System dynamic modelling of agriculture land availability

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Abstract. There exists development in expanding system dynamic to include spatial system model, most application have been restricted to simulate many chances and get the wise argumentized policy. This aim of the study was to analyze the land availability in Kulon Progo Daerah Istimewa Yogyakarta (DIY) Indonesia, especially the agricultural land. The background of the study was the condition of Kulon Progo Area, which the conversion of agricultural land was very high since the construction international airport project in this region. This research focuses in how far agriculture land availability to cover dynamic change condition. We used model of system dynamic and incorporated a partial dynamic system approach especially a causal loop model (CLM) to achieve the goal of research. Our result generally suggests that in Kulon Progo area the land have not been available enough to cover the agricultural land. Many policies must be taken to solve the problem and to keep the land wisely, and also, we must handle of agriculture land to other purpose seriously.

1. Introduction
Kulon Progo is one of the districts in Daerah Istimewa Yogyakarta (DIY) Indonesia located in the southwest area of DIY. In the mid of 2016 there is a big construction named the project to build the international airport. The land of this conversion almost is the agriculture land area. Recently the conversion land had been increased in Kulon Progo District. In 2013 the paddy field area was 10000 Ha, and always decreased every year and in mid-2017, the land width was 4367 Ha. It means the land had decreased 5633 Ha during the project of reconstruction of new airport [1].

![Figure 1. The condition of Kulon Progo land area, 2018](image_url)
Land conversion is influenced by forces of supply and demand of land regarding the increasing of human population, while the availability of land is limited, then the demand of land increasing to any purposes, especially to fulfill the resident area, industry area and also to improve the quality of the human life. In first 2018 the allocation of land as showed in Figure 1. Figure 1 showed that the biggest area of Kulon Progo is dry land (26.27%), follow by non-agriculture land (23%), paddy field land (18%), resident (10%), smallholder forest (10%) and the rests are used by any purpose: coastal area, state own forest, plantation, swamp and freshwater pond. The conversion of land farming to become international airport, industrial area and residence is estimated to be 300 Ha [2].

It made farmers loss of their land and loss of source of livelihood for household, loss of farm income and inability to take advantage relationship in agriculture. On the other hand, the conversion of land farming decreases of the grassland of animal feed [3]. The conversion land also impacts the environment such as biodiversity loss, soil erosion, degradation, loss vegetation cover and also decrease food security. The research conducted to analyze the availability of agriculture land in future time.

2. Methods
The research was conducted with the model of dynamic system approach, especially a causal loop model (CLM). In this study we used system dynamics model to close the condition of agriculture land space to serve the availability of grassland area. All subdistricts in Kulon Progo were included in this study. Causal loop model of every subsystem was simulated with and model validation with mean absolute percentage error (MAPE). In the end of the study we know about the condition of land availability to cover feedlot in Kulon Progo region [4, 5, 6].

The procedures of executing System Dynamic model are as follows:

a. Construct a representative model of total grassland area and agricultural activities. The model is created based on problem identification in causal-loop diagram (CLD).
b. Collect any input data necessary for system modelling, those are total grassland area for livestock feeding data, especially the five (5) type of land such as paddy field land, plantation, dry land, state own forest and smallholder forest [7].
c. Formulate the model inside stock and flow diagram by using powersim 10 software. While doing model formulation, it used 4 kinds of variable which are level, flow with rate, auxiliary, and constant. The following are formulation steps of one of the total grassland areas just only on 5 (five) kind of the land. All of the lands are formed using level tool and the initial value (base year) width (ha). After that click flow with rate tool with inflow direction towards level and click auxiliary tool.
d. Connect the auxiliary tool to flow with rate tool and level tool to flow with rate tool. Auxiliary tool defines the conversion rate of all of the grass land that formulate, whereas flow with rate tool defines the land delta with formulation of ‘the rate of land area’.
e. Verify the model by confirming that relationship among each variable are matched with logic and goal.
f. Validate the model by confirming that the built model had represented existing condition. Model validation is done by testing the model behavior with MAPE method.
g. Simulate the model in existing condition and scenario. The scenarios formed is based on government policies.
h. Get the conclusion of simulation of System dynamic model, that be able to make any policymaker of stakeholder [8].

