International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

An Empirical Analysis of Land-use Change in Indonesia

Deden Djaenudin[a]*, Rina Oktaviani[b], Sri Hartoyo[c], Hariyatno Dwi Prabowo[d]

[a]*Department of Agricultural Economics, Bogor Agricultural Univeristy and Centre for Social Economic Policy and Climate Change Research and Development, the Ministry of Environmental and Forestry, Jalan Gunung Batu No. 5, Bogor, 16610, Indonesia*

[b,c]*Department of Economics, Bogor Agricultural University, Jl. Kamper, IPB Dramaga Campus, Bogor, 16680, Indonesia*

[d]*Forestry and Environmental Research Development and Innovation, the Ministry of Environmental and Forestry, Jalan Gunung Batu 5, Bogor 16610, Indonesia*

[a]*Email: dendja07@yahoo.com.au*

[b]*Email: r_oktavi@yahoo.com*

[c]*Email: hartoyosri@yahoo.com*

[d]*Email: hdwipa@yahoo.com*

Abstract

Indonesia has committed to reduce emissions by reducing deforestation and forest degradation. The commitment implies that Indonesia has to control the conversion of land forests to other uses. Forest conversion to other uses is influenced by social and economic factors. This paper aims to identify patterns of land uses and analyze the impact of economic factors on land use changes. We develop a land allocation behavior model derived from the profit maximization theory. To estimate parameter in each equation, this paper used seemingly unrelated regression (SUR) estimation method that can cope with some statistical issues i.e., contemporaneus correlation, autocorrelation and heteroskedasticity. The results indicate that the behavior of the land use in Indonesia are influenced by commodity prices, wages, investment, population growth, income per capita, and road infrastructure.

---

* Corresponding author.

We also find that land use behavior is varied among six islands group. Response areas on output prices of estate crops and mining are higher than those in forests and food crops. To mitigate climate change on the land use basis, some policies that lead to reforestation can be promoted including increasing timber price by including externality aspect, improving road infrastructure and investing in technology that can increase productivity of estate and food crops. Related to the efforts to mitigate climate change on the land use basis, the policies related to timber prices and road infrastructures are timely. Increasing output prices for timber and improving road infrastructure increase land use for forest which in turn leads to reforestation.

Keywords: socio economic dynamic; profit maximisation; response area; agricultural productivity.

1. Introduction

Decisions of land use and land use change are an emergence issue in climate change mitigation due to its contribution in green house gases emission. Land use, land use change and forestry (LULUCF) emissions accounted for 18% - 20% of total emissions [1,2] and were estimated to contribute about 1.6 billion tons of carbon emitted each year [3]. A mechanism aims to reduce emissions from deforestation and forest degradation has been issued in 2007. This agreement has implications on the requirements of improving forest governance and knowledgement on factors that can support and reduce the level of conversion of forests to other land uses. During the period of 1990-2013 natural forest area showed a decline trend, while land use for forest plantation, crop lands, plantations, mining, and settlements had increased. Table 1 shows that natural forest had continuously decreased. From 113 million hectares in 1990 to about 92 million ha in 2013. On average, natural forest decreased about 1.6 million ha / year in 1990-2013, with the highest reduction rate occurred during period 2006-2009, about 1.8 million hectares per year or 1.79% per year. Certain economic factors were argued as the main factor causing forest lost. In the meantime forest area declined, land use for mining, settlement and agricultural activities such as forest plantation, estate plantations and food crops increased. Among the activities, mining land cover showed the highest increase from year to year (Table 1). For the agricultural activities, estate plantations experienced the highest increase. This phenomenon, changing land use from forest to other uses, are influenced by socio-economic factors such as industrialization and population growth [4] and the expansion of agricultural land [5] both at global and regional levels. Population growth will increase demand for settlement, agriculture and infrastructure development [6].

