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 2\textsuperscript{nd} generation biofuel feedstocks. The utilization of sorghum for 2\textsuperscript{nd} 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 \cite{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          |                                               |                                          |                                                       |            |

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 | 57.142.857.143 |
| - 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 | 57 | 250.000 | 7.142.857.143 |
| - Office (10mx10m) (unit/200 ha) | 1 | 6 | 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%.

Acknowledgements

Acknowledgments to Pertamina RTC for the funding provided so that this study can be conducted.

5. References

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