3. Results and discussions

3.1. Condition of land Kulon Progo DIY
An application of system dynamics for modelling of the availability grassland of feedlot in Kulon Progo district region requires concept of the mind that the system build from five sub models in one system called land area. Based on data from 2001-2017, in future time we predict that in next five year will be decrease seriously. It impacts to the security of food for human and also it impacts to feed cattle because
the land that be able to serve the grassland will be decrease too. Agriculture land that can be planted grass for land cattle feed on 2001 amounted 37395 Ha, decrease by 34380 Ha on 2005 and in 2015 decrease by 33322 Ha. This condition is very dangerous and seriously, it is better if many kinds of program and effort from government and also community must do to manage the land wise and harmonize.

Agriculture land indicate decline condition of almost all the lands: paddy fields, dry field, plantation, state own forest and smallholder. The comparation between this condition is showed in Figure 2. The largest conversion of agricultural land in Kulon Progo is plantation (-0.4713 Ha/year). The other lands decrease with the similar rate of paddy field land (- 0.3468). The rate decrease of dry land is -0.0128 Ha/year, rate decrease of state own forest is -0.00126 and smallholder forest decrease in rate - 0.00308. Base on the rate of each land in Kulon Progo, the simulation was conducted to get the goal of the research to analyze the condition of agricultural land in the next five (5) years and the availability grass land to cover the feed in Kulon Progo.

3.2. Causal loop model of the land availability for grassland area on Kulon Progo DIY

Causal loop model in Figure 3 consisted of element of supply chain in the grassland for animal feeding. The relationship among the element are positive (+) and negative (-). The positive means that if one element in the causal loop is improved it will increase another element, or if one element is decreased then another element is also decreased. On other hand, the negative means that if one element is increased, it will decrease another element vice versa [7].

Based on the decreasing of the agriculture land that be able to serve grassland to animal feed in 2001-2017, the simulation was performed to the condition in next five years (2018-2022). The first simulation calculated the accumulative the width of 5 (five) type of land in Kulon Progo area, there are paddy field land, plantation land, dry land, state own forest land and smallholder land. The five type of lands are the main land of agriculture, that able to planting and main farming land to food security both for human and also for feeding of livestock animal.
3.3. System dynamic model of the land availability for grassland in Kulon Progo District

The simulation using initial model showed that there is any impact from conversion land in Kulon Progo Daerah Istimewa Yogyakarta. To close the objection of the research, we get five scenarios based on the growth rate decreasing of 5 type grassland and we make the simulation to the five years future condition on its grassland. The relationship between decreasing of agriculture land to the availability of animal grass feed was closed by propose the scenarios to be applied in the model for selecting the best scenario for optimizing the good condition. The five scenarios are as follows:

1. Paddy fields decrease rate by 0.3468 Ha/year
2. Plantation decrease rate by 0.4713 Ha/year

![Plantation Decrease Rate](image1)

**Figure 5.** The rate of decrease of plantation area

3. Dry land decrease rate by 0.0128 Ha/year

![Dry Land Decrease Rate](image2)

**Figure 6.** The rate of decrease in dry land area

4. State own forest decrease rate by 0.0126 Ha/year

![State Own Forest Decrease Rate](image3)

**Figure 7.** The rate of decrease in state own forest area
5. Smallholder forest decrease rate by 0.023008 Ha/year

![Small Holder Forest Width (ha)](image)

**Figure 8.** The rate of decrease in smallholder forest area

The width of 5 (five) type lands calculated in grassland area for availability of animal feeding especially for the cow feeding. All the grassland area cumulation conducted by simulation with dynamic system (Figure 9).