Table 1: The rate of land cover change (%/year)

Period	Natural Forest	Forest Plantation	Estate Crops	Food Crops	Mining	Settlement
1990-2000	-1.12	2.29	6.43	1.50	2.72	1.11
2000-2006	-0.60	1.55	1.82	0.33	3.69	0.92
2006-2009	-1.79	4.43	8.66	1.54	8.26	1.19
2009-2013	-1.00	3.37	4.90	0.86	7.00	0.36

Source: The Ministry of Forestry, Indonesia (2014), calculated

Investments in agriculture activities aiming to support food security and energy have led to the expansion of land for agriculture uses (Table 2). Infrastructure development particularly roads has also contributed to forest lost. In fact, such infrastructure is important in order to increase market access (input and output markets) for the society. Another important factor of forest lost is forest encroachment, commonly known as illegal logging particularly in areas where competition for land use is high. It is expected that forest land will continuesly decrease because of the development of such activities.

Table 2: Investment in land based activities in Indonesia in 2010-2014 (Billion Rupiah)

Land base	Year				
Sector	2010	2011	2012	2013	2014
Agriculture	8 863.8	9 514.5	9 729.0	6 949.0	13 358.0
Forestry	171.6	12.5	145.0	0.0	0.0
Mining	3 075.0	3 075.0	10 481.0	18 762.0	59 035.0
Total	60 626.0	76 000.7	92 182.0	128 151.0	156 126.0

Source: National Statistic Agency (2014)

Increasing price of estate crops such as palm oil and rubber contributes to land expansion of estate crops particularly for oil palm or rubber. Changing output prices of estate crops has influenced profitability which in turn influence the decision of land allocation [7]. It is a literature reported that one percent increase in output price leads to a one percent increase in agricultural land [8]. Another factor that influence land allocation decission is population. Population grew rapidly in Indonesia, more than 1% per year in 1971- 2014 (Table 3). Increasing population leads to increasing demand for agricultural and settlement land [9].

Table 3: Population growth in Indonesia (%/yr)

Period	Population growth (%/yr)
1971-1980	2,31
1980-1990	1,98
1990-2000	1,49
2000-2010	1,49
2010-2014	1,40

Source: National Statistic Agency (2014)

Many of the literature examine land use change. However, most only focus on factors influencing land use in forest sectors without considering the competition among land-based activities (agricultural activities, mining). This paper contributes to the previous literature by including the competition among land-based activities in Indonesia. As far as we know, this issue has not been examined in Indonesia. In general this study aimed to examine the competition of land use in Indonesia. The specific objectives of this paper are to analyze the response of land use allocation by including output prices, investment, infrastructure and population density in the model. In this study deforestation is defined as land use change from forest to other land use activities.

2. Method

2.1. Model Spesification

Previous studies have included economic factors contributing to deforestation including economic growth, demography, technologyy, cultural and politic [11][12][13]. Besides, land allocation for a specific use is influenced by output prices, input prices and output prices of other commodities. How do these factors affect land-use change are complex [10]. The literature of land use competition concluded that the decision on land allocation is aimed to maximize profits subject to the constraint of land area [7][14][15][16]. Revenues generated from the use of land are affected by the level of production and output prices at a certain technological level. Suppose there is an area, L hectares that could be allocated for **m** type of land use, l_i so that

$$L = \sum_{i=1}^{m} l_i \qquad (1)$$

For each land use is intended to maximize profit,

$$\pi_i(p_i, w, Z, l_i) \qquad (2)$$

Subject to

$$\sum_{i=1}^{m} l_i = L$$

Where π_i is profit land use in a certain region; p_i is the output price of land use i; w is an input price, and Z is a fixed input used. The solution to the equations (1) and (2) for optimal land allocation can be stated as $l_i^* = l_i(p, w, Z, L)$. It is assumed that l_i^* is a homogeneous function of degree one in L. Thus optimal land allocation l_i^*can be written as

$$l_i^* = l_i(p, w, Z, 1).L \qquad (3)$$

Equation (3) can be expressed as a function of the share as follows:

$$s_i^* = {l_i^*}/{L} = l_i(p, w, Z) \qquad (4)$$

To determine the degree of the influences the socio-economic factors on the allocation of land use we need to estimate the specific function. For this purpose, it is assumed that equation (4) follows the logistics form [15],

