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ANALYSIS

Economic valuation of the Leuser National Park on Sumatra, Indonesia

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Abstract

The Leuser Ecosystem in Northern Sumatra is officially protected by its status as an Indonesian national park. Nevertheless, it remains under severe threat of deforestation. Rainforest destruction has already caused a decline in ecological functions and services. Besides, it is affecting numerous economic activities in and around the Leuser National Park. The objectives of this study are twofold: firstly, to determine the total economic value (TEV) of the Leuser Ecosystem through a systems dynamic model. And secondly, to evaluate the economic consequences of deforestation versus conservation, disaggregating the economic value for the main stakeholders and regions involved. Using a dynamic simulation model, economic valuation is applied to evaluate the TEV of the Leuser National Park over the period 2000–2030. Three scenarios are considered: 'conservation', 'deforestation' and, 'selective use'. The results are presented in terms of (1) the type of benefits, (2) the allocation of these benefits among stakeholders, and (3) the regional distribution of benefits. The economic benefits considered include: water supply, fisheries, flood and drought prevention, agriculture and plantations, hydro-electricity, tourism, biodiversity, carbon sequestration, fire prevention, non-timber forest products, and timber. The stakeholders include: local community members, the local government, the logging and plantation industry, the national government, and the international community. The regions considered cover the 11 districts involved in the management of the Leuser Ecosystem. With a 4% discount rate, the accumulated TEV for the ecosystem over the 30-year period is: US \$7.0 billion under the 'deforestation scenario', US \$9.5 billion under the 'conservation scenario' and US \$9.1 billion under the 'selective utilisation scenario'. The main contributors in the conservation and selective use scenarios are water supply, flood prevention, tourism and agriculture. Timber revenues play an important role in the deforestation scenario. Compared to deforestation, conservation of the Leuser Ecosystem benefits all categories of stakeholders, except for the elite logging and plantation industry.

Keywords: Natural resource valuation; Conservation; Deforestation; Indonesia

1. Introduction

The Leuser Ecosystem in Northern Sumatra (Indonesia) covers 25,000 km^2 and consists of a

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Fig. 1. The boundaries of the pilot analysis.

national park and a buffer zone (Fig. 1). Deforestation in this ecosystem is widespread, despite its formally protected status (van Schaik et al., 2001). This is believed to have severe ecological consequences, such as the probable local extinction of the Sumatran orangutan, rhinoceros, tiger and elephant. In addition, the local economy could become structurally damaged as crucial ecological functions of the rainforest decline. Consequent damage caused by floods, erosion and loss of water supply can greatly exceed the revenues derived from timber extraction and land conversion.

The objectives of this study are to determine the total economic value (TEV) of the Leuser Ecosystem and evaluate the consequences of deforestation. A dynamic simulation model is applied to evaluate the TEV of the Park over the period 2000–2030. The originality of this study lies in the dynamic link exposed between ecological functions and their related economic values. In addition this study provides a breakdown of impacts on different stakeholder groups and geographic units.[1]

To determine both the complex systems dynamics of tropical rainforests and the stakeholder elements, the authors have closely collaborated with social and ecological experts working in

[1] Pet-Soede et al. (1999) presents one of the few economic valuation studies per stakeholder for blast fishing in Indonesia based on a much simpler systems model. Bockstael et al. (1995) present an economic valuation of ecosystems using a sophisticated systems dynamics but they did not consider stakeholder aspects.

Sumatra. The scenarios have been determined through consultations with local policy makers involved in the management of the national park. These include: (1) the 'conservation' scenario, implying that protection of the rainforest is strictly enforced and that logging will be excluded as an economic activity; (2) the 'deforestation' scenario, implying a continuation of the current trend of clear-cutting; and (3) the 'selective use' scenario, in which logging of primary forest is substantially reduced and replanting of logged forest is assumed to be compulsory. The results are presented in terms of the types of benefits, the allocation of these benefits among stakeholders, and the regional distribution of these benefits.

The paper is structured as follows: Section 2 elaborates on the general background of the Leuser Ecosystem, including its main threats and the foreseen scenarios. Section 3 provides a background of the applied methodology. Section 4 addresses the benefits outlined in the analysis. The results of the valuation process are presented in Section 5. Finally, conclusions are drawn in Section 6.

2. The Leuser Ecosystem

2.1. Threats

Despite its protected status, the Leuser Ecosystem is under enormous pressure. Its lowland forests are being rapidly logged and non-timber forest products (NTFP) are being overexploited. Furthermore continued illegal poaching will cause animal species to verge on extinction. An additional threat is the tourist industry which is being developed in an unsustainable manner. At present, 20% of the Leuser National Park has already been degraded (GIS Unit, LDP 2000). Most of this deforestation is taking place through legal or semi-legal conversion of former logging concessions into plantation estate crops (mainly oil palm and rubber). In addition the army is allegedly involved in largescale clear-cutting just inside the park boundaries. The remaining conversions are transmigration areas (often including a plantation component), other forestry plantations, infrastructure areas (roads and bridges), and regions of spontaneous settlement with associated small-scale agriculture. Both local governments and business interests view this development as the first step towards 'developing' the region.

2.2. Scenarios

Three macro-economic scenarios have been selected for further investigation:

2.2.1. Deforestation

In the 'deforestation' scenario, the current trend of controlled and uncontrolled logging and unsustainable harvesting of NTFP is assumed to continue. Eco-tourism will not be developed and international interests to invest in conservation and carbon sequestration funds declines. Furthermore natural functions of the rainforest decline which impacts local community use of these functions. If the current lack of enforcement remains, this development is quite likely to occur.

2.2.2. Conservation

The logging of primary and secondary forest entirely ceases in the 'conservation' scenario. No timber revenues and only a limited amount of NTFP accrue. Eco-tourism is developed to its maximum allowable potential and international interests to invest in conservation funds remain high. Carbon sequestration funds increase and natural functions of the rainforest are maintained for community use.

2.2.3. Selective use

In the 'selective use' scenario, logging of primary forest is substantially reduced and replanting of logged forest is assumed to be compulsory. Although the area of primary forest will decline, the overall forest area remains constant due to the increase of secondary forest. In addition, the harvesting of NTFP is actively developed. Despite efforts to develop eco-tourism, the tourist sector will not reach levels found in the conservation scenario, due to lower levels of biodiversity. Likewise, there is less international interest to invest in conservation and carbon sequestration. The natural functions of the rainforest (such as water supply and flood prevention) are only partially maintained.

2.3. Changes of ecological functions

As shown in the first column of Fig. 4, deforestation changes several ecological functions. The assumptions underlying these changes are described below. Because the study focused predominantly on the economic dimensions of deforestation, the ecological relationships have been somewhat simplified.

2.3.1. Reduction of forest area

In the deforestation scenario increased logging, especially during the first decade, is assumed. After 2010, the logging intensity declines because only the less financially-attractive highland forests remain. This non-linear process is depicted in Fig. 2. Due to the steep slopes of the highlands, only areas of low lands are converted into plantations. This causes an increase in so-called 'waste lands', mainly consisting of grasslands (i.e., alang alang). In the conservation scenario, the allocation of different forms of land use remains the same. In the 'selective use' scenario the area of primary forest will decline. This decline is compensated for by an increase in secondary forest. Because replanting is not successful in every soil type, ultimately wastelands will develop.

