Sustainable Development of Indonesia's Agricultural Sector

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Abstract

The Indonesian agricultural output has been struggling to provide for the demand of the rising population in recent years owing to the sluggish growth rate in this sector as compared to the overall performance of the economy. While the current slash-and-burn technique widely employed by Indonesian peasants is able to boost the output in the short term, its negative implications on the environment and the constraints in available forest area casts doubts to its sustainability in the long run. As the results from our iThink model simulation has illustrated, the output will cease increasing and decline in about 90 years' time due to the drastic drop in forest coverage. Based on the sensitivity analysis of the affecting factors, three policy amendments are proposed to avert the gloomy perspective, namely increasing funding for Research and Development, curbing burning activities, and actively returning abandoned land to forests. With the effective implementation of the suggested policies, the growth in the agricultural sector will be steered back to a sustainable track, which is further confirmed by the model projection.

1 Introduction

Agriculture is one of the pillar sectors of Indonesia's economy as it keeps more than half of the workforce employed. According to an economics study, agriculture also plays a crucial role in economic development and poverty reduction in Indonesia [1]. Therefore, growing the agricultural sector consistently and augmenting the agricultural output have always been priority concerns in Indonesia. The slash-and-burn technique has been a traditionally popular practice in Indonesia to create new fertile land for agricultural activities because of its simplicity in implementation as well as its swiftness in taking effect [2]. With the productiveness of such measures in generating higher levels of output in the short run, there is little incentive for the government to invest in Research and Development (R&D) of the agricultural sector, which is often seen as an important solution to a long-term sustainable development. However, the symptomatic measure is palpably unsustainable as the current rate of deforestation is much higher than the rate of replanting [3]. Once the forests are depleted, it is foreseeable that the agricultural output will experience stagnation and an ensuing drastic decrease. Therefore, it is imperative that the Indonesian government find alternative solutions to the slash and burn method, so that the agricultural sector development is sustainable and the output level in the future will still be sufficient.

Our perspective is to examine the current "slash-and-burn agriculture" in Indonesia, analyse its inherent problems and predict future trends, justify the importance of R&D as a possible fundamental solution, and propose policies that would steer this transition to a more promising future for Indonesia's agriculture sector.

2 Problem Motivation

In recent years, many Southeast Asian countries including Indonesia, Singapore, Malaysia and Brunei have experienced several serious outbreaks of air pollution crisis [4]. Following the 2013 Haze Crisis, the problem repeated itself again in 2015 and continued to evoke large-scale disputes among the affected countries. As reported by BBC news, the cities in the affected countries were shrouded in a dense, pungent haze for weeks because of the forest fires in Indonesia [5]. Such situations are the direct result of forest burning in Indonesia.

While the slash-and-burn technique efficiently clears land for agricultural plantations, it takes a heavy toll on the environment in the region. The minister of law of Indonesia mentioned that the Pollutant Standards Index (PSI) level in Sumatra and Kalimantan reached a new high of 2000 this year, which was 6 times more than the PSI level of 1995 [6]. In addition to impeded visibility, the haze also poses a serious threat to the health of residents. It is reported that around 10,000 to 30,000 Indonesians have been affected by respiratory illnesses due to the haze [7]. More specifically, one study collated that a total of 25,834 people were suffering from respiratory infection, 538 from pneumonia, 2,246 from skin irritation, while another 1,656 people were suffering from eye irritation [8]. A state of emergency was declared in the most affected state, Riau, by the Indonesian government, resulting in the displacement of thousands of people to nearby provinces [9]. So far, there have been no effective measures implemented to ameliorate the current situation, and the haze issue continues to be a long-term concern for the entire region.

Given the long-term nature of the problem and its severity, our group is motivated to go in depth and target the root cause of this issue, which is to devise measures to sustainably boost the Indonesian agriculture sector without jeopardizing the environment and health of the residents.

3 Problem Overview

3.1 Project Objective

The aim of this study is to explore measures that can increase agricultural output in a sustainable and environmentally friendly manner, and thus allow the country to stand in a better position to meet the demands of the population.

3.2 Problem Description

The growth in the agricultural sector of Indonesia is outpaced by the GDP growth of the country. From 2000 to 2014, agriculture sector GDP grew at an average rate of 2.67% per year, while the aggregate real GDP was growing by 4.73% per year [10]. The agriculture sector as a percentage of real GDP declined from 16.67% to 13.72% [11]. Furthermore, the population in Indonesia increased at 1.45% per year over the same period [12], which poses the problem of insufficiency in agricultural output in meeting rising demand. The increasing gap between the demand and supply of agricultural output impedes the development of economy, reduces food availability and thus exacerbates the poverty problem in the country [13].

The commonly adopted measure – slash-and-burn technique is a symptomatic method that is not sustainable in the long run. After years of farming, some farmers and oil companies may choose to abandon the original farming land and clear new arable land by burning because of the decline in the productivity of the original land [14]. The recovery of tropical forest after desertion will take at least 100 years due to the poor soil condition [15]. Since the forests are destroyed at a faster rate than it can be recovered, there will be the potential problem that forests will be depleted [16]. Thus, this policy is not sustainable as the country will face more severe shortages of agricultural output in the future.

4 Current Fix

In order to address the insufficiency in farming land, the current solution that Indonesian farmers and conglomerates in the palm oil sector adopt is slash-and-burn, especially burning. Burning is the fastest and cheapest way to clear a large scale of forests for agricultural use. The burnt ashes of trees also contribute to increasing fertility of the land, which can enhance the agricultural output.