[17]. The use of logistics form is utilized to ensure that the value of the share is between zero and one. In this paper, the model specification for land use in the form of logistics is as follow.

$$s_i^* = \frac{\exp(f_i(p,w,Z))}{\sum_{i=0}^{4}\exp(f_i(p,w,Z))} \qquad (5)$$

Where exp () is an exponential function. The denominator in equation (5) is the sum of the allocations for four land use activities (forest, estate crops, food crops and mining) and the allocation of the remaining land that is not allocated to the four land use activities (i = 0). As the implications of these conditions, equation (5) can be written:

$$\ln\left(\frac{s_i^*}{s_o}\right) = f_i(p,w,Z) - f_0(p,w,Z) \equiv g_i(p,w,Z) \qquad (6)$$

In the process of estimation of parameters in the model, ***g*** is assumed to be linear function [15]. For example $g_i(p,w,Z)$ is specified as a linear function as follows:

$$g_i = a_i + \sum_{j=1}^{m} b_{ij} lnP_{ij} + \sum_{k=1}^{n} b_{ij} lnZ_{ij} + \mu_i \qquad (7)$$

Thus the equation is specified as follows:

$$S_i = ln\left(\frac{s_i^*}{s_0^*}\right) = a_i + \sum_{j=1}^{m} b_{ij} lnP_{ij} + \sum_{k=1}^{n} c_{ij} lnZ_{ij} + \mu_i \qquad (8)$$

This equations system (8) consists of four land use activities as outlined above. The dynamics of the share of land use is determined by the output prices, input prices, population density, investment, and infrastructure. To capture the competition, it is necessary to impose a symmetry and a homogeneity restriction [18] as follow

$\sum_{i=1}^{4} a_i = 0$ and $\sum_{i=1}^{4} c_{ii} = 0$ (homogeneity restriction)

$b_{ij} = b_{ji}$ for $i \neq j$ (symmetry restriction)

2.2. Elasticiticy of land use allocation

Elasticity in this paper shows the response in land use allocation relative to a percentage change in prices and other factors influenced land use allocation in equation (8). Because $\sum_i s_i^* = 1 - s_o^*$, then by adding the share of all land use and share, s_o^* can be obtained.

$$s_i^* = \frac{\exp(f_i)}{1+\sum_{i=1}^{4}\exp(f_i))} \qquad (9)$$

Elasticity of land use allocation can be calculated using the value of the share area response coefficients [15].

Thus the coefficient of elasticity can be calculated by transforming the equation (9) into the natural logarithm, to obtain

$$\ln(s_i^*) = f_1 - \ln(1 + \sum_{i=1}^{4} \exp(f_i)) \qquad (10)$$

The elasticity can be calculated as follows:

$$e_{ij} = \frac{\partial \ln(s_i^*)}{\partial \ln(P_j)} = \beta_{ij} - \sum_{i=1}^{4} \beta_{ij} . s_i^* \qquad (11)$$

2.3. Data

To determine land use and land use change, we used analysis of Geographic Information Systems (GIS). The land use was approached by the land cover data. The land cover data used in this study is a spatial data at provincial-level from 2000- 2013. Based on the interpretation of satellite imageinary (The interpretation of satellite imageinary is the process of identifying land cover types that exist in a satellite image based on colour), the Ministry of Forestry divided land cover types into 23 classes. To meet data requirements for the analysis, we aggregated all cover types into five classes, namely forest, estate crops, food crops and mining, and other. Then, we calculated the share of each type of class for each year and province by dividing the area of each land use by the corresponding total amount of area.

