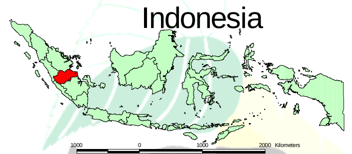
Dynamics of Land Use Change in Jambi
Issues, Data, and Methods

K M Chomitz, D Deborah, D Hadi, F Stolle, T P Tomich, U R Wasrin



Facts and figures, Jambi

Population 1983:	1.5 million
Population 1993:	2.1 million
Total Area:	49 000 sq km
Forest cover 1980:	23 000 sq km
Forest cover 1990:	13 000 sq km
Smallholder land cover 1980:	15 000 sq km
Smallholder land cover 1990:	17 000 sq km

Policy Question: Where is smallholder "encroachment" on logged-over forest most likely to lead to forest conversion?

Background of the study

Forest conversion in Indonesia, using slash-and-burn as a land clearing technique, can involve a range of actors and objectives. Local smallholders, migrants, loggers, large-scale treecrop estates (including industrial timber plantations), and government-sponsored resettlement schemes (called transmigration) all play a role in forest conversion. Although smallholders often receive much of the blame for forest conversion, there has been little empirical work on this in Indonesia. Here we examine one aspect of this complex issue: the two-stage deforestation process in which smallholders 'encroach' on logged-over forest. The focus of this study is the peneplains and piedmont (below 300 masl) of Jambi Province in central Sumatra, a relatively homogenous lowland region (once) covered by rich Dipterocarp forests and well-suited to rubber, oil palm, and timber planting by smallholders or large estates. Three events may have had a big effect on deforestation in Jambi in the 1980s:

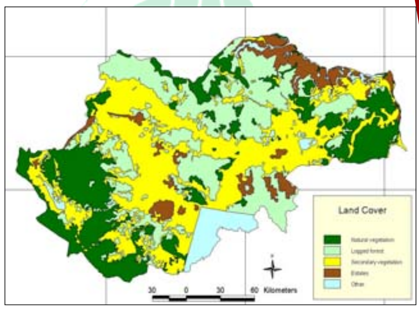
- The Trans-Sumatra Highway was completed, an all-weather road spanning the island and linked to population centers in Java by ferry
- Large areas were logged by commercial firms
- Government-sponsored transmigration projects expanded

Hypotheses about forces driving deforestation by smallholders

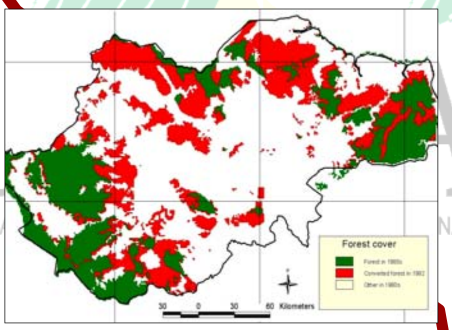
Smallholder conversion of logged forest to other uses is most likely:

- near main roads and rivers, which provide **access to markets** (especially for exports)
- near **social amenities** (neighbors, schools, clinics)
- where favorable **biophysical factors** increase profitability of conversion

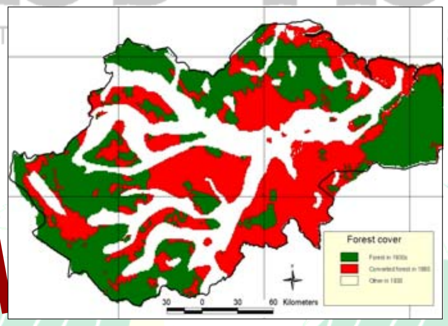
Land cover in Jambi 1992



Land cover change in Jambi 1980-1992



Land cover change in Jambi 1930-1980



Data on land cover change:

Three sets of digitized land cover maps for Jambi Province are used, one for the 1930s, one for the early 1980's, and one for 1992. The 1992 map was prepared for this project by BIOTROP. The map for the early 1980s was compiled by BIOTROP from maps created by RePPProT, with additional detail on logged forest from a map by Y. Laumonier. The map of forest cover from the 1930s is from van Steenis. For Jambi as a whole, more than a third of the natural forest standing in the 1930s was converted prior to 1982; a rate of 260 km²/yr. Conversion accelerated to over 1000 km²/yr in the 1980s, with almost half the forest standing in 1980 converted by 1992.

Rubber marketing

Slash-and-Burn

Natural forest

Explanatory data

Land cover data are combined with spatially-referenced data on explanatory variables in a Geographic Information System (GIS), which includes:

a) distances to rivers
b) distances to main roads built in the 1930s, before 1980, and between 1980-90
c) distances to main towns and settlements in 1930s, before 1980, and between 1980-90
d) distances to processing facilities (data to be added)
e) distances to transmigration sites before 1980 and between 1980-90
f) distances to large-scale tree crop estates before 1980 and between 1980-90
g) distances to industrial timber estates planned in the 1980s
h) distances inside (or outside) logging concessions before 1980 and between 1980-90
i) whether the site was logged commercially by 1982
j) biophysical characteristics, including soil physical and chemical data
k) agronomic suitability and limiting biophysical factors for 68 spp, including rubber and timber

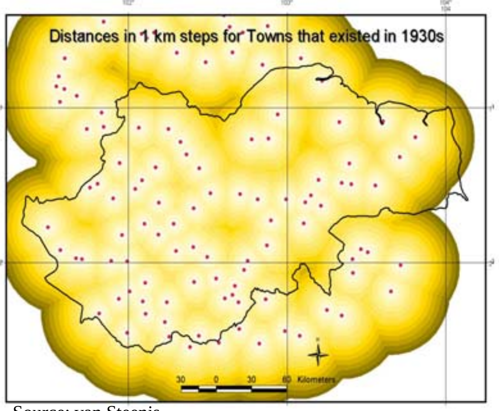
Access to markets for exports is affected by a, b, c, d; a, b, c, and e affect access to social amenities. Secondary road construction associated with e, f, g, h, and i links main roads and forests. Biophysical determinants of attractiveness of conversion are captured in j and k.

