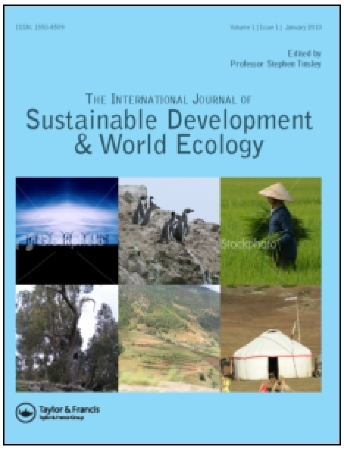

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A system dynamics model for evaluating collaborative forest management: a case study in Indonesia

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A system dynamics model for evaluating collaborative forest management: a case study in Indonesia

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This article presents a system dynamics (SD) method to examine the problem of forest degradation. The model developed takes a system-oriented view of forest management, embracing both social and biophysical factors affecting deforestation. Social factors examined are socio-economic variables or elements that influence behaviour and decision-making choices at the household level. Biophysical factors are four sub-components that are considered major land uses namely, the paddy field component, rattan plantations, coffee plantations and forest stands. The model was applied in a case study located in Pasir District of East Kalimantan, Indonesia. The site covers an area that includes a protected forest and a privately allocated timber license concession. Three village communities are examined in the case study. The SD model developed was applied to the case study focusing on three management policies or scenarios, which are based on access rights to the forest resources within the study area. Specifically, the property arrangements examined in each scenario are: Policy 1 – status quo (i.e. continue present property rights arrangements); Policy 2 – local communities manage the forest exclusively; and Policy 3 – collaborative management involving both local communities and a private company. Results from the model show that the third policy is the most viable option, and also lead to a win–win solution.

Keywords: system dynamics; forest degradation; access rights; property right; policy simulation

Introduction

Much has been said and written about the widespread problem of deforestation, particularly in tropical forests. There is also widespread agreement that deforestation generally refers to the clearance of forests for agriculture and other land uses. It is now also widely accepted that deforestation or forest degradation threatens both ecological sustainability of the forest and the socio-economic development of local and regional communities (Bass et al. 1997; Campbell and Sayer 2003). Forest degradation is a complex problem; seeking solutions to address it requires comprehensive understanding of the social and biophysical factors that operate at multiple geographic scales and also shape the human – forest dynamic interaction that ultimately affects deforestation and degradation. In Indonesia, deforestation and forest degradation are estimated at 2.8 million hectares of forest annually, which is one of the highest in the world. Many studies have been done and reported in the literature examining the causes of, and potential solutions for, forest deforestation and degradation (Kaimowitz et al. 1998). Most of these studies generally examined deforestation either as an ecological problem, and thus offer technical solutions, or as a social problem, and thereby propose socio-economic approaches to address it.

This article proposes an approach that embraces the complexity of the human–forest interaction. It takes a broad system-oriented view of the problem, recognising that there are a myriad factors or actors that impact the forest and its capability to provide the ecological services important to local communities. Beyond recognising these 'drivers' or 'impact factors', the article also offers a methodology that explicitly embraces these factors and examines their dynamic interactions by providing the analytical depth and breadth necessary for treatment and potential resolution of the problem. The methodology is generally referred to as 'system dynamics' (SD). It is adopted as a model to better understand the complex 'chain' of ecological and social factors, which are often 'nested' into a network of interacting elements.

The case study

The case study was conducted in areas of Gunung Lumut Protection Forest and Telaga Mas Forest Concession, located in the Pasir District of East Kalimantan (see Figure 1). This location has large areas of natural forests and also includes many local communities whose livelihoods depend on the resources found within the forest. Because of the presence of local communities and other stakeholders within the area, high levels of conflict characterise the site. The Lumut Mountain Forest, which was previously a part of the Telaga Mas concession, covers an area of approximately 35,350 ha. The Indonesian government, through a Forestry Ministerial Decree, designated Lumut Mountain Forest as a protected forest in 1993. Telaga Mas originally managed this area as a concession; hence, during the period between 1970 and 1993,

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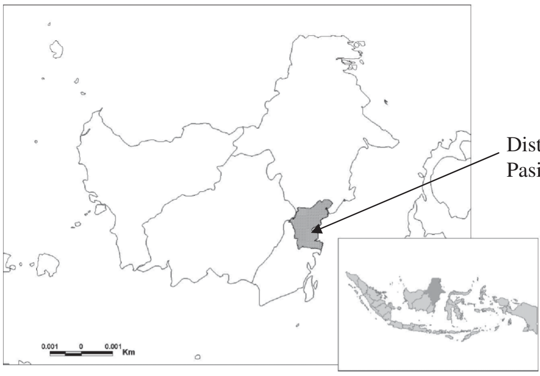


Figure 1. District of Pasir, East Kalimantan.

the company harvested timber from the area, and retained 130,000 ha as forest concession outside the protected area. The Indonesian government had allocated the area to Telaga Mas in 1970 with little input from, and little consideration about the concerns of the local communities. This area also functions as a water catchment area for conserving water and soil and for preserving biodiversity. The main tree species are *Artocarpus elasticus*, *Madhuca sericea* and *Shorea leprosula*.

This study was conducted in the villages of Rantau Buta and Rantau Layung. Both villages are situated between the Lumut Mountain Forest and Kasungai River. Figure 2 shows the approximate boundary and juxtapositions of the study area with respect to the two villages and the current Telaga Mas concession area. Rantau Layung has 52 families and covers 18,913 ha, while Rantau Buta has 20 families and covers an area of 16,546 ha. Most of the villagers are farmers. Livelihoods in both villages are mostly dependent on rattan, coffee and timber products. The villagers collect forest products such as eaglewood (*gaharu*), honey, latex and candlenuts. The farming system used for growing paddy is usually one of shifting cultivation. They plant paddy only twice in the same area in 1 year, and then move to a neighbouring area in order to open a new field for the next year, with permission from customary tribal leaders. After 5–8 years they return to their first paddy field. Each family has 1.5–2.0 ha of paddy fields each year.

