A Linear Programming Model for Hybrid Corn Seed Cultivation Planning

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Abstract

This paper proposes a modelof hybrid corn seed cultivation planning system that can help for decision making in a certain period. This paper develops a linear programming models to find the optimal solution of hybrid corn seed cultivation planning. The model developed is tested at PT Citra Nusantara Mandiri (PT CNM) that produce hybrid corn seed in West Sumatra cooperating with PT Pertani (Persero). The model developed has decision variables that are land allocation of each area for each variety and total cost of hybrid corn seed cultivation planning. The model then is solved using Software Lingo 16.0. The model developed has been verified and validated. Sensitivity analysis is also performed to see the effects of changing parameter values to the optimal solution such as contract volume, land availability, and seed productivity. This sensitivity analysis is useful for PT CNM and other companies to control and manage those three parameters in order to achievean optimal hybrid corn seeds cultivation planning.

Keywords: hybrid corn seed; linear programming model; cultivation planning; land allocation; seed productivity

1. Introduction

Corn as one of potential and strategic food commodities. Its development is focus to animal feed in addition to food diversification. The need for corn continues to increase in line with increasing population and increasing demand for food, animal feed and industrial fuel. Until 2015, the national corn production has not yet fulfilled the domestic corn requirement. This can be seen from the huge amount of corn imports and increase every year. In 2012, Indonesia's corn imports reached 1.92 million tons, while in 2013, 2014 and 2015 respectively 3.2 million tons, 3.37 million tons and 3.5 million tons. The volume of corn import is inversely proportional to the volume of corn export in 2012, 2013, 2014, and 2015 respectively 70.86 thousand tons, 20.49 thousand tons, 44.84 thousand tons, and 250.97 thousand tons. The trend of export and import volume of Indonesian corn is presented in Figure 1.

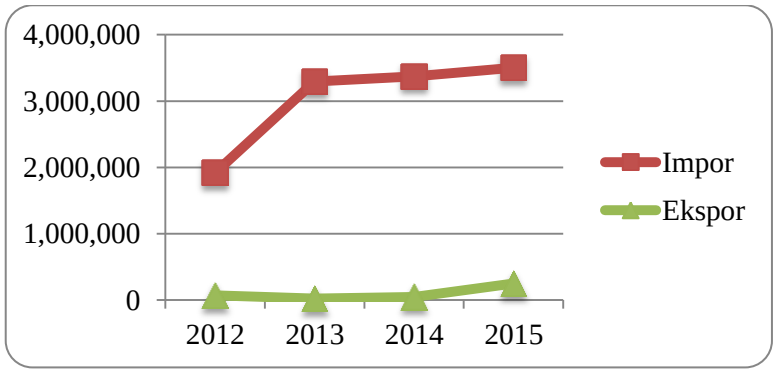

Figure 1 Export and Import volume of Indonesian Corn
(Ministry of Agriculture, 2015)

PT CNM's business activities started with a contract agreement with PT Pertani (Persero). Then proceed with the production process of hybrid corn seed consisting of two stages namely cultivation stage in the field and post-harvest process stage. Then, corn seeds are distributed to PT Pertani (Persero) warehouse in various regions in Indonesia. The trend of the number of PT CNM corn seeds contracts is presented in Figure 2.

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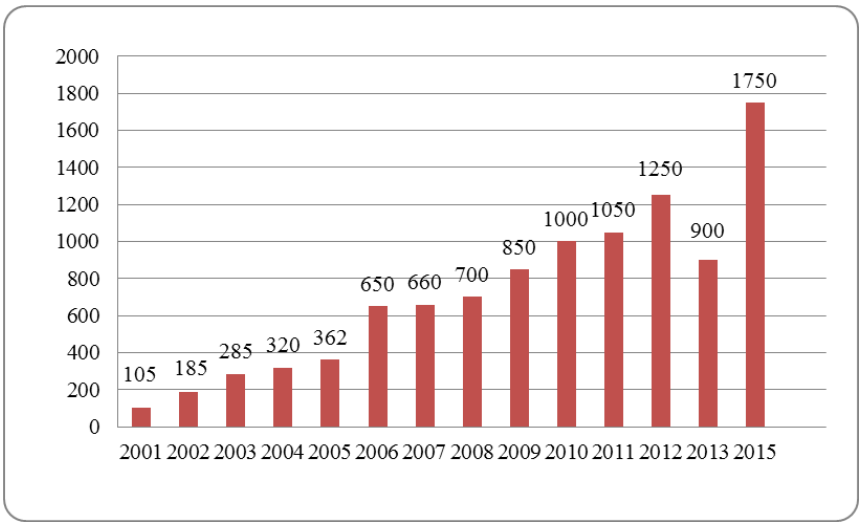

Figure 2 Recapitulation of the contracts of PT CNM with PT Pertani (Persero) (PT CNM, 2016)

The high volume of corn seeds contract makes the management system of seed production in PT CNM increasingly complex. According to Field Managers, there are several factors that affect the realization of corn seed production such as seed productivity that depends on natural factors such as climate that can be anticipated by arranging planting schedule and harvesting of corn seeds, cultivation of controlled cultivation factor with application of technology and good cultivation. In addition, the realization of seed production is also influenced by the area of captive land. The increased volume of corn seeds contract resulted in increased demand for corn seed cultivation areas.

