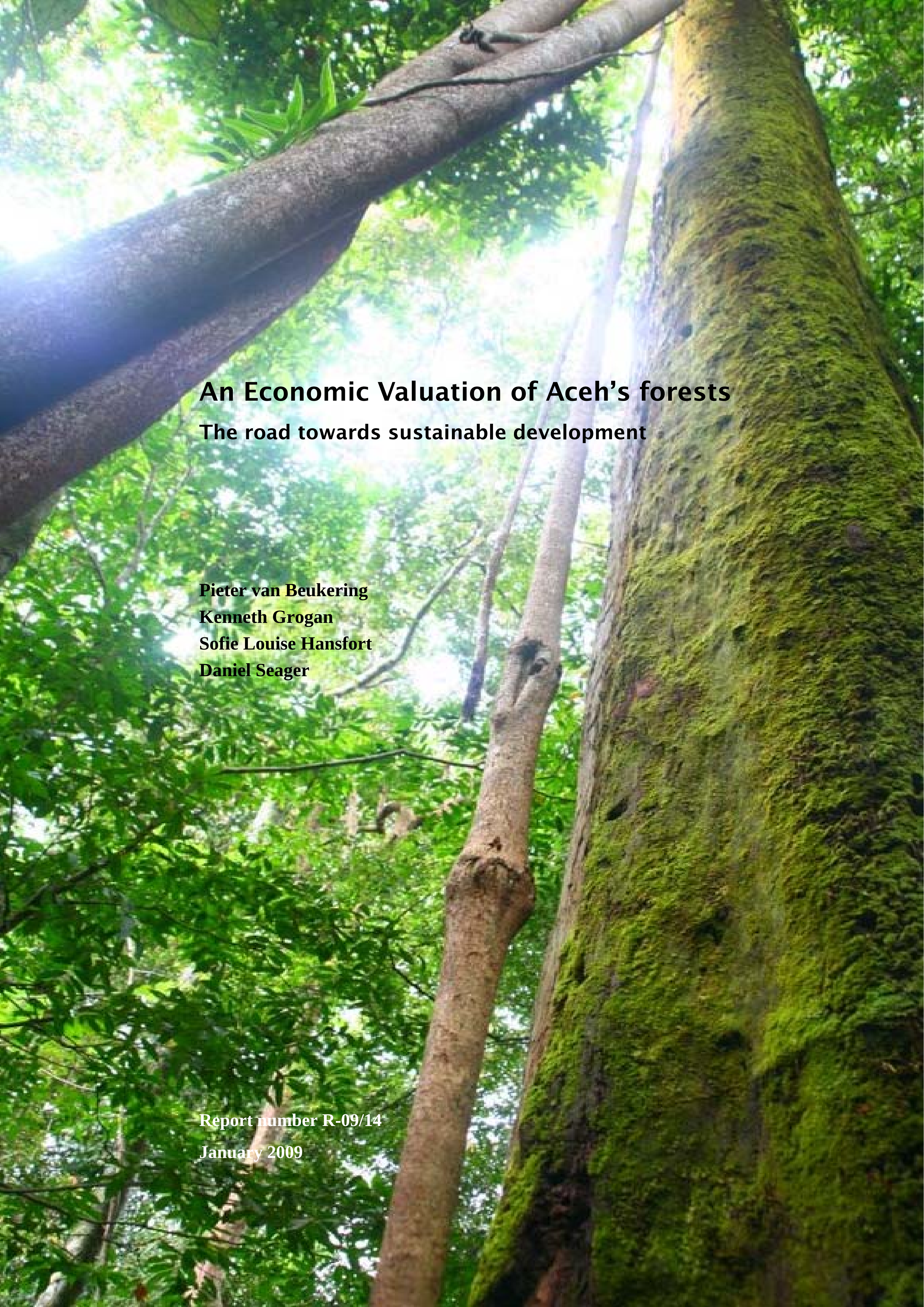

An Economic Valuation of Aceh's forests

The road towards sustainable development

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Executive summary

Indonesia is a country that has shown one of the highest rates of deforestation in the world. With a large majority of the island states' forest gone, the province of Aceh is one of the last areas in the country that still retains a large part of its forest ecosystem intact. The forest area in Aceh comprises of over 3.1 million hectares. Aceh has been spared from the high deforestation rates elsewhere in the country due to years of civil conflict between the government and the *Gerakan Aceh Merdeka* (GAM) making commercial timber activities precarious. However, times are catching up with Aceh. Following the devastating tsunami in December 2004 and the more recent peace accord in 2005 large pressures are re-emerging to use the forest resources to fuel re-construction plans and economic development. With the disappearance of the forests, vital ecosystem services such as water retention, erosion control and pollination services also disappear, services that play an important role in varying economic activities.

In 2006 a new governor (Mr. Irwandi Yusuf) was elected who endorsed a Green Economic Development and Investment Strategy for Aceh Province, (*Aceh Green* for short) following years of ineffective command and control policies plagued with inefficiencies and corruption. His vision is a comprehensive, holistic strategy to re-build Aceh's economy with a focus on employment, income and protection and preservation of Aceh's natural forest resources. In order to allow the governor and associated parties time to develop this plan and the new laws a moratorium on all logging activities has been declared in the province. "*Aceh Green* will integrate and expand carefully and consciously integrated themes of climate change via renewable energy and land use management, community development, commerce and conservation. The governor recognises that achieving environmentally sustainable outcomes is only possible with economically sustainable livelihoods for the people of Aceh, especially the dispossessed and disenfranchised." (Aceh Green, 2008 p.2)

In order to aid the initiation of *Aceh Green* this study focuses on valuing the forest resources and services therein by applying various valuation techniques. Economic valuation has been applied to evaluate the Total Economic Value (TEV) of the forest ecosystem in Aceh Province. A comprehensive model was built using data on forest cover, socio-economic indicators and various ecosystem services provided by the forest. Two scenarios are evaluated:

1. *Conservation* scenario: All extractive activities cease to occur. Forest ecosystem services are fully maintained and the economy continues to enjoy the benefits from these services into the future.
2. *Deforestation* scenario: This scenario assumes *business as usual* where deforestation continues at 1.3% per year into the future. A certain proportion of land is converted to agriculture but yields gradually fall as ecosystem services become depleted.

The TEV of the Aceh forest is comprised of benefits enjoyed by eleven sectors in the economy in Indonesia and abroad. These sectors are shown in the first column of Table E.1. This table also shows a major change in the composition of the TEV between the deforestation and the conservation scenarios. Deforestation may be considered an easy way to generate fast cash, however, once land is converted to plantations soil erosion rapidly follows reducing yields. Timber sales reduce as low-lying forest is cleared and ecosystem service degradation begins to take its toll. Over a 30-year time frame the conservation scenario yields higher benefits (US$ 13.4 billion) than its deforestation counterpart (US$ 12 billion) as can be seen in Table E.1.

Table E.1 Total value and distribution of benefits amongst sectors for both scenarios (30-year time frame, 3.5% discounting).

Sector	Deforestation Value (in million US$)	Proportion (%)	Conservation Value (in million US$)	Proportion (%)
Water supply	1,059	8.8	2,487	18.5
Fishery	2,025	16.9	2,490	18.6
Flood prevention	1,622	13.5	1,860	13.9
Agriculture	3,512	29.2	3,991	29.8
Hydro-electricity	15	0.1	26	0.2
Tourism	25	0.2	139	1.0
Biodiversity	103	0.9	582	4.3
Sequestration	-	0.0	1,217	9.1
Fire prevention	183	1.5	225	1.7
Non-timber forest products	161	1.3	391	2.9
Timber	3,308	27.5	0	0.0
Total	**12,011**	**100.0**	**13,408**	**100.0**

Discounting these benefits at higher levels means that eventually the short-term benefits yielded under the deforestation scenario become more preferable. At an 8% discount rate, both scenarios yield equal net benefits, after which the deforestation scenario becomes ever so slightly more preferable with each incremental raise in discounting. Having mentioned this, it must however be mentioned that under such circumstances, clear felling the forest resources, apart from being irreversible is an activity fraught with uncertainties as to the ecological side effects. For the sustainability of future generations and to avoid ecological and economic future uncertainties the precautionary principle should be adopted as a logical and indeed responsible decision as to the fate of Aceh's diverse and rich forest ecosystem.

1. Introduction

Indonesia has shown one of the highest rates of deforestation in South East Asia. Since 1950 over 40% of its standing tropical rainforest has already been felled to make way for agriculture, population growth, grazing land and more recently a seemingly clean source of fuel and cooking oil, Palm Oil (GFW, 2008). With the conversion of its once extensive forest comes short-term prosperity in the name of permanent loss of long-term wealth. Forest ecosystem services such as water retention, local climate control, pest control and pollination services for subsistence agriculture, fire risk prevention and water runoff attenuation are being substituted for hard capital in order to fuel current development priorities such as public health, infrastructural developments, post tsunami reconstruction and repayments of burgeoning foreign debt. What goes unnoticed however is the gradual depletion and deterioration of these ecosystem services. Services, without which, the cost of replacement and derived damages possibly surpass the immediate benefits yielded by increased primary production and raw timber sales. The decline of several crucial ecological functions of the rainforest may have serious consequences for numerous economic activities in and around the deforested areas.

A recent push for conservation is underway in the province of Nanggroe Aceh Darussalam (hereinafter referred to as simply 'Aceh Province') located in the north of Sumatra. Following the recent historic gubernatorial elections in December 2006 the province of Aceh elected its first democratically elected governor. Govenor Irwandi Yusuf has refined his vision to rebuild Aceh in the aftermath of the Tsunami into a more holistic and comprehensive strategy that will focus on peace, the economy **and** sustainable development. Following the cessation of conflict in 2005 which ravaged the area for many years and the tsunami in December 2004 there has been a massive increase in the demand for timber, both for re-construction and to supply the global timber market, placing serious pressure on Aceh's largely intact forest ecosystem. Since Irwandi Yusuf's election a moratorium on all logging activities has been declared in the province in order to allow time to a) gather data and information regarding the current status of Aceh's forest resources and to b) develop and redesign a proper sustainable forestry management plan which can eventually be put into place with an aim at managing the remaining forest resources in a more holistic and sustainable manner. The moratorium is also sending a message to the international community that Aceh is willing to embrace conservation and sustainable forestry management but not without receiving something in return.

For the governors' policies to succeed it is clear that consideration must be given to the poor, ex-combatants and disenfranchised. Policies must address the need to create employment, improve health care, education and housing facilities and ultimately create the right conditions for economic growth. At the same time it must also focus on the conservation of Aceh's remaining forest cover, a resource which not only boasts beauty and biodiversity but a resource which is ultimately *key* in ensuring sustainable economic development for the provinces' future generations.

1.1 Forest resources of Aceh

Aceh comprises roughly 12% of the Indonesian Island of Sumatra at 5.74 million hectares. (Provincial Forestry Office 2007, cited in Blackett and Irianto, 2007). The province boasts the largest contiguous area of forest remaining on the Island of Sumatra stretching from the northern tip of the island (the city of Banda Aceh) right down to the border with North Sumatra. The forest is located primarily in the interior of the island spread over a strongly dissected mountain range, the Bukit Barisan range. Along this mountain range that stretches down the spine of northern Sumatra two distinct but connected ecosystems namely the Leuser Ecosystem and the Ulu Masen Ecosystem occur. The forests, although distinct in flora and fauna due to their geological divisions comprise of several similar ecosystem types namely; Lowland forests; Montane forests; Freshwater Swamp forests; Mangrove forests and; Peat Swamp forests.

In 1999 the Government of Indonesia re-defined (by law) a categorisation for land considered as forest area. Of the 5.64 million hectares in Aceh Province 3.35 million are officially considered 'forest area' which is subdivided into several sub-categories. For example 638,580 ha are currently designated as production forests (either permanent or limited) where various extraction activities are permitted thus deteriorating the forest ecosystem sometimes significantly (see Table 1.1). Other categorisations of land include non-forested area and unclassified land (APL), which is designated for future community uses such as building, subsistence agriculture, and large-scale agriculture plantations (oil palm) it may also contain forested areas but is not classified as forest. The subcategories which belong to the forested areas are; Protection forest; Permanent and Limited Production forest; and Conservation forest; Table 1.1 provides an explanation of the land division categories and their associated areas in the Province of Aceh.