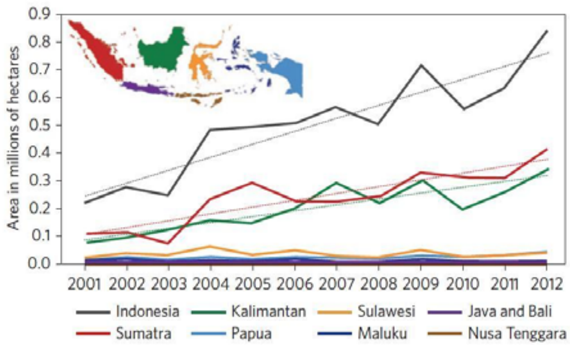


Figure 1. Land burning in some Asian countries

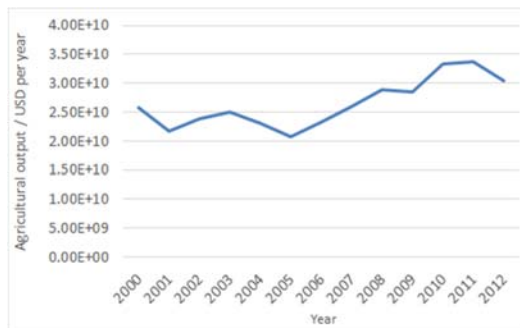


Figure 2. Graph of Indonesian agricultural output (US$) from 2000 – 2012

Figure 1 above shows the increasing trend of cleared areas through burning each year. From the graph, we can see that the total area of burnt forests has increased three-fold since 2001. As a result, Indonesia's agricultural output has increased steadily across the years as reflected from Figure 2 [17]. Hence, the current fix has been effective in generating higher level of output in recent years. However, it will lead to many long-term problems, which are discussed in earlier sections. In the subsequent section, the archetype of "shifting the burden" will be used to demonstrate how the current solution will eventually fail to provide for the population in the long run.

5 System archetype

5.1 *“Shifting the Burden” Archetype*

In this study, the “Shifting the Burden” system archetype (Figure 3) is identified as an appropriate model to illustrate the negative consequences of burning. In this archetype, there is a conflict between the symptomatic solution and the fundamental solution, and the symptomatic solution tends to be more attractive. The “+” and “-” signs represent positive and negative causal relationships respectively. While the fundamental solution aims to solve the root of the problem but requires much more effort (time, fund, patience, etc.), the symptomatic solution is much easier to implement and effects are significant in the short run. As a result, the symptomatic solution tends to be favoured, which results in the loss of interest to explore the fundamental solution. However, the symptomatic solution will eventually fail and the fundamental problem will remain unsolved.

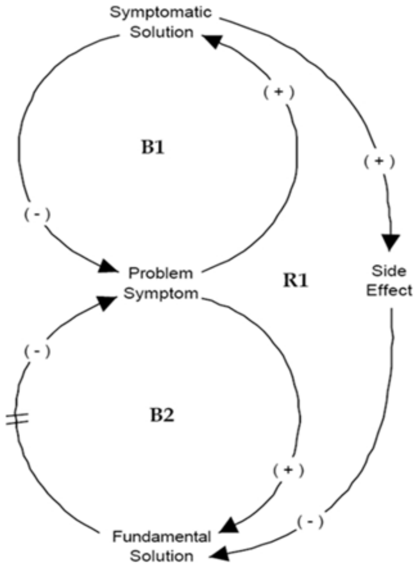


Figure 3. “Shifting the Burden” archetype

5.2 *Causal Loop Diagram*

The causal loop diagram that illustrates the problem is shown in Figure 4. The symptomatic solution is to clear the forest through burning, while a possible fundamental solution is to discover ways to improve land productivity through R&D and enhance the output. The Indonesian peasants prefer to adopt the burning method to increase agricultural output because it is much cheaper and faster in clearing land for farming. The newly cleared land is also more fertile, which allows the farmers to replace the land that has lost its fertility. There is a conflict between the symptomatic solution of burning and fundamental solution of increasing R&D spending as burning has been deemed as an effective measure in increasing the agricultural yield in the short run, and thus the government has few incentives to allocate more budget for R&D. Nevertheless, burning is not a sustainable method, and will eventually fail to provide sufficient food due to the negative side effects and constraints in available forest area of the country.

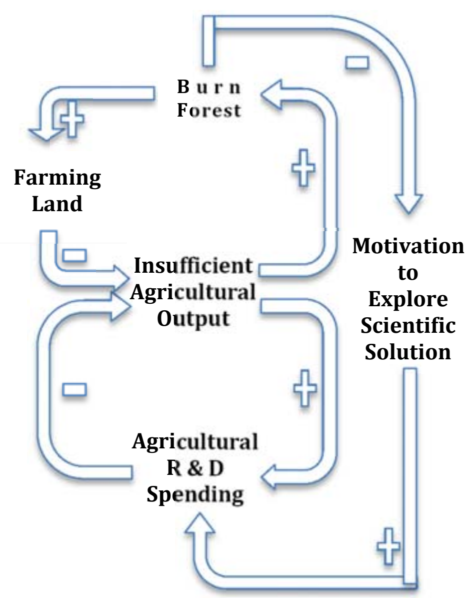


Figure 4. Causal loop diagram

5.3 *Base Stock and Flow Diagram*

Based on the causal loop diagram, a complete stock and flow model is developed with the software iThink, and simulation details can be found under supplemental information.

The model illustrates the pivotal factors that affect the agricultural output in this problem and how forest burning, as a symptomatic solution that alleviates the agricultural output shortage in short term, replaces the fundamental solution of increasing agricultural R&D investment in the current context. This model will subsequently take into consideration 4 sub-components, namely "Land", "Population", "Agricultural output gap" and "Agricultural R&D" for further discussions and explanations.