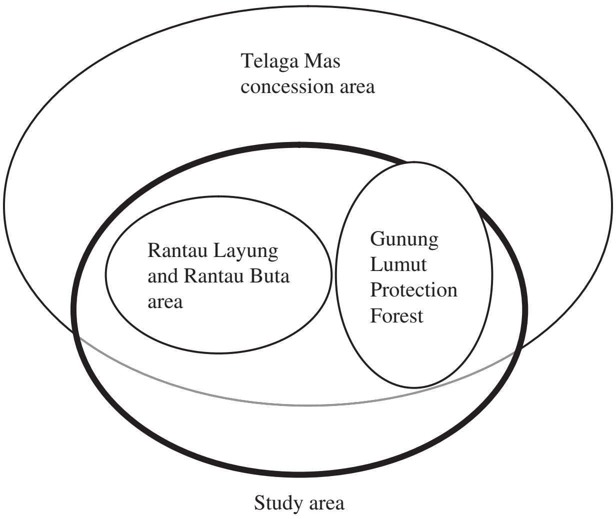


Figure 2. Boundary model of the study area.

Structure of the system dynamics model

SD is a general methodology developed particularly for studying the dynamic behaviour of a variety of complex systems (Sterman 2000). From its early conceptual development (Forrester 1961), SD has been used extensively to examine the dynamics of population, ecological and economic systems, which usually interact strongly with each other. Typically, influence diagrams or flow charts using nodes and directed arrows are used to denote the interrelationships between and among the system elements. Relationships are sometimes referred to as feedback loops or causality loops, which can be either positive or negative. This influence diagram serves as the ‘sense’ -making device for the purpose of identifying the dynamics and causality relationships. The diagram also helps provide a ‘graphic picture’ of the interactions among the system elements, and therefore serves as a window to begin to address the ‘chain’ of relationships among a network of system components.

The objective of the model is to examine policy options that can reduce forest degradation at the forest management unit level. To accomplish this, it is necessary to understand the dynamic interactions between the communities and the forest resources and how they affect forest cover, human well-being and forest resources under different policy scenarios. Hence, the focus of the ‘system’ under study lies at the intersection of forest, people and economic and policy environments. Figure 3 broadly illustrates the architecture of the model. At the top are policy scenarios that may consist of a set of policy options. At the bottom are performance indicators that can be measured or evaluated relative to a policy or a scenario. The middle component consists of the social and biophysical factors, which are at the ‘core’ of forest degradation. For the case study, the social sub-system includes the two local communities, the forest concessionaire and the local and central government sub-models. The biophysical sub-component includes sub-models of forest stands, rattan plants, coffee plants and paddy fields.

Figure 4 further unpacks the model in Figure 3 by showing, in more detail, the elements of the different sub-models. Figure 4 shows the conceptual model, using blocks and arrows to indicate the dynamic links of the sub-models. A block signifies a state component, while an arrow signifies an influence of a component on other components. The model and sub-models are briefly described in the preceding sections. For a complete description of the model and sub-models, readers are referred to Purnomo et al. (2002).

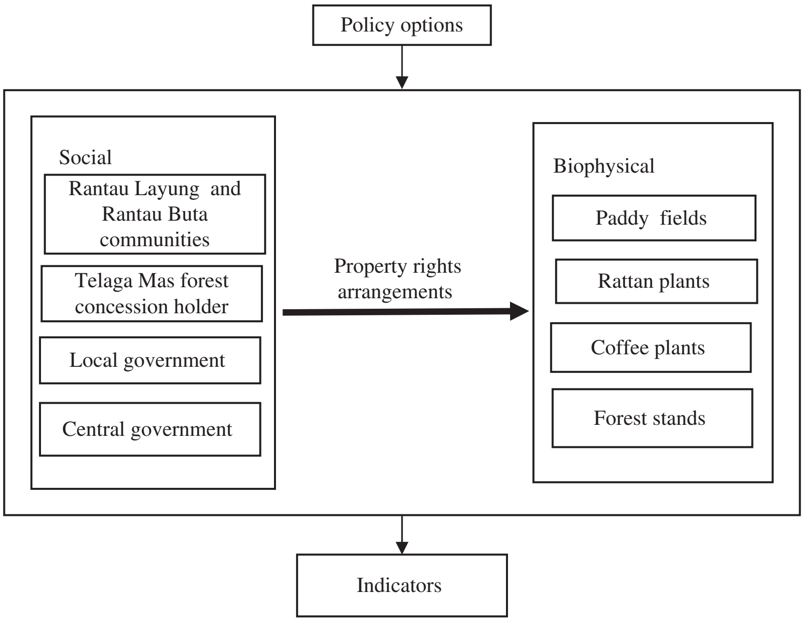


Figure 3. Architecture of the model.

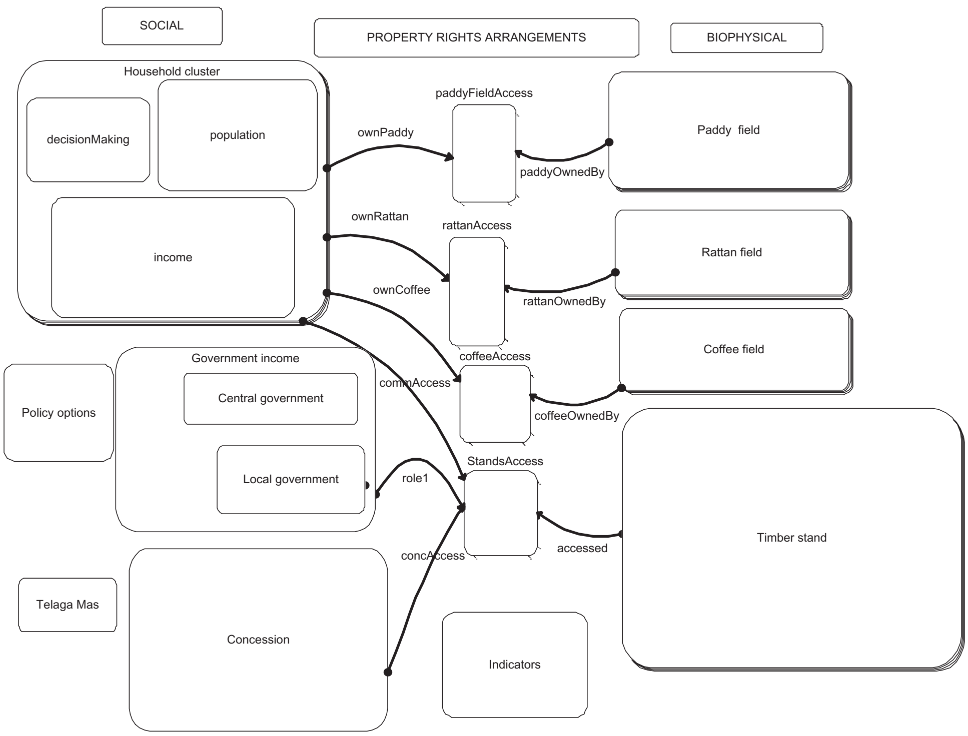


Figure 4. Conceptual model.

