TRANSPORT ACCESSIBILITY AND DEFORESTATION: EMPIRICAL EVIDENCE FROM THE KLANG-LANGAT WATERSHED STUDY

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Abstract: Changes in land use/land cover including deforestation are not entirely due to the forces of nature. Several human activities that are driven by socio-economic conditions may also cause land use and land cover changes (Turner and Meyer, 1994). One determinant of change that has not received much attention in the literature is transport accessibility. Economic theory tells us that the construction of a new road near forest areas reduces the relative price of forest utilization. Consequently, one would expect a systematic association between the degree of transport accessibility and likelihood of deforestation. This paper shows how remotely sensed satellite imageries could be combined with road network and other socio-economic data to estimate the impact of transport access on deforestation. Several policy implications were also discussed and they can be useful in an effort to balance the urgent need of economic development and the goal of a sustainable forest management.

Key Words:
Transport accessibility, Deforestation, Transport and the environment.

1. INTRODUCTION

Changes in land use/land cover are not entirely due to the forces of nature. Several human activities that are driven by socio-economic conditions and considerations may also cause land use and land cover changes (Turner and Meyer, 1994). Broad groupings of socio-economic causal factors that have been identified include, among others, population dynamics, economics, technology, political and economic institutions and culture (Richards, 1990; Vesterby and Heimlich, 1991; Dale, O'Neill, Pedlowski and Southworth, 1993; Medley, Okey, Barret, Lucas and Renwick, 1995). Some of these causal factors have indeed been empirically shown to cause land use change in the South East Asian region. For example, deforestation in Borneo and parts of the Philippines is found to be largely the result of timber extraction for export (Kummer, D., 1992) while in Peninsular Malaysia, agricultural clearing is the main proximate source (Brookfield *et al.*, 1990).

One determinant of change that has not received much attention in the literature is transport accessibility. This is despite the fact that the impact of transportation network, in particular roads, on economic development and the resulting increase in the utilization of land as an input to production is generally well-understood (Owen 1964, 1984, 1987). Economic theory tells us that the construction of a new road network essentially reduces the price of land utilization (that was hitherto inaccessible) relative to other factors of production. The price of land may, of course, go up as a result of improved accessibility. However, it is still lower compared to the prohibitively high utilization price without access. Easier access thus causes reallocations of inputs in favour of greater utilization of land in the production of goods and services. Consequently, one would expect a systematic association between degree of transport accessibility and changes in land use/land cover.

Assuming that variations in land use/land cover and at least some of the causal factors (such as transport access) could be appropriately identified and quantified, it is possible in principle to empirically estimate a model that explains land use/land cover change. Model building and estimation are useful for at least two reasons. First, they provide a framework for testing the significance of some of the factors that have been hypothesized to be responsible for change. Second, it also enables forecasting of future land use/land cover change. Both are important inputs to policy analysis related to land use/land cover change.

This paper intends to provide a description of the methodology adopted in modeling and estimating the impact of accessibility through road transport on a particular type of land use change (deforestation) in the Klang-Langat river basin. Some findings will also be presented.

2. A PRODUCTION MODEL TO EXPLAIN LAND USE CHANGE

Assume initially that there exist many firms currently operating close to a large tract of forest area. Each of these firms have the options of utilizing several type of inputs for the production of one output with price p. Let $x = (x_1, x_2 \ldots x_L \ldots x_n)$ represents the vector of inputs with the corresponding price vector $r = (r_1, r_2, \ldots r_L(A) \ldots r_n)$ where x_L refers to the amount of forest land used in production with utilization price, $r_L(A)$. Accessibility, A, is an exogenous factor and is assumed to be negatively related to utilization price i.e. $r_L'(A)<0$. Assume further that each firm faces a concave production function given by $f(x)$. Given these assumptions, the firm's problem reduces to maximizing $p\,f(x) - rx$. It is easy to show that the optimal quantity of forest land to be used in production is chosen so that the condition $\partial f(\mathbf{x^*})/\partial x_L = r_L(A)/p$ is satisfied. This condition merely states that the value marginal product of forest land must be equal to its price. As a result, when the price of land utilization is high (say because of poor access), a firm tends to use a relatively smaller amount of forest land and vice versa when it is low. If this is true for a firm, it must also be true for all other firms that use land in their input mix. Thus to the extent that road transport network lowers utilization price, deforestation is expected to be positively related to accessibility.