2.3.2. Increased erosion

Population pressure and inappropriate agricultural techniques cause local communities to encroach on the park. Given the mountainous landscape, people often farm steep slopes where soil depths are only between 50 and 100 cm. The removal or alteration of the forest vegetation has immediate repercussions. Studies have shown that the removal of the forest floor litter layers alone may cause a 20-fold increase in soil erosion (Edwards, 1994). In the Leuser Ecosystem, annual losses of up to 1,350 tonnes ha^{-1} of maize cultivation area have been measured. Within a few years, these lands will be unfit for any agricultural, forestry or tourist activity (BZD, 2000a). In this study, increased erosion has been incorporated indirectly as a degrading impact on

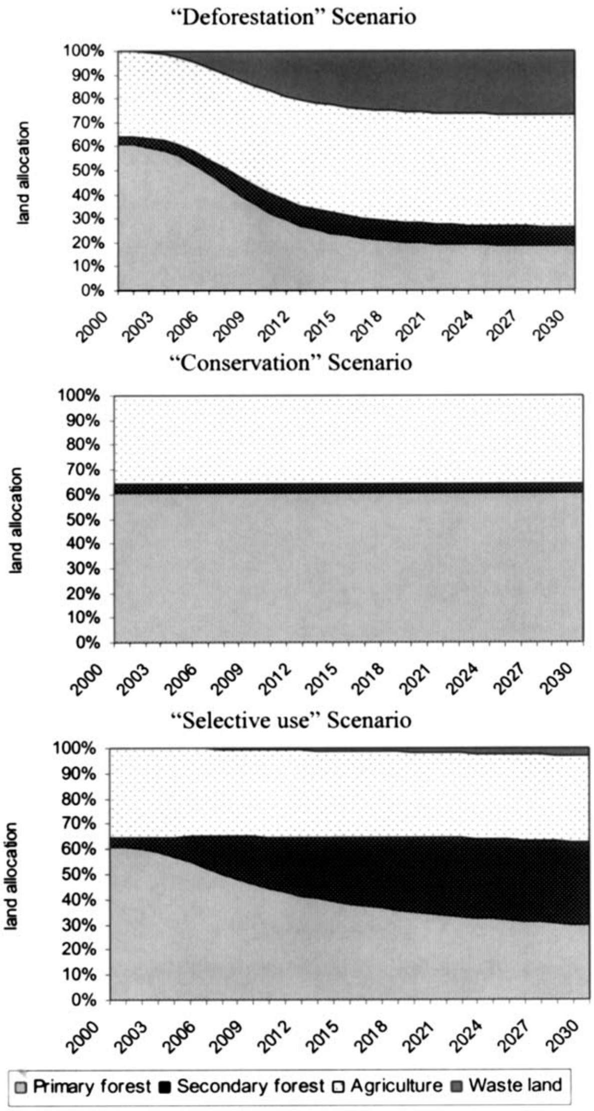

Fig. 2. Projected land allocation for each scenario (period 2000–2030).

agriculture. This influence varies for the type of crop and region considered.

2.3.3. Water retention

Deforestation reduces the water retention function of rainforests thereby increasing the frequency and intensity of floods and droughts. Moreover, due to the change in the micro-climatic conditions, less water is generated in perpetuity. These effects are clearly recorded: compared to 10 years ago, approximately 50% of the streams in Aceh have less than 50% of the typical water flow in the springtime. Furthermore 20% of the flows are completely dry throughout the year. For North Sumatra the situation is comparable: on average 80% of the rivers contain less than 50% of the usual water flow. Roughly 15% of the rivers have fallen completely dry (BZD, 2000b).

Fig. 3 shows how, due to reduced water availability, local communities' consumption of surface and groundwater provided by the Leuser Ecosystem declines in the deforestation scenario. If the rainforest is conserved, the availability of water is assumed to be sufficient to meet the demands of the local communities.

2.3.4. Reduced pollination and pest control

Rainforest flora and fauna provide indirect benefits by creating and maintaining the forest environment. In many ways they sustain the ecological services (e.g., pollination, decomposition, seed dispersal, seed predation, herbivory and predation) on which human livelihoods depend. They influence the reproductive success of plants, contribute to soil fertility and serve as regulators of pest populations (Redford, 1996). A typical example of this function in Leuser is the role of fruit bats. At least 443 products useful to man are derived from 163 plant species that rely to some degree on bats for pollination and seed dispersal. The destruction of the habitat of the fruit bat would, for example, lead to the disappearance of the popular durian (Mickleburgh et al., 1992). The degree of pest control is assumed to be proportional to the amount of remaining primary and secondary forest. Thus, as more forest is logged, the production costs of agriculture increase, while production levels fall.

2.4. Stakeholders

The stakeholder dimension can be viewed in two ways: (1) at the societal level (e.g., local, national, international level), and (2) at district or regency level (i.e., Kabupatens). At both levels stakeholders can gain or lose from deforestation depending on location-specific characteristics (for instance whether the stakeholder is located upstream or downstream from a certain logging concession). Both levels are considered here.

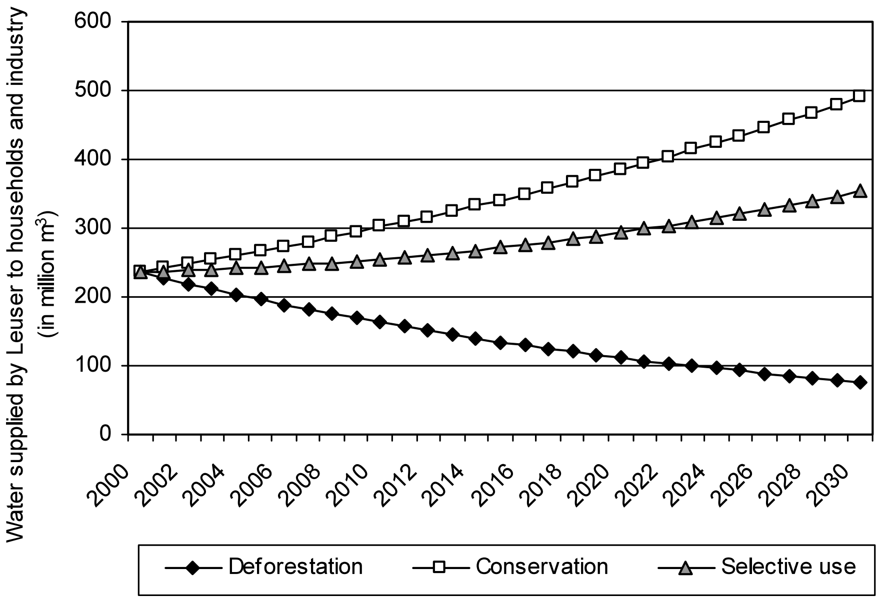

Fig. 3. Exogenously determined water supplies to households and industries.