Table 4: Summary statistics for land use at 2000, 2013 and the whole panel for four land use activities

Land use[a)]	2000		2013		Whole panel (2000-2013)			
	Absolut (1000 ha)	Share (%)	Absolut (1000 ha)	Share (%)	Mean (%)	SD	Min	Max
Forest	104821.03	0.553	97041.53	0.512	0.412	0.202	0.096	0.903
Estate Crops	7406.72	0.039	10454.55	0.055	0.045	0.055	0.000	0.279
Food Crops	42660.18	0.225	45618.57	0.241	0.349	0.193	0.012	0.7
Mining	343.66	0.002	577.76	0.003	0.004	0.012	0.000	0.072
Others	34358.06	0.181	35709.27	0.189	0.191	0.093	0.058	0.467

[a)] land use of 32 provinces (without DKI Jakarta)

Because of data availability in the land cover area, we cannot separate the forest area into natural forest and forest plantation, rather we use the whole forest area. Another limitation of land cover data is the ability to disagregate each land use type into spesific commodity. For example, for food crop land there are more than five commodities that could be cultivated such as paddy, cassava, corn, sweet potatoes, and peanut. In such situations, we calcluated a weighted output price for each land use. To determine output price of forest area, we used the timber prices that was retrieved from the Ministry of Forestry (national and provincial level) and the Central Agency on Statistics. For the output price of mining, we used the coal price from the Ministry of Minreal Resources and Energy. For output prices of estate and food crops, we used price data from the Central Agency on Statistics and the Ministry of Agriculture. Then the weighted output prices of estate crops were calculated from productions and prices of oil palm, rubber, cacao, coconut, and coffee. While the weighted output prices for food crops were calculated from the productions and prices of paddy, corn, cassava, sweet potato, and peanuts. The statistic summary of explanatory variables is presented in Table 5.

Table 5: Statistics summary of explanatory variables used in the land-use model

Explanatory variables	2000		2013	
	Mean	Standard Deviation	Mean	Standard Deviation
Timber price (000 Rp/m3)	307.26	254.74	1289.53	225.62
Estate crop price (Rp/Kg)	911.69	760.89	3886.95	4037.85
Food crop price (Rp/kg)	696.36	587.13	2876.27	804.91
Coal price (000 Rp/ton)	174.52	111.55	471.43	18.44
Wage (000 Rp / month)	182.07	274.06	882.21	197.46
Investment (million Rp)	2996.59	4189.34	32981.81	40540.32
Income per capita (000 Rp/capita/yr)	4288.83	4389.19	20876.84	17.42

3. Results

3.1. Statistical issues

As outlined previously, the data used in this study is panel data at the provincial level from 2000 to 2013. By using panel data, there is a possibility for high variation among provinces and times; therefore, the problems such as groupwise heteroskedasticity, contemporaneous correlation, and serial autocorrelation might emerge. We tested such issues, i.e., the contemporaneus correlation by using the Breusch-Pagan test, groupwise heteroskedasticty by using the Lagrangian Multiplier test, and serial autocorrelation by using the Durbin-Watson test. The test results of the tests are presented in Table 6. The tests show that contemporeanus correlation, heteroskedasticity, and autocorrelation emerge in the four equations. To cope with these statistical problems, we estimate the equations simultaneously by using SUR method [7,15]. The results of estimation with SUR method are presented in Table 7.

