

Cease and Disperse: The unintended effect of Indonesia's moratorium on deforestation

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Abstract

Tropical deforestation accounts for roughly 15% of annual carbon emissions, more than the combined emissions from road, rail, air, and marine transportation, worldwide. Any viable effort to mitigate climate change must address tropical deforestation. This paper assesses the impact of Indonesia's 2011 moratorium on new concessions for deforestation in Kalimantan, Indonesian Borneo. The results suggest that, relative to Malaysian Borneo, the moratorium shifted the spatial distribution of deforestation rather than reducing the overall rate, as intended. The price responsiveness of new clusters decreased significantly, relative to the responsiveness of clearing around existing clusters. The price responsiveness of overall clearing activity remained unchanged, suggesting significant leakage associated with the policy. This pattern of deforestation is consistent with leakage through both space and time, as the moratorium has a widely known expiration date of May 2013. The results also suggest that the extension of the two-year moratorium will face much greater opposition from industry than was seen for the initial implementation, as it will have a more significant economic effect.

Outline

1. The moratorium restricts new clusters of clearing activity.
2. The price responsiveness of Type 2 clearing has gone down, whereas the total rate of clearing has gone up.

Introduction

There are conditions such that, as Hartwick, *et al.* (1986, pp. 219) note, the set-up costs will destroy the optimal schedule of extraction. The optimality, here, is not the important part, but rather that there are price and set-up costs conditions such that the second resource pool will not be extracted, given the relatively high set-up costs and the relatively low price. A somewhat higher price, however, will yield a mix of the two resource pools. The current cluster may be extracted up to a point where the marginal cost of extraction is higher than it would have been if both resources pools were being utilized. As soon as the price increases to the point to "turn on" the second resource pool (and incur the set-up costs) then the developer will switch to the new resource pool, and the proportion of new aggregate clearing activity in new clusters will rise (since some clusters will come online that weren't being exploited before, turning off the overexploited resource pools).

Indonesia has become increasingly active in managing its forests, which account for over 10% of the world's remaining tropical forests. This increased oversight is part of a broader trend in Indonesia's shift toward stronger regulation in important economic sectors since the mid-1990s; but the forestry sector has become a central focus with international scrutiny of deforestation as a driver of climate change. The forestry sector in Indonesia contributes about 3.5% to gross domestic product, and employs about 4% of the workforce. Carbon emissions from global deforestation represent over 15% of total annual emissions, more than the global transportation sector. Various international initiatives to reduce the rate of forest clearing have been announced, shot down, announced again, but there is still no unifying approach to addressing global emissions from deforestation. The first major, bilateral pledge that is tied to a reduction in deforestation is

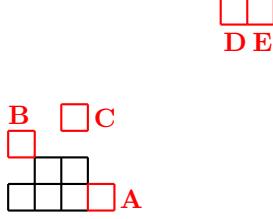


Figure 1: Illustration of clusters

between Norway and Indonesia. Norway has promised USD\$1 billion in aid if Indonesia is able to reduce its emissions from deforestation.

In response, Indonesia enacted a moratorium on new concessions for the exploitation of primary natural forests and peat lands in May 2011. The moratorium was announced a year prior, and was set to be enacted in January 2011, but was delayed by almost 6 months because of continued arguments about the parameters of the moratorium. The moratorium has been widely attacked as having had no effect on the deforestation rate. The Jakarta Globe reported on the “continuing forest destruction by several companies despite the moratorium” in May 2012, exactly one year into the two-year moratorium. Environmental advocates blame the anemic reduction on a “series of loopholes” and changing concession maps, even after the moratorium was enacted. Every six months, the maps indicating the extent of the moratorium are amended, creating uncertainty that must have economic implications. Additionally, the two-year moratorium does not apply to existing concessions and secondary forests, allowing for new investment and continued development.

“The worst thing about the moratorium,” according to the REDD monitor, “is that it has not reduced deforestation.” It is true that the rate of deforestation has increased since May 2011. But it is likely that this opinion is so simple that it misses contours of the economic response to the moratorium that may affect the evaluation of its overall efficacy. The purpose of this paper is to examine the impact of the moratorium on the spatial distribution of deforestation. We split forest clearing activity into two groups based on whether the deforestation results in a new cluster or whether it occurs on the periphery of existing clusters. We find that the moratorium diminished new investment in deforestation clusters, but increased clearing activity on the periphery of existing clusters. The policy focused on one type of clearing activity merely pushed deforestation toward a different class of clearing activity, one that does not require as much upfront investment.