2.4.1. Regency level

As indicated by the map in Fig. 1, the study region is limited to the 11 regencies that are part of the Leuser Ecosystem. Of these 11 regencies, 4 belong to the province of North Sumatra and 7 belong to the province of Aceh. Each regency benefits in a different manner from the Leuser Ecosystem, depending on the structure of the economy, population demographics, land cover, vulnerability to floods and fires. To illustrate these distinctions, and the results are presented at the level of the individual regencies.

2.4.2. Societal level

Table 1 shows how the changes in benefits are likely to affect the different stakeholders. An important question that is addressed by the stakeholder analysis is whether the potential imbalance between costs arising at the local level and benefits accruing at the national and international levels should be neutralised by compensating people living in or near protected areas for their losses (Ferraro and Kramer, 1997).

Five categories of stakeholders are identified: (1) local communities (households, small-scale farmers and entrepreneurs); (2) local government (a responsible body that maintains infrastructure and collects local taxes); (3) the elite logging and plantation industry (the owners of concessions); (4) the national government (a law enforcing body); and (5) the international community (representing global concerns for poverty, climate change and biodiversity loss).

3. Methodology

The road towards sustainable development involves improved integration of the environment into economic decision-making, in particular by using economic techniques to appraise projects and policies. In this study, economic valuation is used as the main analytical tool to compare the advantages and disadvantages of three scenarios in Leuser. Nowadays, most economists agree that the value of natural resources depends not only on the market prices of their direct uses, but also on all other components that generate value in the broadest sense. This is reflected in the concept of the so-called TEV. In this section, a brief description of the applied methodology is given.

3.1. Overall approach

In order to make sound policy decisions with regard to environmental problems, decision-makers need information on the benefits and costs of alternative options. An evident way to organise this information is to consider the underlying processes, starting with the cause, followed by the resultant physical impact and finally the social and economic effects. This is known as the ‘impact pathway approach’.

The impact pathway for Leuser is shown in Fig. 4 indicating the physical and socioeconomic processes resulting from deforestation of the Leuser Ecosystem. The impact pathway approach proceeds in a series of methodological steps. These include (1) defining the study boundaries (i.e., impacts on ecological functions/services); (2) identifying the physical impacts that are economically significant; (3) quantifying the significant socioeconomic effects; and (4) calculating monetary values and conducting a sensitivity analysis. In reality this ‘ideal’ approach can rarely be followed completely. Often there is lack of information. Some impacts can be quantified reasonably well while others can be estimated only by order of magnitude. In these cases, it is particularly important to undertake a sensitivity analysis in order to understand which factors and assumptions influence the overall results the most. Further, the quantitative analyses can be complemented with more qualitative considerations.

3.1.1. Defining the boundaries of the study

To maintain a transparent and comprehensible overview of the TEV of the Leuser Ecosystem, only three scenarios are analysed (see earlier explanation). The temporal boundary of the project is 2000–2030. This period leaves enough time for the main environmental impacts to come into effect, while it is sufficiently short to estimate future developments. The geographic boundaries have two dimensions: the area where ecological impacts occur (the boundaries of the Leuser

Table 1
Impact of deforestation on the main stakeholders of the Leuser Ecosystem

	Local community	Local government	Elite (logging) industry	National government	International community
Water supply	Expensive water	Costs to change distribution system	–	Costs to change distribution system	–
Fishery	Loss of income	Loss of local taxes	–	Loss of federal taxes	–
Flood prevention	Casualties, house damage	Infra-structural damage	Damage to logging roads, perhaps compensation payments	Need for compensation payments	Increased costs of emergency support
Agriculture	Increase food prices, loss of production	Loss of local taxes	Lost production from plantations	Loss of federal taxes	–
Hydro-electricity	Production loss due to power cuts, expensive electricity	Loss of local taxes	Loss of revenue from electricity	–	–
Tourism	Loss of income	Loss of taxes	–	Loss of foreign revenues	Loss of WTP for recreational, less international travel
Biodiversity	–	Loss of foreign revenues	Loss of pharmaceutical benefits	Loss of foreign revenues	Loss of WTP for biodiversity, research
Sequestration	–	Loss of foreign revenues	–	Loss of foreign revenues	Loss of ghg reduction options
Fire prevention	Damage to crops, property and health	Damage to infrastructure	Loss of concession area	Loss of federal tax revenues	Damage to economy and health
Non-timber forest products	Short-term gain in production, long-term loss	Loss of taxes	Short-term gain in production, long-term loss	–	–
Timber	Short-term gain in production, long-term loss	Loss of taxes	Short-term gain in production, long-term loss	Loss of export revenues	–

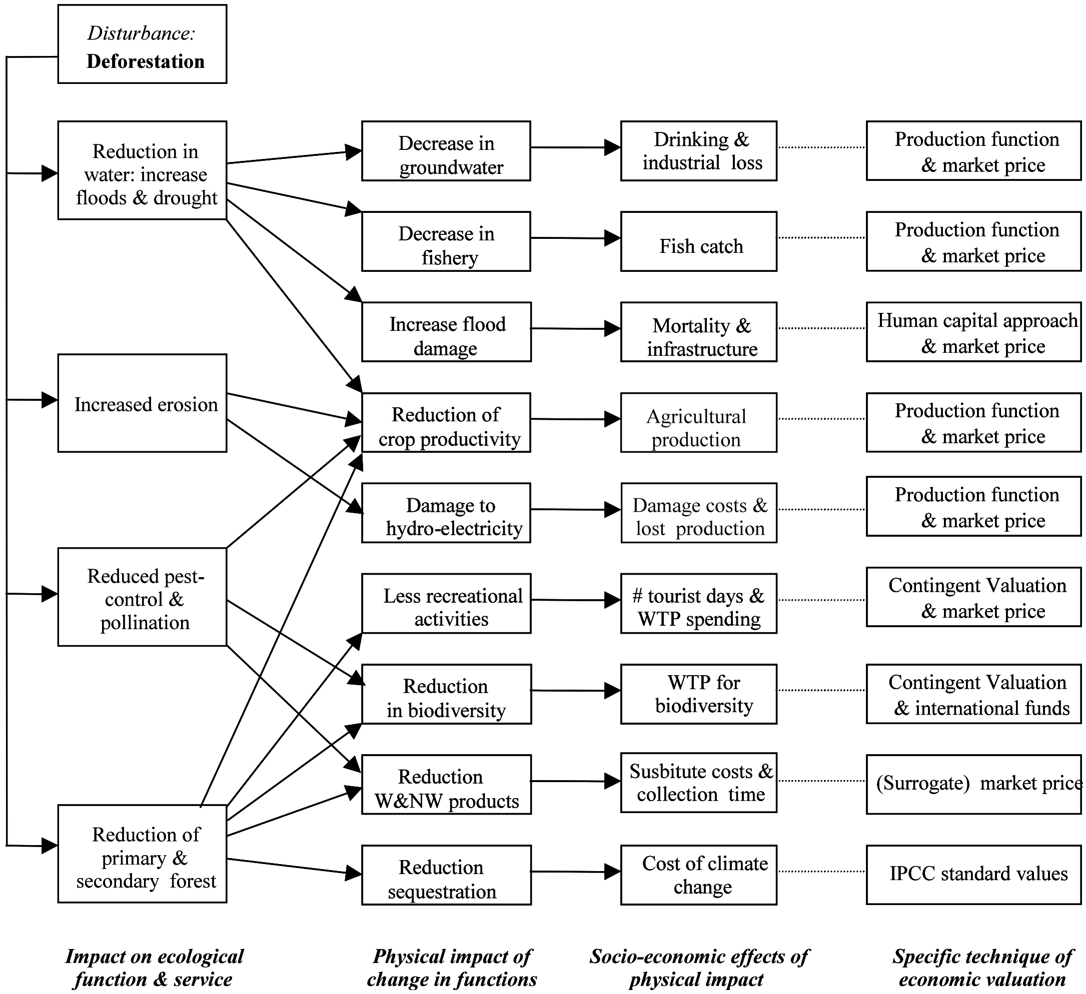

Fig. 4. Impact pathway of deforestation of the Leuser Ecosystem.

