# EXECUTIVE SUMMARY

Beria Leimona / NRP. 99084. ***Modeling Land-use Change and its Driving Factors - A preliminary dynamic landscape-based model of Sumberjaya watershed.*** Under supervisions of Hadi Susilo Arifin and Bruno Verbist.

*The prototype land-use model in this research is intended to provide support for negotiation-making processes with information on the dynamics of land-use change under some combinations of economic scenarios. The main characteristic of the model is to integrate economic and spatial dynamics. A combination of system dynamics and constrained Cellular Automata simulates changes in land-use driven by economic factors. At its current status, it provides insights of past and simulated land-use changes based on economic scenarios.*

Land-use changes are often the result of a greatly increased population, continued economic growth and physical development especially in developing countries, such as Indonesia. In this situation, there is a rising pressure on space and resources, which increases conflict and leads to the degradation of precious land resources.

This study contributes to the development of a negotiation-support model for watershed management – one of the focuses of International Centre of Research in Agroforestry (ICRAF) South East Asia. The objectives of the study are (1) to analyze landscape change and its driving factors in Sumberjaya sub-district, (2) to develop a land allocation model of the area based on land-demand and land suitability as the preliminary part of Negotiation Support System (NSS)

model, (3) to enhance discussion and guide further researches of NSS in order to point out undetected knowledge-gaps or inconsistencies.

Sumberjaya sub-district is located in the uplands of West Lampung district. It is an area with dramatic land-use change over the last four decades with many remaining conflicts, not only between the communities and local government services, but also among communities. The present study intends to predict the impacts of higher or lower coffee-prices on the local farmer level in changing spatial land-use distribution of Sumberjaya sub-district.

The methodology of the preliminary research on dynamic landscape-based model of Sumberjaya watershed is adapted from the methodology of *Rapid Assessment Module for Coastal Zone Management* (RaMCo) simulation model by De Kok and Wind (1999). The integrated modeling will guide further research and ultimately serve as a discussion tool. The research comprises three important steps: (1) qualitative modeling (2) quantitative modeling (3) dynamic modeling.

The research is using two main maps for its analysis (1) basic map for model simulation: manually digitized land-use map year 1985 from National Land Office (*Badan Pertanahan Nasional or BPN*) with scale 1: 25 000, (2) land-cover map year 2000 obtained from Landsat Thematic Mapper satellite imagery (2000) with 30-meter resolution.

To allow the comparisons, land-use classes of the map 1985 and 2000 were harmonized. It resulted in six possible land-use classes: (1) dense and underbrush forest/nature, (2) monoculture coffee field, (3) multistrata coffee field, (4) rice culture, (5) rural residential and (6) other agricultural/natural land-uses.

In historical land-use/cover change analysis, Syam *et al* (1997) concluded that the land use and cover in Sumberjaya watershed changed drastically in the past 20 years (from 1970 to 1990) due to transmigration policy and agro-economical circumstances.

The land-suitability data for conducting suitability maps for each land-use are (1) soil map scale 1:250 000 (1990) and its analytical tabular data, (2) topographic map scale 1:50 000, (3) land-use map scale 1:50 000 from BPN (1985).

The economic data were obtained from several government-offices and private institutions. Coffee plantation is the most dominant agricultural systems in Sumberjaya and its production demand is mainly external. Rice culture is cultivated near the village or on the riverbanks and its production is self-consumed by the community.

The coffee farming system in Sumberjaya has been varying gradually. Budidarsono *et al* (2000) developed a classification of coffee system with seven coffee-farming typologies based on three criteria: (1) vegetation structure complexity, (2) management intensity, and (3) tenurial security of land on where farmers grow coffee.

Profitability of coffee system is analyzed from average of local coffee prices and coffee-yield gained from Input-Output (IO) Table for each coffee systems (Budidarsono *et al*, 2000). The economic-analysis used time-series of coffee real-price with constant price of 1997. According to calculations of Budidarsono *et al* (2000) on the profitability of various coffee systems (local farm gate real-price Rp 3,167/kg), all systems have positive sign of Net Present Value

(NPV) that means they are financially and economically profitable. The NPV of multistrata systems are relatively higher than the monoculture ones since the complex systems have other commodities to harvest rather than just coffee.

Similar to the previous agricultural product, revenue from rice culture is calculated based on its local price and productivity. Revenue analysis uses time-series of real prices with constant price of 1997. Comparing the time-series and land-use change maps, it was concluded that land demand in Sumberjaya is not well correlated with real price of rice, probably because the production of paddy in this area is self-consumed.

*Balai Pusat Statistik* (BPS) Lampung Province is the main source of data for describing the population growth. The population of Kecamatan Sumberjaya consists dominantly of migrants. As the growth rate in this last decade is almost zero, this model building block is excluded in the next step of the study.