Biophysical-based sub-models

The biophysical sub-models primarily describe the growth of planted plants, dynamics of the forest stand, and the value of their products in nearby markets. The planted plants are: paddy fields, rattan and coffee. These plants produce an annual yield. These sub-models are described in the following sections.

Paddy field sub-model

Each household (HH) in the study area has approximately 1–2 ha of paddy field (Table 1); the maximum and minimum values show the range of values found in the field. HHs plant 20 kg of seed per hectare per year. For each kilogram of seed planted, 40–60 kg of un-hulled paddy is produced. Thus, each HH harvests between 800 kg and

Table 1. Household paddy field gross production and income.

Component	Minimum value	Maximum value
Area (ha)	1	2
Un-hulled paddy produced (kg/ha/year)	800	1200
Conversion from un-hulled to hulled paddy	0.7	0.7
Price (Rp/kg)	2500	2500
Gross income (Rp/year)	1 × 800 × 0.7 × 2500 = 1,428,571	1 × 1200 × 0.7 × 2500 = 4,285,714

Table 2. Household rattan gross income per year.

Component	Minimum value	Maximum value
Area (ha)	1	2
Number of clumps/ha	1500	1500
Harvested (stem/clump)	1	1
Trading unit (stem/bal)	300	300
Production (Bal/yr)	1500/300 = 5	1500/300 = 5
Price (Rp/yr)	50,000	60,000
Gross income (Rp/yr)	1 × 5 × 50,000 = 250,000	2 × 5 × 60,000 = 600,000

1200 kg of un-hulled paddy per hectare per year. One kilogram of un-hulled rice is equivalent to 5/7 of hulled paddy. The price of hulled paddy in the market is Rp[1] 2500 per kg. Figure 5 shows a system dynamics diagram of the paddy field sub-model. The notations used in Figure 5 and succeeding figures are typical and standard graphics used in system dynamics modelling. Readers can refer to Hannon and Matthias (2001) for details about graphical system dynamics models. Arrows going to or coming from the sub-model boundary (e.g. 'paddyfield' and 'rfID') indicate that they relate to components in other sub-models. This figure describes a stock of 'un-hulled paddy', which is symbolised with a rectangular node. Paddy 'seed' flows (symbolised with a valve) to the stock. This seed, after a certain time, will grow and mature, and become harvestable, symbolised with a valve of 'uhharvest'. The total hulled paddy yield is determined by the 'flow out' of harvestable un-hulled paddy, extent of the paddy field 'area' variable, and the ratio between hulled paddy and un-hulled paddy, which is 5/7.

Rattan field sub-model

Each HH has 1–2 ha of rattan area (Table 2). One hectare of rattan contains about 1500 clumps. For each clump, which consists of about 15 stems, HH harvests one stem per year on average. The trading unit is called a 'bal', which comprises 300 stems. The price of one 'bal' is Rp 50,000–60,000 in a nearby market.

Coffee small plantation sub-model

Each HH has about 0.5–1.0 ha of coffee area. HH harvests 60 kg per hectare per year. The coffee area is growing by about 5% per year. HH sells the coffee at a price of about Rp 3000 per kg in a nearby market; therefore, the gross income from coffee is between Rp 90,000 and Rp 180,000 per year.

Forest stand sub-model

The forest stand model uses a diameter projection method; one of the traditional forest growth models particularly suited for selectively logged forests in the tropics. The basic concept of the method is that the forest is represented in a stand table containing trees organised by diameter class. A change in the stand table is calculated over a growth period, usually between 5 and 10 years, using periodic increment data obtained from re-measured growth plots. On the basis of information generated from the permanent growth plots, upgrowth (i.e. number of trees moving up to higher diameter class), mortality and ingrowth (i.e. number of trees growing into the smallest diameter class) are calculated. Finally, forest growth can be projected. The projection method involves estimates of recruitment (R) representing ingrowth, outgrowth (O) or upgrowth and mortality (M). The projected number of trees

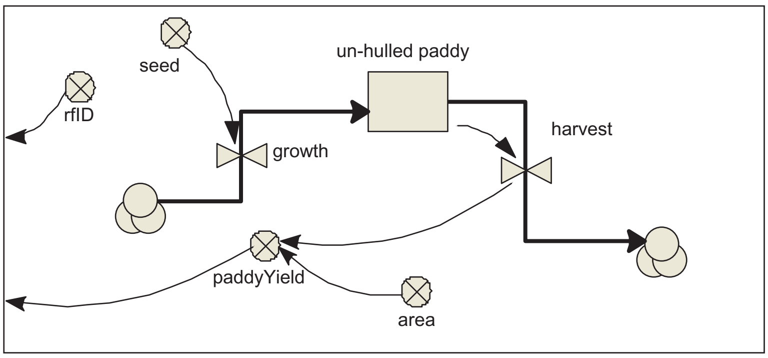


Figure 5. Paddy field growth sub-model.

at any diameter class 'j' and after a growth period '$t + 1$', ($N_{j,t+1}$), is defined as

$$N_{j,t+1} = N_{j,t} + R_j + O_j - M_j,$$

where $N_{j,t}$ is the initial number of trees in diameter class j at time t. These growth components were taken from Septiana (2000), who calculated them based on permanent sample plots located close to the area (Table 3). If we incorporate logging (L) and its damage (LD), the model is changed to

$$N_{j,t+1} = N_{j,t} + R_j + O_j - M_j - L_j - LD_j.$$

The total study area is approximately 70,350 ha and is dominated by mature logged over forests. The study area includes 35,350 ha of Lumut Mountain Forest and 35,000 ha of Telaga Mas forest concession. The area is now legally protected and cutting is no longer allowed. However, the local villagers do carry out some logging, known in the local language as *blambangan*, and illegal logging also occurs in the area. It is difficult to predict accurately the extent of this logging. The log price of *blambangan* is about Rp 300,000 per m^3, while the log price for legal logs is Rp 800,000 m^3. The villagers sell their logs to log collectors (*cukong*) in the sub-district of Batu Kajang, the closest sub-district where Rantau Layung and Rantau Buta are located.