3. EMPIRICAL MODEL, DATA AND ESTIMATION

Even though the main goal of this paper is to determine the impact of road access on deforestation, there certainly is a need to control for the effect of other physical as well as socio-economic factors. These other factors are therefore included in the estimating equation.

Availability of data and measurement problems also put a constraint on the kind and number of factors that were eventually used in the estimation.

The empirical model is constructed with the basic assumption that the current land use pattern is in a long run equilibrium. Any plot of land under study is assumed to be currently devoted to its most profitable (land) use, either forest or non-forest, depending on several relevant attributes that were earlier termed "causal factors". With these assumptions in mind, a logistic model as specified in equation (1) below could then be estimated to link land use type with the causal factors.

$$Log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} .... + \beta_3 X_{n,i} \qquad (1)$$

where P_i is the probability of a plot being non forest and the X's are the causal factors.

The Klang-Langat river basin was chosen as a study area. It is located between longitude 101° 17′ and 101°53′W and latitude 2° 40′ and 3°16′N. It spans the boundary of the states of Selangor and Negeri Sembilan and contains eight administrative districts. These districts are Gombak, Kuala Lumpur, Ulu Kelang, Sepang, Petaling, Kelang, Kuala Langat in the state of Selangor and Seremban in the state of Negeri Sembilan. In total, it covers an area of 3.809 million hectares. The watershed represents the most urbanized region in Malaysia. Kuala Lumpur, the capital city of about 1.37 million people in 1999, is located at the confluence of Klang and Gombak rivers. Combined with Kuala Lumpur, Klang-Langat region has a population of 4.18 million (1999), which accounts for 20% of the country's total population. The importance of this region is reflected by its dominant position in the Malaysian economy contributing about 28% of the GDP with the area occupying only 1.3% of the total area of Peninsular Malaysia.

In this study observations were made at the 'pixel' level. A pixel is a square plot of land measuring 30 meters on each side. Land use and land cover classification in this paper was carried out using satellite remote sensing imageries for the years 1989 to 1999. The methodology involved in the mapping of land use includes data preprocessing by applying the radiometric and geometric correction. The imageries were the geo-coded to topographic map with the scale of 1:50,000. Unsupervised classification was carried out that was later verified using ground truth data. Selection of training sites was based on spectral and spatial characteristics as well as digitizing of land use map from the Department of Agriculture. Supervised classification was carried out and post classification procedures further ensure the accuracy of the map derived. Global Positioning System on many selected points was used for further field validation and accuracy of results.

There are of course millions of pixels from which a random selection can be made for model estimation. However, in this study, 598 pixels at more or less equidistant from one another were manually selected. This selection method is adopted in order to maximize the distance between selected pixels to attenuate the problem associated with spatial auto-correlation. A value 1 is assigned to a non-forest pixel and 0 otherwise.

Various physical as well as socio-economic causal factors were considered in this study. Table 1 below provides a list of factors along with their operational definitions.

The variable of prime interest in this study is, of course, transport accessibility (DIS2ROAD) where it is measured by the shortest distance in km from a pixel to the nearest road.

Measuring the distance requires overlaying a road network on a digitized satellite image of the area.

Table 1: Definitions of Causal Factors

Factors	Definitions
DIS2ROAD	The distance measured in km from the middle of a pixel to the nearest road.
DIS2TOWN	The distance in km from the middle of a pixel to the boundary of the nearest urban center.
LANDCLASS	Classified according to the Geological Department set criteria. Value=1 if land not suitable for agriculture and 0 otherwise
DENSITY	Corresponding district population density (Population in thousand per square km).
AGRIEMP	Agricultural employment as a percentage of district total employment
FOR_RES	Value=1 if located outside reserve area and 0 otherwise

A measure of a pixel proximity to the nearest urban center (DIS2TOWN) is also included in order to capture the impact of access to product markets on land use. Boundaries of urban areas were drawn on digitized maps before measurements were made.