5.3.1 Key Model Assumptions

In simulating the real life situations, the following assumptions are made to generate more meaningful results.

Firstly, the base year is set to be Year 2000. Before 2000, the burning activities are in random patterns with outstanding spikes in certain years (such as the worst Indonesia forest fire in 1997-1998). Since 2000, the burning activities tended to stabilize because of stricter enforcement of legislations.

The length of simulation is set to be 200 years in the base model, from Year 2000 to Year 2200. The historical data of 2000 to 2012 is used to validate the model as an actual reflection of the actual situations. The ensuing simulation of years 2012-2200 will project the future trend if Indonesia continues adopting the symptomatic solution in a large scale to address the agricultural product shortage. A simulation length of 200 years is chosen as it is a reasonable period of time that allows us to explore the sustainability of burning forests in the long run. Moreover, it also allows us to test if the possible fundamental solution of investing in agricultural R&D will be a more effective and sustainable solution than that of the slash-and-burn technique.

5.3.2 Land

In this section, the "Land" component of the model is discussed. Figure 5 shows an overview of the model.

The "land" component comprises of three major stocks, namely "Forest", "Agricultural land" and "Abandoned land", indicated by the three rectangular boxes. "Forest" has the initial value of 994090 km^2, which is the forest area of Indonesia estimated by Food and Agriculture Organization of the United Nations in base year 2000 [18]. According to World Bank, Indonesia's agricultural land area in 2000 is 477000 km^2 [19], which is set as the initial value of "Agricultural land". As for "Abandoned land", the initial value is set as 0. This is

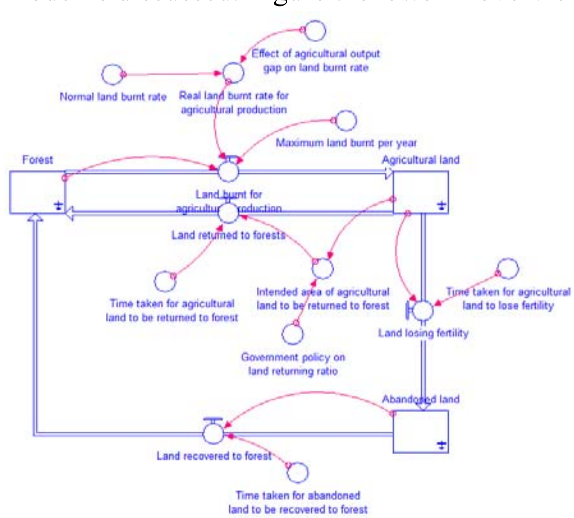


Figure 5. Base model describing land

because year 2000 is set as the base year, and only the deserted land after year 2000 is within our scope of our discussion.

There are 4 major flows among these stocks, as indicated by the thick arrows in Figure 5. Firstly, forest is burnt and transformed into agricultural land, contributing to the "Land burnt for agricultural production" flow. There are 2 quantitative convertors associated with this flow. The normal burn rate for land in Indonesia is 8.64% [20], and clearing land for agricultural production is the main reason for forest burning [21]. The ratio of land burnt for agriculture is assumed to be 70% for calculation. Therefore, the "Normal land burnt rate for agricultural production" is initialized to be 0.605%. In addition, the converter of "Maximum land burnt per year" sets a limit to the areas of land burnt in extreme conditions when the agricultural output gap becomes too large. According to Indonesian law, a farmer can burn up to 2 hectares of forest land, which converts to a maximum allowable limit of 8000 km^2 forest land per year [22].

In fact, the Indonesian government has also implemented policies returning agricultural land to forests to recover the forest area, and about 0.65% of the agricultural land is converted back per year [23]. On the other hand, after long years of cultivation, agricultural land will slowly lose fertility and get abandoned by peasants, and the abandoned land will eventually return to forest through natural processes if not utilized for other purposes. Both of the time taken for land to lose fertility and the recovery processes are extremely long, about 100 years on average [24], [25].

As shown in Figure 6, the converter of "Total land" is a sum of the above-mentioned three stocks ("Forest", "Agricultural land" and "Abandoned land"), and the "Burnt land/total land ratio", which has a direct impact on the air quality, can thus be derived. Air quality in turn affects both the death rate as well as the land productivity. Graphical functions are used to clearly illustrate these trends.

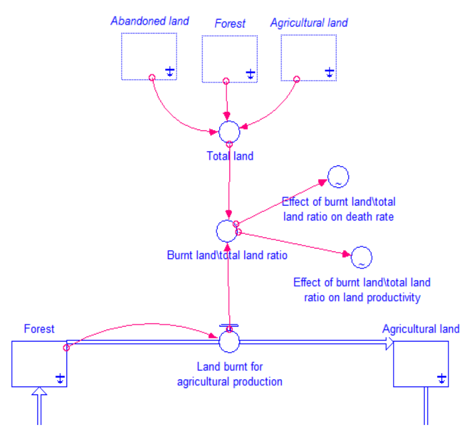


Figure 6. Base model describing the total land

As illustrated by Figure 7 below, the effect that the ratio of burnt land places on death rate is modelled by an exponential curve with a lower bound of 0.8 and an upper bound of 10. Real death rate can be below the normal death rate in the extreme condition of zero burning. In this case, the death rate is approximated to be 80% of the original death rate. When larger portions of land are burnt, the air quality will deteriorate drastically, resulting in higher possibilities of dying from related diseases. The limit is set to be 10 times of the original death rate, which is a reasonable estimate of the maximum impact poor air quality can have on human health.