Figure 6 shows the system dynamic representation of the stand class diameter projection. According to current logging rules, each concession implements a 35-year rotation, which means that after 35 years the concession will be able to re-cut the same area. Hence, 70,350 ha of the study area was divided into 70 compartments (standID 1–70); each compartment is 1000 ha. Half of each compartment is for production and the other half for conservation and light timber utilisation.

For each compartment or standID, there are five stocks of different diameter class (see Table 3). Diameter Class 1 has recruitment as 'flow in' valve and mortality and outgrowth as 'flow out' valves. Diameter Classes 3–5, in addition also have harvesting 'flow out'. Total standing stock (see variable 'standStock') is a combination of trees in all diameter classes. Annual log production is controlled by the variable 'harvSchedule', which determines the compartment to be logged. Logging is allowed in Diameter Classes 4 and 5, which are equal or above 50 cm. The variable 'annualLogProd' determines the indicator 'income' of

Table 3. Stand structure dynamics components (Septiana 2000).

Diameter class component	Diameter class 1: 20–29 cm	Diameter class 2: 30–39 cm	Diameter class 3: 40–49 cm	Diameter class 4: 50–59 cm	Diameter class 5: >60 cm
Number of trees in virgin forest per ha	20.745	8.195	5.693	4.088	13.245
Recruitment (number of trees)	1.6				
Outgrowth (%)	0.086	0.115	0.101	0.087	
Mortality (%)	0.020	0.010	0.020	0.015	0.020

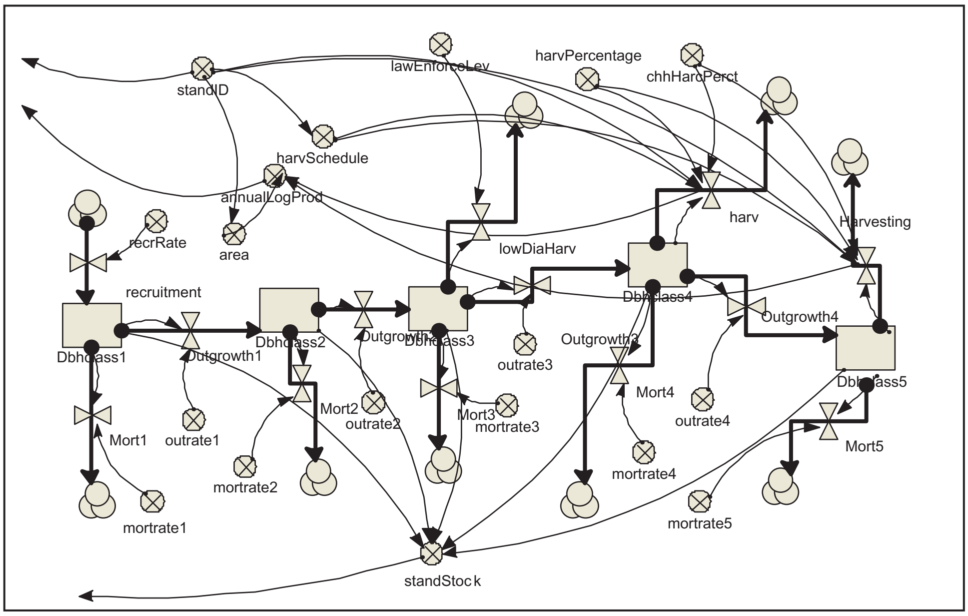


Figure 6. Forest stand dynamic sub-model.

the concession, while 'standStock' determines the indicator 'total standing stock' in the area under different policy options.

Social sub-models

Communities sub-model

Individual components of the communities sub-model are manifested as clusters of households (CHHs). CHHs were chosen instead of individual HH because of homogenous characteristics among HH inside a cluster, and because the behaviour of a CHH is more predictable than a household. There are two main categories of villagers, namely, on-farm and off-farm communities. The on-farm communities were organised into three clusters based on *a priori* cluster analysis (Achdiawan 2001). Table 4 shows the clustering of households. Clusters I and II include households with middle level incomes, which are between Rp 1 and 2 million per month. Cluster III has high incomes (more than Rp 2 million per month) and large areas of land (more than 10 ha). Cluster I households have smaller areas (less than 2 ha) of land but more productive assets, such as a small boat or chainsaw, compared to Cluster II. Cluster I households are dominated by farmers who depend on the land, while Cluster II households have more diverse sources of income. Table 5 shows the parameters within the clusters.

CHHs are the primary analytical construct for the three sub-models, namely population, income and decision-making (Figure 7). The CHH population model is a typical one. It consists of birth, death, immigration and emigration of CHH. The second sub-model is CHH income. This reflects how each CHH obtains income from their activities, such as rice fields, rattan, coffee and timber. Biophysical models determine the volume of each. Each CHH is linked to the biophysical models through property rights arrangements or access rights. These rights indicate CHH access to rice fields, rattan, coffee and timber. The prices of the last category are treated as driving variables. Variables influence the system, but are not influenced by the system.

The third sub-sub-model is the CHH job decision-making model. This model shows how decisions concerning the job of cluster CHH IV are made. Decisions are made based on the comparison of CHH IV goals and incomes. If the income from 'onFarm' activities is higher than its current off-farm income, they will decide to be part of clusters CHH I–III, otherwise they will stay at cluster CHH IV. Entering on-farm clusters (CHH I–III) would decrease the per capita income of the whole on-farm population.

Forest concession company sub-model

The revenue of Telaga Mas comes from the timber logged and sold. The net revenue of every m^3 (volume) is equal to Rp 300,000, after production cost and taxes, Rp 500,000,

Table 4. Clustering of on-farm community households.

			Asset			
Cluster	Land	Income	Transportation (motor boat, motorcycle, bicycle, truck, etc.)	Production (chainsaw, small sawmill, saw, axe, mattock, etc.)	Entertainment (TV, radio, VCD/DVD player, etc.)	Number of household members
I	Small (less than 2 ha)	Middle (Rp 1–2 million per month)	Middle	High	High	Many (more than 10 households)
II	Middle (2–10 ha)	Middle (Rp 1–2 million per month)	Few	Low	Few	Few (less than 10 households)
III	Big (>10 ha)	High (Rp >2 million per month)	Many	High	Few	Many (more than 10 households)

Table 5. CHH characteristics and livelihood options.