Table 1.1 Showing categorisation of forests in Aceh Province with associated descriptions.

Category	Area (ha)	Description
Forest area	3.335.693	Total area officially classified as forest
Protection area	-	Conserved forest and protected forest
• Conservation forest	852.613	Protected forest with officialy designated status such as Nature Reserve
• Protection forest	1.844.500	Protected forest without officially designated status
Production forest	-	Forest designated for production of timber and NTFP's comprised of Permanent and Limited Production Forest
• Permanent production forest	601.280	Forest designated for production with harvesting permitted of trees above 50cm diameter
• Limited production forest	37.300	Forest designated for production with harvesting of trees above 60cm diameter

Source: Blackett and Irianto, 2007.

Whilst it seems a large proportion of forested land still exists, enormous pressures are being asserted upon these forests to aid economic development across a range of sectors. At the same time it is increasingly becoming apparent that standing forests and the unique ecological services they provide may be even more valuable for economic development than their timber and alternate land use values. Valuing these services is not without its controversies however it can yield important information for decision making over the fate of a tropical forest.

Table 1.2 provides values derived in a study performed by Seidl and Moraes (2000) on the value of forest resources in the Pantanal, Brazil. The total value of all ecosystem services and products derived from a conserved forest summed to a massive US$ 5840 per hectare, the same study found that the value of the same land if converted to grazing grounds would only be between US$ 100-300.

Table 1.2 Shows estimated annual value of ecosystem services for the Pantanal de Nhecolandia, Brazil.

Ecosystem Service Categories	US$ (1994) per hectare per year
Water supply	1.977,11
Disturbance regulation	1.747,19
Waste treatment	505,05
Cultural	425,13
Water regulation	378,81
Nutrient cycling	185,06
Recreation	157,37
Habitat/refugia	105,88
Raw materials	75,05
Gas regulation	67,35
Erosion control	63,41
Food production	53,40
Climate regulation	44,76
Soil formation	22,37
Pollination	12,27
Biological control	11,29
Genetic resources	8,23
Total annual p/ha value	**5.839,73**

Source: Reproduced from Seidl and Moraes (2000). Calculated from Costanza et al., 1997 and Costanza et al.,1998, Abdon et al., 1998 and Silva et al., 1998.

1.2 Objective

The main objective of the present study is to determine the Total Economic Value (TEV) of the forest ecosystem in the province of Aceh as per the area shown in table 1-1 (with corrections for intermittent deforestation) and evaluate the consequences of deforestation for its main stakeholders. Economic valuation has been applied to evaluate the TEV of the Aceh Forest Ecosystem under two scenarios:

1. The 'conservation' scenario, implying that protection of the rainforest is strictly enforced and thus logging will be excluded as an economic activity and;
2. The 'deforestation' scenario, implying a continuation of the current trend of clear-cutting (business as usual).

The benefits included in the economic valuation are: 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 current level and the change of a large number of benefits have been determined as a critical part of the economic valuation process. The valuation techniques and modelling of cost and benefit distribution is largely based on, and builds upon a previous study in the region (Van Beukering *et al* 2003) where a portion of the forest ecosystem in Aceh was valued under three contrasting scenarios. This study amplifies the area to Aceh Province as a whole and provides a more up to date valuation using latest developments both on the Island and in the economic valuation techniques which are constantly developing and improving.

1.3 Structure of report

The report is structured as follows. In Chapter 2, a background on economic valuation is provided. It addresses the general philosophy of economic valuation, and discusses the different types of economic values. Chapter 3 provides a general background to the case study on the Aceh forest ecosystem. The main threats to the Aceh forest ecosystem and the selected scenarios are described in more detail. Moreover, the ecological impacts of deforestation of the Aceh forest ecosystem as well as its main stakeholders involved are identified. In Chapter 4, the main focus is on the benefits included in the analysis. Finally the results of the valuation process are presented in Chapter 5.

2. Economic valuation

The road towards sustainable development involves better integration of the environment into economic decision-making, in particular through the use of economic techniques for the appraisal of projects and policies. A method central to this effort is 'economic valuation of ecosystem services'. In this study, economic valuation is used as the main analytical tool to compare the advantages and disadvantages of two scenarios in the Aceh forest Ecosystem.

Valuing ecosystems is a subject not without its controversies, primarily from the ethical perspective. It can be argued that one looses his/her soul by putting a dollar value to a forest, river system, wetland, clean air or clean water. However, agreeing to it or not, valuing ecosystems has been occurring since ancient times and will continue to occur in the future. People are always forced to make trade-offs, deliberately or not, about the environment each and every day. Politicians may make a decision which values an added economic activity more than it values the natural area and its associated services without even regarding it as an implicit (low) valuation of Nature, although that is exactly what happens. Environmental valuation must be embraced so as to move away from an economy where decisions made are based solely on "*real"* marketable inputs towards one that accounts for and embraces "*natural*" values and "Nature's services". The valuation of ecological services translates benefits derived from Nature into a language that can be understood by decision makers, providing for a more explicit (and thus conscious) trade off instead of the implicit one that generally occurs.

In traditional economic decision making a cost-benefit analysis (CBA) is performed using a limited set of financial parameters, such as capital investments and expected returns. When considering ecosystems, more often than not the costs and benefits are not marketable and readily observed, but are rather side effects generated by a main activity that have multiplying effects down the physical interaction chain such as flood protection provided by standing forests. Decision makers, thus, require the development of several alternative scenarios that ultimately must be weighed upon their holistic costs and benefits, encompassing all users, in order to illustrate and guide an as wise as possible decision. CBAs of this nature are known as extended or environmental cost benefit analysis (Van Beukering, 2005).

Ecosystem valuation is central to extended cost benefit analysis since it enables us to identify these interlinked relationships that exist between Nature and socio-welfare. These relationships can then be analysed as to their likely impacts under different management and development scenarios, such as decisions over conservation, logging or selective logging, in order to arrive at a decision that yields maximum socio-welfare gains or bears minimum welfare costs

In this chapter, a brief description of economic valuation and the values comprised in the TEV is provided. The description aims to illustrate that the principles of environmental economics have much to contribute to environmental analysis. The description is fairly general and does not attempt to provide a complete introduction into economic valuation. The following methodological issues are discussed: (i) Overall approach; (ii) Types of values; (iii) TEV over time; and (iv) Valuation techniques.

2.1 Overall approach

Decision-makers are called upon to make decisions on the basis of the full range of advantages and disadvantages of a particular policy. In order to make sound policy decisions, decision-makers need information on the benefits and costs of alternative options for addressing a particular environmental problem. In order to determine the costs and benefits involved in a particular decision, a wide range of information is required. A plausible way to organise this information is to pursue the sequence of underlying processes, starting with the cause of an impact such as deforestation, on to the physical impact like for example, reduced flood control, and ending with the social and economic effects in this case being increased damage from floods.

For this study we have adopted, to the extent possible, the impact pathway approach (EC, 1995) for valuing the environmental goods and services of the Aceh Forest Ecosystem. The impact pathway approach is a methodology that proceeds sequentially through the pathway, linking causes to impacts as described above, and valuing these impacts sequentially. The advantage of this approach is the fact that it offers a reasonably high level of transparency, and offers a large potential of comprehensiveness to those less acquainted to such studies of ecosystem valuation. The framework of the impact pathway is shown in Figure 2.1 and represents the physical and socio-economic processes resulting from deforestation of the Aceh Forest Ecosystem.

The impact pathway approach proceeds in a series of methodological steps. A pathway typically contains the following steps:

- Stage I: Defining the study boundaries (*i.e.* impacts on ecological functions/ services);
- Stage II: Identifying the physical impacts that are economically significant;
- Stage III: Quantifying in physical terms the significant socio-economic effects;
- Stage IV: Calculating monetary values and conduct sensitivity analysis.

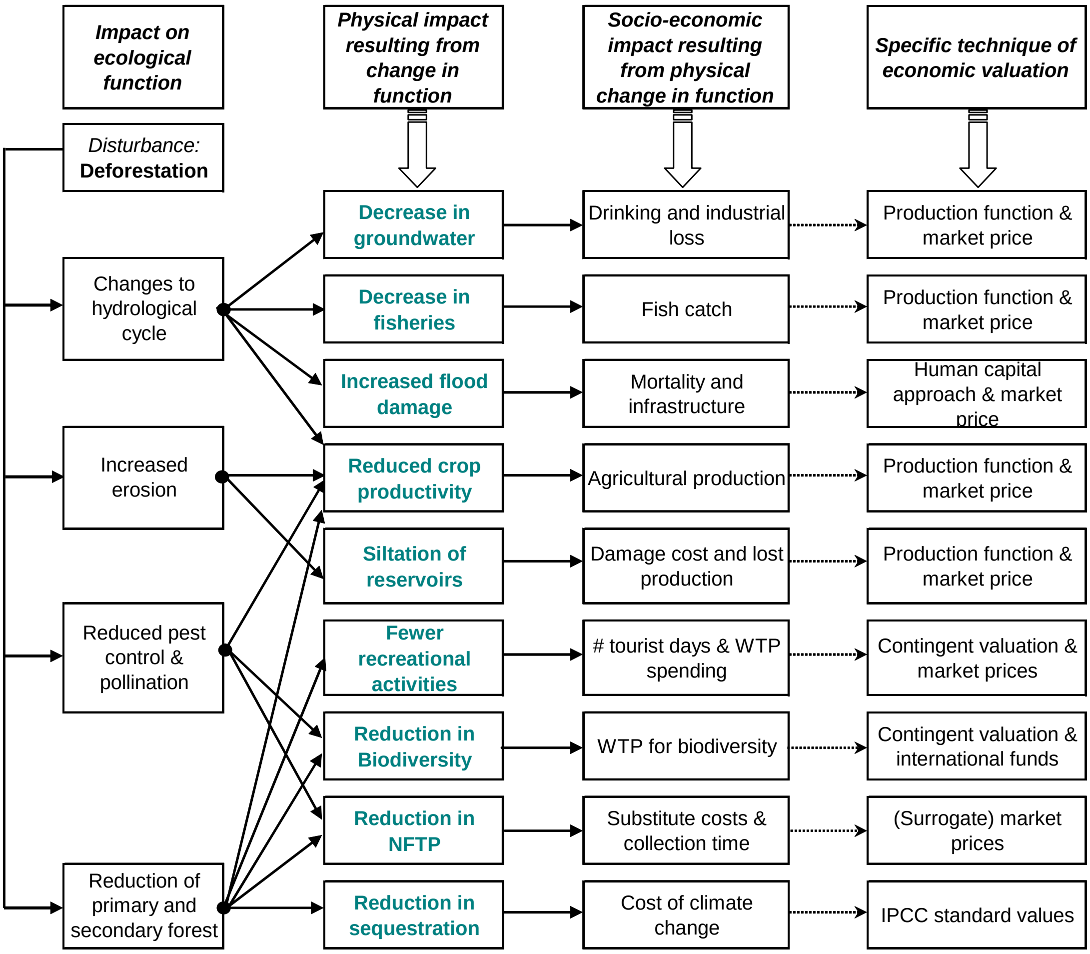

Figure 2.1 Impact pathway approach for the Aceh Forest Ecosystem.

In reality this 'ideal' approach can generally not 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 show which factors and assumptions influence overall results the most. Further, the quantitative analyses of the uncertainty can often be complemented with more qualitative considerations adding value to the overall results.

Stage I: Defining the boundaries of the study:

To maintain a transparent and comprehensible overview of the TEV of the Aceh Forest Ecosystem, only two scenarios are analysed. These two scenarios are: (1) Continued deforestation; and (2) Conservation of the Aceh Forest Ecosystem. These scenarios are further explained in the following chapter.

To estimate the TEV of each scenario, all project boundaries should be clearly defined. The temporal boundary of the project is set for the period 2008 to 2038. This period leaves enough time for the main environmental effects to come into effect, while it is short enough to still be able to make some prediction about future developments. The geographic boundaries have two dimensions. The boundaries of the actual forest ecosystem area in Aceh are used as the area where certain policies could be addressed. The beneficiaries, however, are not limited to this area. For example, also tourist benefits arising for travel agents abroad may change as a result of changes in the Aceh forest ecosystem.