3.2. Response area behavior

<u>*Output Prices*</u>

Fluctuations in output prices in the markets determine the direction of land cover changes. Output price has positive effect on the allocation of forest land means that if the price of timber increase, forest land will increase. However, the impact is not statistically significant. This is related to the function of forests in Indonesia consisting of natural forests (production, protection and conservation forest inside forest areas) and community forests that are outside the forest area. As outlined previously, in 2009-2013 natural forest area had decreased about 1%. Meanwhile, at the same period forest plantation increased by about 3.37% per year. The effect of the price of timber to forest area as a whole is not significant. In addition, although wood prices in the domestic market and international market showed upward trend, empirically encourage the exploitation of natural forests for timber. In other hand, increasing timber price motivates people or forest companies to increase forest plantation or community forest area. This situation occurs in Java Island in which community forest area increase [11]. Meanwhile the price of estate crops has n negative effect on forest share and significant at 5% level. This shows that if the price estate crops increase, forest land will reduce. The conversion of behavior of land allocation for estate crops is positively influenced by the price of estate crops and significant at the level of 10%. Prices of food crops and timber have significant negative impact on the share of estate crops at the level of 1% and 5%, respectively. The price of mining (coal) does not affect significantly on estate crop allocation. Food crop land allocation is affected by food prices positively and significantly at 5% level but negatively affected by fluctuations in the price of real estate and significant at the level of 5%. While timber and coal prices do not affect significantly. It can be explained that land for food crops is fertile and productive, therefore the food crop land would be like to convert to estate crops than mining or forest.

Share of land in mining is not statistically influenced by output prices (mining price and other commodity prices). This is because the production potential of the mining product (coal) does not only depend on the exploitation of the land area, but also the depth of exploitation of mining land itself. In such situations, increasing the price of coal, the mining is done in the direction of depth, so it does not need to open up a new area. When other output prices change, the conversion of mining areas to other activities seems to be difficult because of fertility issues. Mining land can be categorized as marginal land with low fertility rates, while other activities focus in the research needs high quality land in terms of the fertility. In general, the changes in output prices of forests, estate crops and food crops have led to the competition of land-use among them.

Table 6: Testing for contemporaneous correlation, autocorrelation, and heteroskedasticty issues

Equation	Contemporaneous Correlation		Autocorrelation		Groupwise heteroskedasticity	
	Breusch-Pagan Test (χ^2(df))	p-value	Durbin Watson	p-value	Lagrangian Multiplier	p-value
Forest	21.04	0.0863	0.2157	0.0001	320.07	0.0001
Estate crops	30.94	0.0057	0.2193	0.0001	322.78	0.0001
Food crops	41.73	0.0001	0.3810	0.0001	139.55	0.0001
Mining	68.14	0.0001	0.2490	0.0001	326.34	0.0001

Other Economic Factors

The impacts of the economic variables on land-use allocation vary. The variable of wage has negative impact on the forest land and significant at the l 10% level. Meanwhile, this variable does not significantly effect on other land use allocation. Variable of investment has significant effect on the allocation of land use except for mining. The influence of investment to share the forest is negative, but it has positive impacts on the land allocation for estate and crops. Variable income per capita has negative impact on the share of land allocation for estate and food crops. Increasing in per capita income will encourage the expansion of land use for mining, and reduce land use for estate and food crops.

Table 7: Estimation results of land allocation model

Variable	Forest	Estate Crops	Food Crops	Mining
Intercept	1.4812	2.6820	-1.9140	-2.2492
Output Prices				
Forest	0.1053	-0.1401***	0.1134	-0.0786
Estate Crops	-0.1401***	0.2448*	-0.1299**	0.0252
Food Crops	0.1134	-0.1299**	0.2707**	-0.2542
Mining	-0.0786	0.0252	-0.2542	0.3077
Economic Variables				
Wage	-0.1282*	0.0085	0.0727	0.0470
Investment	-0.0389***	0.0092*	0.0093**	0.0204
Income per capita	-0.0436	-0.1624**	-0.2533***	0.4594**
Population density	-0.1935***	-0.3211**	0.3499***	0.1648
Roads	0.0682*	0.0487	0.0104	-0.1272
Island dummy variables				
Sumatra	-0.3937**	0.0113	-0.1873	-1.3195***
Jawa	0.1486	0.0971	-0.6713**	-2.9252***
Bali and Nusa Tenggara	-0.3180	-2.8453***	-0.8889***	-2.8143***
Kalimantan	-0.4995***	-0.0561	-0.1036	-0.2772
Sulawesi	-0.0127	-0.7005	0.0550	-2.1320***
Lag (endogen)	0.6833***	0.6833***	0.6833***	0.6833***
System Weighted MSE	0.9736			
Degrees of freedom	719			
System Weighted R-Square	0.8039			