Table 1 showed in next 5 (five) year in future time, the total grassland from 5 type of land in Kulon Progo DIY not able to fulfill to cover the annual cow feed needed. The availability of cow feed in Kulon Progo Area had been decreasing year to year.

| Year | Annual Livestock Feed Needs | Total Grassland Area for Livestock Feeding | Availability of Livestock Feed |
|------|-----------------------------|------------------------------------------|--------------------------------|
| 2018 | 42,743.80                   | 31038                                    | - 11,705.80                    |
| 2019 | 42,964.79                   | 30697                                    | - 12,267.79                    |
| 2020 | 42,988.28                   | 27320                                    | - 15,668.28                    |
| 2021 | 42,996.44                   | 24315                                    | - 18,681.44                    |
| 2022 | 42,734.45                   | 21640                                    | - 21,094.45                    |

Source: Secondary data analysis by software Powersim Version 2010

In 2018 the availability of cow feed in -11,705.8 decrease until –21.094,45 in 2022. It means that the Kulon Progo agricultural land in future time get in serious condition. Government and appropriate stakeholder must be having solution to solve the problem. Some policy is suggested to be set to solve the problem in respect to management of paddy field and dry field, state owned forest width, plantation width and smallholder forest width as well. The government must be strike to build the rule of land management so can handle the conversion of land. In other hand the improving of technology must be done to make the livestock feeding available and get sustainability in future time.
4. Conclusion and policy implication

The conversion of agriculture land in Kulon Progo DIY was changing to the main purpose mainly to project new Yogyakarta airport, residential, and economic space area. The conversion of land in Kulon Progo DIY especially in agriculture area are 11%/year. There is conversion from of Paddy Fields decrease in rate by 0.3468 Ha/year; Plantation decrease in rate by 0.4713 Ha/year; Dry land decrease in rate0.0128 Ha/year; State own forest decrease in rate 0.0126 Ha/year and Smallholder forest decrease in rate 0.023008 Ha/year.

Some policy is suggested to be set to solve the problem in respect to management agriculture land especially focus on paddy field land, dry land, plantation land, state owned forest and smallholder forest as well. To cover the availability of grassland for livestock feeding any improving of Technology must be taken, for example improve the livestock feeding not only from grassland but another source to substitute the grass. The conversion of agriculture land in Kulon progo DIY, in the next five year there is un-sufficient in the availability of grassland to livestock feeding, because of that the government must be wise and strict to protect the rule of management of agricultural land in this area.

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References

[1] Badan Pertanahan Nasional (BPN) 2017 Analisis Dampak Lingkungan Pada Lahan Persiapan pembanguna Bandara Internasional Kulon Progo Yogyakarta Report Paper Unpublished
[2] Badan Pusat Statistik (BPS) 2017 Demand and Supply of Beef in Yogyakarta Region of Indonesia Report Paper Unpublished
[3] Directorat General of Livestock and Animal Health, Departement of Agriculture Republic of Indonesia Livestock and Animal Health Statistic 2010, 2011,2012 and 2013 Annual Report (Jakarta: Departement of Agriculture Republic of Indonesia)
[4] Sterman, J D 1984 Appropriate Summary Statistics For Evaluating The Historical Fit Of System Dynamic Models (Uniterd State od America: .Massachusetts Institute of Technology)
[5] Sterman 2000 *Business Dynamics: System Thinking and Modelling For a Complex World* Irwin/McGraw-Hill

[6] Sterman 2002 *System Dynamics Review* 18 pp 501–531

[7] Neuwirth C and Simonovic A P 2015 *Journal Environmental Modelling and Software* 65 pp 30–40 doi: 10.1061/j.envsoft.2014.11.026

[8] Zhang X, Izaurralde R C, Manowitz D H, Sahajpal R and West T O 2015 *Journal Environmental Modelling and Software* 63 pp 199–216 doi: 10.1016/j.envsoft.2014.10.005.