LINGO software. The optimal solution can be seen in Table 2 to 5.

Table 2 Feed requirements for each cow in each period

Period (t)	Farmer 1 (kg)			Farmer 2 (kg)			Farmer 3 (kg)	
	S_{111}	S_{112}	S_{121}	S_{211}	S_{212}	S_{221}	S_{311}	S_{321}
1	176.68	190.68	212.73	141.68	169.68	156.73	197.68	212.73
2	181.58	195.58	217.63	146.58	174.58	161.63	202.58	217.63
3	186.48	200.48	222.53	151.48	179.48	166.53	207.48	222.53
4	191.38	205.38	227.43	156.38	184.38	171.43	212.38	227.43
5	196.28	210.28	232.33	161.28	189.28	176.33	217.28	232.33
6	201.18	215.18	237.23	166.18	194.18	181.23	222.18	237.23
7	206.08	220.08	242.13	171.08	199.08	186.13	227.08	242.13
8	210.98	224.98	248.43	175.98	203.98	192.43	231.98	248.43
9	215.88	229.88	251.93	180.88	208.88	195.93	236.88	251.93
10	220.78	234.78	256.83	185.78	213.78	200.83	241.78	256.83
11	225.68	239.68	261.73	190.68	218.68	205.73	246.68	261.73
12	230.58	244.58	266.63	195.58	223.58	210.63	251.58	266.63
13	235.48	249.48	271.53	200.48	228.48	215.53	256.48	271.53
14	240.38	254.38	276.43	205.38	233.38	220.43	261.38	276.43
15	245.28	259.28	281.33	210.28	238.28	225.33	266.28	281.33
16	250.18	264.18	286.23	215.18	243.18	230.23	271.18	286.23
Q_T	3414.88	3638.88	3993.08	2854.88	3302.88	3097.08	3750.88	3993.08

Table 3 Selected cows for subsidy program

Farmer (i)	Type (l)	Number (g)	Selected cow (y_{ilg})
1	1	1	
		2	y_{112}
	2	1	
2	1	1	
		2	
	2	1	
3	1	1	y_{311}
	2	1	y_{321}

Table 4 Cost components and income received by farmers

i	Initial capital (M_0), Rp	Total cost of feed (B_T), Rp	Income from cow sales (M_T), Rp	Profit (P_T), Rp
1	18,560,000,-	3,952,116,-	25,819,400,-	3,307,284,-
2	14,960,000,-	3,701,936,-	21,219,400,-	3,557,464,-
3	13,040,000,-	2,323,188,-	18,257,000,-	2,893,812,-

Table 5 Welfare changes during the program

Farmer (i)	Initial welfare (H_{0i})	Welfare changes (Δh_i)	Final welfare (H_{Ti})
1	20	28,07	48,07
2	27	25,57	52,57
3	15	28,93	43,94
	$DevH_0$ =6,03		$DevH_T$= 4,32

Table 3 shows that the optimal solution was selecting the second local cow of the first farmer (y_{112}), the first local cow of the third farmer (y_{311}), and the first imported cow of the third farmer (y_{321}). Based on the calculation result, there was no cow selected from the second farmer. In addition to feed availability, as indicated in Table 5, the welfare of the second farmer (27), which is better than the first farmer (20) and the third farmer (15), could be one reason that made the second farmer was not selected.

Table 5 shows that at the end of the program the welfare of all farmers increased. The level of the welfare was calculated based on the sale of both subsidized and non-subsidized cow, and the living costs of the farmer. This condition indicates that the company subsidy program could help farmers reduce feed costs and thus improve welfare as a result of greater income. The subsidy policy could also minimize welfare deviation among farmers, which was from

5 DISCUSSION

Table 2 shows feed requirements per period and total feed requirements until the end of the program for each cow. The table shows that feed requirements of each cow are different. This is because feed requirements depend on the weight of the cow. Feed requirements of each period will continue to increase along with the increasing weight of cattle.

6.03 to 4.35. This shows that such subsidy program could be used as a strategy to improve social welfare distribution. Table 5 also shows that although there was no cow selected from the second farmer for the subsidy program, the welfare of the second farmer increased relatively higher than other farmers. This suggests that in selecting the cow for the program, the company should pay attention on the income and living costs of the participated farmers.

6. SUMMARY

We have presented a model of sustainable agro-livestock industry. The problem discussed in the paper deals with a subsidy program established by an agro industry called PT GGL in which pineapple skin waste generated by the industry is utilized as the main cattle feed in cow fattening as a grass substitute. The subsidy program is desired to improve welfare of the stock farmers that the company in cooperation with as well as minimize welfare deviation among farmers.

The model presented in this paper discussed the optimization problem faced by the company. With regards to feed availability and the objective of the program, the company needs to select the cows proposed by the farmers.

The model was examined using a case study. The result of the study shows that the subsidy program could improve welfare of the farmers as well as minimize welfare deviation among farmers. This indicated that such a subsidy policy could be used as a strategy to promote sustainable development. This is because the policy could improve social welfare and income distribution while reducing company waste.

6 ACKNOWLEDGMENTS

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