Figure 7. Graphical function of the "Effect of burnt land/total land ratio on death rate"

Figure 8. Graphical function of the "Effect of burnt land/total land ratio on land productivity"

Furthermore, burning also has an adverse effect on land productivity, as displayed in Figure 8. This is because cleaner air is more conducive for the respiration and photosynthesis of plants [26], which in turn results in higher agricultural yields. Furthermore, poor air quality also reduces the working hours of the farmers because of their growing unwillingness of outdoor exposure. This multiplicative effect of air quality on land productivity is modelled by the curve above. With a higher ratio of land being burnt, the effect becomes more drastic and productivity drops at a higher rate.

5.3.3 Total demand

On the demand side, there is only one stock, which is "Population" (Figure 9). The population in year 2000 is 208,300,000 while the birth rate and death rate are 2.26% and 0.613% respectively [27]. It should be highlighted that this death rate figure is the "Normal death rate", which is affected by the ratio of burnt land discussed in the previous section.

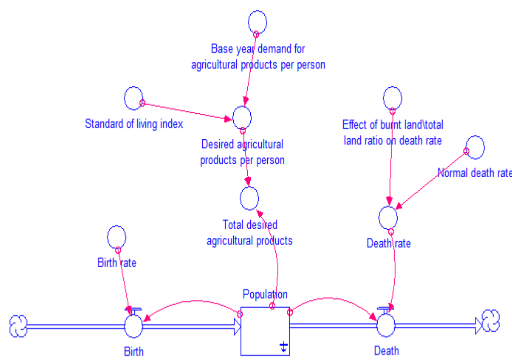
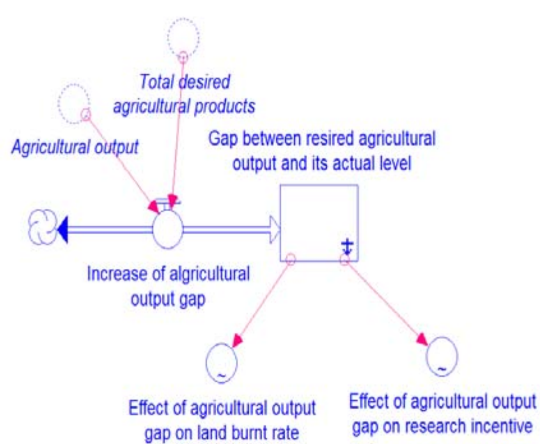


Figure 9. Base model describing the total demand for agricultural product

The "Base year demand for agricultural products per person" factor is approximated by the demand for various types of agricultural products, and the average value is about US$115 per person per year [28].

However, given the fact that people will enjoy a higher living standard due to economic development, they will subsequently spend more money on agricultural products. Therefore, the converter "Standard of living index" is introduced and it is modelled by a "RAMP" function with 1% increment per year, which is an approximation based on the Food Price Index released by Food and Agricultural Organization [29].

5.3.4 Agricultural output gap



The agricultural output gap component connecting the demand and supply of the agricultural product is illustrated in Figure 10. It is represented by a cumulative stock as the surplus of current year can be stored, whereas the shortage in current year can also be covered by last year's surplus. The "Increase of agricultural output gap" flow is a bi-flow and is obtained by subtracting the agricultural output from total demand. This agricultural output gap will be impacting both the burning rate as well as the research incentives, which are the symptomatic solution and the fundamental solution to the problem respectively.

Regarding the effect of agricultural output gap on burning, it is intuitive to deduce that with a larger gap, peasants will clear more land to boost the output. Figure 11 models this relationship, where the rate of burning increases at a progressively slower rate as its own value exceeds a certain limit. This trend occurs because the tolerance level of the ecosystem towards burning will be significantly reduced with higher levels of pollution; thus, people are forced to conserve the remaining forest so that the adverse effects of forest loss such as climate change will not be intolerable. Notably, even in the extreme condition of zero gap between demand and output, there will still be practices of burning as farmers are eager to acquire fertile land to replace the less fertile land.

Figure 10. Base model describing the agricultural output

Similarly, a larger agricultural output gap will motivate the government to invest more in R&D so as to boost the productivity of land. This is illustrated by the curve in Figure 12 with a positive gradient. However, as the investment level progressively increase, the returns from R&D will diminish. This is why the curve flattens when the incentive level gets higher. The maximum effect on incentive is set as 1 according to the historical statistics of Indonesia's spending on R&D, which shows reluctance in investment as compared to the other Asian countries.

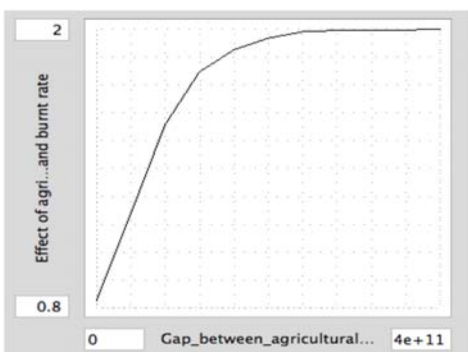


Figure 11. Graphical function of "Effect of agricultural output gap on land burnt rate"

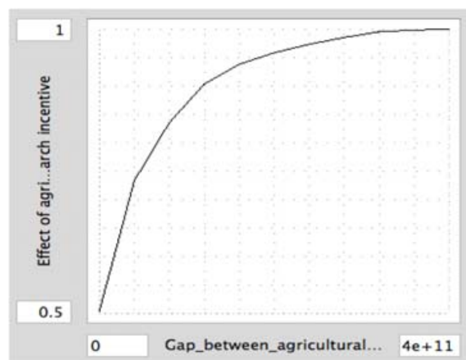


Figure 12. Graphical function of "Effect of agricultural output gap on research incentive"