*** significant at 1%; ** significant at 5%, * significant at 10%

The variable of population density has significant negative effect, at the 5% level on the land use dedicated to forest and estate crops. Population density has significant positive impact (the level of 1%) on the land use for food crops. There is no significant impact of population density on the land use for mining. The variable of road has significant positive effect (at the level 1%) on the land allocation for forest. This is contrary to the previous literature reporting that the construction of road infrastructure will encourage the clearing of forests. However, since this study used the aggregate data of forest in which contains forest plantation and community forest. The improvement of road infrastructure will provide better access to the development forest plantation and community forest. Based on the economic variables used in the model, it can be concluded that the variables of investment and population density have the significant roles in determining the land use patterns in Indonesia compared to other variables.

Dummy Location

Dummy location in this model refers to variability among big islands in Indonesia with respect to the allocation of land uses. The results indicate that the behaviors of forest land allocation vary among islands, indicating by the estimated parameter of dummy location. The behavior of the land share of forest area in Maluku and Papua is similar to those in Java, Bali and Nusa Tenggara and Sulawesi. However, the behavior of the land share of forest areas in Maluku and Papua differ significantly with Kalimantan and Sumatra. The behaviors of land use of estate crops are similar in all islands except for Bali and Nusa Tenggara. The behaviors of land allocations for food crops in Maluku and Papua Islands differ to those in Java and Bali, and Nusa Tenggara Islands. There are similarity of the behaviors of land allocation in mining in Papua and Maluku and Borneo Islands.

3.3. Elasticities

Since the equations used in the model are interrelated each other, the economic interpretation can not be conducted directly from the results in Table 7. To deal with the situation, we calculate the elasticities of all independent variables by using equation (11) . Table 8 and Table 9 show that all the elasticities both for output prices and other economic variables are inelastic. This indicates that the price change is not very responsive to the changes in the land use allocations. This might be related to the fact that the rate of returns and technological levels differ among activities [7].

Table 8: Elasticity of land share on output prices

Variable	Forest	Estate Crops	Food crops	Mining
Price of timber	**0.030**	-0.216	0.038	-0.154
Price of estate crops	-0.050	**0.335**	-0.039	0.116
Price of crops	-0.021	-0.265	**0.136**	-0.389
Price of coal	0.041	0.145	-0.134	**0.427**

Price elasticity

Response area or landshare in each activity relative to the changes in output prices vary (Table 8). Increasing prices of timber by 1%, ceteris paribus, will increase land share for forests and food crops by 0.03% and 0.038%, respectively. The increasing land share of forests and food crops might be obtained from the conversion of other activities: estate crops, mining and other uses. Increasing price of estate crops by 1%, ceteris paribus, will increase the land share for estate crops and mining by 0.335% and 0.116%, respectively. The increase in the land share gain from the conversion of forest land and food crops by 0.05% and 0.039%, respectively.

Increasing in food prices by 1% will increase the share of food crop area by 0.136%, ceteris paribus. . The increase in the share of food crops is obtained from the declining in forest share by about 0.021%, the share of plantations by 0.265% and the share of mining land by 0.389%.

Although the variable of output price of mining is not statistically significant (see Table 5), its elasticity is very responsive. Increasing in price of coal by 1% will increase the share of mining land by at 0.427%. Based on the values of cross-price elasticities, the share of land in mining is more responsive compared to other activities. The level of responsiveness in land share of mining is understandable because nominal mining area is very small. Therefore, changes in the mining area by 1 ha will provide a greater percentage change compared to other land uses.