	On-farm			
Cluster characteristics	Cluster I (CHH I)	Cluster II (CHH II)	Cluster III (CHH III)	Off-farm (CHH IV)
Current number of HH	2	15	33	2
Rate of new HH	0.11	0.11	0.11	0.11
Rate of losing HH	0.05	0.05	0.05	0.05
Livelihood options	Rice field, timber, rattan, coffee	Rice field, timber, rattan, coffee	Rice field, rattan, coffee	Off-farm

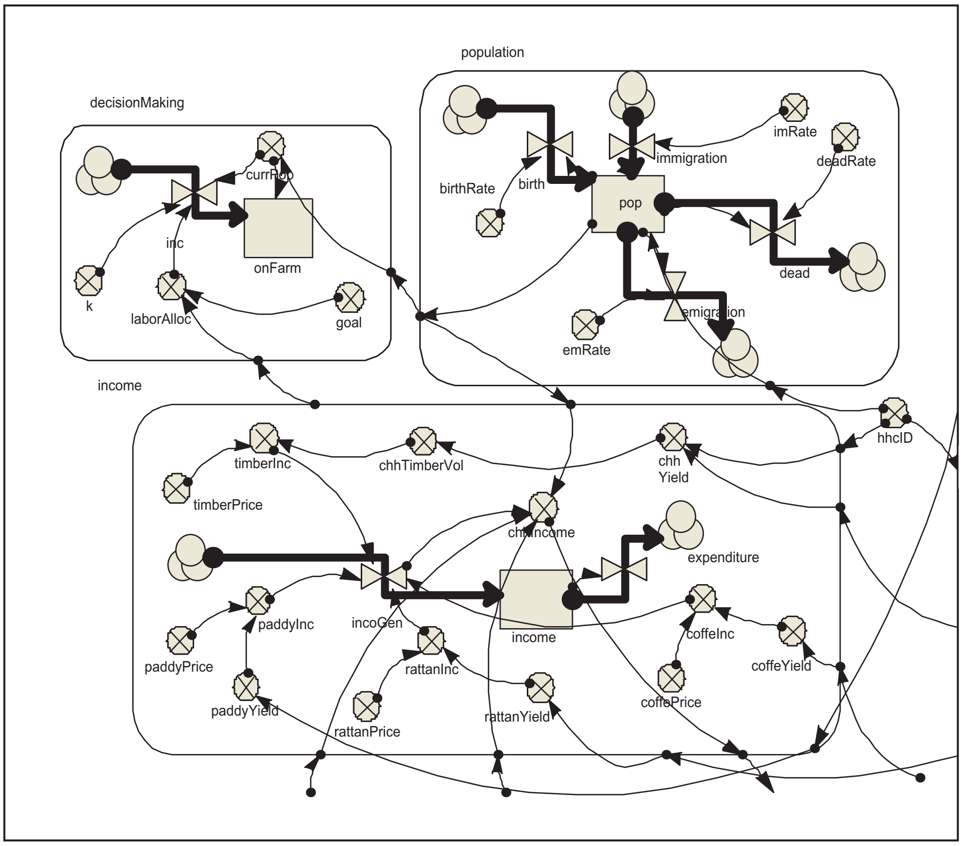


Figure 7. Communities sub-model.

are deducted from the log price of Rp 800,000. The net revenue is formulated as: annual cutting area (ha) × standing stock (m^3/ha) × exploitation factor (0.7) × Rp 300,000. The exploitation factor is the conversion of standing stock into logs through logging. The number that is usually used in Indonesia is 0.7.

Central and local government sub-models

The governments' revenue comes from taxes paid, in this case by Telaga Mas. Table 6 shows the amount of taxes paid by a forest concession holder. The central government creates rules and laws as well as monitoring the uses of the forest. Government spending was difficult to quantify, and therefore not included in the analysis.

Right sub-models

'Property Right Arrangement' as shown in Figure 4 conceptually represents differences in access. There are four types of access to natural resources, namely 'paddyFieldAccess', 'rattanAccess', 'coffeeAccess' and forest 'standAccess'. Social actors (on the left) manage or utilise biophysical components (on the right) through a certain type of rights arrangement. They may have full control, in the case of villagers with paddy fields, or

Table 6. Amount of taxes to be paid by a forest concession holder.

Type	Unit	Amount (Rp)/unit	% received by local governments (province and district)	% received by central government
Reforestation fund	Per m^3 log, annual	48,000	80	20
Resources royalty provision	Per m^3 log, annual	6%	80	20
Concession royalty	Per ha, every 20 years	30,000	80	20
Land tax	Annual	1% of net revenue	100	0

Table 7. Forest access rights.

Forest resources	Area types	Accessed by	Logging activity
Stand ID 1[a]	LOA (Logged-over area)	On-farm household clusters of communities	Yes
Stand ID 2	LA	On-farm household clusters of communities	Yes
Stand ID 3. . .35	LOA	PT. Telaga Mas	Yes
Stand ID 36. . .70	Protected area	Local government	No
Non-timber forest products	Production forests	On-farm household clusters of communities	–

Note: [a]Each stand ID comprises approximately 1000 ha of forest.

share access with other actors in the case of timber access.

The villagers in the study have exclusive access to paddy fields, rattan and coffee fields. Forest resources around the two villages are legally managed by the government for the protected area, and by Telaga Mas for the concession area. As mentioned above, the total area of 703,500 ha of forest is divided into 70 blocks of 1000 ha, and coded into stands ID 1–70 (Table 7). Although the two communities have legal rights to use non-timber forest products (NTFP), this does not extend to timber.

According to government regulations, trees can be harvested if their diameter is larger than 50 cm; however, not all trees can be harvested. Some trees are protected by existing rules and regulations. The number of un-harvested trees amount to about 30%, so that harvestable trees are approximately 70% for each rotation period of 1000 ha. This right to harvest was given to Telaga Mas through the timber concession agreement.

Communities have no legal right to harvest timber from the forest; however, in the field it was observed that community logging or *blambangan* in the local term does occur. Villagers harvest a small amount of timber for subsistence purposes. *Blambangan* is estimated to be approximately 1.0–1.5% per year. There is no rotation period for *blambangan*. If Telaga Mas carries out mechanised harvesting the exploitation factor is estimated at 0.7. Un-mechanised community logging has a greater cutting factor, estimated to be approximately equal to 0.9. Both exploitation and cutting factors explain the proportion of timber obtained from the standing stock or stumpage value. Higher exploitation factors equate to more efficient logging.