5.3.5 Agricultural R&D

The fundamental solution of addressing the insufficiency in agricultural output lies in shifting the focus to R&D. The converter "Normal incentive for agricultural R&D" is thus introduced as shown in Figure 13. The initial value is set as 1.482%, which is the average percentage of GDP allocated for agricultural R&D among Asian countries as recorded by World Bank [30]. Investment in

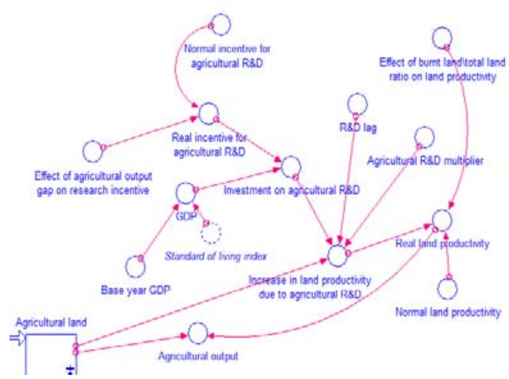


Figure 13. Base model describing agricultural R&D

R&D has been proven to be effective in improving per area output. According to National Bureau of Economic Research, every $1 of R&D investment increases output by $4 in average [31]. Thus, the “Agricultural R&D multiplier” is set as 4, which is used to calculate the increase in land productivity arising from agricultural R&D investment. However, the drawback of agricultural R&D is that there is a time lag of about 10 years before the effect materializes, so the converter of “R&D lag” is incorporated and its value is set as 10 years [32].

6 Modelling result discussion, model validation

6.1 Results and discussion

In this section, the simulation result will be discussed in terms of the various parameters introduced in the model. Figure 14 below shows the simulation results for “Agricultural output”, “Forest”, “Agricultural land” and “Land burnt for agricultural production”. The result spans 200 years from year 2000 to year 2200. According to data retrieved from the World Bank, the area of “Forest” and “Agricultural land” are 994,090 km^2 and 477,000 km^2 respectively in the base year 2000.

The graph of “Forest” decreases with time, because peasants continue with the tradition of clearing the forest annually by slash-and-burn methods.

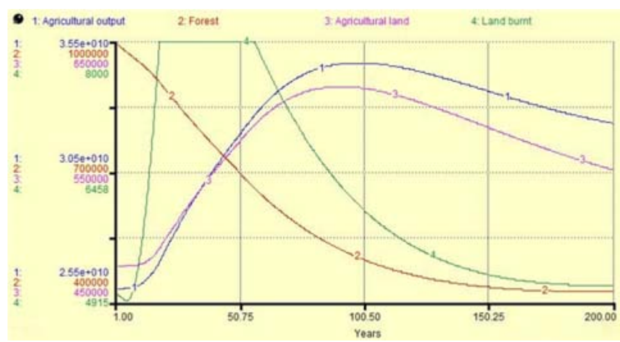


Figure 14. Base model simulation result

The graph of “Land burnt for agricultural production” increases rapidly and reaches its maximum in year 2018. This is because there is a positive “Increase in agricultural output gap” initially and the “Land burnt for agricultural production” increases with increasing “Gap between agricultural output and its desired level”. Since “Land burnt for agricultural production” cannot exceed “Max land burnt per year” as it is limited by the forest land allowable for burning, the graph remains at its maximum of 8000 km^2 for 38 years. After that, the graph of “Land burnt for agricultural production” starts to decrease because of the decline in both the “Forest” area and the “Real land burnt rate for agricultural production” arising from the decrease in the “Gap between agricultural output and its desired level”.

The graph of “Agricultural land” increases initially because the “Real land burnt rate for agricultural production” is faster than the rate of land abandonment. However, “Agricultural land” gradually starts to decrease after 38 years of the reduction in “Land burnt for agricultural production”.

The graph of “Agricultural output” initially increases because of the expansion in the area of “Agricultural land” and the improvement of “Real land productivity”. In spite of the increase in “Real land productivity” throughout the years, “Agricultural output” decreases from year 2098 due to the decrease in “Agricultural land”. This is attributed to the stronger effect of “Agricultural land” on “Agricultural output” as compared to “Real land productivity”.

According to the figures, both “Agricultural land” and “Agricultural output” experience a decline after reaching the maximum. Since “Forest” land cannot be replaced fast enough to meet the rising demand for agricultural land, “Forest land” area keeps decreasing and eventually there will not be sufficient land left for burning. This largely restricts the growth of agricultural output and ultimately leads to the decline in output level. This implies that current solution of relying on burning land is not a sustainable way for agricultural development.

6.2 Model validation

A validation check is performed by comparing the model output with the historical data to prove the validation of our model. Referring to Figure 15, the indicator of our study – the inter-temporal agricultural output from 2000 to 2012 generated by our model simulation fits relatively well with the trend of historical data. However, some small deviations arise because in our model, we assume that GDP is increasing at a constant rate and do not take the actual fluctuations in the performance of the Indonesian economy into consideration. For instance, in 1997-1998, Indonesia was severely affected by Asian financial crisis, and the economy experienced an exceptionally high inflation rate (65%) and unprecedented recession (-13.6% GDP growth) [33]. Hence, in 2000-2002, Indonesia’s economy has not fully recovered, and the output level fell short of the projected values. In addition, our model does not capture the impact of natural disasters like the tsunami in 2004, which also adversely affected the level of agricultural output.

On the other hand, in 2005, the Indonesian government launched “Masterplan for Acceleration and Expansion” which successfully expedited the economic growth in the following years [34]. As a result of the better overall performance of the economy, agricultural output grew faster after 2005, which explains the reason why the historical data is higher than our simulation results. Based on the coherent general trend, we can conclude that our model is able to closely simulate the dynamic behaviour of Indonesian agricultural output level.