Data

Data on clusters of deforestation is derived from satellite imagery. The spectral signals from the raw imagery are interpreted toward a tractable measure of forest clearing activity; and the flagged pixels are subsequently grouped into discrete clusters using a hierarchical clustering algorithm. Reliable information on forest clearing activity ranges from January 1, 2008 through September 23, 2012. The result is a time series of deforestation that can be decomposed into incremental clearing activity (1) that occurs on the periphery of existing clusters, and (2) that constitute new clusters of deforestation. Consider, for example, the illustration in Figure 1 where the black, unlabeled pixels constitute an existing cluster and the red, labeled pixels indicate newly cleared areas. Within this sample area, the rate of clearing would be five pixels, which can be further decomposed into two groups, based on distance from the existing cluster. The standard specification for analysis throughout the rest of the paper would place pixels **A**, **B**, and **C** on the periphery of the existing cluster and define pixels **D** and **E** as a new cluster. This study attempts to identify the effect of Indonesia’s moratorium on the composition of incremental clearing activity, indicated here by 2/5, as well as the effect on the overall rate. The results are robust to different specifications of clusters, which could include pixels **D** and **E** in the existing cluster, depending on the buffer. New pixels clusters require, on average, more up-front investment to clear than pixels on the periphery of existing clusters. We assume economies of scale, with decreasing average costs.

Initial analysis

The attacks on the efficacy of the moratorium often ignore the increased price of palm oil, which peaked in January 2011. The baseline rate of clearing should be conditional on the price of the agricultural products, which drive investment in cleared land, rather than the unconditional, pre-moratorium rate. The palm oil price is charted in Figure 6a. The palm prices track the general trend in global agricultural prices, suggesting that the price increases were exogenous, despite the fact that Indonesian palm oil accounts for about 40% of global supply.

Empirical evidence suggests that the moratorium shifted the spatial distribution of clearing away from the counterfactual. Increases in output price generally increase the spatial dispersion of clearing. A larger proportion of clearing activity takes place in new clusters, rather than on the periphery of existing clusters when the price is high. This makes sense. A higher price will slowly begin to shift developers' expectations on the return to cleared land, which is an input to production of agricultural products. Assuming a constant and stable marginal cost of clearing, the fixed costs of clearing become more palatable as the price of agricultural products increase: there is more of a chance of a positive return on investment (all in expectation). The proportion of new clearing in *new* clusters, then, will increase with the expected return (price of oil palm) — there is more of a chance that the investment will be made. There will be some lag, some time for developers' expectations to adjust, but even looking at the contemporaneous data, the signal is reasonably clear.

The moratorium reduced the price responsiveness of deforestation in new clusters, relative to old clusters. Less of incremental clearing occurred in new clusters than we would expect, given the sustained and rapid price increase of oil palm. This makes sense, too. The moratorium restricted new concessions for deforestation, but did not restrict clearing activity within existing concessions. On average, only 70% of existing concessions had been cleared; much of the concession area remained untouched, presumably stored for future exploitation [citation needed].

The natural next question is “what are the assumptions that would cause the shift to old clusters to completely offset the overall reduction in new clusters?” The data suggest that the total or overall rate of clearing may have increased after the moratorium was enacted, or equivalently that the *more than offset* the reduction of clearing in new clusters.

Points to make (in no particular order):

1. Tropical deforestation accounts for roughly 15% of annual carbon emissions, more than the combined emissions from road, rail, air, and marine transportation, worldwide.
2. Borneo is 73% Indonesia, 26% Malaysia, and 1% Brunei (which is not considered in this study to keep it compact). It is home to one of the oldest rainforests in the world.
3. The moratorium constrained investment in new deforestation clusters, shifting the spatial distribution of deforestation and ultimately increasing the overall rate of deforestation.
4. Indonesia announced the two-year moratorium in May 2010 to be enacted in January 2011, but it wasn't actually enacted until March 2011 after disputes between government, industry, and environmental advocates. Three stages of the moratorium.
5. The moratorium was catalyzed by a \$1 billion promise from Norway, cash on delivery to Indonesia, contingent on a reduction in the deforestation rate. The promise of aid made the government's previously feeble attempts to manage deforestation much more credible.
6. We use the island of Borneo as a social lab, of sorts, given that Malaysian Borneo is similar in weather and agricultural output as Indonesian Borneo, but was not subject to the moratorium. While the border was drawn based on physical attributes of the land – to divide the watersheds – the similarity of the two sides is reasonable. The one complication may be that Indonesian Borneo is three times the size of Malasian Borneo, potentially affecting the possible spatial dispersion.