Stage II: Identifying impacts that are economically significant:

Effects may be either economically significant or insignificant. Only the former category is relevant to this appraisal. Inevitably, judgement must be used in deciding what is and what is not significant. In order to judge the magnitude and significance of environmental effects, a range of criteria may be identified:

- The effect on the natural, human, chemical and physical environment depending on their relative sensitivities,
- The location of the effect, whether within the confines of the study site or beyond (local, regional, national and international),
- Timing of the effect (during the construction, operational or post-operational stage),
- Whether the effect is reversible or irreversible, and
- Whether the effect is positive or negative.

A general rule is that only first order effects should be evaluated. In other words, one would, for example, estimate and value the agricultural production loss due to the lost natural function of pest control of the rainforest. Second order effects, say, environmental and health effects caused by the increased use of pesticides due to the reduced function of pest control are ignored.

Stage III: Physically quantifying the significant impacts:

The evaluation of the physical effects of deforestation of the Aceh forest ecosystem is a very complex exercise. Ideally, a dynamic simulation model assists in predicting the precise physical consequences of the various scenarios. As this task is beyond the scope of this project, a basic spreadsheet model has been designed. The spreadsheet model approximates the main effects of each scenario on the various benefit categories.

Stage IV: 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 that will be covered in the respective chapters include:

- Changes in *water supply* (households/industry) due to lower groundwater availability and changes in run-off patterns;
- Changes in *fisheries* catch due to destruction of breeding grounds and aquaculture farms;
- Damage to health and infrastructure due to increased *flooding*;
- Changes in *agricultural* production due to reduced water availability, increased erosion and reduction in pest control and pollination by the rainforest;
- Damage to *hydro-electricity* due to increased sedimentation;
- Changes in the *tourism* due to degraded forests and rivers and depleted biodiversity;
- Reduction of *biodiversity* due to habitat destruction.

- Changes in production of *timber and non-timber forest products* due to deforestation;
- Changes in *sequestration* of carbon due to reduced forest area.

2.2 Types of values

Although the terminology regarding the TEV is still not completely agreed upon, and can sometimes be somewhat confusing, all discussions of the TEV take as a starting point that there are two main sources of value: use value and non-use value. This distinction is illustrated in Table 2.1.

Utilitarian or use values refer to the value of using ecosystem services for both current and future benefits (Constanza, 1989). Utilitarian values can be subdivided into direct use and indirect use values. Direct use values are derived from the uses made of a forests resources (Brander *et al* 2006) and may include; subsistence fishing (whereas the fish breed and live forest rivers and may be dependent on the nutrient cycle the forest provides); timber extraction, wood for charcoal; recreational uses like hiking and tourism. Indirect use values are usually harder to define since they are often not obvious and neither are they directly marketable. They include flood protection, nutrient cycling, erosion control, groundwater recharge, and carbon sequestration. A classic example of an indirect use value as it relates to rainforests ecosystems is the water retention function that the forests support to downstream agricultural areas, the benefits are often accrued outside the forest sometimes very far away. These indirect services are often harder to value since their relationships with marketable goods are often not existent and if so are not clear. Property rights are also a problem in this area since the benefits of the services do not always accrue to the owner of the forest. This causes the forests to be overlooked and undervalued in important forest conversion decision-making (Brander *et al* 2006).

Table 2.1 Total Economic Value, use values and non-use values in Aceh forest ecosystem.

Use values			Non-use values
(1) Direct value	(2) Indirect value	(3) Option value	
Sustainable timber	Watershed protection		Bequest or existence value
Non-timber forest products	Nutrient cycling	Future use as per (1) and (2)	Cultural heritage
Recreation and tourism	Air pollution reduction		
Medicine	Micro climate functions		
Plant genetics	Carbon sequestration and storage		
Education	Biodiversity		
Human habitat	Erosion control		
Water supply	Pollination		
Raw materials	Soil formation		

Source: Reproduced from Bann, 1997 with added categories

The bequest value relates to an individual's WTP to secure the continued existence of a good or service so his or her heirs can (or have the option to) use it in the future. In our opinion, the term 'intrinsic value' is somewhat unluckily chosen.

2.3 Comparing TEV over time

Most projects and scenarios yield benefits at least intermittently over its lifetime, 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 (NPV)[1] by discounting both categories of values. Discounting is the practice of placing lower values on future benefits and costs as compared to present benefits and costs, reflecting peoples' preferences for the present rather than the future. The usual way to deal with temporal effects in the analysis is to apply a discount rate to future impacts. Suppose an annual damage of the value X \$ will occur over a period of T years, and a discount rate of r per cent is applied, then the present value of the total damage over time is:

$$\sum_{t=0}^{T} X / (1+r)^t$$

Discounting is always a delicate issue. The choice of a time horizon and a discount rate can greatly influence the results of a TEV. This study follows the recommendations of the UK Government to utilize a discount rate of 3.5% (HM Treasury, 2003). To deal with the controversy and to cater for different time preferences of the reader we apply different discount rates in the sensitivity analysis as to allow the decision maker to choose the most appropriate rate.

If all effects are measured in monetary terms, the aggregation is straightforward: Simply sum the total discounted annual net benefits. This results in the TEV expressed in Net Present Value (N*PV*) terms:

$$NPV = \sum_t (B_t - C_t) \cdot (1+r)^{-t}$$

where B is all benefits over time and C is all costs over time. The scenario with the highest NPV is most preferred from an economic point of view. For example, if the 'conservation' scenario generates higher discounted net-benefits than the 'deforestation' scenario, the following condition would hold:

$$NPV_{conservation} > NPV_{deforestation}$$

In practice, however, not all effects can be expressed in monetary units and some effects can only be assessed qualitatively. Therefore, $NPV_{conservation}$ or $NPV_{deforestation}$ can not always be directly compared. This may explain part of the variation in values in earlier

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[1] The net present value (NPV) is a way of bringing a stream of future monetary flows to a "present value" in order to make such streams comparable to any other monetary choice possible in the present. The NPV is calculated by discounting the stream of money by a certain discount rate, which represents the time preference shown when comparing something today against the same thing tomorrow. The vast majority of people would prefer to have something in the present than in the future, and this "rule" applies unquestionably for nearly everything man produces such as soft drinks, houses and wrist watches. The same cannot be said, however, for nature and irreversible events, such as the loss of a species due to over-harvesting or habitat degradation. Many argue that the discount rate should even be negative (i.e. the future being more valuable than the present) when "discounting" nature's services and other values such as existence and bequest values.

studies investigating the NPV of rainforests conversion. It is important therefore that the NPV, based on the quantifiable parts of the TEV should not be the sole criterion for selection. All impacts should be mentioned in an analysis irrespective of quantification or not. It is better to give a description of the impacts than having no valuation and not mentioning the impact at all.

2.4 Valuation techniques

The last column of Figure 2.1 shows the specific valuation technique applied to estimate the economic value of a particular effect. The selection of a specific valuation technique depends on the characteristic of the cost or benefit to be valued. Broadly speaking, the monetary values that comprise the TEV can be broken down into costs and benefits for which the following four categories apply (Van Beukering *et al*. 2007):

1. Market prices exist that correctly reflect social values (e.g. Non-subsidised farm commodities);
2. Market prices exist that do not correctly reflect social values (e.g. Subsidised electricity);
3. No market prices exist but appropriate social values can be approximated in monetary terms by inferring what consumers would be willing to pay for the product or service if a market existed (e.g. Eco-tourism),
4. No market prices exist and it is difficult to simulate a market-like process capable of registering a meaningful monetary value (e.g. cultural or religious values).

Applying market values of the category (1) and (2) can capture many of the benefits of the Aceh forest ecosystem. As mentioned, some values can be based directly on market values of productivity. For example, if water shortages adversely affect agricultural yields in the region, the values of foregone crop losses can serve as a measure of the environmental damage of insufficient investments. This technique is called the 'production function approach'. A similar approach can be followed for industrial output. Other items can be indirectly valued on the basis of market prices for surrogate products or services. For example, unsustainable forestry may lead to a lack of firewood. The alternative sources of firewood, such as petroleum, may again represent the external environmental value of mismanagement.

The more complicated benefits are the ones listed in category (3). Because they occur outside the market, these benefits originate from 'externalities'. The techniques for the valuation of these non-market effects are generally classified into methods that are derived from 'stated preferences' and values that are based on 'revealed preferences' (Freeman 1993). Revealed preference methods calculate external benefits indirectly by using the relationships between environmental goods and expenditures on market goods. This category includes, for example, the averting behaviour method (ABM) and the hedonic pricing method (HPM).

Stated preference methods ask the individuals their willingness to pay (WTP) for the environmental good directly by using structured questionnaires. The WTP is defined as the maximum amount of money a person is willing to pay to obtain a good or service. An individual's WTP for a good is a reflection of his/her preferences for this good relative to other goods. The contingent valuation method (CVM) is the most well-known technique belonging to this category. In this study, the stated preference method is applied to estimate non-market goods such as biodiversity and the perception of health risks.

A complete description of all these methods is beyond the scope of this report, and the descriptions will be very brief. More extensive discussions of these methods can be found in the papers in Braden and Kolstad (1991) or in Freeman (1993). These two references provide extensive discussion of the micro-economic foundations of these methods and also of the econometric issues involved in applying these methods. Dixon and Sherman (1990), Brown et al. (1993) and Bann (1998) provide a very practical and detailed description of the steps involved in applying the methods described below, specifically designed for the valuation of tropical rainforest. Appendix section 9.2 provides an overview of several valuation techniques.

3. Background, boundaries and physical impacts

As previously explained whilst following the impact pathway approach it is necessary to firstly define the study boundaries and the treats to it followed by identifying and estimating the physical impacts which these threats may have. This chapter elaborates on these issues by addressing the following aspects:

- Defining forest types in Aceh
- Main threats for the Aceh forest ecosystem;
- Defining future scenarios;
- Ecological impacts of deforestation.

3.1 Forest types

The forests, although distinct in flora and fauna due to their geological divisions comprise of several similar ecosystem types namely; Lowland forests; Montane forests; Freshwater Swamp forests; Mangrove forests and; Peat Swamp forests. A brief description of each biome follows below.

Lowland Forests are found typically below 1200 metres above sea level (masl). They are rich in valuable timber namely tropical hardwood of the *dipterocarp* family that typically grows at much higher density than similar hardwood species such as Teak and Mahogany in South America for example. The high density of these species and the fact that lowland forests areas are most suitable for post logging conversion into plantations makes timber extraction a very financially attractive venture even on high gradient slopes. In the past, harvesting of lowland forests could yield up to $100m^3$ of valuable timber per hectare (Whitten *et al* 2000). The lowland forests also exhibit enormous diversity of both fauna and flora and are among the most diverse ecosystems in the world (Blackett and Irianto, 2007). Due to its high species diversity and density, the lowland forests are also the largest repositories of carbon, containing as much as 500 tons of biomass per hectare (Whitten *et al* 2000). Balancing the immediate revenue from timber extraction with the future option value of carbon sequestration is an important decision making consideration that will be explored later in this report.

Box 3.1 Haiti: deforestation causes more landslides.

The Caribbean Island of Haiti has seen 98% of its once standing forest cover depleted. Hillsides once covered in forest are now bare and exposed to the elements. Despite the vast commercial exploitation of the counties natural resources Haiti still remains one of the poorest countries in the world and the poorest in the western hemisphere.

Recent hurricane Gustav that swept over Haiti on the 26th August 2008 caused landslides on the southern peninsula claiming 15 lives and causing vast devastation. Without the tree cover landslides are becoming more and more frequent and hillside agriculture is repetitively lost. Deforestation of mountain forests has served to further entrench the people of Haiti in poverty with little sign of improvements.

Photo credit: Panorama Productions
Source*:* News Bulletin on Newser.com. Report by Jonathan M. Katz August 27th 2008

Montane Forests are found typically above 1200 masl and stretch up to areas at altitudes of roughly 3000 metres beyond which tree cover gradually gives way to grass and scrub lands. Up to roughly 2100 masl the montane forests inhibit similar species characteristics of the lowland forests however with increasing altitude tree species grow smaller and eventually the dominance of the *dipterocarp* gives way to trees belonging to the Oak and Laurel family (Whitten *et al* 2000). The Indonesian ministry of forestry (prior to the current moratorium) permitted timber extraction up to an altitude of 2000 metres and on slopes of up to 40% gradient (or up to 15% if a large risk of land slides and erosion existed)[2] (Blackett and Irianto, 2007) meaning that very little of the ecosystem was out of the reach of the logging concessionaires. Forests located on steep gradients such as montane forests serve to hold together the topsoil and prevent erosion caused by heavy rainfall. The deforestation of forests on steep slopes is of grave concern since it reduces the soil cohesion and can lead to landslides often damaging property, infrastructure and causing loss to human lives (see box 3.1) The increased protection of montane forests has to be a priority for the provincial government of Aceh and indeed that of the national government. Protected montane forests can also be expected to qualify for carbon credits in the future given the further development of this new market thus creating a source of revenue for avoided deforestation.