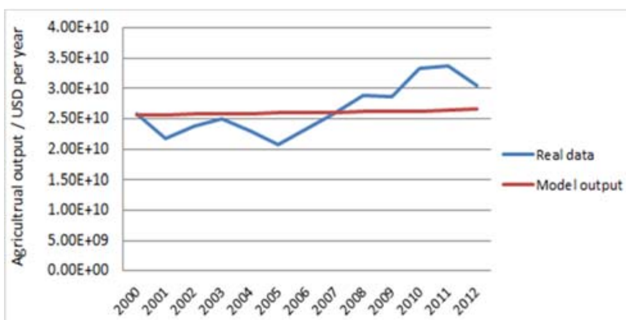


Figure 15: Fitness of model output to real data

6.3 Integration error testing

The model is constructed in continuous time and calculated by numerical integration. A numerical integration method and time step (DT) result in the approximation of the underlying continuous dynamics. Thus, integration error testing is conducted to test the sensitivity of “Agricultural output” to the change in integration method and DT value. Table 1 shows that the agricultural output in year 2100 and 2150 remain unchanged at $ 34.7 billion and $ 33.6 billion respectively regardless of the integration method and the value of DT used. This implies that the agricultural output which is the key indicator of this model has passed the integration error testing and is proven to be insensitive to the change of integration method or the DT value.

Table 1: Results of integration error testing

Integration method	DT	Agricultural output in year 2100/ billion US$	Agricultural output in year 2150 / billion US$
Euler's Method	0.125	34.7	33.6
Euler's Method	0.25	34.7	33.6
Runge-Kutta 2	0.125	34.7	33.6
Runge-Kutta 2	0.25	34.7	33.6
Runge-Kutta 4	0.125	34.7	33.6
Runge-Kutta 4	0.25	34.7	33.6

7 Sensitivity analysis

In the base model, the "Agricultural output" demonstrates an increasing trend initially and starts to decrease after reaching a peak value of $34.6 billion. In reality, the value of "Agricultural output" may vary due to the differences in the value of other variables. Sensitivity analysis is done to determine the sensitivity of "Agricultural output" to the change in different variables.

7.1 Change in "Government policy on land returning ratio"

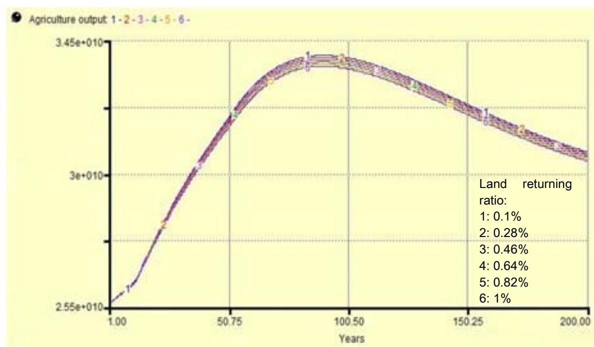


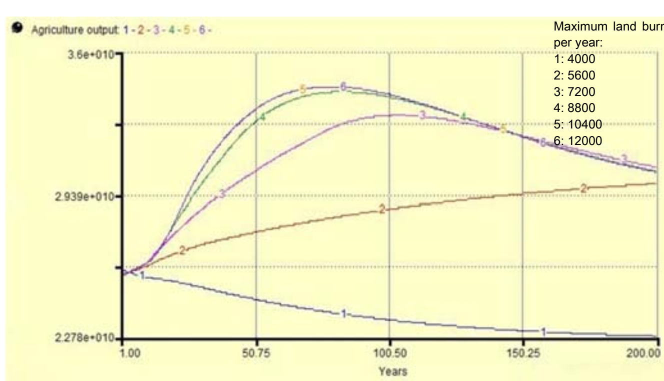
Figure 16. Impact of change in government policy on land

The sensitivity of "Agricultural output" to the change in "Government policy on land returning ratio" is examined by varying its value from 0.001 to 0.01.

Figure 16 shows that the increase in land returning ratio yields slightly lower agricultural output. This is due to the decrease in agricultural land area because of land being returned to forests. When keeping other variables constant, the smaller the agricultural land area, the lower the total output.

7.2 Change in "Maximum land burnt per year"

Since the area of land burnt per year is also a possible variable that influences the agricultural output, the sensitivity of "Agricultural output" to the change in "Maximum land burnt per year" is tested by varying its value from 4,000 km^2 to 12,000 km^2. The result illustrated in Figure 17 shows that "Agricultural output" increases with an increase in "Maximum land burnt per year". "Maximum land burnt per year" has significant impact on the shape of the graphs. As the area of maximum land burnt becomes lower, the new available agricultural land per year



decreases accordingly, leading to a smaller increase in agricultural output per year. Thus, the gradient of the graphs becomes gentler with decreasing values of area of maximum land burnt. For graph 1 in Figure 17, the agricultural output shows a decreasing trend. This is because the maximum land burnt per year is lower than the area of abandoned land per year, resulting in the decrease in total agricultural land and thus fall in output level. Therefore, it is important to keep the maximum area of land burnt at an appropriate level in order to maintain the replenishment of the agricultural land and prevent the fall in output level.

7.3 Changes in "Time taken for the abandoned land to be recovered to forest land"

In the base model, the "Time taken for the abandoned land to be recovered to forest land" is 100 years. By varying this value from 50 to 150, the sensitivity of "Agricultural output" is tested against the change in "Time taken for the abandoned land to be recovered to forest land". The result displayed in Figure 18 shows that a shorter time taken for forest land recovery will result in higher maximum output and slower rate of decline in agricultural output after reaching the peak. Since the limiting factor to agricultural growth is the limiting capacity of forest land that can be burnt for planting crops, when the recovery rate increases with shorter recovery time, it helps to curb the problem of forest land shortage and thus, yields higher peak and slower rate of decline in output.