7. The overall effect of the moratorium was an *increase* in the rate of deforestation, relative to Malaysia, but to decrease the proportion of deforestation due to new clusters. The spatial pattern of deforestation became more condensed, with clearing occurring disproportionately on the periphery of pre-existing clusters.
8. The new paradigm under the moratorium resembles the short-term response to increased supply of cleared land, on the outskirts of existing clusters. Lower cost to clear, no investment. Short-term response to quick changes in the demand for cleared land are met with deforestation near previously cleared clusters.
9. Intertemporal leakage. Induced short-term behavior in place of long-term behavior, potentially waiting out the two-year moratorium. Similar to spatial leakage: Restrictions on clearing in a certain time or place will just induce clearing in a different time or place.
10. The theoretical structure should have the ability to distinguish between alternatives, to select a model based on testable hypotheses: (a) race to the bottom? (b) lower productivity of land near existing clusters? (c) freed up resources due to a lower fixed cost?
11. Use the physical layout of the land to help distinguish between hypotheses. Examine the attributes of the land that was cleared near existing clusters over time, before and after the moratorium was enacted.
12. Potentially cluster the rate-proportion graph, looking to see if the inclusion in each group was sequenced. A different approach to the standard diff-n-diff, potentially providing more intuition about the way the data are clustered through time.
13. Disney has stopped sourcing from suppliers with a poor track record on deforestation.

Model Considerations:

1. Areas around clusters should be modelled with option value, reflecting the fact that short term supply of cleared land is mainly around existing clusters.
2. The return on land cleared around existing clusters is lower than that of new clusters. Thus, to get the same amount of product out of the land, more has to be cleared. **Check this, ask someone else.** Examine the characteristics of land cleared *around existing clusters* to see if the moratorium had an appreciable impact on, say, the slope of cleared land (something related to yield).
3. Dynamic programming problem, with option value and stochastic element. Two types of resources and one investment term that determines the next period's level of new land.
4. Look at the effect of increasing the risk of appropriation associated with new land, drastically lowering the expected return.
5. There is inertia in the data, allow for time to adjust expectations and to realize gains from previous investment.
6. Is the elasticity of supply of cleared land near *existing* clusters greater than the elasticity of supply of cleared land in *new* clusters. Different cost structures of clearing. If so, then a shock in demand will have a more than proportionate effect on the land around existing clusters. (This is seen in the data.) The greater supply elasticity may be due to (a) less time to mobilize resources and (b) excess capacity or inventory of land near existing clusters. Lower marginal costs will imply a greater elasticity of supply.
7. The supply shock that came with restricting new clearing will induce a more than proportionate response in supply (?) Inelastic demand for cleared land. Why doesn't the new supply just flood the market, immediately driving back down the price?

8. Ultimately, the firms will have to invest in new clusters; but they are content to use up their reserves now, knowing that the moratorium is set to expire in May 2013.

Basic results:

1. The moratorium had the unintended consequence of *increasing* short-term clearing activity by shifting the spatial distribution of deforestation to the periphery of existing clusters. Potential cause: lower returns on land around existing clusters, and steady demand for the yield from cleared land.
2. Deforesters are treating the set moratorium period as a short term hit to investment activity, such that they are responding as if there was a short-term increase in the demand for cleared land (which would and has happened in the past). This can be seen from the stratified scatter plots.
3. The implication is that if the moratorium is lifted after two years, then there will be temporal leakage – restricting clearing in one period only pushed it into another. If the moratorium is maintained, however, it may actually reduce long-term clearing, since investment hasn't been made. Another prediction: way more outcry from industry over a long-term moratorium extension than for the initial two-year enactment to respond to the Norwegian aid promise.
4. Much of the effect happens when the moratorium was *supposed* to be enacted, the other half, so far, has occurred after the moratorium was *actually* enacted.