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2 Regulation SK101/Menhut II/2004

Freshwater Swamp forests are found in areas that are perennially inundated by swelling rivers or heavy seasonal rains. The perennial flooding often results in highly fertile soils and thus these forest types are under high pressure for draining and conversion to agricultural land. Whitten *et al* (2007, cited in Blackett and Irianto, 2007) reports that these types of forests once comprised of 450,000 hectares in Aceh, although today only small-interspersed patches remain. Similar to montane forests a future option value exists for the carbon storage these forests inhibit if conserved.

Mangrove forests, although vastly different from the aforementioned forest types are highly important for the marine ecosystem as a source of rich nutrients such as nitrogen and phosphorous. Mangrove forests also play an important role in preventing salt water intrusion, coastal flooding protection as well as filtering harmful chemicals in land to sea water flows thus preventing the deterioration of the marine ecosystem. They also provide an important habitat and nursery for marine and riverine species. Various studies exist showing the important linkages between mangrove ecosystems and marine fisheries especially shrimp, an important commodity of high trade value (e.g. Barbier, 1994, 2000, Barbier and Strand 1998, Sathirathai, 1997, Ellison, 2007). Turner in Whitten *et al* (2000) estimate that the destruction of one hectare of mangrove forest results in a reduction of 480 kilos of offshore prawn catches per year (cited in Blackett and Irianto, 2007, pp 12). The conservation of mangrove forests should be an important consideration given its highly valuable function in maintaining marine fish stocks offshore, an important commodity for the population of Aceh as will later be illustrated.

Peat Swamp forests are found mainly along the west coast in Aceh. They comprise roughly 250,000 hectares and occur on poorly drained lands that eventually turn into deep peat with low soil acidity. Few species of commercial value can be found on such forest type. The carbon content of the peat however is high and if cleared, drained and converted to agriculture can result in high releases of carbon dioxide into the atmosphere.

3.2 Threats

Forests in Aceh are rich in tropical hardwood species like *semaran, meranti* and *merbau* that are high priced making logging a highly attractive venture. This and the pressure to expand the area and production of valuable cash crops such as oil palm and coffee are the major factors driving deforestation in the province. The two major threats envisioned for the conservation of the forest resources in Aceh are therefore logging and land conversion to plantations.

Until the early 1970's for a number of historic and geopolitical reasons Aceh remained largely a marginal and economically underdeveloped province within Indonesia. Its population in 1971 was exactly 2 million spread primarily along the provinces coastline. Between 1976 and 2005 the province suffered from strong guerrilla resistance against the central government by the *Gerakan Aceh Merdeka* (GAM) The central government by means of the Indonesian army (TNI) reacted with massive military force to prevent independency of the province. During the first period of the war (1976-1990) large concession areas were granted to business partners of the army under their vigilance irrespective of formal land categorisation and status. Logging operations, legal and illegal followed by encroaching agriculturalists plagued upon the forests. As a result deforestation in the province began to grow. Despite the growing deforestation the rate was believed to be low considering the hostile environment serving to keep many commercial opportunists away. Whilst the rate of deforestation during the period is not known unpublished studies by Conservation International estimate that the annual deforestation rate between 1990 and 2000 was of 0.86%. (Usher and O'Niles 2007, pp.22)

In 2004 the tsunami caused vast devastation to many coastal communities. It claimed the lives of approximately 150,000 people and destroyed 127,000 households leaving over half a million people homeless. Moreover it destroyed a large amount of infrastructure from roads to factories to aquaculture farms as well as destruction of over 37,500 hectares of productive land (Provincial Government of NAD, 2007). This has placed an enormous added pressure on the provinces' forestry resources as people begin the arduous process of re-construction.

In August 2005 Aceh signed the Helsinki Peace Accord bringing peace to the province following years of conflict. Since the peace accord trade insecurities have eased and the market has opened up. Illegal timber operations and oil palm plantations have gained ground in the area, the former has been further stimulated by the tsunami and the resulting increased demand for construction materials. Since 2004/2005 the demand for timber has increased threefold from around 260,000m^3 to about 700,000 m^3. Illegal logging has become rife aided by corruption and high demand for the resource. Official government estimates suggest that forests in Aceh are disappearing at a rate of 21,000 ha per year (0.67% per year) (Provincial Government of NAD, 2007) however this rate is believed to be vastly under-estimated. Usher and O'Niles (2007) estimate a more realistic deforestation rate post tsunami and peace accord to be in the region of 1.3% per year.

Logging in Indonesia is intended to follow the requirements of the Indonesian Selective Felling and Replantation system (TPTI – *Tebang Pilih dan Tenam Indonesia*) (Blackett & Irianto, 2007). This system came under fire in 1997 when Yasman (1997) reported difficulties in its implementation and management and drew questions over the systems overall ability to ensure sustainable forest timber harvesting. Such difficulties include ill defined property rights, confusion over concession boundaries and an inability to enforce regulations. Often commercial logging companies break regulations i.e. over-logging; this can be done either inside their designated logging concession or outside their logging concession. Illegal logging inside approved logging concessions; by either local people or by bands of illegal loggers who parasitise on a logging company's concession are also to blame for the ineffectiveness of the TPTI, a problem which ultimately roots from a lack of funds and/or will for enforcement. The crux of the problem facing efforts to stop illegal logging, however, is corruption and collusion within the enforcement apparatus.

3.3 Development of a Green Aceh

Since the recent elections in December 2006, which saw Irwandi Yusuf, elected as the first democratic governor or the province of Aceh, Governor Irwandi has endorsed a Green Economic Development and Investment Strategy for Aceh Province. The plan is to conserve some 3.1 million hectares of forest leading to the effective protection of the forests ecological integrity involving the local (Kabupaten) Governments. The plan is set to represent a major pillar of 'good governance' and set the foundations for investments in forest conservation and earn revenues from the varying ecological services/assets provided by the forests. Unlike other provinces in Indonesia, the province of Aceh was in 2006 confirmed as an autonomous state following the signing of a Memorandum of Understanding between the Indonesian National Government and the Free Aceh Movement (GAM). Aceh is the only region in Indonesia to receive such status and the movement provides hope for Aceh's forest resources allowing the local government to control its fate and determine the rules of extraction and conservation.

Following years of ineffective and corrupt administration and a cut and run mentality by the private sector, the Governor has appointed a Redesign Team of experts to advise him on a new institutional set up for forest land allocation and management by December 2008. The forest redesign covers all aspects of forest management including planning, monitoring, conservation, sustainable utilisation, conversion and marketing of forest assets. "The new strategic concept is based on the premise that the will to protect a potential economic asset can be stimulated by generating financial revenues from the functions of the intact forest" (FEDA, 2008, pp6). In order to attract foreign investment and market other assets of the forest, two conditions must be met; "(1) A forest law which gives clear custodian rights to an Authority so that such an Authority can be held accountable and; (2) A professional authority with full administrative and political backing of the government" (FEDA, 2008, pp.5) A moratorium on all logging activities has been put in place since June 2007 to allow the governor and associated parties time to develop this plan and the new laws. It is envisioned that once the Green Economic Development and Investment Strategy is established, very little disturbance to existing forest areas will be tolerated and none whatsoever within protected areas.

3.4 Scenarios

Following the earlier performed TEV of the Leuser Ecosystem (Beukering *et al* 2003), a large part of which is contained within this study's study area, we have chosen to adopt the same scenarios as used previously. Two scenarios have been selected based on stakeholder and policy consultation performed by Van Beukering in 2003 and they are as follows:

Deforestation: In the 'deforestation' scenario, the current trend of controlled and uncontrolled logging and unsustainable harvesting of non-timber forest products is assumed to continue. Eco-tourism will not be developed, international interests to invest in conservation and carbon sequestration funds disappear, and various ecological services of the rainforest to the local community decrease. If current enforcement conditions remain the same, this development is likely to occur.

Conservation: The logging of primary and secondary forest entirely ceases in the 'conservation' scenario. No timber revenues, and only a limited amount of non-timber forest products (NTFP) accrue. In this scenario, eco-tourism will be developed to its maximum allowable potential, international interests to invest in conservation funds remains high, carbon sequestration funds increase and various natural functions of the rainforest for the local community are completely maintained.

By selecting these two extreme scenarios the physical and socio-economic effects are most prominently presented, thereby supporting the didactic purpose of this study.

3.5 Changes in underlying drivers of ecosystem services

As shown in the first column of Figure 2.1, deforestation causes four main ecological function drivers to change. These include water retention, erosion prevention, pest control, and forest cover. The assumptions underlying the change in these ecological function drivers are described below.

Reduction of forest area

The reduction of forest area is the main driving force of the impact pathway. In the deforestation scenario, a pattern is assumed with an increased intensity of deforestation, especially in the first decade. After 2018, the logging intensity declines because only the less-financially-attractive highland forests remain. I.e. the lowest hanging fruit have been picked leaving the harder to pick overlying ones. The 30-year average deforestation rate is assumed to be 1.6% per annum, which is a weighted average between the 5-year deforestation rate in Ulu Masen and the Leuser Ecosystem. Due to the steep slopes of the highlands, only part of the deforested lands is converted into plantations. Therefore, the so-called ‘waste lands’, mainly consisting of grass lands (namely: alang alang), increase substantially. In the conservation scenario, the allocation of the different forms of land-use remains the same as present in the year 2008.

It could be argued that ‘conservation’ also implies rehabilitation of degraded forests. In fact, The Green Vision report states that some 250,000 hectares of degraded forest should be rehabilitated and added to the “permanent forest estate”. However, we decided that given the high population pressures, this strategy might be too difficult to achieve\. Therefore, we follow a conservative approach and assume that no degraded land is reforested. This implies that the estimate for the conservation scenario can be considered a lower bound estimate.

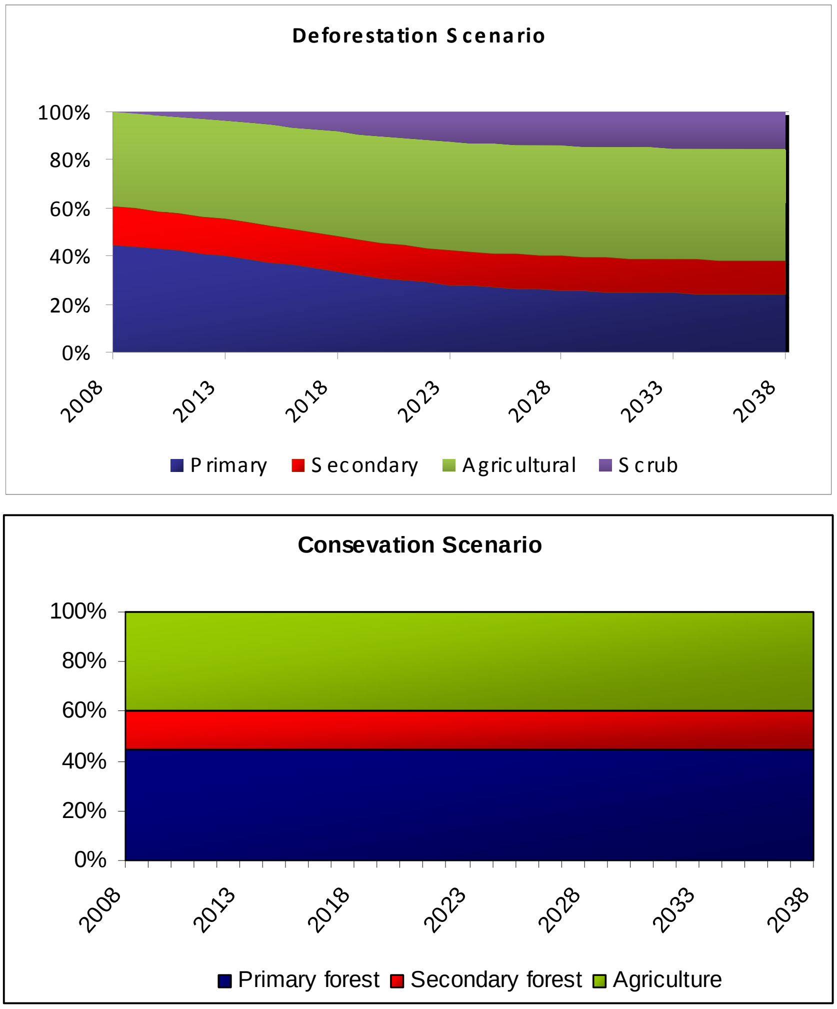


Figure 3.1 Shows land use change over both scenarios.