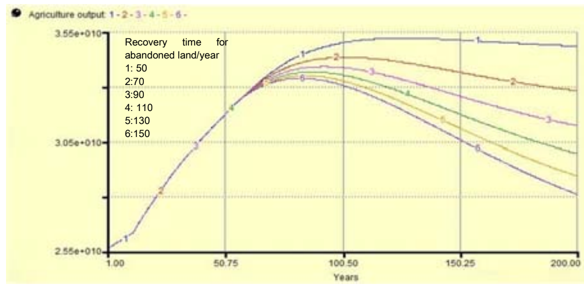


Figure 18. Impact of change in government policy on time taken for the abandoned land to be recovered to forest land

7.4 Changes in "Normal incentive to agricultural research and development"

Since the "Normal incentive to agricultural research and development" can be a possible key variable in varying the "Agricultural output", a sensitivity test is carried out by varying the value of normal incentive to research from 0.01 to 0.1.

The sensitivity analysis result in Figure 19 shows that the increase in "Normal incentive to agricultural research and development" leads to obvious increase in "Agricultural output". Since research and development is able to boost the productivity directly, a higher value of incentive to research and development will lead to higher output levels.

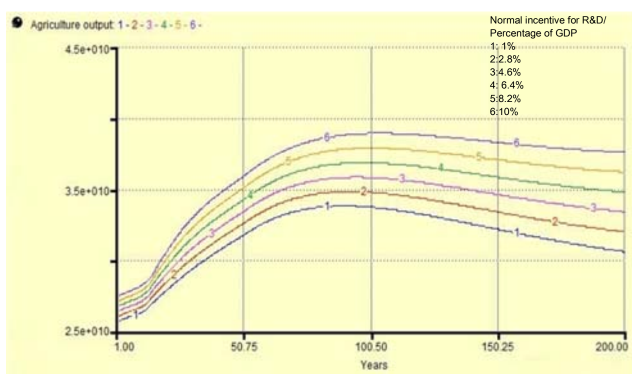


Figure 19. Impact of change in government policy on normal

From the sensitivity testing, we can conclude that "Government policy on land returning ratio" has the least impact on the output level, as the general trend of the graphs are not subjected to major changes. Thus, it can be concluded that "Agricultural output" is not very sensitive to the changes in "Government policy on land returning ratio". However, the "Maximum land burnt per year", "Time taken for the abandoned land to be recovered to forest land" and "Normal incentive to agricultural research and development" are shown to have significant impacts on "Agricultural output", implying that "Agricultural output" is sensitive to changes in these three variables.

8 Proposed policies

8.1 Rationale of policy suggestions

In order to prevent the foreseeable decline in agricultural output in the long run, we maintain that the Indonesian government needs to adopt a set of policies to stimulate the agriculture sector growth in a sustainable manner. Based on the sensitivity analysis in the previous session, it is discovered that among the different factors that the government is capable of adjusting effectively, the agricultural output is highly sensitive to three main factors: normal incentive to research, maximum area of land burnt per year and the returning time from abandoned land to forest. Therefore, government should consider approaching this issue from these three perspectives. Firstly, government should invest more in R&D for the agricultural sector to improve land productivity effectively. Secondly, on top of the legal limitation on the area of land that can be burnt within a time span, the government ought to further tighten regulations and put in more effort to enforce related laws. In this manner, the forest in Indonesia will have a better chance to survive the extinction that our model projection suggests. Thirdly, government should strive to reduce the time taken for the abandoned land to recover back to forest by re-planting and re-fertilizing. Our proposed solution is a combination of these three measures.

8.2 Explanations of proposed policies

8.2.1 Normal investment on agricultural R&D

Based on the sensitivity analysis Figure 19 in the previous section, if the government invests more on research and development in the agricultural sector, agricultural output will be able to increase more sustainably and will no longer face the eventual decline in the long run in the base model. According to our simulation results, while holding other factors constant, if investment on research can be increased to five times the current amount, the agricultural output will reach an equilibrium instead of a decline in the long run. In our prediction, even if agricultural land area decreases in the future, we will still obtain steady levels of output with the augmented productivity. In fact, with the adjustment in the other two factors which will be discussed in next two sub-sessions, the government only needs to increase investment by 2% of the Indonesian GDP in order to achieve desirable levels of output consistently.

8.2.2 Maximum land burnt per year

Moreover, the government should also consider tightening the ceiling of land allowable for burning (currently 5000 km^2per year). According to the sensitivity analysis results in Figure 17, we discover that if this ceiling is set too high, agricultural land and forest will diminish in the long run and agricultural output will become spontaneously less sufficient. However, if this maximum is set too low, agricultural output will keep decreasing due to insufficient arable land. According to a geography expert at the Miami University, the slash-and-burn technique is not an entirely detrimental farming practice, and if it is applied properly in moderate scales, it can expand agricultural land and improve soil fertility [35]. Therefore, in the long run, it is desirable to burn a certain amount of forest in exchange for fertile agricultural land to replenish the loss due to the loss in fertility. Therefore, it is the government's role to set this maximum carefully in the proper range to achieve a sustainable increase in agriculture output. Based on the model simulation results, the government should set 5000 km^2 per year as the maximum value.

8.2.3 Time taken for abandoned land to be recovered to forest

According to Figure 18, similar to normal incentive to agricultural research and development, when the duration of recovery for unusable land decreases, agriculture output will increase, and if the returning time is sufficiently low, the agricultural land will converge to a stable amount in the long haul. Based on our simulation, the Indonesian government should aim to halve the average returning time to 50 years in order to achieve consistent and stable increases in agricultural output. Measures can be actively taken to facilitate the returning process. For example, hardy plants can be planted on abandoned land to reduce erosion and restore fertility.

