

Economic analysis of sorghum plant cultivation as biomass source for 2nd generation biofuel feedstock

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Abstract. Sorghum plant (*Sorghum bicolor* L.) is a potential cereal plant to be cultivated and utilized. Currently, sorghum cultivation is not well developed and sorghum production is still very low, despite the fact that sorghum biomass including its roots, stems, and leaves is very potential to be utilized as 2nd generation biofuel feedstock. The utilization of sorghum for 2nd generation biofuel has several advantages, such as not competing with food, recent developing technology reduces the conversion cost of production process, and it is environmentally friendly. Therefore, the aim of this research was to calculate the economic feasibility of sorghum cultivation in order to fulfill the requirement of biomass feedstock for bio-oil industry, with calculation performed for capacity of 100, 200 and 2,000 tons/day. The feasibility calculation results of the sorghum cultivation business showed that the sorghum cultivation for biomass requirements of the bio-oil plant is feasible for all capacities. For all capacities, the business is still feasible when there is a 50% increase in seed prices, and it becomes unfeasible when the selling price of sorghum seeds decreases starting from 5%.

1. Introduction

According to the Asian Biomass Handbook, biomass is a material that can be obtained from plants either directly or indirectly and utilized as energy or other material in large quantities [1]. In the context of biofuel production, the term "plant biomass" generally refers to a material containing lignocellulose because the largest component of non-food crops is lignocellulose [2]. One of the potential crops as a provider of biomass for the 2nd generation biofuel feedstock is sorghum.

Sorghum plant (*Sorghum bicolor* L.) is a potential cereal crop to be cultivated and developed, which has a wide range of agroecological adaptability, resistance to drought stress, high production, requires fewer inputs and is more resistant to pests and diseases in food crops. Sorghum plant has long been known and has been widely planted by farmers in Indonesia, usually farmers plant sorghum by intercropping with other food crops. However, this plant is less well developed. Sorghum production in Indonesia is currently very low, even in general, sorghum products are not yet available in the market. Considering that Indonesia is an agrarian, maritime and archipelagic country with strategic



geographic and geological location, where the potential of tropical climate and high rainfall and mineral-rich land, sorghum plant is potential to be cultivated in Indonesia as a biomass provider for 2nd generation biofuel feedstocks. The utilization of sorghum for 2nd generation biofuel has several advantages such as not competing with food materials, emerging technology developments to reduce the cost of production process conversion, and it is environmentally friendly.

Development and cultivation of sorghum in Indonesia is still limited in some areas such as East Nusa Tenggara and some areas in West Java and Central Java. The main products of sorghum plants are seeds and stems. Sorghum seeds contain high flour and starch. Sorghum stems, especially sweet sorghum type has the content of sap (nira), like sugarcane. Sorghum nira can be used as raw material for producing sugar and bioethanol. Another product that can be developed from the whole part of the sorghum plant is biomass. Stems, leaves and roots are potential parts to be developed as biomass feedstocks.

2. Experimental

The analysis was conducted using financial feasibility criteria of Net Present Value (NPV), Net Benefit Cost Ratio (Net B/C), IRR and PBP, and sensitivity analysis, with calculations performed for 100, 200 and 2,000 tons/day capacities. The data and assumptions used in this study are secondary data that were obtained from literature studies, books or reports published by various agencies.

3. Results and Discussions

The feasibility analysis of sorghum cultivation to fulfill the requirement of biomass feedstocks in the bio-oil production process was conducted for three production capacities of 100, 200 and 2,000 tons/day. The assumptions used were applied to these three capacities. Specifically for the capacity of 2,000 tons/day, the cultivation mechanization was performed. Some assumptions used as the basis for calculation in the feasibility analysis were as follows: Dollar exchange rate (March 2018) IDR 13,700; proportion of funding: 70% loan and 30% own funds; discount rate 10% per annum; project period 15 years; weekdays of 300 days/year.

Sorghum plants in one year can be harvested 2 times. Sorghum plant productivity reached 35 tons/ha/year and biomass productivity (stems) was 21 tons/ha/year [3-4]. Considering the average productivity of biomass sorghum, to meet the capacity of bio-oil industry of 100 tons/day (30,000 tons/year), the required land was 1,429 Ha; for 200 tons/day capacity (60,000 tons/year), the required land was 2,857 Ha; and for capacity of 2,000 tons/day (600,000 tons /year), the required land was 28,571 ha. The selling price of sorghum seeds was IDR 5,500/kg and IDR 8,000/kg, while the price of biomass (stems) was IDR 250/kg. Production inflation was 6% and HOK/HMK was 2%.

3.1. Variable Costs and Fixed Costs

Production costs were calculated based on variable costs and fixed costs. Variable costs consist of the cost of seeds, fertilizers, and pesticides. Fixed costs include labor costs for land management, planting, fertilization, and others. For the capacity of 100 and 200 tons/day, operation is performed manually; while for the capacity of 2,000 tons/day is performed mechanically. The variable cost requirements (seeds and fertilizers) are presented in **Table 1** and fixed costs are presented in **Table 2** and **Table 3**.