Increased erosion

World wide, each year around 16 million hectares of arable land are lost as a result of soil degradation and erosion (UNEP Global Assessment of Soil Degradation (GLASOD, 1990) study). Soil erosion is one of the most serious threats to the sustainability of agriculture, silviculture and forestry. Various studies have shown that natural ecosystems are more efficient in erosion control than systems where the understory is removed or the litter layer is removed or destroyed as in e.g. forest plantations or overgrazed pastures (e.g. Wiersum, 1984; Bruijnzeel, 2004).

In Figure 2.1 increased erosion (the change in ecological function) results in two physical functions: Reduction in crop productivity and damage to hydro electric plants. Moreover, the related increase in sedimentation and euthropication negatively affects fresh water and marine fisheries through the degradation of the spawning and breeding grounds. Whilst the link between the physical function and the socio-economic effect will be dealt with in turn in the following chapter this chapter seeks to examine the link between the change in forest cover and the physical impact.

Under this sub category there are seen to be two defining links; (1) from land use to erosion and; (2) from erosion to sedimentation. Erosion is the removal of topsoil and nutrients from a land mass, sedimentation is the (gradual) transportation of the eroded particles either from one location to another within the same ecosystem or out of the ecosystem altogether. The former has implications for agriculture and newly converted land for agriculture whilst the latter has implications for the operation of hydropower plants.

It has been claimed that groundcover rather than canopy is the defining factor as to the rate of erosion (Chomitz, 1998). Whilst the canopy often acts to slow the passage of water to the ground this is seen to be the case for only the first few minutes of a heavy downpour and once penetrated, the drops are actually intensified by the canopy due to the drip tips classic to most rainforest leaves. This has been widely documented (e.g: Wiersum 1985; Hamilton 1987 and Brandt 1988). Forest groundcover is typically dense, with decomposing organic material (litter) acting as a cover to the bare soil beneath. It increases the permeability of the topsoil for water and slows the velocity with which raindrops hit the soil surface. The removal of this groundcover leads to the soil being directly exposed to rain drops and flowing surface water and is subsequently carried away (eroded). In plantations where weeds and litter debris remain on the ground erosion rates can be quite similar to those experienced in natural forests. However in slash and burn plantations where the ground cover vegetation and debris is perennially burned to release nutrients back to the soil, erosion rates can be up to 100 times higher than in the natural forested counterparts (Wiersum (1984), reproduced in Bruijnzeel 1990. p 117). Oil palm plantations typically involve clearfelling and burning the land following logging activities thus exposing the topsoil to erosion.

Often erosion is also caused as a result of road building. Access roads to logging concession sites have been reported to increase erosion by up to four times over an entire area and up by a factor of 260 if only considering the area covered by the road itself. Thus Hodgson and Dickson (1988 recited in Chomitz 1998) found that for a forest in the Philippines, although roads only accounted for 3% of the surface area, they were responsible for 84% of the surface erosion. Erosion is also increased as a result of soil compaction, which can be caused by a number of activities like, mechanized agriculture, logging machinery and cattle herding. Soil becomes more compact thus reducing its capacity to absorb water (infiltration) and water washes over rather than infiltrating, resulting in erosion.

It is fair to conclude that erosion does indeed increase as a result of forest clearing, particularly when the alternative land use results in higher exposure rates of the top soil (i.e. the layer of litter is removed) and/or compaction of the soil, however this leads onto the issue of sedimentation.

Sedimentation is the motion and transportation of sediment particles (in this case resulting from erosion) away from one area to another, usually by force of gravity and transported by water. The sedimentation rate as will be later addressed plays an important role in the functioning of a hydro power plant. Various studies have attempted to study the rate of erosion and the associated transportation (sedimentation) of the eroded matter away from the site of erosion with mixed results. The amount of sedimentation depends on the size of the catchment basin as well as the geology, pedology and more importantly the gradient of the land (relief). In a larger basin, more areas exist to trap sediment than in a smaller basin and in basins characterised with steep slopes, groundwater flows faster thus potentially carrying more sediments away and faster. Mahmood (1987 recited in Chomitz 1998) suggests that the sediment delivery ratio declines from almost 100% in small basins measuring 200 ha, to about 10% in larger basins of millions of square kilometres.

Sedimentation ultimately clogs up rivers, raising the riverbed and interfering with hydro-power plants. It also represents a net loss of nutrients to a ecosystem where as these nutrients are lost forever. The erosion of sediment leads to shorter agricultural land lifespan as well as reduced yields culminating from the diminishing nutrients. In this study, increased erosion has been incorporated indirectly as a degrading impact on agriculture. This influence varies for the type of crop and across the districts. At the same time sedimentation has been integrated into this study under the deforestation scenario as altering the lifespan and potential costs of hydropower generation.

Changes in hydrological cycle

The water-vegetation interaction with this change in ecological function follows the same function as described in section 3.3.2 (erosion control). Natural forests serve to regulate the hydrological cycle. They attenuate water during heavy downpours by trapping the falling water firstly within the canopy and secondly by infiltrating it into the soil and groundcover. The run-off of rainwater is attenuated and partially absorbed by the soil and roots of the vegetation. This water is then released at slower rates, helping to keep the annual flow of water constant. Dry season river flows are often largely fed by the slow release of water from forest soils. Deforestation is known to reduce the water retention and release function of rainforests. As a result, the frequency and intensity of extreme events, such as floods and droughts, increase. Moreover, due to the change in the micro-climatic conditions, caused by deforestation, less water will be generated in perpetuity by the Aceh forest Ecosystem.

The water retention and hydrological control functions that natural forests provide is a very important feature which is often not easy to quantify. With this change in ecological function 4 physical changes in the impact pathway map (Figure 2.1) were identified stemming as a result of the change namely: decreases in groundwater recharge, decreases in fisheries, increased flood probability/intensity and reductions in crop productivity.

Forest serve to regulate water flows in various ways. Their floors comprising of decaying leaves and porous soils can easily accommodate heavy rains store the water and then slowly release it later. Some of the water remains in the canopy eventually evaporating without even touching the ground. Some of the water evaporates off the ground and gets trapped between the canopy and the ground as a fine mist, later to condense and flow away. Trees absorb much of the rainfall and later transpire it back into the air (evapotranspiration). Forest soils are often lightly packed and infiltration rates are fast. Needless to say the interaction that forests play with water is highly complex and interrelated. A series of changes can occur as a result of changing land use. These changes occurring largely depend on what happens to these countervailing influences of infiltration and evapotranspiration.

Deforestation can have a pronounced effect on the timing and intensity of floods and dry-season flows. However the exact relationship is difficult to identify. Whilst a reduction in tree cover increases the runoff speed, it can also reduce rainfall due to the microclimate function that rainforests have. However on the other hand, a reduction in evapotranspiration of rainfall can result in an increase in water actually reaching the ground, thus Chomitz mentions that: 'Converting a tropical moist forest is roughly equivalent, in water yield, to increasing rainfall by 300mm per year (2006, pp118). During heavy rains, depending on the alternative land use, water will run off faster thus increasing the likelihoods and intensity of floods.

The relationship between dry-season flow and deforestation on the other hand is not so clear and likely to be counterintuitive. This is because the conversion of forest to alternative land uses has two opposing effects on the ground water table. On one hand it increases run off since the canopy is no longer slowing water fall and neither is the ground litter attenuating surface run-off. Absorption into the ground is also lower especially if the alternative land use is causing soil compaction. This by itself would serve to lower groundwater tables. On the other hand however, trees are very efficient water pumps removing water from the ground and transpiring it into the air. Replacing trees with crops with shallower roots can serve to increase the ground water content (Chomitz, 1998). Studies by Vincent *et al* (1995) in Thailand, Hamilton and King (1983) in various locations and Nepstad and Schwarzman (1992) in the Brazilian Amazon found that deforestation actually increased dry season groundwater tables however, Hamilton and King (1983) and Kumari (1995) found the contrary in other locations where soil compaction and gulling resulting from alternative post deforestation land uses actually served to reduce the dry season ground water tables. This is backed up by more recent reviews on the subject by Bruijnzeel (2004) where he reports that decrease in dry season water tables is mainly a result of post deforestation land uses rather than deforestation in itself but can also be more prone to occur in areas characterised by clearly defined wet and dry seasons.

Studies by the Leuser Development Programme have showed that in at least the Leuser National park (a large part of which falls into this reports' study area) water tables are actually falling, causing a marked reduction in river flows. For example, compared to 10 years ago, approximately 50 percent of the streams in Aceh have less than 50% of the water flow in the springtime. Approximately 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 during the spring and roughly 15% of the rivers have completely fallen dry (LMU, 2000). Similar trends have been registered for precipitation in North Sumatra and Aceh.

Changes in the hydrological functions will impact the agricultural sector, fisheries sector, the supply of fresh water to households and the probability and severity of floods and droughts causing changes in socio-welfare, which will be exemplified in Chapter 4 and quantified in Chapter 5.

Reduced pollination and pest control

The high biodiversity value which tropical forests posses provide indirect services to agricultural plantations and subsistence producers located close to forests. Insectivore Bats native to forested areas can eat up to their own weight in insects each night. Very often the insects that they prey on are considered pests and nuisance to farmers and estate owners. Bats provide a valuable service to farmers in the sense that they are a natural pest control for agricultural producers, without which the application of artificial pesticides would increase, thus raising the cost of production. Bees and other nectar loving animals such as the humming bird provide valuable pollinations services for fruit trees and crops helping farmers ensure viable seeds for the next seasons production. Other ecological services provided by the high biodiversity of forests include: decomposition, seed dispersal, seed predation, herbivory and predation (Redford, 1996).

These influence the reproductive success of plants, contribute to soil fertility and serve as regulators of pest populations. A typical example of this function in the Aceh forest ecosystem is the role of the fruit bat. 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 almost certainly lead to the disappearance of durian in the Aceh (Mickleburgh et al. 1992). The degree of pest control is assumed proportional to the amount of remaining primary and secondary forest. The agricultural sector will experience reduced production and higher production costs the more forest that is logged.

3.6 Districts

The study region is made up of 18 districts (*Kabupatens*) and 5 municipalities (*Kota*) however, two districts have been aggregated to neighboring ones for data availability reasons due to the fact that they have only recently become officially autonomous and government data still shows them aggregated to the previous political divisions. The two districts concerned are Pidie Jaya that has been aggregated with Pidie and Subulussalam which has been aggregated with Aceh Singkil. This report therefore considers 16 districts (and 5 municipalities) as the study area. Each district will benefit in a different manner from the forest ecosystem, depending on the structure of the economy, population demographics, land cover, vulnerability for floods and fires. Unfortunately given the time span available for this valuation a per district illustration of how costs and benefits accrue is not possible and will only become possible given the collection of more segregated spatial data.

To get a better idea of the characteristics of each district, several economic and geographic indicators have been summarised in Table 3.1 and Table 3.2. A map of Aceh province showing the political divisions between districts can be found overleaf.