Model evaluation

Several researchers (e.g. Vanclay 1994; Grant et al. 1997; Vanclay and Skovsgaard 1997) have advocated the terminology ‘model evaluation’ instead of ‘model validation’. This emphasises relative utility: a model that is useful for one purpose might be misleading for other purposes. To evaluate a model, Grant et al. (1997) proposed three criteria, namely reasonableness, comparison of the model’s behaviour and the expected pattern, and comparison of the model’s prediction and the ‘real’ system. The model was evaluated primarily based on the first two criteria, viewed from the perspectives of Pasir district policymakers, namely Pasir Forest District Unit, Pasir Regional Planning Agency, Pasir Environmental Agency and Pasir Land use Agency. A comparison of the model with the real system was not accomplished systematically due to the inherent complexity of the forest system addressed. It is difficult, if not impossible, to generate ‘real’ data that match the configuration of the scenarios and policy options examined in the study. Moreover, the primary purpose of the model was to examine policy options aimed at reducing forest degradation as well as increase the well-being of its stakeholders, particularly the local communities. Prediction was not the goal of the model; rather, it was intended to serve as a tool to examine forest degradation and community well-being, in general, and to understand the impacts of different policy options, in particular.

Assessment on the ‘reasonableness’ of the model was based on systematic scrutiny of all the relationships within the model, from the simplest sub-model (forest stand increment), to the more complex sub-models (e.g. the interrelationship between stand increment and communal logging). Evaluating the model based on this criterion led to the conclusion that the model complied sufficiently with the basic principles of ecology, and was consistent with socio-economic theory. Hence, the model constitutes an adequate tool to initiate discussions about alternative courses of action. The model evaluation process was conducted through a participatory process involving policymakers who made their judgements about the model after examining the model and sub-models presented graphically, and through a number of simulation runs involving different scenarios. The output shows that the model and sub-model results are reasonable and match the expected pattern. The policymakers thought that the model was useful for developing their understanding of the complexity of forest management and scenarios to decrease forest degradation in Pasir.

The policymakers who examined the model from an application point of view found it quite useful. They also confirmed the value of the model in developing and assessing scenarios or policy options, particularly policy options that can impact the sustainability of the forest. Following Fahey and Randall (1998), the scenarios are not intended to 'prove' that what is projected will take place; rather, the scenarios need to be plausible, possible, credible and relevant. To be possible and credible they must pass the logic test. The logic test was similar to the first criterion of the evaluation (reasonableness), which the model passed based on judgement of the policymakers involved in the study.

Results and discussion

One of the primary goals in formulating the model is to examine 'access rights' or institutional arrangements that involve access to the resources available in the study area. Hence, three policy options were examined in the study. The proposed policy options represent different collaborative management strategies reflected in terms of access arrangements among the stakeholders. Five indicators are used to measure impacts of the options, namely income of local community, condition and productivity of forest stand, revenue of timber company and local government income.

Policy option 1: status quo – continue with current access rights arrangement

This option represents current access rights arrangement where local communities have no legal access to commercial timber. The output indicators after a 50-year simulation under this policy are shown in Figure 8. The figures show the long-term impacts of this option with respect to the five indicators (Figure 8a–e). The household income is about Rp 20 million on average per year, and continues to decrease, in part because the standing stock of the forest area accessible to the community is also decreasing. The simulated results also show sharp income variations in the short term, that is first 10 years. The standing stock shows a consistent decreasing trend from 7 million m^3 to 3 million m^3. The concession revenue is fluctuating, with an average income amounting to Rp 10 billion in the first 33 years and decreasing thereafter. The concession generally spends significant capital in the first year for different activities, such as forest inventory and planning, road building, heavy equipment, buildings, etc. This accounts for the sharp decline in revenue shown in Figure 8c. Moreover, the concession revenue is also highly variable and on a decreasing trend within the first 30 years. In general, the government incomes, both local and central, follow the same pattern as the concession revenue. The local and central governments also obtain concession royalties every 20 years because, according to regulations, every concession must renew their permit every 20 years.

Policy option 2: local communities manage the forest exclusively

Under this policy option, the government re-allocates a part of the logged over area (LOA) amounting to 35,000 ha, previously allocated to Telaga Mas, to the local communities. Telaga Mas will still manage the other part of the concession area. All taxes previously paid by Telaga Mas related to the concession area are now the responsibility of the local communities. Under this option, if the communities apply forest management currently practiced by Telaga Mas, then the output indicators are similar to those shown in Figure 9. The local communities receive all revenues, and Telaga Mas, in this case, receives none. The indicators of standing stock and government income remain the same as in Policy 1.