Models of land use change

Geographically explicit studies of tropical deforestation have employed a simple but powerful model: forests are converted to agriculture when it is profitable to do so. These studies (e.g. Chomitz and Gray 1996) use a von Thunen approach, deriving the potential agricultural rent at each point on the landscape; points with positive rent are predicted to be converted. Because farmers value access to medical, educational, and social facilities, the supply price of labor increases with distance to the road. Labor supply price is lower, however, when there is a nearby transmigration site. Both labor productivity and farmgate prices may increase if the plot is in a working forest concession. Construction of logging roads reduces transport costs; logging activities remove trees and facilitate slashing and burning.

Results from a preliminary econometric model

A sample of 9477 data points was drawn from forest logged in the 1980s using a one km grid and a multivariate econometric model (a probit) was used to control for biophysical differences and to estimate effects of distances to main roads and rivers on probability of conversion to rubber agroforests and other uses. This simple prototype model correctly predicted 85% of conversion from logged forest to smallholder uses and 78% of the logged forest that was not converted. Site characteristics (soil and topography) were highly significant, indicating smallholders are selective in their choice of sites. This model indicated that conversion of logged forest is much more likely within 10 km of main roads.



Source: van Steenis

Developing a better econometric model

The prototype model would work well in a long-term comparative static framework—say comparing land cover in Jambi in the 1970s with the 1930s. It fails, however, to capture short term dynamic adjustments. When new roads and large projects enter remote areas – as in Jambi in the 1980s -- the economic frontier expands instantly, but deforestation proceeds at a slower pace. The rate of deforestation is constrained by available labor and capital, by the limited season during which slash-and-burn is possible, and by the rate of diffusion of information about the quality of new areas. For situations such as this, a 'hazard model" may be employed in which the hazard (instantaneous probability of deforestation, conditional on no prior deforestation) is related to the attractiveness of the point for conversion. Hazard models employ an exponential specification long used in epidemiology and other fields for survival analysis. Suppose then that the benefit/cost ratio is increased by a factor $\exp(kF_{it})$ where F_{it} is a dummy indicating that i is in an active concession at t. Putting these factors together and summing individually unidentifiable parameters, then the log of the benefit/cost ratio is:

$R_{it} = \beta_0+P_t + \Sigma\beta_{1j} Q_{ij} +\beta_2 D_{it} + \beta_3 S_{it} +\beta_4 F_{it}$ where Q_{ijt} is a dummy=1 if plot i has soil type j

We now assume that the hazard rate λ of forest loss at point i (the instantaneous probability of deforestation at time t, given that the forest has survived till that time) is proportional to the benefit/cost ratio at t:

$\lambda(t) = \exp(\alpha+Rit)$ This is an exponential survival model.

This model can be estimated by maximum likelihood, where the ln likelihood function is

$\ln \text{likelihood}(\alpha,\beta) = \Sigma [D_i \ln S_{iT} + (1-D_i) \ln(1-S_{iT})]$ and D_i is a dummy variable indicating the presence of forest at time T

Tackling further econometric issues

The data set also has been enhanced to allow forthcoming analyses to address 3 statistical concerns – selection bias, spatial autocorrelation, and endogenous regressors -- that could bias the results of the simple prototype model discussed above. Data from the 1930's vintage von Stennis map will be exploited to address **selection bias** – which may arise from focussing only on areas logged in 1982. **Spatial autocorrelation** can be minimized by increasing the distance between points in the sample grid and by using the characteristics of neighboring areas as additional regressors. (For instance, holding the characteristics of point i constant, it may be more attractive for conversion if neighboring points have good soil quality). The enhanced formulation also includes auxiliary equations to account for possible **endogenous regressors** for contemporaneous road, logging concession, large-scale estate, and transmigration location variables. Chomitz and Gray (1996) demonstrate a method to construct instrumental variables for road location.

ASB Alternatives to Slash-and-Burn

ICRAF

World Bank

BIOTROP

Disclaimer: These are preliminary results, subject to revision, and are not for citation or quotation. The findings, interpretations, and conclusions expressed in this poster are entirely those of the authors. They do not necessarily represent the views of the World Bank, its Executive Directors, or the countries they represent.

Financial support from: Asian Development Bank

Photos: T P Tomich **Maps:** F Stolle **Layout:** T Atikah

Reference: Chomitz KM and Gray DA. 1996. Roads, land use, and deforestation: a spatial model applied to Belize. *World Bank Economic Review* 10 (3): 487-512.

ALTERNATIVES TO SLASH-AND-BURN