PT CNM has currently not been able to fulfill the contract with PT Pertani (Persero) on time. Based on interviews with Field Managers, it is known that in fact there is still potential land and not yet utilized by PT CNM for cultivating corn seeds. The lands are spread in several regencies/ cities in West Sumatera such as Solok Regency, Solok City, South Solok Regency, Tanah Datar Regency, Dharmasraya Regency, and other areas. The company certainly needs a systematic planning for the potential land use, especially planning concerning the cost aspects of corn cultivation by considering the agreement of purchase price of corn seeds from PT Pertani (Persero) to PT CNM. The cost of corn cultivation consists of seed costs, labor cost of dettaselling (male wage removal rate), harvesting cost, crop purchase cost, and male cutting cost (compensation cost for harvested crops). With the difference of potential land location, the cost of corn cultivation between locations also varies.

Thus, the problem of not fulfillment of the contract is not due to the unavailability of land that can be utilized. However, the company has not yet optimized the utilization of potential land. Therefore, systematic corn planning for PT CNM is required to optimize potential land utilization by considering the cost of corn seed cultivation that must be incurred by PT CNM.

2. Formulation of the Model

Formulation of hybrid corn seed cultivation planning model based on linear programming model approach consists of:

a. Determination of decision variables
   X_{ij}: land area per nagari $i \in I$ for each variety $j \in J$

b. Determination of objective function

The aim of hybrid corn seed cultivation planning model is to minimize corn seed cultivation breeding cost at PT CNM. The cost of hybrid corn seed cultivation consists of seed costs, labor cost of dettaselling, male cutting compensation cost, purchase cost of harvest, and the cost of transporting the harvest from cultivation area to factory. The formulation of each cost of hybrid corn cultivation costs is as follows:

Seed cost

Seed cost is obtained from multiplication of seed price per kg with seed requirement per hectare and captive cultivation area. Here is the cost formulation of seeds in a hybrid corn seed cultivation system.

$$\text{Cost of seed} = \sum_{i \in I} \sum_{j \in J} X_{ij} \; Bb \; Kb \qquad (1)$$

Labor cost of detta selling

This cost is derived from the multiplication of labor wages with labor requirements per hectare and the area of captive land. Here is the cost formulation of dettaselling labor in a hybrid corn seed cultivation system.

Labor cost of dettaselling = $\sum_{i\in I}\sum_{j\in J} \boldsymbol{X_{ij}}\ \boldsymbol{Lc_i}\ \boldsymbol{Kt}$ (2)

The cost of malecutting compensation

The cost of malecutting compensation is obtained from the multiplication of malecutting cost per hectare with the area of captive land. Here is the cost formulation of male cutting compensation in a hybrid corn seedling cultivation system.

Compensation cost malecutting = $\sum_{i\in I}\sum_{j\in J} X_{ij}\ Bm$ (3)

The cost of purchasing the corn crops

This cost is derived from the multiplication of the cost of purchasing the corn crops with the productivity of each region's harvest per variety and the area of captive land. Here is the formulation of the cost of purchasing the crop.

Purchase cost of harvest = $\sum_{i\in I}\sum_{j\in J} X_{ij}\ Bhp_j\ P_{ij}$ (4)

Cost of transporting corn crops

The cost of transporting the corn crops is obtained from the multiplication of the cost of harvesting and the productivity of each area per variety and the area of captive land and divided by the capacity of the truck used. Here is the formulation of the cost of transporting the crop.

The cost of transporting the crops = $\sum_{i\in I}\sum_{j\in J} \frac{X_{ij}P_{ij}}{Ct} Bap_i$ (5)

Based on the formulation of each cost of hybrid corn seed cultivation, total cost is obtained by summing all costs of cultivation as follows:

$$Min\ Z = \left\{\left(\sum_{i\in I}\sum_{j\in J} X_{ij}\ Bb\ Kb\right) + \left(\sum_{i\in I}\sum_{j\in J} X_{ij}\ Lc_i\ Kt\right) + \left(\sum_{i\in I}\sum_{j\in J} X_{ij}\ Bm\right) + \left(\sum_{i\in I}\sum_{j\in J} X_{ij}\ Bhp_j\ P_{ij}\right) + \left(\sum_{i\in I}\sum_{j\in J} \frac{X_{ij}P_{ij}}{Ct} Bap_i\right)\right\} \quad (6)$$

c. Determination of constraints

Some constraints of hybrid corn seed cultivation planning model are as follows:

- Constraints to ensure that the cultivation lands per nagari $i \in I$ for each variety $j \in J$ do not exceed the availability of lands on nagari *i* and greater or equal to zero.

$$\sum_{j\in J} X_{ij} \leq X_i \qquad \forall\ i\ \in I \quad (7)$$

$$\sum_{j\in J} X_{ij} \geq 0 \qquad \forall\ i\ \in I \quad (8)$$

- Constraints to ensure that the production of hybrid corn seeds of each variety is greater or equal to the number of contracts of each variety. Production is obtained from the multiplication of cultivation lands per nagari $i \in I$ for each variety $j \in J$ with productivity $j \in J$ and shrinkage of yields worth 0.48.

$$\begin{aligned} &\sum_{i\in I} X_{ij}\ P_{ij}\ Shp\ \geq\ D_j \qquad \forall\ j\ \in J \\ &\sum_{i\in I} X_{ij}\ P_{ij}\ 0.48\ \geq\ D_j \qquad \forall\ j\ \in J \end{aligned} \quad (9)$$

- Constraints to ensure that the value of cultivation area per nagari $i \in I$ for each variety $j \in J$ d is positive value.

$$X_{ij}\ \geq 0 \qquad \forall\ i\ \in I, j\ \in J \quad (10)$$

3. Results and Discussion

Cultivation of hybrid corn seeds at PT CNM requires systematic planning to fulfill contracts from PT Pertani (Persero). Contracts can be fulfilled by utilizing the potential land available in the cultivation area. Utilization of potential land would require planning especially in terms of cost planning. This is applicable because the difference in land leads to differences in the cost of captive cultivation. By modeling the corn cultivation system at PT CNM, potential land allocation plots in cultivation areas for each variety of hybrid corn seed can minimize the cost of captive cultivation.

Then, sensitivity analysis can be performed. Sensitivity analysis is used to determine the conditions and risks that may arise in the implementation of captive cultivation. Sensitivity analysis aims to see whether the model is sensitive to model parameter changes. This analysis is performed by changing the value of model parameters consisting of changes in the coefficient of constraint function such as the productivity of the seed of each variety per region and the value of the resource *i* is the availability of land and volume of contract.

Changes in model parameter values were performed with a certain percentage of ± 5% and ± 10%. Changes in parameters such as land availability (≤ 10 Ha) at a percentage of ± 5% and ± 10%, will result in a small change of objective function of the dual price value. This is performed because the parameter value has not reached 1 unit or 1 Ha. Then, the percentage change of parameters both land availability, contract volume and seed productivity are presented.

Based on sensitivity analysis both one parameter change and two model parameters, it was found that the model that has been proposed is not sensitive to changes in parameters, either contract volume parameters, land availability, and seed productivity. In other words, changing those parameters does not significantly impact the total cost of cultivation costs. However, PT CNM should be able to plan and control the change of model parameters in fulfilling the contract with PT Pertani (Persero).

The volume of hybrid corn seed contracts will affect the planning of the production of hybrid corn seeds. The volume of contracts can be achieved if the area of planted land and crops is in accordance with the planning. The realization of cultivation land area depends on cooperation with farmer breeder. Thus, it is necessary to have a plan that can increase the interest of farmers in doing the hybrid corn seed cultivation. The company has attracted farmers in several ways such as free seeding, the dettaselling labor cost of the company and the costs of malecutting compensation. However, it will be more attractive to farmers, if PT CNM can establish other policies such as increased cost of purchasing corn crops to farmers' breeders. When compared with other food commodities such as rice, the cost of purchasing corn crops is still low. Therefore, PT CNM needs to raise the cost of purchasing the crops to farmers.

The volume of the contract can be met if the number of crops in accordance with the estimation or planning. The number of crops is related to the productivity of the seeds produced. PT CNM should continue to improve the productivity of seedlings by making various efforts such as quality control of seeds to be planted, improving the procurement of production facilities and management of good corn cultivation through the application of technology and on-site supervision on a continuous basis so that farmers catch all breeding procedures, especially in terms of care of corn crops

4. Conclusion

This research has proposed a hybrid corn seed cultivation planning model using linear programming method. The output of the model is the optimal potential land allocation with minimum total cost of captive cultivation. Hybrid corn seed cultivation planning model can also determine the production capability of corn seeds owned by PT CNM.Hybrid corn seed cultivation planning model is already verified and valid based on the numerical example given. The sensitivity analysis has also been performed. It found that the proposed model is not sensitive to parameter changes such as changes in contract volume parameters, land availability and seed productivity. However, PT CNM must keep controlling the change of parameters. For further research, it is necessary to develop an integrated information system on a hybrid corn cultivation planning system. The system can also be developed with other purpose functions such as minimization of the achievement of the volume contract.

Acknowledgements

Authors thank reviewers for their suggestion and comments to improve the quality of this article.

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