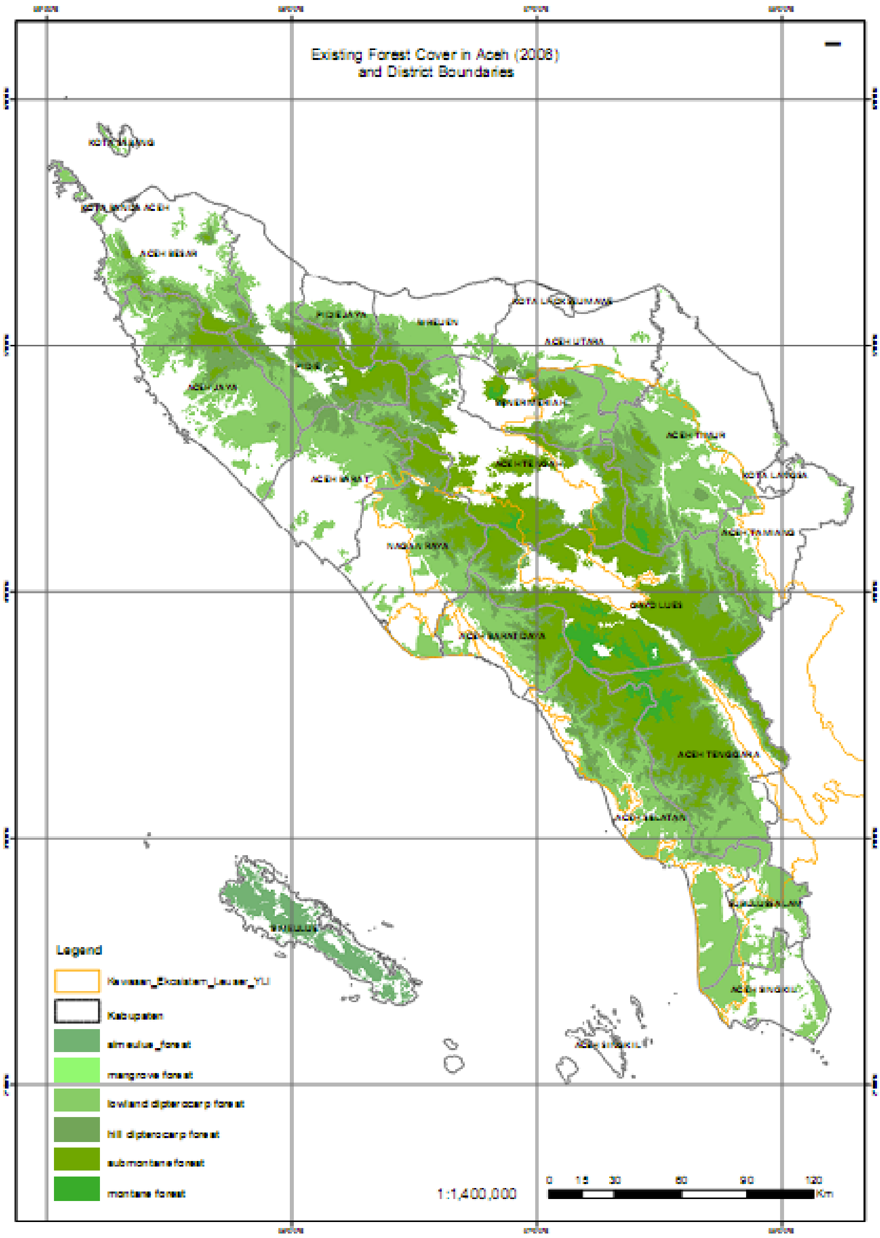


Figure 3.2 Map of Aceh Province showing district divisions and forest cover.

Table 3.1 Economic structure of the districts in 2007 (in million US$[3]).

Regency/industry	Fisheries	Agriculture	Industry	NTFP
Simeulue	2.89	15.65	Breakdown not available	1.16
Ache Singkil	8.28	100.33		0.73
Aceh Selatan	17.73	64.96		1.34
AcehTenggara	22.50	87.71		1.63
Aceh Timur	27.71	198.64		0.85
Aceh Tengah	5.44	37.99		1.24
Aceh Barat	7.56	92.58		0.81
Aceh Besar	9.53	128.37		0.49
Pidie	27.44	157.67		0.59
Bireuen	42.44	120.37		0.31
Aceh Utara	32.81	193.97		0.22
Aceh Barat Daya	16.18	92.43		1.12
Gayo Lues	0.50	37.85		0.60
Aceh Tamiang	25.65	148.34		0.35
Nagan Raya	3.90	163.53		1.05
Aceh Jaya	2.27	47.67		1.65
Bener Meriah	0.50	4.95		0.90
Kota Banda Aceh	11.52	2.82		0.10
Kota Sabang	4.18	0.70		0.22
Kota Langsa	8.98	5.23		0.10
Kota Lhokseumawe	11.16	3.44		0.10
Total	**289.19**	**1,705.21**	**4,604.18**	**15.55**

Source: BPS, 2007.

[3] Exchange rate used 1US$ = 9416 IRP

Table 3.2 Population and number of households.

Regency	Population	Number of households	Total Area (ha)
Simeulue	82,064	20,614	205,148
Ache Singkil	183,214	40,284	228,900
Aceh Selatan	218,138	60,955	385,169
AcehTenggara	170,105	39,632	418,926
Aceh Timur	362,611	87,808	604,060
Aceh Tengah	203,628	50,405	431,514
Aceh Barat	170,002	89,285	292,795
Aceh Besar	318,949	91,509	296,900
Pidie	528,715	133,391	288,529
Bireuen	365,973	88,883	190,122
Aceh Utara	534,411	153,137	323,686
Aceh Barat Daya	117,727	29,689	233,401
Gayo Lues	80,351	22,073	571,957
Aceh Tamiang	264,626	71,245	193,972
Nagan Raya	173,959	90,065	392,800
Aceh Jaya	64,141	19,582	381,700
Bener Meriah	125,075	38,194	145,734
Kota Banda Aceh	179,266	42,961	54,567
Kota Sabang	35,073	95,14	6,136
Kota Langsa	178,496	47,418	15,300
Kota Lhokseumawe	169,507	41,213	26,241
Total	**4,526,031**	**1,267,857**	**5,687,557**

Source*:* (BPS, 2007).

3.7 Stakeholders

Stakeholders play an important role in the Aceh forest ecosystem in terms of allocation of the benefits accruing in the deforestation and conservation scenario. Stakeholders can be viewed at different levels, distinguishing between various scales, such as local, national and international beneficiaries.

shows how the various changes in benefits are likely to affect the various stakeholders. Although the global benefits of conservation of the Aceh forest ecosystem may outweigh the total costs, the local costs of restricting access to an important resource as the provinces forests may be substantial for residents and communities. The imbalance between costs arising at the local level and benefits accruing at the national and international levels has raised questions about whether people living in or near pro_tected areas ought to be compensated for their losses, and if so, how compensation should be made (Ferraro and Kramer 1997). In the case of the Aceh ecosystem, however, it is not clear whether conservation would cause net costs for the local communities.

Table 3.3 Impact of deforestation on the main stakeholders of the Aceh forest ecosystem.

	Local Community	**Local Government**	**Elite (logging) industry**	**National Government**	**International community**
Water Supply	Expensive water	Cost to change distribution system	N/a	Cost to change distribution system	N/a
Fisheries	Loss of income	Loss of local taxes	N/a	Loss of federal taxes	N/a
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	Increases food prices, loss of production	Loss of local taxes	Lost production from plantations	Loss of federal taxes	N/A
Hydro-electricity	Production loss due to power cut, expensive electricity	Loss of taxes	Disruption of processing operations	N/A	N/A
Tourism	Loss of income from tourists	Loss of tourism derived taxes	N/A	Loss of foreign revenue	Loss of WTP for recreation, less international travel
Biodiversity	Reduced pollination and pest control	Loss of foreign revenues	Loss of pharmaceutical benefits	Loss of foreign revenues	Loss of WTP for biodiversity, research
Sequestration	Loss of potential foreign revenues	Loss of potential foreign revenues	N/A	Loss of potential 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
NTFP's	Short-term gain produc-tion, long-term loss	Loss of taxes	Short-term gain production, long-term loss	N/A	N/A
Timber	Short-term gain produc-tion, long-term loss	Loss of taxes	Short-term gain production, long-term loss	Loss of export revenues	N/A

4. Ecosystem services

Because the focus of the study is limited to the first-order effects, the valuation of the individual benefits of the Aceh forest ecosystem can be considered as separate and independent analyses. This assumption is not very heroic, because the benefits are to a large degree compatible and interrelated.

An intrinsically inherent problem with ecosystem valuation which environmental economists must deal with is the often un-exact science of ecosystem functions and derived services. It is reasonable to assume that in-order to develop a decision making tool which aims at preserving forests in the name of ecosystem services, there must be a clear understanding about the linkages between land use and economic activities. In order to do this it is needed to:

- Identify and quantify the specific services which forest ecosystems provide;
- Identify how these services are quantified into different user-group; and
- Value the benefits or costs to the user groups accordingly.

Whilst such knowledge is advancing in the valuation literature and many studies have been completed, no studies are viable without having to rely to a certain extent on assumptions over dose response effects of changing ecosystems. Arguably however, whilst we still don't know exactly the effects of land use changes on climate, water flows, erosion and sedimentation, the simple facts exacerbate a clear relationship between land use change and economic activities which cannot be ignored. The precautionary principle should be applied and assumptions must be accepted as long as they are properly backed up and/or tested for influence and sensitivity to the final results. In this study the analyses are based on a large number of methodological and empirical assumptions that are supported by the literature, expert opinion and anecdotal evidence. Other studies have also been carefully used in transferring benefits and underlying scientific relationships between ecosystems and their services. Major assumptions and other uncertainties are tested for sensitivity in chapter 5. The underlying assumptions of the following benefits will be explained:

- Water supply;
- Fisheries;
- Flood and drought prevention;
- Agriculture and plantations;
- Hydro-electricity;
- Tourism;
- Biodiversity;
- Carbon sequestration;
- Fire prevention;
- Non-timber forest products;
- Timber.

This chapter looks at each of the 11 sectors listed above in a logical format. Firstly the sector is described in terms to its relationship with forest cover secondly, an analysis of relevant literature is presented, furthermore the methodology and data used for the valuation is described and finally the per-sector results are depicted.

4.1 Water supply

Forest performs an important function as a source of water supply. Various groundwater reservoirs and surface water bodies are replenished by the rainforest. As described in Section 3.5, the first signs of reduced water replenishment have already been seen in and around the forests in Aceh. 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, which in turn leads to structurally higher costs for the provision of water as well as permanently lower levels of ecological support from the forest.

Literature

Several studies have attempted to place a value on watershed protection and regulating functions of forest ecosystems. Table 4.1 below provides the results for a number of these studies. Most of these studies present combined values for multiple watershed functions (soil protection, reduced flooding, etc.) and not only water supply. The values presented suggest that watershed protection values can be high, especially in tropical countries. Most studies produce values above US$ 200/ha/year. Rosales *et al.* (2005) valued watershed protection functions in Lao between US$ 309-1576/ha/year.

Table 4.1 Economic valuations for various water services per hectare of forest.

Service	Location	Value	Source
Watershed protection benefits	Philippines	$223-455/ha/year	Paris & Ruzicka (1991)
Watershed protection	Kenya	$273/ha/year	Emerton (1999)
Watershed protection functions	USA, Hawaii	$1022/ha/year	Kaiser and Roumasset (2002)
Consumptive use of all water flowing from forests	USA	$90/ha/year	Dunkiel & Sugarman (1998)
Value of watershed protection functions	Lao PDR	$309-1576/ha/year	Rosales *et al*. (2005)
Protection of irrigation	Malaysia	$15/ha for irrigation water.	Kumari (1996)

Consumption of clean drinking water has both direct and indirect economic and health benefits. The direct economic effects are decreasing healthcare expenditure, while the indirect effects are increased productivity from the workforce from the avoidance of falling ill (Harahap and Hartono 2007). The value of water supply has been elaborately studied. Table 4.2 depicts studies from various countries. This overview indicates that there is considerable variance in WTP values for improved water services. The studies presented show that WTP ranges from US$ 0.50 to US$ 8.50 per household per month. This may be explained by the differences in income throughout regions. Jiwanji (2000) found that WTP for drinking water is usually between 0.2-4.5 percent of income. This phenomenon can also be seen in studies in Indonesia. Harahap and Hartono (2007) found the average WTP for piped or pumped drinking water to be US$ 0.75 per month in urban areas while in rural areas the WTP was much lower at US$ 0.02. The WTP in urban areas of different provinces also varied. In South Kalimanten the WTP is US$ 0.50 while in Jakarta, the city with the highest average income per capita, the WTP is US$ 2.01. The effects of drought can have severe consequences for crop production and livelihood. Pattanayak and Kramer (2001) found the average WTP for drought mitigation in Indonesia to be US$ 0.34 per household per month.