Ecosystem) and the area where changes in benefits take place. The beneficiaries are not limited to the Leuser Ecosystem. For example, tourism benefits for travel agents abroad may change as a result of deforestation. This economic loss, however, is partly avoided because rather than not making the journey, tourists may simply choose another destination.

3.1.2. Identifying impacts that are economically significant

Effects may be economically significant or insignificant. Only the former category is relevant to this appraisal. Inevitably, judgement must be used in deciding what is and is not significant. To judge the magnitude of environmental effects, the following criteria are used: (a) the location, timing and reversibility of the effect; (b) the potential effect on the natural, human, chemical and physical environment; and (c) whether the effect is positive or negative.

3.1.3. Physically quantifying the significant impacts

To assist in the prediction of the approximate physical consequences of the scenarios, a dynamic simulation model was developed. The model approximates the main effects of each scenario on the various benefit categories and evaluates the changes for the various stakeholders (i.e., local/national/international agents and the involved regencies). To calculate these impacts, simplifying assumptions have been adopted for certain aspects (for example, climatic/hydrological conditions and future economic activities).

3.1.4. Calculating monetary values and conducting a sensitivity analysis

Having established and tabulated the full range and significance of the effects, changes are valued in monetary terms. The main impact pathways, including nine categories, will be covered in the following sections. The last column of Fig. 4 shows the specific valuation technique applied to estimate the economic value of a particular effect. The selection of a valuation technique depends on the characteristics of the cost or benefit to be valued. We lack the space to elaborate on the techniques applied. Dixon and Sherman (1990) and Brown et al. (1993) and Bann (1998) provide a practical and detailed description of the steps involved in applying the methods described, specifically for the valuation of tropical rainforest.

3.2. Calculating the overall value

Most scenarios yield benefits at least intermittently over their lifetimes, and usually they incur costs over that lifetime. Because the distribution of these costs and benefits may vary for different scenarios over time, they need to be converted to net present values (NPVs) by discounting both categories of values. The choice of the appropriate discount rate remains a controversial issue because it may have a significant impact on the outcome of the analysis. The usual way to deal with this is to apply different discount rates so as to allow the decision-maker to choose the most appropriate rate. Following Pearce and Ulph (1995) we adopt a 4% discount rate as a starting point and report values for other discount rates as well.

Not all effects can be expressed in monetary units and some effects can only be assessed qualitatively. Therefore, NPVs of different scenarios cannot always be directly compared. This underlies part of the variation in earlier studies investigating the NPV of rainforest conversion. Therefore, the NPV based on the quantifiable parts of the TEV should not be the sole criterion for selection.

We acknowledge that there are many conceptual and empirical problems inherent in producing TEV estimates for the Leuser Ecosystem under the given scenario conditions. For example, the valuation approach taken here assumes that there are no sharp thresholds, discontinuities or irreversibilities in the ecosystem respond functions. Also, different valuation techniques have been used simultaneously to estimate the TEV. Although we have carefully prevented overlapping values, such an approach is rather uncommon in valuation studies. Studies that have attempted similar exercises have been criticised in the scientific community for their disregard for the significant uncertainties in the data and their underlying assumptions (e.g., Constanza et al., 1997). We stress, however, that given the uncertainties involved, we may never have a precise estimate of the TEV of the Leuser Ecosystem. Nevertheless, the crude estimate we have assembled is a useful starting point for further research.

4. Benefits

Because the focus of the study is limited to the first-order effects, the valuation of individual benefits of the Leuser Ecosystem can be considered as separate and independent analyses. This assumption is plausible because benefits are largely compatible. The analyses are based on a number of methodological and empirical assumptions (van Beukering et al., 2001), which will be summarised in this section.

4.1. Water supply

As mentioned, the first signs of reduced water replenishment have already been seen in and around the Leuser Ecosystem. Groundwater reservoirs are rapidly being exhausted and several rivers fall completely dry during part of the year. This has severe consequences for the local community. Both households and industries need to anticipate water shortages and higher costs for water.

The economic damage of reduced water supply from the Leuser Ecosystem for households and industries is based on a 'quantitative' component (volume of water provided per m^3 of ecosystem) and a 'price' component (focusing on the minimal cost (Rp. m^{-3})). The 'quantitative' component refers to reduced water availability. In the deforestation scenario, this water shortage increases (Fig. 3) and demand will have to be met by another water source. The dependency on water from Leuser declines from 74% in 2000 to 12% in 2030. In the conservation scenario, the water supply is sufficient to meet the increasing demand. The 'price' component of the water value refers to the cost-reducing impact of water supply. In the deforestation scenario, water will be retrieved from more costly sources with prices increasing by 0.3% annually. In the conservation scenario, prices remain constant at their 2000 level.

4.2. Fishery

Coastal fisheries and aquaculture in and around Leuser are very important. They provide a large portion of the animal protein in local people's diets and generate ample foreign exchange. Their annual value currently exceeds US \$171 million. If the Leuser Ecosystem is degraded, the decline in fresh water may have a detrimental impact on the functioning of the fishery sector. In the valuation of the Leuser fishery sector the following subdivisions are used: (1) maritime fishery, (2) brackish water fishery, (3) brackish water aquaculture, and (4) freshwater aquaculture.

The dependency of fisheries on Leuser varies across these different categories and between the regencies. The average share of the fishery sector dependent on Leuser is estimated at 2% for the maritime fishery, 9% for brackish water fishery and 100% for brackish and freshwater aquaculture (van Beukering et al., 2001). This generated an economic value of US \$33 million in the year 2000. In the 'conservation' scenario, this value is assumed to remain constant. In the 'deforestation' scenario, support from the Leuser Ecosystem is expected to decline at an annual rate of 1% and the prices are assumed to increase at 0.5% annually.