The total cost of production was assumed to be fixed annually, and will continue to increase each year following the inflation. For the capacity of 100 tons/day, the total production cost reached IDR 32.49 Billion; for the capacity of 200 tons/day, the total production cost reached IDR 65.14 Billion; and total production cost for capacity of 2,000 tons/day reached IDR 971.44 Billion.

Table 1. The variable cost requirements (seeds and fertilizers).

Item	Number of plantings per planting season/ha	Number/year/ha	Price/Unit (IDR)
Seeds kg/ha	10	20	7.000
Fertilizer			
Urea (kg/ha)	100	200	2.500
dolomit (kg/ha)	2.500	5.000	400
Sp-36 (kg/ha)	60	120	2.500
KCL (kg/ha)	60	120	6.000
NPK Ponska (kg/ha)	125	250	9.000
Manure (kg/ha)	2.500	5.000	700
Pesticides/herbicides		-	
Matador (kg/ha)	2	4	150.000
Actara (kg/ha)	1	2	220.000
Amistartop (kg/ha)	1	2	540.000

Table 2. Fixed costs for 100 and 200 tons/day capacities.

Labor (HOK)	Number required per planting season/ha (HOK)	Number of activities in 1 planting season	Capacity 100 tons/day		Capacity 200 tons/day	
			Number required per total planting area/year (HOK)	Wage (IDR)	Number required per total planting area/year (HOK)	Wage (IDR)
Land Processing	5	1	7.143	30.000	14.286	35.000
Planting	5	1	7.143	30.000	14.286	35.000
Pests Extermination	5	1	7.143	30.000	14.286	35.000
Fertilization continuation	5	1	7.143	30.000	14.286	35.000
Spraying	5	1	7.143	30.000	14.286	35.000
Weeding	5	1	7.143	30.000	14.286	35.000
Irrigation	2	1	2.857	30.000	5.714	35.000
Harvesting	10	1	14.286	30.000	28.571	35.000
Harvest and Transport			10%	of sales	10%	of sales

Table 3. Fixed costs for 2,000 tons/day capacity.

Labor (HOK)/Machine	Number required per planting season/ha (HOK/HMK)	Number of activities in 1 planting season	Number required per total planting area/year (HOK/HMK)	Wage (IDR)
Land Processing	1	2	57.143	2.500.000
Planting	1	2	57.143	1.500.000
Maintenance	3	3	257.143	35.000
Harvesting	1	2	57.143	2.200.000
Harvest and Transport			10%	of sales

3.2. Investment Cost

The total investment cost for sorghum cultivation in order to meet the requirements of bio-oil industry for capacity of 100 tons/day was IDR 19,77 billion, with contingency cost reached IDR 1.5 billion and working capital reached IDR 3.3 billion (**Table 4**).

Table 4. Estimated investment cost requirements and working capital for 100 tons/day capacity.

Investment cost	Number Required (unit)	Total Requirement (unit)	Unit cost (IDR)	Total cost/year (IDR)
a. Land rent (per ha/year)	1	1.429	6.000.000	8.571.428.571
b. Equipment				
-Hand sprayer (unit/ha)	4	5.174,29	375.000	2.142.857.143
-Pesticide drum (unit/ha)	2	2.857	130.000	371.428.571
-Hoe (unit/ha)	5	7.143	150.000	1.071.428.571
-Land fork (unit/ha)	5	7.143	150.000	1.071.428.571
-Chopper (unit/ha)	5	7.143	75.000	535.714.286
-Warehouse (5mx10m) (unit/50 ha)	1	28.57	1.000.000	28.571.429
-3 wheel motorcycle (unit/50 ha)	1	28.57	24.000.000	685.714.286
-Tarpaulins 6x8 m (unit/ha)	1	29	250.000	357.142.857
-Office (10mx10m) (unit/200 ha)	1	3	50.000.000	142.857.143
Total equipment and office				6.407.142.857
Total project cost				14.978.571.429
Contingency	10%			1.497.857.143
Fixed costs				16.476.428.571
Working capital	20%			3.295.285.714
Total Investment Cost				19.771.714.286

Total investment cost for sorghum cultivation in order to meet the requirements of bio-oil industry for capacity of 200 tons/day was IDR 39.54 Billion, with contingency cost reached IDR 2.99 billion and working capital reached IDR 6.59 billion (**Table 5**). The total investment cost for sorghum cultivation in order to meet the requirements of bio-oil industry for capacity of 2,000 tons/day was IDR 324,72 billion, with contingency cost reached IDR 24.6 billion and working capital reached IDR 54.12 billion (**Table 6**).

Table 5. Estimated Investment cost requirements and working capital for 200 tons/day capacity.