Policy option 3: collaboration between the local communities and Telaga Mas

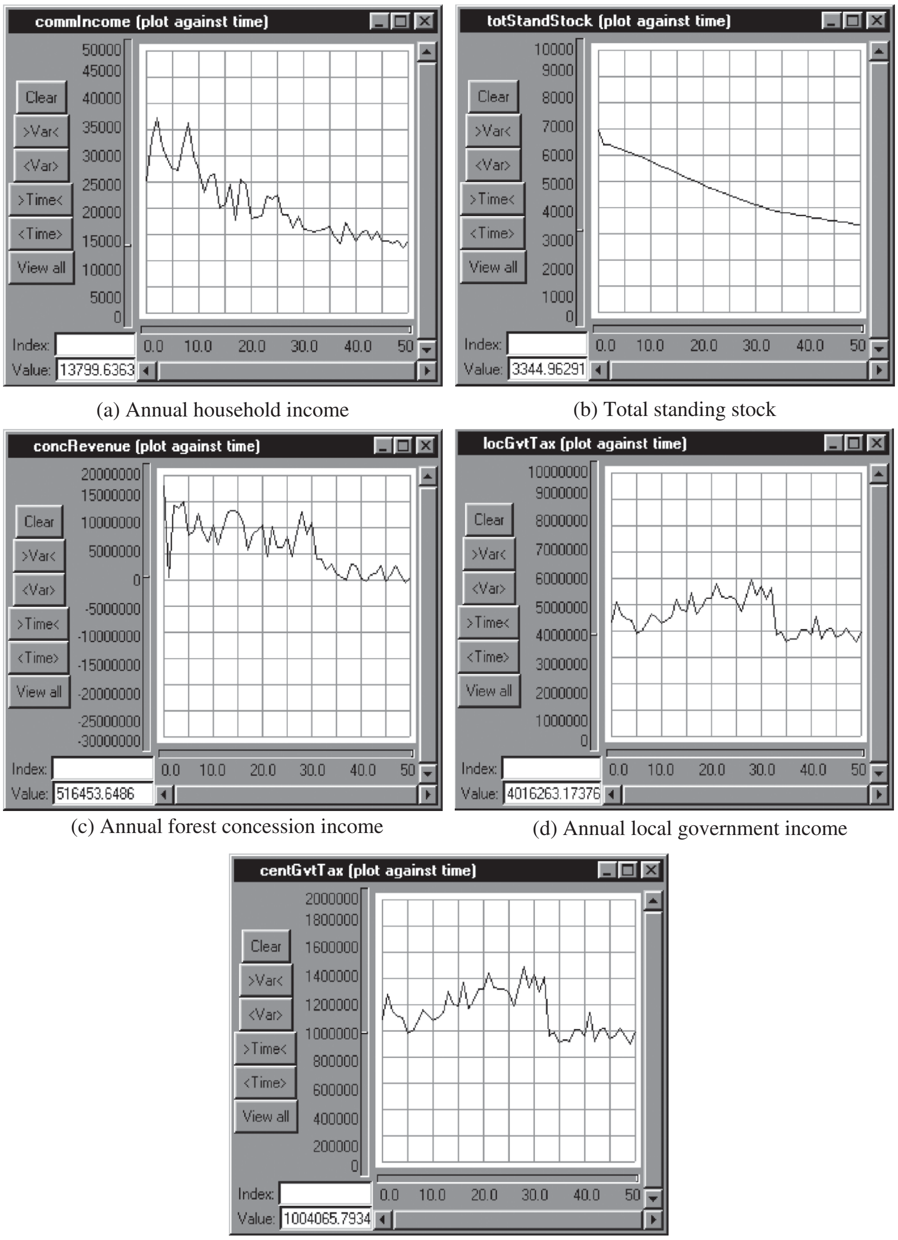
This option involves some form of co-management between the local communities and the private timber company. The option involves an area, which is approximately 35,000 ha, being managed collaboratively between the local communities and Telaga Mas. Access rights and responsibilities of each party are specified as follows:

- Local communities may utilise the area using their traditional methods, but they must also conserve the forest;
- Payment of all taxes will be shared equally between the local communities and Telaga Mas;
- Telaga Mas will receive a compensation fee of 50% of the timber logged by local communities.

Under this policy option, the local communities cut timber every year in all areas. The results show that they harvest only 1.0–1.5% of the total harvested area in any given year to secure adequate income. The standing stock (Figure 10b) is better compared to the other policy options (see Figure 8b). This standing stock is expected to increase if the areas allocated for local communities to log also increases. The first year shows significant community income and concession revenue. Concession royalties paid every 20 years by the local communities and concessionaire are reflected in the local and central government accounts.

Comparison of policy options

A comparison of each policy option is shown in Table 8. The first two policy options do not offer better alternatives in any aspect of managing the forest (except in terms of government income). However, if the objectives are to improve community income and reduce forest degradation, the last two options appear to be better. As can be seen from the results, the simulation analysis shows the potential impacts from, and implications of, each forest



(a) Annual household income

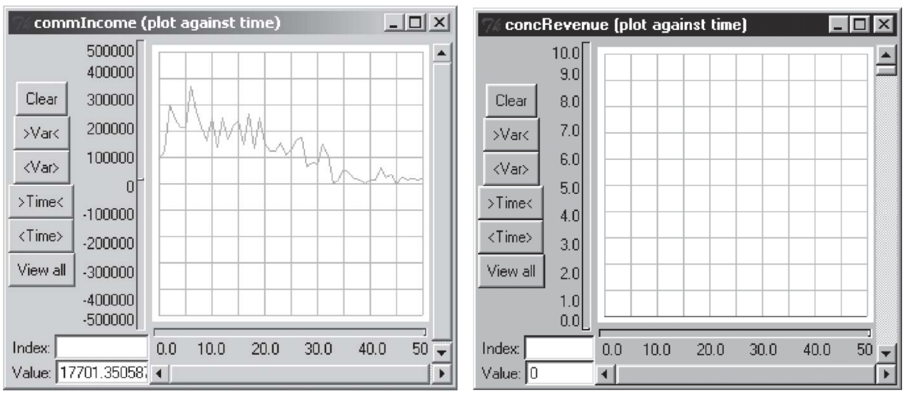
(b) Total standing stock

(c) Annual forest concession income

(d) Annual local government income

(e) Annual central government income

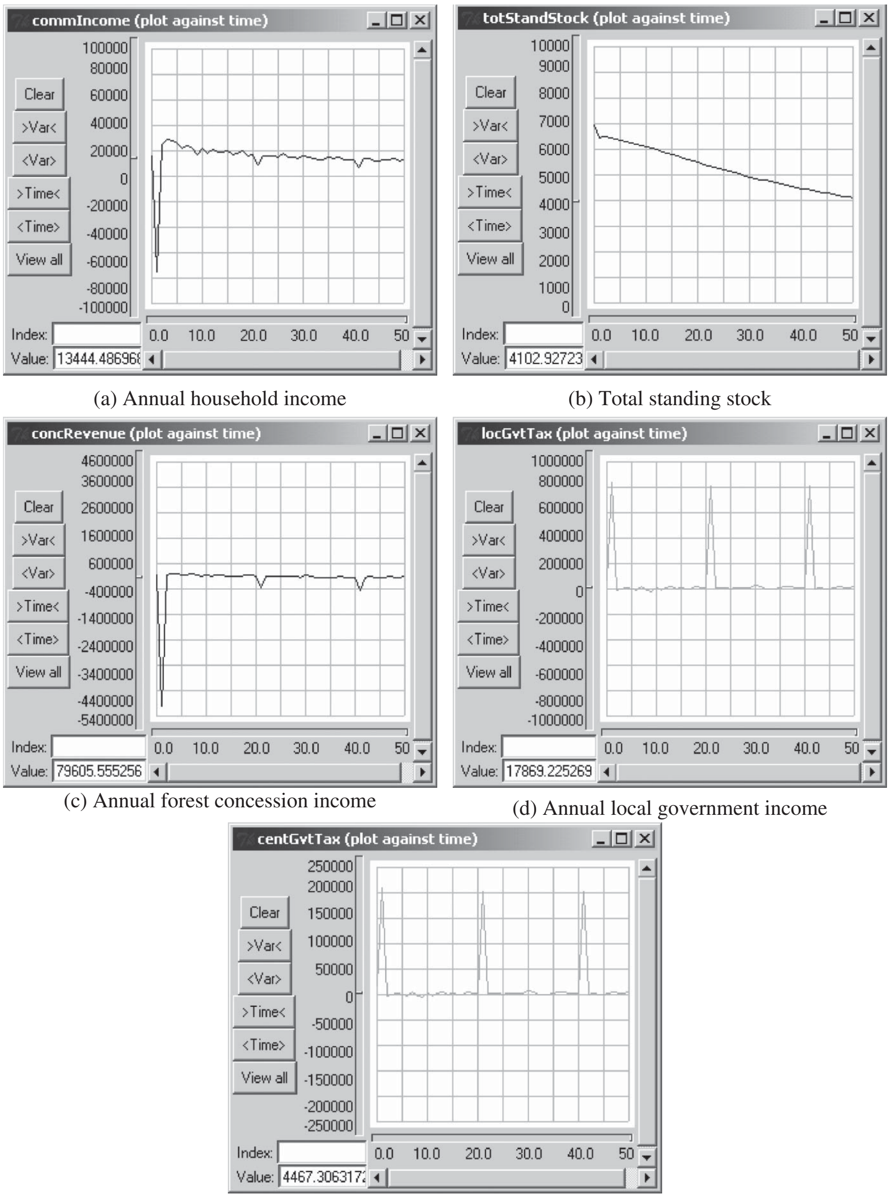
Figure 8. Outputs under policy option 1.