4.3. Flood and drought prevention

Flooding generally becomes more frequent and more destructive as a result of converting forests to other uses. Annual storm flows from a secondary forest are about threefold higher than from a similar-sized primary forest catchment area (Kramer et al., 1995). In Aceh, local farmers have reported an increasing frequency of drought and damaging floods due to degradation of the water-catchment area. In May 1998, over 5,000 ha of intensive rice growing areas were taken out of active production. This was the result of the failure of 29 irrigation schemes due to a water shortage. Furthermore, floods in December 2000 cost the lives of at least 190 people and left 660, 000 people homeless. This cost the Aceh province almost US \$90 million in losses (Jakarta Post, 2000a). Logging companies are slowly recognising their role in increased flooding and have made large donations to support the victims (Jakarta Post, 2000b).

For this study, the following three damage categories of floods and droughts are identified: (1) residential houses; (2) infrastructure (such as bridges and roads); and (3) mortality.[2] The probability of a flood occurring in the area is assumed to increase linearly with the area of deforestation.

4.4. Agriculture and plantations

Agriculture is a major source of income for the local communities around Leuser. Large rubber and oil palm plantations in northern Sumatra play a major role in the national economy. Almost all remaining lowland forest has been given out officially for oil palm plantations. Yield decline has been recorded, however, in several Leuser

[2] The individual values of impacts are estimated to be US \$3000 per residential house, US \$5000 for 1 km of road, and US \$15 000 for a mortality case. The first two values are based on local prices while the latter value was derived through benefit transfer of the value of mortality in Western Europe (US \$3 million) corrected for purchasing power parity differences between the Europe and Indonesia.

regencies. This decline can be ascribed mainly to a deterioration of nutrients in the soil, along with soil erosion, drought and floods, and an increase in weeds. Clearly, these causes of decline are linked to the deforestation of Leuser. For example, the logging of water-catchment areas in Leuser is found to be responsible for taking 94% of failed irrigation areas out of production (BZD, 2000a).

A simplified dose–response relationship is applied to estimate agricultural losses due to flooding, erosion and droughts. In the case of flooding, damage is estimated based on the following parameters: area of inundation, and depth, duration, seasonality, intensity and frequency of flood events. Kramer et al. (1995) calculated that all 654 ha would be lost over a period of 100 years. For year 1, this results in a damage of US $51 700, given an average annual net return of US $453 on 1 ha. The damage in the 'with park' scenario is only US $50 800. Therefore, the NPV of conservation for avoided crop loss is US $900 per year. To determine the economic value of the agricultural sector of the Leuser Ecosystem, three types of crops are considered: (1) rice, (2) vegetables and (3) cash crops.

Deforestation is assumed to result in a reduction of output volumes and an increase in the production costs. As shown in Fig. 5, deforestation has two types of impacts on the volume of agricultural production. On the one hand, converting forest-land to other uses will have a positive effect on the overall agricultural yield. However, steeps slopes in the high lands and soil acidity in peat swamps makes agriculture in these areas unviable in the long term; production will decline after a few years. Also, deforestation will have negative structural effects on off-site agriculture. We therefore assume an annual decline in off-site agricultural output of 2%. In addition, the costs of production are assumed to increase by 0.1% per year.

4.5. Hydro-electricity

Several regencies, such as Aceh Tenggara., have hydro-electricity plants that use water from Leuser. The plants operated in Aceh Tenggara are designed as small-scale economic activities, and may therefore be considered as supplementary to the conservation scenario. It appears that the operational conditions for the hydro-plants have worsened in recent years. Increased erosion of the waterways has forced the operators to remove excessive sediments from their turbines. This has led to frequent interruption of the power supply, higher operational costs and damage to the blades of the turbines. One plant closed down due to lack of water supply. Most of these disturbances are considered abnormal and may therefore be attributed to deforestation.

To determine the value of power generation dependent on the Leuser Ecosystem, the amount of electricity potentially produced through hydropower technologies is estimated at 22%. In the conservation scenario, this share will stay constant over time. In the deforestation scenario, this share is assumed to decline from 22 to 16%. Furthermore, the cost of electricity generation is assumed to increase by 2% per year.

4.6. Tourism

Low-impact eco-tourism can be one of the most important sustainable, non-consumptive uses of Leuser, thereby giving local communities powerful incentives for conservation. Wildlife tourism accounts for approximately 20–40% of international tourism and in 1988 there were between 157 and 236 million international eco-tourists world-wide (Ceballos-Lascuráin, 1996). Fig. 6 depicts the number of visiting tourists in the period 1989–1999, showing the dramatic decline since 1995 in response to the security problems in Aceh. Nevertheless, given the opportunities to view wildlife such as orang-utans, some experts view eco-tourism as a major potential source of revenue for communities living around Leuser (van Schaik, 1999).

To improve our understanding of the motivations and preferences of local and foreign tourists, a survey was conducted in 2000–2001. Special attention was paid to spending patterns and willingness to pay (WTP) for the conservation of the Leuser Ecosystem. Table 2 provides an overview of the results. Interestingly, the differences in spending patterns between local and foreign tourists are much lower than expected. Respondents

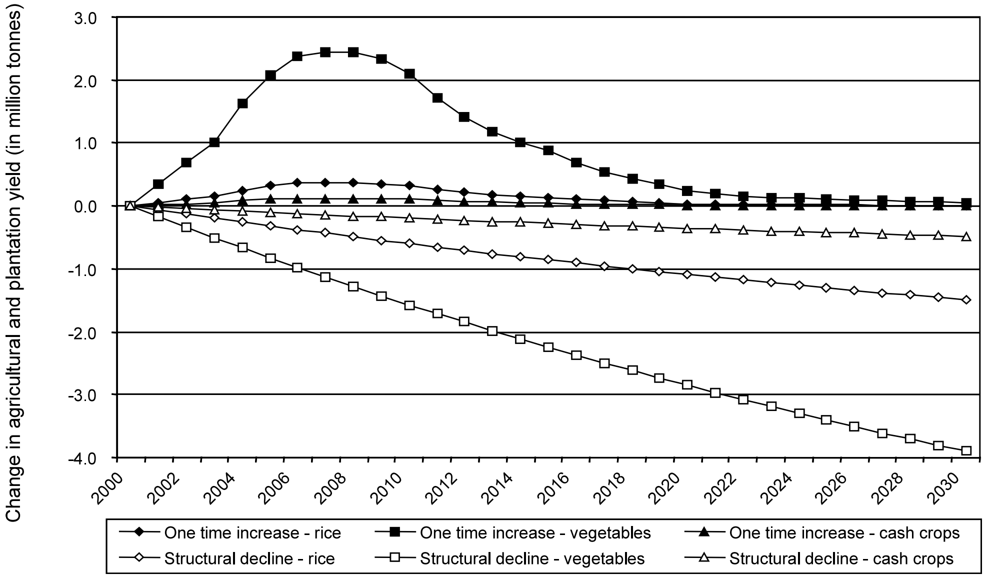

Fig. 5. Assumed change in production due to deforestation.

were also asked about their WTP a 'general' donation for the purpose of biodiversity conservation in Indonesia, regardless of whether they would ever visit a natural park. This value represents the non-use value of biodiversity. Here, a large difference between local and foreign tourists can be observed. The main reason for not providing any donation is not so much a disinterest in nature but more a distrust in the institution that collected the donation.