The suitability factors of the model are based on *slope*, *soil*, and *present land-use*. The volcanic group of Sumberjaya land-unit that distributes all over the center area of the watershed has marginally to moderately suitable ranges for coffee plantation. The alluvial lands are suitable to rice culture and spread along the river on the bottom of valley. The main indicator for residential land-suitability is the current land-use and roads.

The transition capacity for a grid cell to change to certain land-use depends on the current state of land-use and is function of distance. Cells within the neighborhood are weighted differently depending on their current state and distance from the center cell. The closer a cell is, the stronger will be its effect,

either positive or negative. The effect may also change sign as the distance increases.

In this research, the effective neighborhood of a cell is considered a circle with a radius of 1 km. As the cellular automaton is based on a regular grid, there are 5 discrete distances in the distance of 200 meter or the expansion area of 4 ha within the neighborhood. The neighborhood consequently consists of 81 cells

The economic model building block calculates the amount of land demand required by certain land-uses to allocate their activities. It applies to economical and managed land uses, such as monoculture coffee, multistrata coffee and rice culture. The mathematical formulation accounts for profit-driven expansion and intensification. The internal parameter of land-demand is growth coefficient ($g_i$) as an expansion rate of the economic sector. The growth-rate is the function of land-use change and economical-profitability over time. To determine the growth coefficient, a simultaneous time-series of spatial and economical data is needed and in this first approach, a linear relationship was assumed.

Using the NPV profitability assessment of 1991-1999 (Budidarsono *et al*, 2000), growth coefficients for each coffee systems were calculated by averaging the profitability of the two most common systems. Those are simple and complex coffee system since the spatial map could only capture these two classes of coffee.

The growth coefficient of complex coffee system is higher than the one of simple coffee system. It can be easily understood since in the period of 1991-2000, the area of complex coffee expanded more (45%) than the area of simple coffee did (22%). The profitability of complex-multistrata coffee system is higher

since, on the same plot, the system also produces other commodities (fruits and timber). The growth coefficient of rice culture is relatively low. It is in accordance to the spatial data that the area of rice culture is relatively constant. Then, the growth-rate of each land-demand is determined.

In the case of an average coffee price Rp. 3,167, there is a gradual shift from monoculture coffee to multistrata coffee as the result of the higher profitability of multistrata coffee. Rice culture slightly declines due to the competition with more profitable coffee plantation. Residential area increases along the road. Using this average price could well indicate land-demand for each land-use, especially coffee in Sumberjaya sub-district.

A robustness analysis was conducted in order to determine the relevance and boundaries of different conditional rules. Therefore, the effects of two extreme coffee real-price conditions on land-use were explored. The two prices are Rp. 2,178/kg (nominal: Rp. 1,397/kg) in 1991 and Rp. 7,066 (nominal: Rp. 11,410/kg) in 1998.

The result shows that land demand for both monoculture and multistrata coffee is sensitive to varying coffee-prices. Monoculture coffee is more sensitive than the multistrata one since multistrata coffee includes other commodities. In case of very low coffee-price, the multistrata coffee is still profitable because of the side-commodities.

Lower price of coffee leads a slower increase of land-demand for coffee, especially the monoculture coffee. Rice culture increases, as growing rice for self-consumption is considered more profitable. Deforestation rate also decreases.

Higher prices of coffee trigger greater expansion of monoculture coffee, to the extent that multistrata coffee, at some point in time, starts decreasing. A significant deforestation occurs if there is no strict policy or regulation applied in this area.

To assess the spatial accuracy, two maps in raster format with 200-meter resolution are used: land-use 2000 map PC Raster as the modeled data and land-cover map ETM 2000 as the reference data. The total accuracy of the six land-use classes is less than 40%. The low accuracy of the modeled map was caused by the differences of classes and class contents of the initial and reference maps, low-accuracy of the reference map in classifying some land-use classes and underestimation/ overestimation of some land-use areas in the modeled map. There was also a major confusion between the two coffee classes. Both maps were reclassified into 5 classes to improve the total classification result. The reclassification increased the overall accuracy by 27 %.

The modeled data can describe the spatial distribution of the land-use of Sumberjaya quite well. Rice field land-use class is even more representative in the modeled map than in the reference map. However, some improvements, such as enhancing the spatial data accuracy and data qualities, re-calibrating the model-parameters are still needed to minimize misclassification among land-uses.

At this stage, the dynamic land-use change model helps to guide ongoing research and to point out what data are currently weak and needed in order to develop a negotiation-support model for watershed management. As the area might be representative of many other watersheds all over Sumatra, this research will probably be exemplary and can be put in to use on a wider scale.