Let $x_1(t)$ and $x_2(t)$ be the amount of land cleared in time t , where the subscript 1 indicates that the land is on the periphery of an existing cluster and the 2 indicates that the land constitutes a new cluster. Let $p_1(t)$ and $p_2(t)$ be the respective prices for the cleared land, which are functions of the physical characteristics of the land. We expect that $p_1(t) < p_2(t)$, since new sites of land clearing will tend to locate in land with the highest net return. Landowners will progressively clear less valuable land according to an option value approach, effectively storing the forested land until the return is high enough to merit the marginal cost of clearing. For now, though, consider the simple dynamic programming problem to

$$\max_{x_1, x_2, I} \int_0^T \pi_1(x_1(t)) + \pi_2(x_2(t)) - I(t) dt \quad \text{subject to} \quad \dot{R}_2 = f(I(t)) \quad \text{and} \quad \dot{R}_1 = f(I(t-1)) - x_2(t) \quad (1)$$

where $I(t)$ indicates the level of investment in infrastructure or exploration costs in order to create new clusters of cleared land in the following period. For a given amount of land, \bar{x} , we assume that $\pi_2(\bar{x}) > \pi_1(\bar{x})$. The profit from the newly cleared land is greater than that of land near older clusters. This gives landowners an extra incentive to clear new land, above and beyond the incentive to expand production. The function f is increasing and maps investment costs into the amount of land available in the new area.

Tables and figures

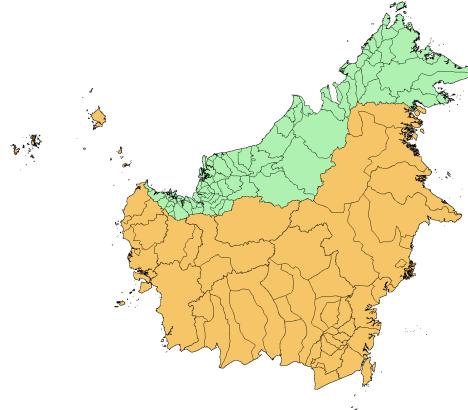


Figure 2: Sample area, Malaysia in green and Indonesia in orange. Borders indicate subprovinces.

References

- [1] H. Bohn and R. T. Deacon. Ownership risk, investment, and the use of natural resources. *The American Economic Review*, 90(3):pp. 526–549, 2000.
- [2] R. Burgess, M. Hansen, B. A. Olken, P. Potapov, and S. Sieber. The political economy of deforestation in the tropics. Working Paper 17417, National Bureau of Economic Research, September 2011.
- [3] R. D. Cairns and P. Lasserre. The role of investment in multiple-deposit extraction: Some results and remaining puzzles. *Journal of Environmental Economics and Management*, 21(1):52 – 66, 1991.
- [4] C. Costello and S. Polasky. Optimal harvesting of stochastic spatial resources. *Journal of Environmental Economics and Management*, 56(1):1–18, July 2008.
- [5] R. S. Epanchin-Niell and J. E. Wilen. Optimal control of spatial-dynamic processes: The case of biological invasions. Discussion Papers dp-11-07, Resources For the Future, Mar. 2011.
- [6] M. Fujita, P. Krugman, and A. J. Venables. *The Spatial Economy: Cities, Regions, and International Trade*, volume 1 of *MIT Press Books*. The MIT Press, 2001.
- [7] J. M. Hartwick, M. C. Kemp, and N. V. Long. Set-up costs and theory of exhaustible resources. *Journal of Environmental Economics and Management*, 13(3):212 – 224, 1986.
- [8] H. Hotelling. The economics of exhaustible resources. *Journal of Political Economy*, 39(2):pp. 137–175, 1931.
- [9] G. G. Judge and R. C. Mittelhammer. *An Information Theoretic Approach to Econometrics*. Cambridge University Press, 2012.
- [10] A. Pfaff, J. Robalino, R. Walker, S. Aldrich, M. Caldas, E. Reis, S. Perz, C. Bohrer, E. Arima, W. Laurence, and K. Kirby. Road investments, spatial spillovers, and deforestation in the brazilian amazon. *Journal of Regional Science*, 47(1):109–123, 2007.
- [11] A. S. P. Pfaff. What drives deforestation in the brazilian amazon?: Evidence from satellite and socioeconomic data. *Journal of Environmental Economics and Management*, 37(1):26–43, January 1999.
- [12] J. N. Sanchirico and J. E. Wilen. Optimal spatial management of renewable resources: matching policy scope to ecosystem scale. *Journal of Environmental Economics and Management*, 50(1):23–46, July 2005.
- [13] K. E. Schnier and C. M. Anderson. Decision making in patchy resource environments: Spatial misperception of bioeconomic models. *Journal of Economic Behavior & Organization*, 61(2):234–254, October 2006.