Similar to the WTP from households, industries are affected by reduced water supply. Theoretically, this damage can be calculated by applying production functions of the dependent industries. An example of such estimates is provided in a World Bank study for the Chinese industry (Wang and Lall 1998). They provide estimates of the water dependencies of industrial outputs of 15 different sectors. These can be used to calculate the foregone industrial production as a result of constrained water supply.

Table 4.2 Previous CVM studies estimating water-related goods.

Service	Location	Average WTP household per month	Source
Safe drinking water	Seoul, South Korea	US$ 3.34	Kwak & Russel (1994)
Improved water service	Manaus, Brazil	US$ 6.12 -8.67	Casey et al. (2006)
Improved water supply	San Dionisio, Nicaragua	US$ 0.38	Johnson & Baltodano (2004)
Improved water supply	Atyrau, Kazakhstan	US$ 1.46	World Bank (1999)
Piped or Pumped water	Indonesia		
	Urban	US$ 0.75	Harahap & Hartono (2007)
	Rural	US$ 0.02	
	Province (urban)		
	North Sumatra	US$ 0.60	
	West Sumatra	US$ 0.75	
	South Sumatra	US$ 0.59	
	Jakarta	US$ 2.01	
	Bali	US$ 1.15	
	South Kalimantan	US$ 0.50	
Drought mitigation	Indonesia	US$ 0.34	Pattanayak & Kramer (2001)

There are also a number of studies that use the replacement cost valuation method to estimate the value of ecosystem influences on water supply. Willis (2002), for example, estimates the cost of the reduction in surface and groundwater due to forests in England

and Wales. The costs of these decreases in available water were expressed in monetary terms by using the estimated replacement costs of water companies to increase water supply, for example through bore-hole abstraction, treatment etc. The increased cost was found to be approximately US$ 7.5 million per year. Folke (1991) estimates the value of wetlands in maintaining both the quantity and quality of drinking water. The value of water quantity maintenance is estimated as the cost of water transport and piping water from distant sources. The value of water quality maintenance is estimated as the cost of water quality inspections, purification facilities, and nitrogen filtering.

Methodology and data

Given the limited timeframe, a rather straightforward and simple approach has been adopted to generate estimates for the economic damage of reduced water supply from the forests in Aceh. As shown in Equation 4.1, the two groups in society that are considered to contribute to the value of water supply (V_{water}) are households (W_H) and industries (W_I) in each regency. Farmers and hydro-electricity plants, which are also dependent on the water supply of the Aceh forests, are discussed in the coming sections.

$$V^i_{water} = W^i_H + W^i_I \qquad \text{for } i \in \{district\} \qquad (4.1)$$

The value of water supply from the forest for each of these groups consists of two components: a quantitative term for the volume of water supply for the ecosystem (m^3), and a price component which focuses on the minimal cost (Rp/m^3) of water from the forest. This is demonstrated in Equation 4.2.

$$W^i_H = (Q^i_D - Q^i_{S\_Forest}) \cdot P_{w(t=0)} + (P_{w(t)} - P_{w(t=0)}) \cdot Q^i_D \qquad \text{for } i \in \{district\} \qquad (4.2)$$

The 'quantitative' component refers to the reduced availability of water from the forest in Aceh (Q_{S_Forest}) to meet the demand of households and industries (Q_D). The water demand for households is based on the average per capita consumption that is assumed to be $38m^3$ per year. This gives total household water consumption of approx. 171,000,000 m^3 in the base year. The average per capita consumption is set to increase by 0.05 percent annually due to developing social conditions. The household water demand is also increased by the growing population. To estimate the Industrial water demand a relationship between annual Industrial production and water consumption is be established. The Industrial production of the primary water consuming industries was found to be approx. Rp 43,400 billion in 2006 (BPS 2007). Data on Industrial consumption of water was unattainable therefore the same industrial production/water consumption ratio used by Van Beukering *et al.* (2003) was used in this study. This gives an annual industrial water consumption of over 16,300,000 m^3 in the base. This consumption is assumed to grow by 1 percent annually with industrial growth.

In the deforestation scenario, water shortage increases. This lack of water supply will have to be met by other water sources. As a result, the dependency on water from the forest is assumed to decline from 74 percent in 2008 to 12 percent in 2038. In the conservation scenario, it is assumed that the water supply from the forest is sufficient to meet the increasing demand therefore the dependency on water from the forest remains constant. The value of the water is valued at the water prices in 2008, which is derived by correcting the water prices for inflation used by Van Beukering *et al.* (2003).

The 'price' component of the water value refers to the cost-reducing impact of the water supply by the Aceh forests. In the deforestation scenario, water will have to be retrieved from more expensive sources or additional costs are necessary to transport the required water to the customers. In the deforestation scenario, the costs are assumed to increase by 0.3 percent annually due to reduced water supply. Prices remain constant in the conservation scenario.

Results

The results of the annual benefits for water supply are illustrated in Figure 4.1. In the deforestation scenario the economic value of water supplied by the forest decreases steadily over time. This is largely due to the fact that the increasing demand cannot be met by what can be supplied by the diminishing forest cover. The value is further decreased as the demand becomes less dependent on water supplied by the forest over time and is forced to change to alternative measures to securing regular water supply, therefore increasing costs. The average annual economic value for water supply in the deforestation scenario is estimated to be US$ 45 million/year totalling US$ 1,355 million over the given timeframe.

In the conservation scenario the economic value of water supplied by the forests increases steadily over time. This is due to increases in both household and industrial demand on water and the fact that the intact forests can sustain a regulated supply. The average annual economic value for water supply in the conservation scenario is estimated to be US$ 138 million/year totalling US$ 4,140 million over the given timeframe.

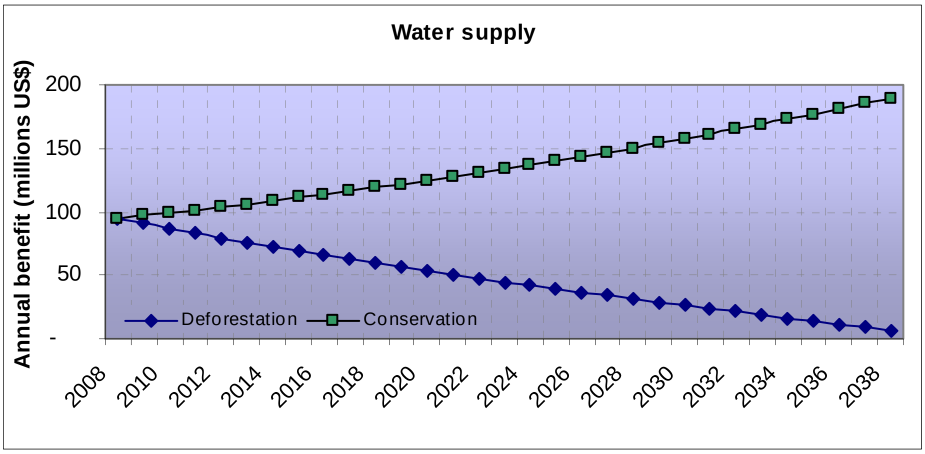


Figure 4.1 Annual benefits for water supply.

4.2 Fisheries

The relationship between fisheries and land cover is a complex one. Freshwater fisheries depend largely on a sufficient and clean supply of fresh water, a service that is largely reliant on the presence of forest cover. As examined in section 3.5 forests play an important role in regulating the hydrological cycle, ensuring sufficient dry-season flows, preventing sedimentation into waterways and supplying the water with nutrients through decomposition of forest litter and woody debris. Many fish species may be highly dependent on the water conditions created by forest vegetation. Shade provided by vegetation as well as debris falling from the canopy above create unique conditions which have defined the species compositions of forest rivers for centuries. The removal of tree cover, shade and litter debris and its replacement with plantations or grasslands causing increased erosion and sedimentation serves to change the biome of the water ecosystem which inevitably has an effect on the biodiversity of the waterways.

Literature

While deforestation of tropical ecosystems has been shown to have significant impacts on terrestrial habitats, few studies have been conducted which aim to quantify its effect on the aquatic ecosystem. (Wright and Flecker, 2004). The same mentioned authors performed a study on the effects of woody debris derived from surrounding forests on the species composition in freshwater streams and rivers in a tropical forest in Venezuela. It was found that large woody debris plays an important role in the species abundance and composition of tropical streams. Those streams in deforested areas contained lower abundance and species diversity than streams located in intact forest areas. Changes in species numbers from non-wood debris waterways to wooded waterways ranged from 0% - 300%.

The reasoning behind the changes relates to an array of theories; the consumption of periphyton which grows on some tree species' bark as food; shade provided by the wood; consumption of the wood itself by certain species; reduced water turbidity and; protection from bird predation. Other studies show mixed results relating to deforestation and fish numbers. In Costa Rica, Burcham (1988) found species richness in pasture streams to be higher than in forest streams. Lyons *et al*, 1995 reached the opposite conclusion for Mexican streams and Kamdem and Teugels (1999) found fewer fish individuals in deforested streams than in forested ones. A clear relationship exists between land use change and aquatic biodiversity often with a negative effect upon the fish species diversity and composition. Despite the conflicting reports from the mentioned studies, anecdotal evidence from Aceh points to a large dependency of freshwater fish species to forest cover. In a news report in the New York Times a fisherman residing in the Sumatran Province of Riau claims that he "earned nearly $100 a week catching shrimp. Now, he said, logging has poisoned the rivers snaking through the heart of Riau, and he is lucky to find enough shrimp to earn $5 a month" (The New York Times, 6/12/07)

The relationship between forest cover and offshore fish productivity is less obvious except for the case of mangrove forests where a clear relationship exists between fish catch and mangrove forest extent. Mangroves serve as an important spawning ground and nursery for many fish species, in particular for shrimps that predominantly retreat to the mangroves to spawn. Juvenile shrimp then spend the early stages of their lives in the shelter of mangrove forests before migrating, often flushed by seasonal increases in water discharge brought about by heavy rainfall, into the open waters bringing them into range of coastal fishing fleets. The area of mangrove, discharge volume and timing of river waters is directly proportionate to the shrimp catch (Gammelsrod, 1992, Hoguane, 2001). Moreover deforestation causes increased erosion and sedimentation of the water-ways as discussed in section 3.5. The increased discharge of sediment into coastal waters changes the visibility and water nutrient composition leading to a change in ecological conditions. Brackishwater fish farms located near off shore will likely be affected depending on their proximity to estuaries and the level of sedimentation.

Methodology and data

In valuing the economic value for the fishery sector of the Aceh ecosystem ($V_{fishery}$), the fishery sector is subdivided in four types: including (1) maritime fishery, (2) brackish water fishery, (3) brackish water aquaculture, and (4) freshwater aquaculture. The total fishery value of the Aceh forestry ecosystem is the sum of these values, to the extent that they depend on the forest ecosystem (equation 4.3).

$$V^i_{fishery} = \sum_T A^i_T \qquad \text{for } i \in \{district\},\ T \in \{maritime,\ brackish,\ aquaculture,\ freshwater\} \qquad (4.3)$$

A comparable approach is followed as for the water valuation exercise. Similarly, the fishery value of the Aceh ecosystem consists of two components: (1) a 'quantitative' element in terms of generating a support in generating and supporting fish stock, and (2) a 'price' component which provides water production function at low costs. This is demonstrated for aquaculture species (A_{aq}) in equation 4.4:

$$A^i_{aq} = (D_{aq} \cdot Q^i_{aq}) \cdot (P_{aq(t=0)}) \qquad \text{for } i \in \{district\} \qquad (4.4)$$

The value of Aceh dependency (Daq) varies across the different categories of the fishery sector and between the districts. For marine and freshwater fishery, for example, the length of the coast and the rivers, are respectively used as indicators for dependency. The average share of the fishery sector dependent on the Aceh ecosystem for maritime fishery is then 27 percent, for brackish water fishery is 9.5 percent, and for brackish and freshwater aquaculture it is 100 percent. This generates an economic value of US$ 128 million in the year 2008. In the 'conservation' scenario, this value is assumed to remain constant. In the 'deforestation' scenario, the support from the Aceh ecosystem is assumed to decrease at an annual rate of 1 percent (ΔD_{aq}) and the prices are assumed to increase with 0.5 percent per year ($\Delta p_{aq(t)}$). This causes a marked decline in the economic value of the fishery sector.