The LANDCLASS variable measures the suitability of land to agricultural production. The probability of forest in a plot being cleared should be positively related to its suitability for agricultural production. This was found to be particularly relevant for forest clearing in Peninsular Malaysia (Brookfield *et al.*, 1990). Again, a digitized maps containing information on suitability of land for agriculture was overlaid on the satellite image.

Population density (DENSITY) is intended to capture the impact of population pressures on deforestation. It is measured by the number of people in thousand per square kilometer. Agricultural employment (AGRIEMP) is also expected to influence the rate of forest clearing. Since agricultural activities tend to be relatively land intensive, variations in the percentage of agricultural employment to total employment across districts should explain differences in land use change including deforestation. Finally, a variable (FOR_RES) is also included to represent the impact of legal restriction on landuse on deforestation. This variable also allows for an assessment of the effectiveness of the law and the relevant enforcement agency in preserving administratively designated forest reserve.

Results of the logistic regression are given in Table 2 below. Five variables were found to be significant at the 5% level, namely DIS2ROAD, LANDCLASS, DENSITY, AGRIEMP and FOR_RES. Only one variable (DIST2TOWN) was not significant and had the wrong sign. In the case of DIS2ROAD, a kilometer increase in the distance of a pixel from a road network

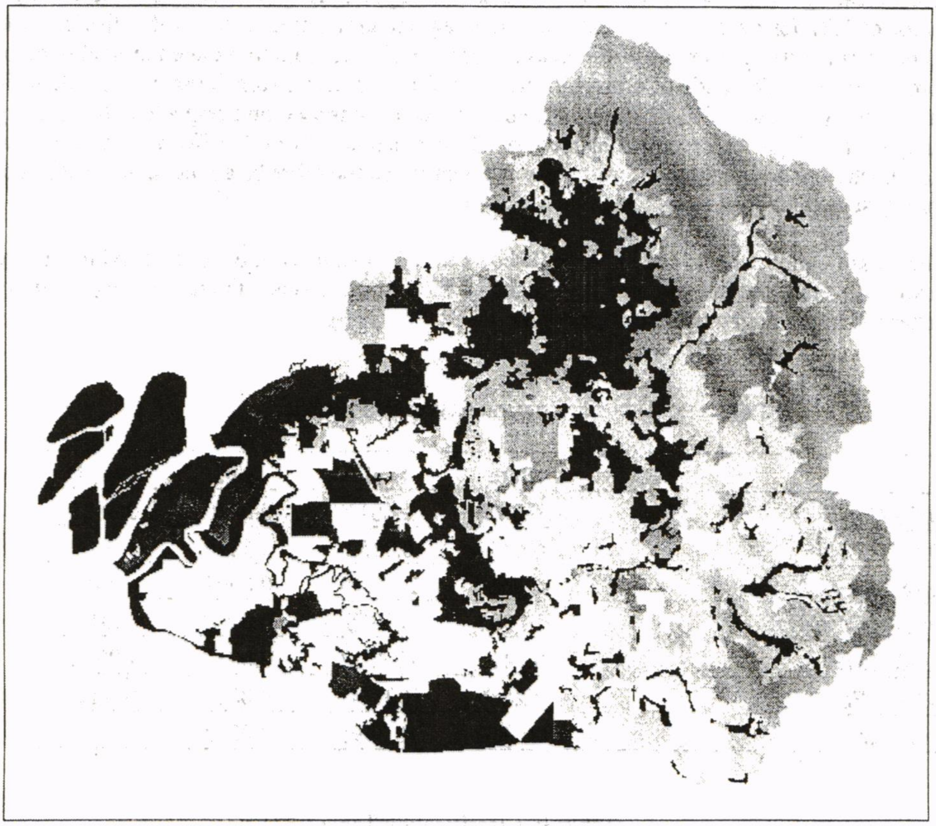

Figure 1: A Sample Post Classified Satellite Image of the Klang-Langat River Basin (The original image is color coded)

access to a road network increases the probability of land being cleared for other uses. In addition, this finding implies that a carefully drafted policy on road construction can be a potent tool in influencing land use changes in general and deforestation in particular. It also tells us that a poorly planned road provision may result in unintended consequences. For example, providing a road link that passes through a forest area is likely to result in eventual conversion of land into other uses. This is true despite the fact that it was originally intended only to facilitate travels between two points. Conversely, it could be argued that providing road access to a previously undeveloped forest area can be a very attractive development policy instrument. The rapid rate of development along some stretches of the previously underdeveloped corridor of the North-South Highway's serves as an illustration of the impact of road access on land development.