(a) Community income

(b) Concession/private company income

Figure 9. Annual household income and concession revenue outputs under policy option 2 in thousand Rupiah.



(a) Annual household income

(b) Total standing stock

(c) Annual forest concession income

(d) Annual local government income

(e) Annual central government income

Figure 10. Outputs under policy option 3; (a, c–e) in thousand Rupiah, (b) in thousand m^3.

Table 8. Comparison of policy options 2 and 3 to the current policy (policy option 1).

Policy	Community income	Standing stock	Government income: Local	Government income: Central	Concession revenue
Policy option 2	Higher	Same	Same	Same	Lower
Policy option 3	Higher	Higher	Lower	Lower	Lower than policy option 1, but more than policy option 2

management arrangement on forest degradation. This is particularly significant in Indonesia, which is facing public pressures to reduce the rate of forest degradation as well as improve well-being of the local communities living in its forests.

During the presentation and discussion of result with the stakeholders, the concession company representatives could accept the last policy option, collaboration between community and concession holder. The concession company could accommodate the decrease of revenue in exchange for security of its logging operation. Understandably, they disagreed with the second policy option, because they stand to totally lose all their revenues. They argued that the company cannot lose the revenue they need for investment, employment and other people who involved in the business. On the other hand, the local community did not ask much, as long as their livelihood is secured. In fact, this was accomplished by giving only a part of the forest concession to be managed by the communities.

The system dynamics model and framework adopted in the study were able to model the stakeholders' understanding of the forest management system and its impact. The model seemed to offer a convenient forum for stakeholders to present, discuss and debate their concerns, opinions and preferred options. It was observed that the system dynamics model provided a 'graphical' picture of the management problem depicting the decision environment that the stakeholders were facing. The model served as an objective 'platform for negotiation', where management options were examined in depth and stakeholders were able to debate positive and negative impacts of their options. The model developed was not aimed at generating accurate results for policy options; instead, it was primarily designed as a tool that policymakers can use to examine the impacts of different policy options in the future. Feedback received from policymakers at the district level seemed to indicate that they were able to understand the model; an important consideration when using a model as a learning tool (Lane 1994; Morecroft and Sterman 1994). Consequently, the model could enhance the capability of policymakers to craft policy options, and make appropriate decision(s) that can help reduce forest degradation and improve community well-being.

The trade-off between model complexity and the learning process of the stakeholders was noticeable during model construction and implementation, and during examination of different policy options. The model needs to be simple and 'comprehensible', especially by the local communities. During the modelling process, a local facilitator helped in simplification of the model. The role identity and stature of the local facilitator was deemed important by the local communities. It was significant that the facilitator came from one of the villages. Without a trusted facilitator, the case study and the modelling exercise may be clouded with suspicion. It was noted that while the facilitator was not familiar with system dynamics modelling, the graphic model was quite intuitive to him. Consequently, he was able to comprehend the 'system' and articulate many of the factors that influence their livelihood as well as how these factors are related to each other.

A large percentage of Indonesian production forests have been legally allocated to logging companies. This situation constraints policymakers from trying to make new arrangements for forest management. Policymakers need to consider existing arrangements in order to bring about progressive changes. This study confirms that collaboration between forest logging companies and local communities are highly desirable. However, the arrangement of this collaboration, including rights, responsibilities, returns and relations, should be as far as possible not only for the present stakeholders but also for future stakeholders (Colfer et al. 1999; Castro and Nielsen 2001). An inappropriate/unbalanced collaborative arrangement may result in one stakeholder being better off while others are worse off. This kind of scenario cannot be implemented in the field without great difficulty.

Conclusion

A system dynamics model can facilitate the construction and examination of policy options for managing forests. In the real world, forest degradation and its attendant social problems are complex. Providing policymakers with a model that can deal with complex problems and still remain comprehensible and within the grasp of local communities is a challenge. This article describes the use of a system dynamics model for exploring policy options, particularly those involving co-management of natural resources with multiple stakeholders. In the study, co-management of forest areas involving local villages and a timber company was explored. The joint problems of reducing forest degradation and improving communities' well-being on the one hand, and concession revenue and government incomes on the other, is obvious. The problems have the potential to create adversarial positions among stakeholders, which can easily lead to conflict. This study has shown how a simulation model can be a useful tool in evaluating collaborative forest management scenarios. As observed in the study, collaboration can be induced and enhanced if options are objectively examined, and the stakeholders are able to explicitly evaluate the impacts of the different options through simulation. Experience gained from the study shows that true collaboration in developing a management scenario that is acceptable to all stakeholders is quite challenging (Lalonde 1993; Ostrom et al. 1993) but doable if properly and objectively executed with active participation from all stakeholders.

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Note

1. Rp stands for Rupiah, the Indonesian currency, US$1 = Rp 9000 (2004 value).

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