Table 1

	Model 1	Model 2	Model 3	Model 4
(Intercept)	5.691*** (0.230)	7.992*** (0.838)	6.164*** (0.329)	4.868* (2.533)
price	0.427 (0.274)	1.141*** (0.368)	-0.175 (0.406)	0.058 (0.592)
ctry	2.546*** (0.114)	2.546*** (0.112)	1.541*** (0.465)	8.439*** (2.770)
post	0.123 (0.149)	0.137 (0.146)	-1.636 (1.233)	-1.463 (1.211)
ctry:post	-1.249*** (0.186)	-1.249*** (0.183)	2.939* (1.743)	2.921* (1.679)
idn.exch		-27.438*** (9.630)		
price:ctry			1.279** (0.575)	
price:post			1.840 (1.210)	1.711 (1.170)
price:ctry:post			-4.346** (1.712)	
idn.exch:ctry				-66.937*** (12.899)
mys.exch:neg.ctry				0.331 (0.641)
ctry:price				2.799*** (0.782)
ctry:price:post				-4.334*** (1.635)
R ²	0.741	0.751	0.752	0.781
Adj. R ²	0.736	0.745	0.743	0.771
Num. obs.	214	214	214	214

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

- [14] G. R. van der Werf, J. T. Randerson, L. Giglio, G. J. Collatz, M. Mu, P. S. Kasibhatla, D. C. Morton, R. S. DeFries, Y. Jin, and T. T. van Leeuwen. Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). *Atmospheric Chemistry and Physics*, 10(23):11707–11735, 2010.

Table 2

	Model 1	Model 2	Model 3	Model 4
(Intercept)	1264.913*** (466.868)	464.855*** (14.549)	514.937*** (45.413)	398.610*** (57.746)
date	-0.052 (0.032)			
post	149.622*** (33.555)	86.545*** (24.017)	785.999*** (171.078)	591.097*** (217.539)
cntry		94.159*** (20.576)		232.654*** (81.665)
cntry:post		35.816 (33.965)		389.805 (307.647)
price			-3.797 (55.765)	83.778 (70.909)
price:post			-655.696*** (167.842)	-506.043** (213.425)
price:cntry				-175.151* (100.281)
price:cntry:post				-299.307 (301.828)
R ²	0.138	0.277	0.193	0.360
Adj. R ²	0.130	0.267	0.182	0.339
Num. obs.	218	218	218	218

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

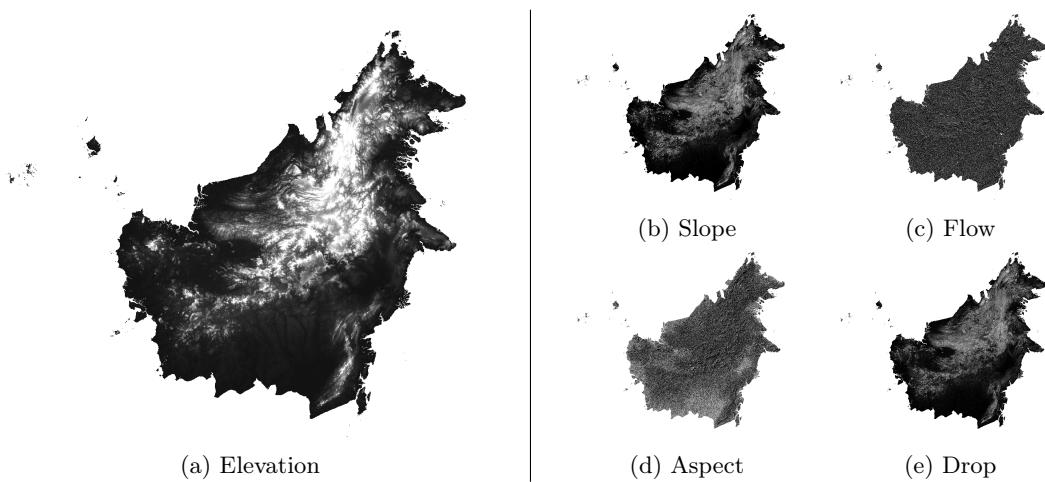
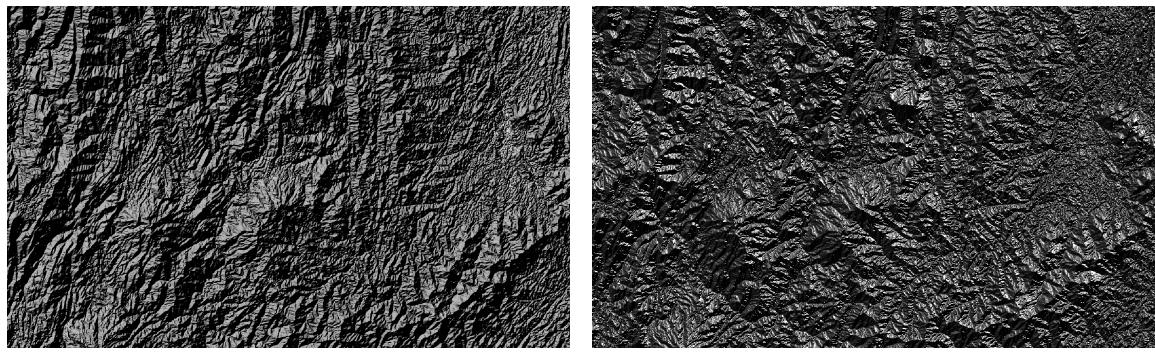