8.3 Summary of proposed policies

Our proposed policies are summarised in Table 2. We recommend the government to implement the following combination of policies starting from this year to prevent future declines in agriculture output.

Table 2. Summary of our proposed solution

Sensitivity factors	Current value	New value
Normal investment on agriculture R&D	1.482% of GDP	3.482% of GDP
Maximum amount of land burnt per year	8000km2	5000km2
Duration of recovering for unusable land	100 years	50 years

8.4 Projected results of policy implementation

With the proposed policies of reducing the "Time taken for abandoned land to be recovered to forest" and reducing annual "Maximum land burnt", the graph of "Forest" decreases at first but eventually stabilizes at 730, 000 km^2, as shown in Figure 20 below.

Initially, the graph of "Land burnt for agricultural production" increases at an increasing rate. However, there is a sharp decrease in the year 2015 and the graph remains constant at 5000 km^2 afterwards. This is due to the policy of lowering the "Maximum land burnt per year" to 5000 km^2 taking effect in the year 2015.

The graph of "Agricultural land" increases and stabilizes at a

constant value. Unlike the case in the base model, the graph of “Agricultural land” reaches an equilibrium with “Forest” and “Land burnt for agricultural production” after year 2500, which ensures the sustainable development of agricultural output.

The trends of “Investment on agricultural R&D”, “Real land productivity” and “Agricultural output” are summarized in Figure 21 below. The graph of “Investment on agricultural R&D” still shows an increasing trend but the rate of increase is faster as compared to the one shown in the base model. This is due to the change in policy from 2015 onwards, where the “Investment on agricultural R&D” increases by 2% of total GDP.

The graph of “Real land productivity” increase simultaneously with the increase in “Investment on agricultural R&D”. Since the impact of research on productivity is large enough to offset the negative impact of air quality resulting from land burning, the “Real land productivity” increases with increasing “Investment on agricultural R&D”.

Figure 21: Model with proposed policy simulation result II

The graph of “Agricultural output” increases at the same rate as “Real land productivity”. This is because “Real land productivity” becomes the dominant factor in influencing the level of output after the stabilization of the area of “Agricultural land”.

With these three proposed policies, “Forest”, “Land burnt for agricultural production” and “Agricultural land” will finally reach an equilibrium. In addition to spending 2% more of the country’s GDP on “Investment on agricultural R&D”, “Real land productivity” will significantly increase. Therefore, a sustainable growth in “Agricultural output” can be achieved.

8.5 Comparison with previous simulation efforts

Similar simulations regarding the agricultural sector growth in Indonesia were conducted in 1998 by the International Food Policy Research Institute. [36] This paper examined the relationship between the production and consumption of 10 agricultural commodities during the period and projected the effects of different policies on the sector over the following 26 years. This paper is pertinent to our projection effort as it confirmed the importance of public investment in research in order to boost growth in the agricultural sector. According to their projection, increased public investment would sharply boost output for the relevant agricultural commodities by an average of 10%, while a reduction in investment would in turn result in a decline in production and the country would become heavily reliant on imports to support the growing population. As the projection from this paper largely adheres to the current trend reflected, we have strong reasons to believe that our proposed policies will have tremendous benefits on the future growth of this sector.

9 Limitations

9.1 Difficulties in changing people’s mindset

Since the slash-and-burn technique has been a long-standing tradition of Indonesian peasants, it would be difficult for them to change their mindset and halt their myopic practices in the short run. Hence, the policy of reducing the “Maximum land burnt per year” may not be effective as many peasants are likely to ignore this legislation and continue with illegal forest burning to improve their welfare in the short term.

However, the benefits of our policy are more palpable in the long term as it ensures a sustainable level of agricultural output in the future, which may be impervious to the peasants. Therefore, educational campaigns could be implemented together with our policy to raise their awareness of the long-term implications of land burning activities, thus ensuring that peasants would be able to see the full picture and hence comply with the proposed policy.

9.2 Lack of investment incentive of the government

Another possible limitation to our policy can be the unwillingness of the Indonesian government to invest in agricultural research and development, given the significant short term benefits of the slash-and-burn technique. Moreover, due to substantial level of bureaucracy within the government, the new policies may take a longer period of time to pass through and be implemented.

However, the Indonesian government is surely aware of the repercussions of the current forest fires due to the external political pressure from the neighbouring countries suffering from the haze. Nonetheless, the current measures to suppress the illegal burning activities have not been effective due to the high costs in invigilation. In comparison, the spending will be better utilized if they are invested in R&D, which tackles the root cause of the problem. As the current level of investment in research and development is as low as 1.48% of the total GDP, there is still significant room for improvement. According to our model projection, a 2% increase in the percentage of GDP spending will bring about a sustainable output increment, which will ultimately eliminate the need for large-scale burning activities. Therefore, despite the short-run delays in policy implementation, the optimistic perspective the fundamental solution is convincing for the Indonesian government to take action.

10 Conclusion

As the projections from our simulations demonstrate, our policies are effective in securing sustainable future agricultural output level and conserving a healthy level of forest land and arable land. Despite the difficulties in convincing the relevant parties of interest to forgo the convenience and short-term benefits from burning forests, the grim long-term implications are alarming and some of the potential detriments have already begun to manifest. Therefore, we have every faith that if the policies recommended are adopted and effectively implemented by the Indonesian government, the current situation can be rectified and the sustainable development in the agriculture sector will eventually oil the path for an ever more promising future for Indonesia.

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