The number of tourist days is assumed to decline annually by 5% in the deforestation scenario. Furthermore, the spending and WTP for the entrance fee is assumed to decrease by 2% annually due to reduced attractiveness of Leuser. The local tourist sector also fears that orang-utans

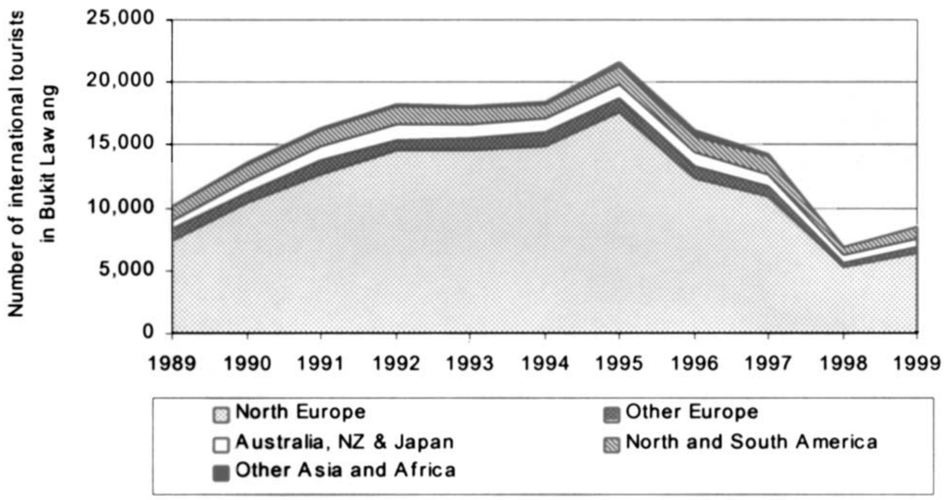

Fig. 6. Number of foreign visitors to the Bukit Lawang entrance to Leuser. Statistics based on visitor numbers provided by the park ranger of Bukit Lawang in 2000.

Table 2
Spending patterns of local and foreign tourists in WTP-survey (in Rp.)

	Local tourists	Foreign tourists
Actual spending	68 030	72 206
WTP entrance fee	783	3800
WTP donation	4008	51 145

Note: 1US$ equals approximately Rp. 10 000 in mid 2001.

will become locally extinct. In the conservation scenario, tourist numbers are assumed to increase gradually until a maximum is reached, with the WTP and spending increasing by 2% annually. Note that few tourists travel to Sumatra just to visit Leuser. Therefore, only half of the ticket cost is included in the calculation.

4.7. Biodiversity

People living in areas with a high biodiversity value tend to be relatively poor. Hence, the highest economic values for biodiversity are likely to be found within institutions and people in wealthy countries. Funds can come from several sources, including bio-prospecting, the GEF and grants from international NGOs (with donations possibly being proportional to biodiversity value) (Wind and Legg, 2000). In the Leuser Ecosystem, both research and conservation interests are active. The Leuser Development Programme was initiated in 1996 as a seven year EU-funded programme with annual costs of US $6 million or Rp. 57.7 billion (LDP, 1994). Of the total amount, 22% is spent on European input (consultants, monitoring) and 78% is used on Sumatra-based inputs (labour, equipment, training, etc.). It is assumed that 50% of European inputs benefit the local community given that certain EU funds are conditional. The programme will continue to run on the same financial basis if the Leuser National Park remains in good condition. If deforestation continues it is expected that the EU will gradually pull out.

Similar assumptions hold for the current national and international research and bio-prospecting interests in the Leuser Ecosystem. The valuation of this research benefit is based on actual expenditures within the park. Although such expenditures do not represent economic value per se, they do indicate a minimum WTP to take advantage of the park resources (IIED, 1994). Also, the potential return from commercial drugs derived from plants species is one strong argument for identifying and preserving the world's biodiversity. About 25% of all Western prescription drugs and 75% of developing world drugs are based on plants extracts. To determine the bio-prospecting value, we used several literature sources such as Pearce and Moran (1995) and Simpson and Craft (1996), and Nunes and van den Bergh (2001). The estimates referring to the value of land for medicinal plants vary substantially from location to location. In the case of the Leuser National Park we have assumed an intermediate value of US $1 ha^{-1} of primary forests. The other types of forest are ignored.

4.8. Carbon sequestration

Anthropogenic increases in the concentrations of greenhouse gases (such as CO_2) in the atmosphere are widely believed to lead to climate change. Carbon sequestration by rainforest ecosystems therefore has an economic value, since the carbon fixed in the ecosystem reduces atmospheric concentrations. For example, according to Aylward et al. (1995), following Pearce (1990), conserving 1 ha of tropical forest would be worth $2,000 in avoided damage.

Each type of conversion generates a different amount of carbon release (Brown et al., 1993). Combining the prevailing conversion pattern in Leuser with standard carbon release values gives these releases. Estimates of the marginal damage costs range between US $6.3 and 228 per tonne of carbon. In this study, the most recent estimates from the FUND model are adopted (Tol, 1999). The carbon value in Indonesia is set 50% lower due to the difficult investment climate, leading to a price of Rp. 50 000 (US $5) for 1 tonne of carbon.

4.9. Fire prevention

The forest fires that engulfed vast areas in Indonesia in 1997 and 1998 were a true disaster. A prolonged dry season caused by El Nino created conditions for uncontrollable forest fires, often initially started by local people as part of slash-and-burn agriculture. Nearly 10 million ha burned, exposing some 20 million people across Southeast Asia to harmful smoke-borne pollutants. Economic damages due to tourism and transportation losses, destruction of crops and timber, health care costs, and other costs have been estimated at around US $10 billion (Barber and Schweithelm, 2000).

To what extent does primary rainforest have a fire prevention function, and thus an additional value for preventing economic damage? There are various factors that make disturbed forest more prone to fires than primary forests. The likelihood that a forest will burn depends on the level of fire hazard and fire risk: (1) fire hazard is a measure of the amount, type, and dryness of potential fuel in the forest. Logged forest has relatively large amount of dry logging wastes lying around; (2) Fire risk is a measure of the probability that the fuel will ignite. In the presence of abandoned logging roads, which provide easy access to otherwise remote forests, the fire risk is greatly increased when settlers use fire for land clearance.

Two impact categories for fires are identified. These include (1) damage to the local economy, and (2) damage to the international economy (e.g., Singapore and Malaysia). The main question is: would damage from fires change if the forest in the Leuser Ecosystem were degraded? In other words this addresses the avoided damage from an intact forest. To calculate the avoided damage for the local economy, we multiplied the total average local damage of a fire event for a specific regency with the probability that the event will occur. The average damage is assumed to grow proportionally with the local economy for each regency. The probability of a fire occurring in the area due to deforestation is determined by the current probability of fire events in different forms of land use multiplied by an indicator of the current composition of land uses. For example, a fire event in a primary forest is assumed to occur once every 50 years. In contrast, fire events in grasslands are assumed to occur every five years.