Investment cost	Number Required (unit)	Total Requirement (unit)	Unit cost (IDR)	Total cost/year (IDR)
a. Land rent (per ha/year)	1	2.857	6.000.000	17.142.857.143
b. Equipment				
-Hand sprayer (unit/ha)	4	11.428,57	375.000	4.285.714.286
-Pesticide drum (unit/ha)	2	5.714	130.000	742.857.143
-Hoe (unit/ha)	5	14.286	150.000	2.142.857.143
-Land fork (unit/ha)	5	14.286	150.000	2.142.857.143
-Chopper (unit/ha)	5	14.286	75.000	1.071.428.571
-Saung, warehouse (5mx10m) (unit/50 ha)	1	57.14	1.000.000	57.142.857
-3 wheel motorcycle (unit/50 ha)	1	57.14	24.000.000	1.371.428.571
-Tarpaulins 6x8 m (unit/ha)	1	57	250.000	714.285.714
-Office (10mx10m) (unit/200 ha)	1	6	50.000.000	285.714.286
Total equipment and office				12.814.285.714
Total project cost				29.957.142.857
Contingency	10%			2.995.714.286
Fixed costs				32.952.857.143
Working capital	20%			6.590.571.429
Total Investment Cost				39.543.428.571

Table 6. Estimated Investment cost requirements and working capital for 2,000 tons/day capacity.

Investment cost	Number Required (unit)	Total Requirement (unit)	Unit cost (IDR)	Total cost/year (IDR)
a. Land rent (per ha/year)	1	28.571	6.000.000	171.428.571.429
b. Equipment				
-Hand sprayer (unit/ha)	4	114.285,71	375.000	42.857.142.857
-Pesticide drum (unit/ha)	2	57.143	130.000	7.428.571.429
-Saung, warehouse (5mx10m) (unit/50 ha)	1	571,43	1.000.000	571.428.571
-3 wheel motorcycle viar (unit/50 ha)	1	571,43	24.000.000	13.714.285.714
-Tarpaulins 6x8 m (unit/ha)	1	571	250.000	7.142.857.143
-Office (10mx10m) (unit/200 ha)	1	57	50.000.000	2.857.142.857
Total equipment and office				74.571.428.571
Total project cost				246.000.000.000
Contingency	10%			24.600.000.000
Fixed costs				270.600.000.000
Working capital	20%			54.120.000.000
Total Investment Cost				324.720.000.000

3.3. Feasibility Analysis Results

The feasibility analysis results showed that sorghum cultivation to meet biomass for bio-oil plant requirements is feasible for all capacities (**Table 7**). Investment criteria of sorghum cultivation for the supply of bio-oil feedstock with capacity of 100 tons/day and the calculation of project life time for 15 years resulted positive NPV (Net Present Value) IDR 3.92 billion, IRR greater than 10%, i.e. 13.24%, PBP in year 6, Net B/C greater than 1, i.e. 1.23. The investment criteria of sorghum cultivation for the supply of bio-oil feedstock with capacity of 200 tons/day achieved positive NPV (Net Present Value) IDR 5.77 billion, IRR greater than 10%, i.e. 12.75%, PBP in year 6, Net B/C greater than 1, i.e. 1.17. The investment criteria of sorghum cultivation for the supply of bio-oil feedstock with capacity of 2,000 tons/day achieved positive NPV (Net Present Value) IDR 63.97 billion, IRR greater than 10%, i.e. 13.10%, PBP approaching the year 7, and Net B/C greater than 1, i.e. 1.22.

Table 7. Feasibility analysis result.

Parameter	Feasibility analysis results of various capacities (ton/day)		
	100	200	2,000
Net B/C	1.23	1.17	1.22
IRR	13.24%	12.75%	13.10%
NPV	IDR 3,921,271,457	IDR 5,774,566,092	IDR 63,973,322,708
PBP (Year)	6.5	6.1	6.8

3.4. Sensitivity analysis

Sensitivity analysis was conducted to investigate to what extent the changes of sorghum seeds price and sorghum selling price influenced the feasibility indicators. The change in the price of sorghum seeds was performed by increasing the price of seeds by 10% (to IDR 7,700) and 50% (to IDR 10,500). The change in the selling price of sorghum was performed by decreasing the selling price by 5% (to IDR 5,225) and 10% (to IDR 4,950). For all capacity, the project was still feasible when there is a rise of seeds price up to 50%, and becomes unfeasible when the price selling sorghum seeds decreased starting from 5%.

4. Conclusion

This study concluded that sorghum cultivation to meet the biomass requirements of bio-oil plants is feasible for all capacities. For all capacities, the project is still feasible when there is a rise in the price of seeds up to 50%, and becomes unfeasible when the selling price of sorghum seeds decreases starting from 5%.

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5. References

- [1] Yokoyama, S., Matsumura, Y., 2008. Asian Biomass Handbook: A Guide for Biomass Production and Utilization. The Japan Institute of Energy.
- [2] Naik, S.N., Goud, V.V., Rout, P.K., Dalai, A.K. 2010. Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews*. **14**,578-597.

[3] Fryer, C.D. 2008. The feasibility of growing sweet sorghum for the on-farm production of ethanol in Oklahoma. Bachelor Thesis. Oklahoma State University.

[4] Setiadi, S. 2012. Kajian teknoekonomi industri bioethanol kapasitas 10 KLPD dengan bahan baku nira sorgum manis. *TEKNOEKONOMI*. 461-468.