Elasticities of other economic variables

Increasing in wage rate by 1%, ceteris paribus, will reduce the share of land forest by 0.104%. The decline in the share of land forests because the land conversion to other uses increase by about 0.097% for food crops, 0.033% for estate crops, 0.072% for mining. Increasing investment by 1%, ceteris paribus, will reduce the share of land forest by 0.027%, but increasing the land share for estate crops, food crops and mining by about 0.021%, 0.021%, and 0.032%, respectively. In general, the share of forest land is more responsive compared to other land use activities. This can be associated with the activities of timber harvesting and the competition of land uses for other activities (estate crops, food crops and mining).

Table 9: Elasticity of economic factors

Variables	Forest	Estate Crops	Food Crops	Mining
Wage	-0.104	0.033	0.097	0.072
Investments	-0.027	0.021	0.021	0.032
Income per capita	0.070	-0.049	-0.139	0.573
Population density	-0.227	-0.355	0.316	0.131
Roads	0.036	0.016	-0.022	-0.160

The responses of land share in mining and forest relative to income per capita are more sensitive compared to food and estate crops. Increasing in per capita income by 1% will increasethe share of mining and forest by 0.573% and 0.07%, respectively. Meanwhile, increasing in income per capita by 1% will reduce the land share for estate and food crops by 0.049% and 0.139% .

Population growth is responded variously by the behavior of land shares. Increase in population density by by 1%, ceteris paribus, will reduce the shares of land forest and estate crops by 0.227% and 0.355%, respectively. The declines in the share of land forests and estate crops are converted to the increases of the land shares for food crops and mining by 0.022% and 0.16% . The increase in the land share for food crops is associated with increase demand for food crops.

4. Conclusions

Demand for land tends to increase along with economic growth and population growth. This indicates by the increasing rate of land forest conversion to other uses leading to land competition among other activities occur. Land allocation is determined by the accessibility of land use, population, and economic development in the region. In such, changes in land use in a certain area depend on sosial, economic and policies factors in the region. The model developed is able to capture the competition of land use in Indonesia.

This research reveals that land allocation behavior is influenced by output prices. Changing in output price leads to land competition among forest, estate crops, food crops and mining. Responsiveness of land uses in the four activities are inelastic. However, it seems that land share of estate crops is more responsive to the changes of output prices compared to forest and food crops.

Response of land share of forest is relatively more sensitive on wages and investment changes compared to other activities. Increase in wages and investment will increase land share for forests and reduce land share for other uses. Population growth, income per capita and road infrastructure affect differently on the response of land share. Population growth increases land share of food crops, decreasing land share for other activities. Road infrastructure increases land share for forest, but reduce land share for food crops and mining.

5. Recommendation

Related to the efforts to mitigate climate change on the land use basis, the policy recommendations are related to output prices, road infrastructures, and investment. Increasing output prices for timber and improving road infrastructure increase land use for forest which in turns led to reforestation. The current timber prices tend to be under-valued since the price is still based on cost cutting basis. Meanwhile social marginal costs (externalities from the environmental impact, social, and biodeviserity) have not been included in the timber prices. It is expected that timber price will increase when private and social marginal costs have been included. Effort to reduce emission of carbon through reducing deforestation and forest degradation can boost the marginal value given to forests through Payments for Environmental Services (PES) or increasing forest prices, the trade-off opposing agricultural and forest rents can then be modified in favor of the forests.

Our model also reveals that investment has negative impact on the share of land use for forest. Historical data shows that investment on estate and food crops is higher compared to those in forest sector. In such, it would be better if investment in the two sectors (estate and food crops) should focus on the technology that can increase agricultural productivity. Increasing agricultural productivity through intensification can reduce demand for land in estate and food crops. Improving road construction can increase market access for plantation forests and community forests. This will lead to increase in land use of plantation forests and community forests.