The coefficient for the LANDCLASS variable indicates that the odds that a plot of land classified as 'unsuitable for agriculture' being non-forest falls by a factor of 0.2310 compared to a similar plot having 'suitable for agriculture' designation. Population density is the other factor that significantly affects the probability of forest clearing. The odds of a pixel being non-forest increases by a factor of 4.0170 for a unit increase in population density. The economic dependency of the local population on agriculture also influences the likelihood of forest clearing. The result indicates that the odds of a pixel being non-forest is increased by a factor of 1.27 for every one percent increase in agricultural employment of the district. The administrative designation of forest areas as reserves also appears to reduce the likelihood of forest clearing. The odds of a pixel located in a forest reserve maintaining a forest status is increased by a factor of 71.41. From the environmental conservation perspective, this finding suggests that legal enforcement against forest encroachment is quite effective in Malaysia. Administrative designation of forest areas as reserves can therefore be a potentially useful tool for a sustainable forest management in Malaysia.

The classification table given in Table 3 shows that the estimated model has good predictive power. Overall, the model correctly assigns 92.63% of the pixels although it does a slightly better job in predicting the non-forest ones.

Table 2: Logistic Regression Results

	Beta	Wald	Sig.	Exp(B)
DIS2ROAD	-0.3823	4.6011	0.0320	0.6823
DIS2TOWN	0.0304	0.3352	0.5626	1.0309
LANDCLASS	-1.4654	14.2219	0.0002	0.2310
DENSITY	1.3905	8.3956	0.0038	40.0170
AGRIEMP	0.2415	10.4513	0.0012	1.2732
FOR_RES	4.2685	1098345	0.0000	71.4122
Constant	-2.7802	10.3495	0.0013	

Table 3: Classification Table

Observed		Predicted		Percentage Correct
		Forest	Non Forest	
	Forest	149	26	85.14
	Non Forest	18	404	95.73
Overall percentage				92.63

Finally, it must be pointed out that the use of cross section data collected from a distinctly heterogeneous cross sectional units is likely to give rise to estimation problems associated with unobserved heterogeneity. The above estimation approach, though reasonably adequate, still fails to completely overcome this problem. The underlying assumption made in estimating the above model is that the dependent variable is generated by a parametric probability distribution function P(Deforestation|K) where K is a real vector of causal factors, that are identical for all cross sectional units (pixels). Unfortunately, this underlying assumption may be violated since the processes linking the causal factors and deforestation in individual cross sectional units may not be the same due to some unmeasured or unobserved heterogeneity. Even though there may exist common influential factors across cross sectional units, their impacts may not be homogeneous. Ignoring, such heterogeneity among cross-sectional units could lead to bias estimates.

Utilizing a panel data set and its associated estimation techniques is one possible solution to the unobserved heterogeneity problem. It requires observations on different variables to be collected not only for different cross sectional units but also at different points in time. The fixed effect or random effect logistic models can then be estimated. For lack of an appropriate data set, such analysis is not feasible in the current study but will certainly be explored in future studies.

4. SUMMARY

This paper provides a brief description of the modeling and estimation method that have been adopted in estimating the impact of transport access on deforestation in the Klang-Langat river basin study. A simple production model was presented to provide a theoretical justification as to why transport accessibility is expected to influence the rate of deforestation. A logistic regression model was then estimated where it was found that transport access, along with four other variables, significantly affect the probability of forest clearing. These variables are the degree of land suitability to agriculture, population density, agricultural employment as a percentage of total employment and forest reserve. Access to a road network increases the probability of land being cleared for other uses. There are at least two transport policy implications of this finding. First, road construction can be a potent tool in influencing land use changes. Second, a poorly planned transport route may result in unintended consequences. For example, providing a road link that passes through a forest area is likely to result in unintended deforestation. Toward the end of this paper, a method to refine the estimation procedure is also suggested to improve the validity and to enhance the predictive ability of the estimated model.

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