4.10. Non-timber forest products

NTFP can provide local communities with cash as long as exploitation does not surpass a threshold level. Here, we assume that harvested NTFP in Leuser does not exceed this threshold, although in reality, this may not be the case. An analysis by Homma (1996) of NTFPs in Brazil suggests that in small markets, extractive activities can survive. However, as markets grow, such as in the Leuser Ecosystem, supply from the extractive sector becomes inadequate, substitutes are developed and the extractive economy can eventually collapse. Moreover, increased market demand may lead to short-term overexploitation and even to local extinction of plants and animals in high demand (Arnold and Pérez, 1998).

Annual values range from US $5 ha^{-1} in the Brazilian Amazon to US $422 ha^{-1} for the Peruvian jungle. Here, we generated the value of NTFP by using local field surveys, as well as expert judgements from LDP staff and local statistics. Three types of products are identified, for which production and prices are given in Table 3. They are categorised according to their value. We assume that in the 'deforestation' scenario, overexploitation of NTFP will occur. As a result, a short-term increase in harvested NTFP will be observed in the first decade after which this sector collapses. This phenomenon can already be seen for rattan, turtles and cobras (van Dijk et al., 1999).

4.11. Timber

The total timber value is derived by applying the market price for a unit of timber to the estimated quantities that could be sustainably harvested from an area of forest (Bann, 1998). In Leuser, this condition of sustainability does not necessarily hold because the purpose of this study is to determine the costs and benefits of unsustainable logging practises, while the conservation scenario assumes a strict ban on logging. Note that the costs of harvesting and transporting timber must be deducted from the market price to establish the net standing timber in the forest. The cost of extraction is assumed to be US $17 m^{-3} (Brown,

Table 3
Overall production and market prices for NTFP in Leuser Ecosystem

NTFP	Production (tonne)	Price in Medan (US$/tonne)
Low value NTFP		
Cotton tree (Randu)	1177	45
Rattan (Rotan)	18 064	45
Resin (Damar)	319	60
Rumbia/Nipah/Sagu	2645	75
Gum benzoin (Kemenyan)	37	100
Medium value NTFP		
Palm sugar (Gula Aren)	870	300
Nutmeg (Pala)	8416	700
Aromatic oil (Nilam)	334	800
Candlenut (Kemiri)	27 027	1000
Cinnamon (Kayu Manis)	156	1000
High value NTFP		
Honey (Madu)	1	3000
Vanilla	233	5000
Bird nest (Sarang Burung)	2209	10 000

Sources: Badan Pusat Statistik (1999), and field study in Leuser Ecosystem.

1999). Market prices should also be corrected for any known market and policy failures. Timber prices in Indonesia are far below international standards due to subsidies, non-tariff barriers and because the market is flooded with illegal timber. Red meranti, for example, is currently sold for US \$50 m^{-3}; without distortions it could sell for US \$80 (Brown, 1999). The rent for a cubic metre sold at US \$80 is roughly US \$58. To establish the economic value of timber, an approach comparable to that applied to NTFP was used.

A future increase in wood prices is a real threat for Indonesia. In 1995, the first signs of a national wood shortage were noticed. A study by the World Bank (1995) stressed that the remaining virgin forest in companies' concessions will last no more than 10–15 years. In addition, it is doubtful that the conditions for regenerating forests will allow for adequate supply beyond that period. The pattern of logging in the three scenarios is shown in Fig. 2. We assume that the harvesting efficiency of meranti, hardwood in general and other types of wood from primary forest is 0.5, 5 and 2 m^3 ha^{-1}, respectively. For secondary forest the logging efficiency for these species is much lower, at 0.25, 2.5 and 1 m^3 ha^{-1}, respectively. To determine the value of the harvested timber we assume a round wood/plywood ratio of 2:1 (Monk et al., 1997).

5. Results

The results are presented in several forms: (1) TEV at different levels of discounting; (2) distribution of TEV among different sectors; (3) distribution of TEV among different regencies; and (4) distribution of TEV among different stakeholders.

5.1. Overall total economic value

By aggregating the net benefits over time, the TEV for the individual scenarios can be determined. Fig. 7 shows the annual net benefits for the scenarios over the period 2000–2030. Until 2010, the deforestation and selective use scenario generate higher socio-economic benefits than the conservation scenario. This is the result of two underlying mechanisms: (1) large revenues are generated from increased logging and harvesting of NTFP, and (2) the negative impacts of deforestation are still manageable. After 2010, however, the net annual benefits of conservation outweigh

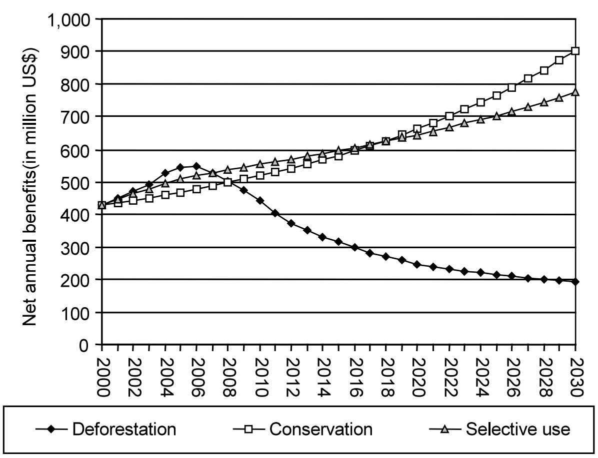

Fig. 7. Net annual benefits over time of Leuser National Park.

the benefits of increased logging. The 'low-hanging-fruits' have been picked and their branches destroyed. The forest that is left is difficult to reach and therefore less attractive to logging industries. Moreover, the negative effects of declining water retention, reduced pest control, increased erosion, and more frequent floods and droughts, now start to take their toll. The net annual benefits of the conservation scenario, on the other hand, increase as the growing economy becomes more efficient in utilising the 'goods and services' of the Leuser Ecosystem. Various sectors, such as the tourist industry, agriculture, and hydro-electricity, gain from the existence of the rainforest. They both expand their activities and generate higher per unit benefits (Fig. 7).

Based on the annual benefits the TEV can be calculated. The choice of the discount rate is crucially important for the calculation of the NPV and hence for the TEV. Fig. 8 shows the TEV for the three scenarios as a function of the discount rate. Discount rates ranging from 0 to 15% have been used. The higher the rate, the more future benefits will be discounted away. Fig. 8 shows the converging TEV of the deforestation, conservation and selective use scenarios with increasing discount rates. This confirms that the former scenario generates high benefits in the short-term while the benefits of the conservation scenario materialise in the long run. Although the curves converge, the NPV of the scenarios only coincide at a 15% discount rate. This implies that within the time frame and the range of discount rates considered, the conservation scenario remains largely superior from a TEV perspective. The results of this study are in line with results from previous research. All values of different land use types lie between US \$500 and 7,000 ha^{-1}, depending on type of conversion and discount rate.