Figure 3: Map of the digital elevation model (left) with derived data sets (right) indicating slope, hydrology, and terrain roughness, 90m resolution.



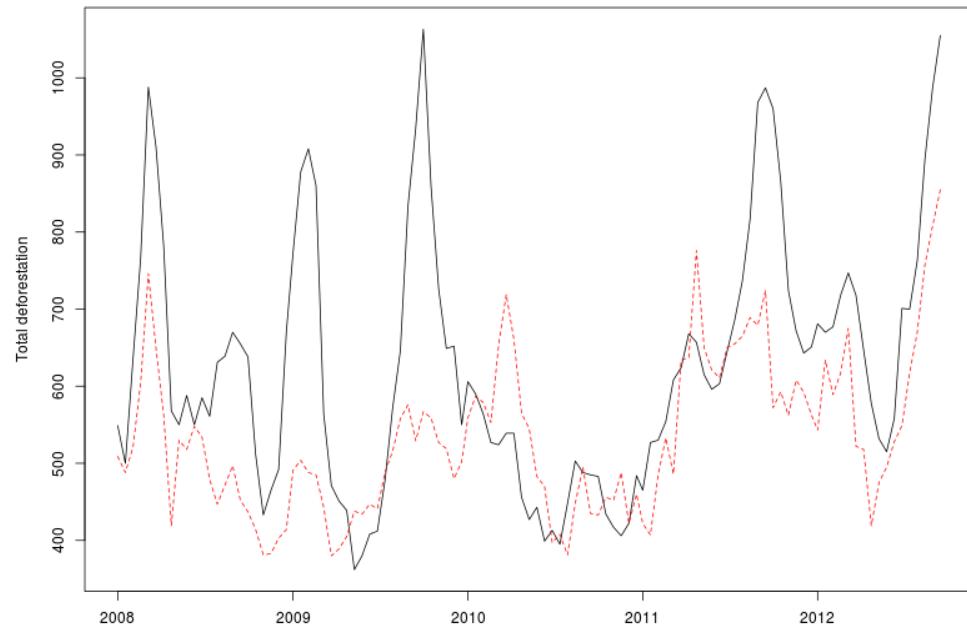
(a) Hillshade

(b) Flow direction

Figure 4: Detailed images of two derived data sets for the same area.