It is important to note that the data of forest area in this paper is aggregated from different type of forests such as natural forests, plantation forest and community forest in which each forest type has different behavior. Thus this paper is not able analyse behavior of specific type of forest. Therefore further research should incorportare all type of forest in the model separately.

References

[1] S. Pagiola and B. Bosquet, "Estimating the costs of REDD at the Country level," For. Carbon Partnersh. Facil., vol. Version 2., no. World Bank, pp. 1–22, 2009.

[2] N. Stern, The Stern Review: The Economics of Climate Change. Cambridge: Cambridge University Press, 2007.

[3] M. Köhl, T. Baldauf, D. Plugge, and J. Krug, "Reduced emissions from deforestation and forest degradation (REDD): a climate change mitigation strategy on a critical track.," Carbon Balance Manag., vol. 4, p. 10, 2009.

[4] H. Long, G. Tang, X. Li, and G. K. Heilig, "Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China," J. Environ. Manage., vol. 83, no. 3, pp. 351–364, 2007.

[5] A. Angelsen and D. Kaimowitz, "Rethinking the causes of deforestation: lessons from economic models," World Bank Res. Obs., vol. 14, no. 1, pp. 73–98, 1999.

[6] J. K. a Benhin, "Agriculture and deforestation in the tropics: a critical theoretical and empirical review.," Ambio, vol. 35, no. 1, pp. 9–16, 2006.

[7] E. Boere, J. Peerlings, S. Reinhard, T. Kuhlman, and W. Heijman, "Effect of output price volatility on agricultural land use," New Medit, vol. 3, 2015.

[8] A. Angelsen, E. F. K. Shitindi, and J. Aarrestad, "Why do farmers expand their land into forests? Theories and evidence from Tanzania," Environ. Dev. Econ., vol. 4, no. 1999, pp. 313–331, 1999.

[9] Y. Zhang and F. Transition, "Deforestation and forest transition: theory and evidence in China," World For. from deforestation to Transit., vol. 2, no. Rudel 1998, pp. 41–65, 2000.

[10] S. S. Scrieciu, "Can economic causes of tropical deforestation be identified at a global level?," Ecol. Econ., vol. 62, no. 3–4, pp. 603–612, 2007.

[11] H. Dwiprabowo, D. Djaenudin, I. Alviya, and D. Wicaksono, Dinamika Tutupan Lahan: Pengaruh Faktor Sosial Ekonomi. Yogyakarta, Indonesia: PT Kanisius, 2014.

[12] P. Meyfroidt, E. F. Lambin, K.-H. H. Erb, and T. W. Hertel, "Globalization of land use: distant drivers of land change and geographic displacement of land use," Curr. Opin. Environ. Sustain., vol. 5, no. 5, pp. 438–444, 2013.

[13] J. K. Vanclay, "Growth models for tropical forests: A synthesis of models and methods," Sch. Environ. Sci. Eng. Cross Univ. ePublications@SCU, 1995.

[14] R. J. Gorddard, "Modeling profit-maximizing land-allocation behavior," University of California, 2009.

[15] J. Wu and K. Segerson, "The Impact of Policies and Land Characteristics on Potential Groundwater Pollution in Wisconsin," Am. J. Agric. Econ., vol. 77, no. 4, pp. 1033–1047, 1995.

[16] J. Wu and M. Li, "Land use change and agricultural intensification: key research questions and innovative modelling approaches," 2013.

[17] J. Wolfersberger, P. Delacote, and S. Garcia, "An empirical analysis of forest transition and land-use change in developing countries," LEF – AgroParisTech/INRA, vol. 33, no. April, 2015.

[18] W. W. H. . Greene, Econometric analysis, vol. 97. 2012.

Acknowledgments

We wish to thank Sahara for her assistance in building dataset. All views, interpretations and conclusions expressed are those of the authors.