5.2. Sectors

The TEV comprises numerous benefits of ecosystem goods and services provided by Leuser Ecosystem. The composition of the accumulated benefits is shown in Table 4. The configuration varies widely between the three scenarios. A trivial difference between the scenarios is the role of timber, which is significant in the deforestation scenario but absent in the conservation scenario. What is also typical is the fact that the average net value for agriculture is higher in the deforestation scenario. This is the result of the short-term encroachment of farmers after the forest has been cleared. Besides timber and agriculture, all

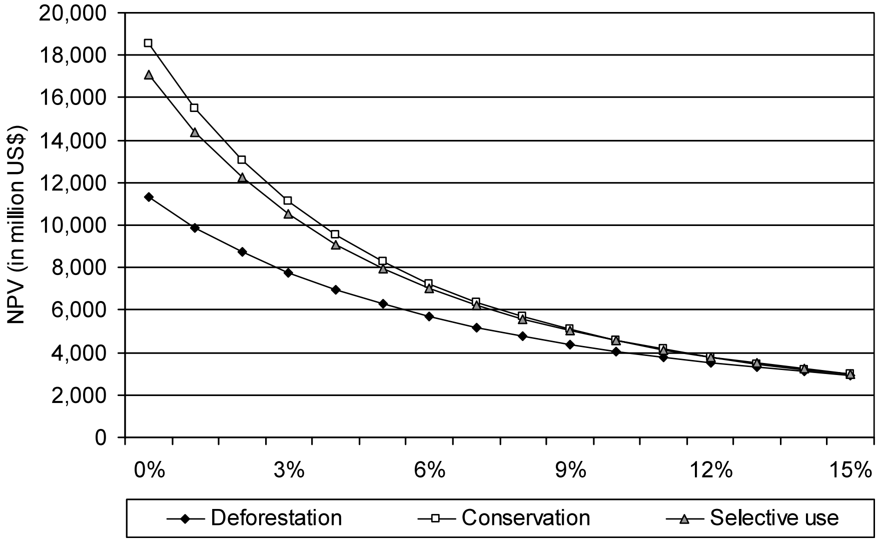

Fig. 8. TEV of Leuser Ecosystem per hectare for different discount rates.

Table 4
Distribution of benefits to the different sectors (in million US$)

	Deforestation		Conservation		Selective use	
	Value	Proportion (%)	Value	Proportion (%)	Value	Proportion (%)
Water supply	699	10	2419	25	2005	22
Fisheries	557	8	659	7	674	7
Flood prevention	1223	18	1591	17	1396	15
Agriculture	2499	36	1642	17	1016	11
Hydro-power	252	4	898	9	696	8
Tourism	171	2	828	9	407	4
Biodiversity	56	1	492	5	92	1
Carbon sequestration	53	1	200	2	125	1
Fire prevention	30	0	715	7	643	7
NTFP	235	3	94	1	1222	13
Timber	1184	17	0	0	825	9
Total	6958	100	9538	100	9100	100

Note: for the period 2000–2030, at a discount rate of 4%.

other benefits are higher in the conservation and selective use scenario. The most important benefits in these latter two scenarios include water supply and flood prevention. In the selective use scenario, NTFP comprise an important share of the TEV.

5.3. Regencies

Table 5 presents the distribution of the TEV across the 12 regencies. The allocation of the benefits depends on geographical characteristics, the size of the economy and the level of dependency on the park. Aceh Utara and Aceh Tengah receive only a small share; Langkat and Deli Sardang generate a high TEV. The regencies in North Sumatra are least affected by the negative impacts of deforestation. All regencies in the province of Aceh, however, remain net losers in the deforestation scenario. Typically, most of the political and military power in the region is concentrated in North Sumatra. This may be considered the driving force of this unbalanced distribution of losses of deforestation.

5.4. Stakeholders

Table 6 shows the distribution of the NPV among the stakeholders for the different scenarios. Several typical features can be observed. The local communities are by far the main beneficiaries of the Leuser Ecosystem. As such, their share will grow in the conservation scenario. As expected, deforestation benefits mainly the logging industry in the short run. In the long run, however, deforestation also harms the wealthier stakeholders to a certain extent. As owners of large plantations and industries, they suffer negative consequences of reduced ecological services from the Leuser Ecosystem. The local and national government may also gain in the short-term by collecting part of the rent from the harvested timber. In the long run, however, infrastructural damages increase while tax income decline. The international community only benefits from conservation of Leuser. Both the biodiversity and sequestration values are important gains for developed countries.

A striking element is that the elite (logging) industry collects a much larger share of the total value in the deforestation scenario (23%). If the Leuser Ecosystem were strictly conserved, their share would only be 11%. This reduction in value for the elite industry in the conservation scenario contrasts with benefits for the local and international community. The power structure of the elite (logging and plantation) industry and the socio-spatial distribution of the local and the international community, however, prevents the conser-

Table 5
Distribution of the NPV of Leuser Ecosystem among the regencies over the period 2000–2030

Regency	TEV Deforestation [a] (million US$)	TEV Conservation [a] (million US$)	TEV Selective use [a] (million US$)
Aceh utara	274	540	498
Aceh tengah	290	319	354
Aceh barat	293	417	422
Aceh selatan	452	559	612
Aceh tenggara	602	552	668
Aceh timur	285	523	474
Aceh singkil	380	351	411
Langkat	1331	1811	1590
Karo	671	778	748
Diari	390	458	460
Deli serdang	1165	898	1082
Medan	829	2334	1781
Total	6961	9538	9101

[a] TEV calculated as NPV for a time period of 30 years and a 4% discount rate.

vation scenario from being realised. For similar reasons, compensation of the latter by the former group is constrained.

5.5. Sensitivity analysis

A large number of assumptions have been made in order to generate the results given data, budget and time constraints. These assumptions need not be problematic as long as the results are relatively robust vis-à-vis changes in the assumed parameter values. Several crucial parameters are tested for robustness (van Beukering et al., 2001). These include population growth, the deforestation rate and the value of timber and water. None of these parameters change the results fundamentally. Therefore, the conclusions still hold.

6. Conclusions

Economic valuation has proved to be a strong and useful tool in the analysis of welfare changes for the different scenarios in the Leuser Ecosystem. Several lessons can be learned from the analysis: (1) with a 4% discount rate, the accumulated TEV for the ecosystem over the 30-year period is: US $7.0 billion under the 'deforestation scenario', US $9.5 billion under the 'conservation scenario' and US $9.1 billion under the 'selective utilisation scenario';. (2) Conservation spreads the benefits of Leuser equally among regencies and thus prevents further social conflict, while deforestation widens the regional income gap and thus may be a source of conflict. This may form a strong incentive for the regencies to develop and enforce a common plan; and (3) Finally, conserva-

Table 6
Distribution of NPV among stakeholders (in%)

Scenario	Local community (%)	Local government (%)	Elite industry (%)	National government (%)	International community (%)
Deforestation	45	11	23	7	13
Conservation	56	9	11	5	19
Selective use	53	10	14	5	18

Note: NPV over the period 2000–2030 at a discount rate of 4%.

tion promotes social and economic equity because it mainly supports the underprivileged majority of society. Deforestation widens the gap between rich and poor.

Despite these positive features of conservation, deforestation continues uninterrupted in the Leuser Ecosystem. The main reason for this destruction is the strong political power of the logging and plantation industries as well as the wide dispersion of the main beneficiaries of conservation. This stops the most economically desirable scenario from occurring and prevents the losers of deforestation being compensated by those who gain.

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