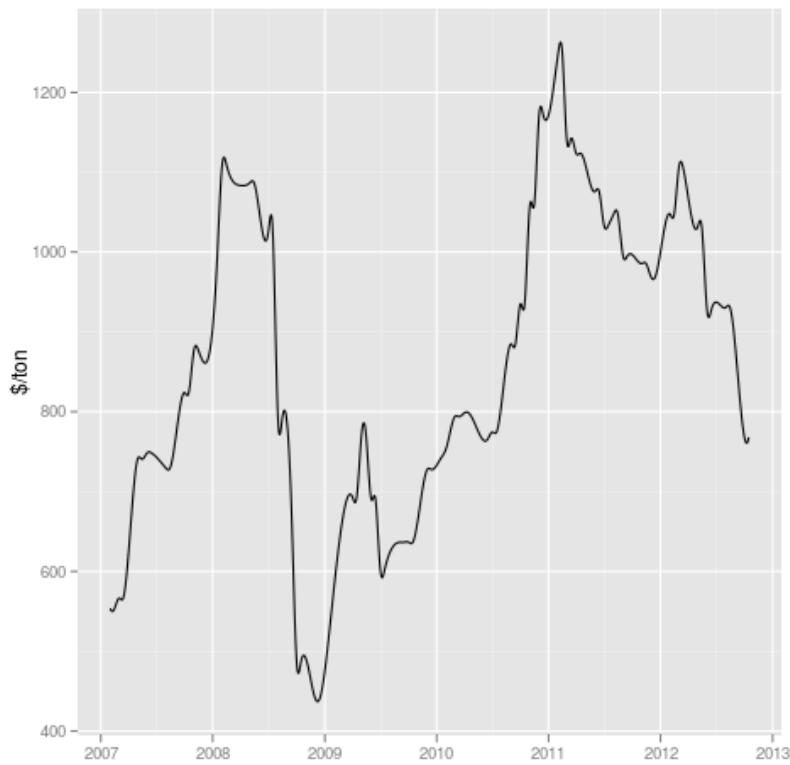


(a) 2-month moving average of proportion measure

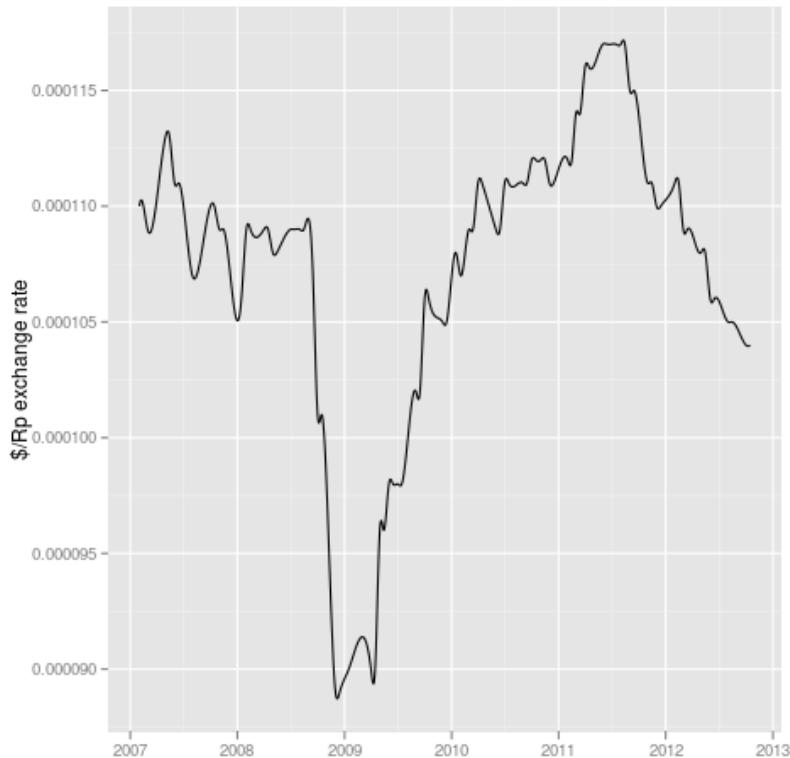


(b) Total number of alerts

Figure 5

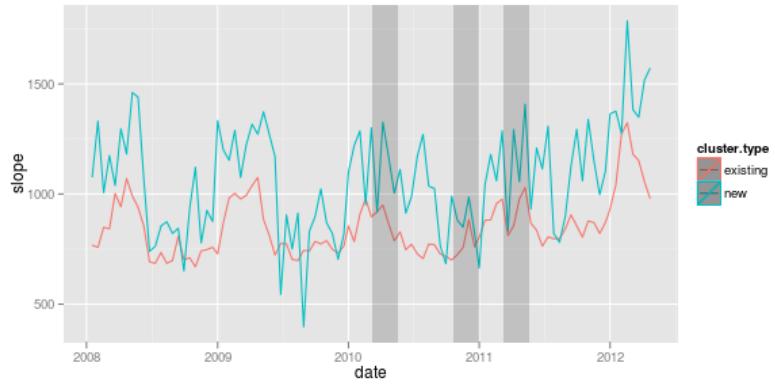


(a) Oil palm price



(b) Indonesian exchange rate

Figure 6: Economic indicators.



(a) Indonesia

Figure 7: Slope of cleared land in different types of clusters.