All catch data was obtained from the Provincial governments' statistical report (BPS, 2007) and were already subdivided into the four categories (freshwater, marine, brackishwater aquaculture and freshwater aquaculture). Prices were obtained at a major fish market in Banda Aceh in September 2008. As can be seen from Table 4.3 the fisheries sector in and around Aceh is very important to society. Fish provide a very important source of protein for the local population. Annual production reaches 189 thousand tonnes and the total annual value is around US$ 289 million based on local market prices. The most important source of fish is the ocean followed by freshwater fisheries sourced from the numerous rivers and streams many of which are sourced from the Bukit Barisan Mountain range and the surrounding forests. Brakish water aquaculture accounts for 10% of the total production and freshwater aquaculture 6.5%. A large amount of the brackish-water fish farms were wiped out during the tsunami of 2004, many fishing boats were also damaged but both have largely been repaired since and production is now reaching near pre-tsunami levels overall with some sectors reporting higher catches (BPS, 2007). The values in the below table and used in the TEV are for 2006 due to the yet unpublished data for 2007-08.

Table 4.3 Production in the fishery sector (tons)[4] for 2006.

Regency/fish source	Maritime Fisheries ton	Freshwater Fisheries ton	Brakishwater Aquaculture ton	Freshwater Aquaculture ton
Simeulue	1,765	34	0	19
Ache Singkil	5,163	19	0	19
Aceh Selatan	10,769	231	6	148
AcehTenggara	0	7,981	0	7,622
Aceh Timur	10,268	4,105	3,941	164
Aceh Tengah	0	2,112	0	1,534
Aceh Barat	4,526	138	39	61
Aceh Besar	5,605	219	219	0
Pidie	14,029	1,844	1,835	10
Bireuen	17,061	5,460	3,676	1,784
Aceh Utara	14,029	3,844	3,303	346
Aceh Barat Daya	10,037	94	11	9
Gayo Lues	0	173	0	173
Aceh Tamiang	6,603	5,477	5,422	55
Nagan Raya	1,894	340	0	257
Aceh Jaya	1,428	0	0	0
Bener Meriah	0	176	0	176
Kota Banda Aceh	7,213	12	9	3
Kota Sabang	2,619	2	0	2
Kota Langsa	5,172	267	267	0
Kota Lhokseumawe	5,494	871	869	2
Total	**123,673**	**33,396**	**19,596**	**12,380**
Percentage share	65,4%	17,7%	10,4%	6,5%

Results

In year 2008 the fisheries sector (sum of all four categories) generates an Aceh forest ecosystem dependent revenue of US$ 128 million. This value stays constant under the conservation scenario however due to the gradual deterioration of the forest ecosystem services under the deforestation scenario, the value for fisheries decreases over the 30 years to US$ 69 million in 2038. The average annual value of the fisheries sector is

4 Throughout this report when the term ton(s) is used it refers to metric ton(s).

US$ 98 million under the deforestation scenario and US$ 128 million under the conservation scenario. Total benefits are US$ 2.9 billion and US$ 3.85 billion for deforestation and conservation respectively over the 30-year period.

The decline under deforestation is brought about by two functions built into the model as described above. Firstly the dependency rate (the extent to which each fishery sector is believed to be dependent on the forest ecosystem) is reduced by 1 percent per year and as a result prices rise by 0.5 percent per year to account for the increased costs of fishing a depleted resource. The results from the fisheries section are depicted in Figure 4.2.

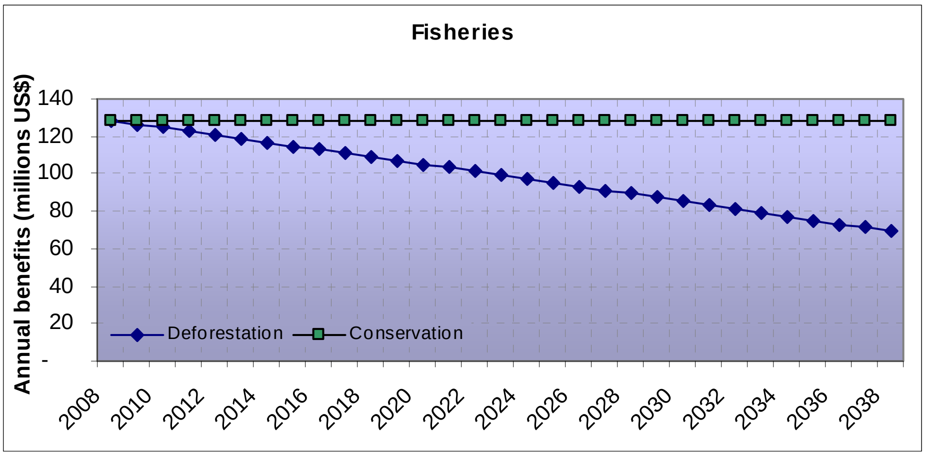


Figure 4.2 Annual benefits for fisheries.

4.3 Flood and landslide prevention

Among the watershed protection benefits of forest, flood and landslide damage alleviation is crucial. Lying in a monsoon belt, Indonesia is prone to floods and landslides. In Aceh, floods and landslides have been a hazard to the region for decades. The magnitude and frequency of both seem to be increasing, and several medias, as well as the World Bank (2007) attribute this increase to deforestation. A severe flood struck seven districts of Aceh in late 2006. Although the deaths and injuries were relatively low, the disaster affected more than half a million people and resulted in loss and damages of an estimated US$ 210 million, primarily concentrated in infrastructure, housing and the productive sector. In total more than 42,000 homes and 24,000 ha of agricultural land were damaged (World Bank, 2007).

Literature

Flooding generally becomes more frequent and more destructive as a result of converting forests to other uses. Since a fully-grown forest cover has a higher water use as well as higher infiltration capacity than any other land use type, forest clearing will result in an increase in water drainage as runoff, potentially leading to flooding (Van Beukering *et al.* 2003). Kramer *et al.* (1995) found that annual storm flows from a secondary forest were about three-fold higher than from a similar-sized primary forest catchment, and 4 to 5 times higher from a catchment dominated by swidden agriculture.

Although there is some consensus on forest's effect on reducing run-off on the local scale, recent literature questions the ability of forest to prevent large-scale flood events caused by major rainfall (FAO 2005, Bruijnzeel 2007). However, Bradshaw *et al*. (2007) found a relation between flooding and deforestation with a comprehensive study of flood frequency, duration and damage from 1990 to 2000 in 56 developing countries. The study found that native-forest cover and the rate of forest loss account for 14% of the variation in flood frequency and duration. Associations between forest cover and the damage caused by floods were found to be weaker but still evident. However, the study received heavy critique from Bruijnzeel (2007) who provides an alternative interpretation of the results of Bradshaw *et al.* (2007) and concludes that "There are many good reasons to protect remaining natural forests, but the hypothesis of 'flood protection' at national scale remains unsupported."

Due to the high uncertainties surrounding this ongoing debate and considering the low association between forest cover and damage of floods found by Bradshaw et al (2007), a rather conservative dependency rate on forest has been chosen in the valuation of prevented flooding of the Aceh forests.

In relation to landslides, there is evidence that tree-roots bind soil together and by removing trees the risk of landslide thereby increase. When large amounts of vegetation are removed from an area the delicate root systems eventually die off leaving the soil vulnerable to over saturation on steep slopes with erodible soil, the risk of landslides therefore increase (Heiken 1997). The frequency of mass erosion (landslides, debris flows, earth flows, etc.) is linked to the type and intensity of land disturbance. Although most mass movements are associated with roads and their drainage systems, many originate on open slopes after logging has raised soil water tables and decreased root strength (Meehan and Bjorn 1991)

Due to limited information on landslides in the Aceh region, the valuation is purely based on data on flood frequency and damage of floods.

The economic value of flood protection can be derived by estimating the avoided flood damage. Two such studies have been done in Cameroon with values ranging from 0 to 24 US$/ha (Yaron 2001, Ruitenbeek 1988). The methodology of avoided damage will also be used in this study. The main question is what the damage from floods would be if the forest in Aceh were degraded.

Methodology and data

In valuing flood prevention, the following four impact categories are identified: (1) damage to residential houses; (2) damage to infrastructural facilities (roads have been used as indicator); (3) increased mortality; and (4) damage to agriculture. The latter category will be estimated separately (see section 4.4). As shown in equation 4.5 below, the avoided flood damage (V_{flood}) is the sum of the damage to houses (F_H), infrastructure (F_I) and people (F_P) for the various regencies.

$$V^i_{flood} = F^i_H + F^i_I + F^i_P \qquad \text{for } I \in \{district\} \qquad (4.5)$$

For illustrative purpose, one damage category is elaborated. To calculate the avoided damage to residential houses, we multiply the difference between total number of houses subject to potential floods ($H_{potential}$) and the actual number affected (H_{actual}) with the probability that flooding will occur (P_{flood}) times the average price of a residential house in the regency (p_{house}).

$$F_H^i = \left(H^i_{potential} - H_{actual}\right) \cdot P^i_{flood} \cdot p^i_{house} \qquad \text{for } I \in \{district\} \qquad (4.6)$$

The number of houses that are subject to potential floods ($H_{potential}$) is calculated by multiplying the total number of houses in the regency with an impact factor (Φ), which is a function of the length of major rivers (L), the average slope of the area (S), and whether the regency is up- or downstream (U).

$$H^i_{Potential} = \phi \cdot H^i_{Total} \qquad \text{for } I \in \{district\} \qquad (4.7)$$

$$\phi = f_R(L^i, S^i, U^i) \qquad \text{for } I \in \{district\} \qquad (4.8)$$

The probability of a flood occurring in the area due to deforestation (P_{flood}) is determined by the current probability of flooding ($P_{baseline}$) times the ratio of standing forest in year t (F_t) and forest cover in the first year ($F_{t=0}$).

$$P^i_{flood} = P^i_{baseline} \cdot (F^i_t / F^i_{t=0}) \qquad \text{for } I \in \{district\} \qquad (4.9)$$

Due to limited time resources, extrapolation and several assumptions have been used to do the valuation. First of all, the impact factor ϕ has been calculated based on data given in Van Beukering *et al* (2003). A relationship between average annual rainfall added with the frequency of flooding (referred to as the flooding potential) and the impact factor (ϕ) was found (Figure 4.3).

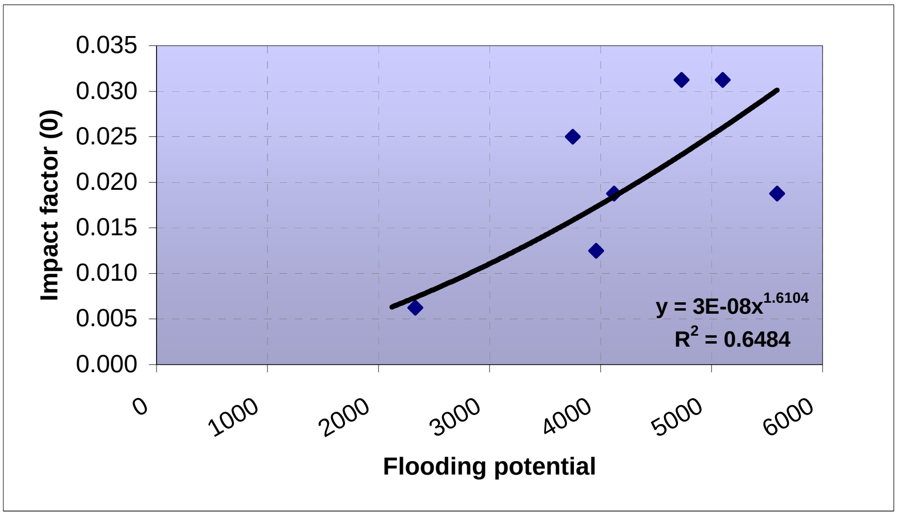


Figure 4.3 Correlation between flood frequency added with rainfall and the impact factor for the 7 districts in Aceh that lies within the Leuser Ecosystem.

The following types of data have been used in the valuation process. First, the power function, as well as new data on average annual rainfall and flood frequency during the last seven years, has been used to calculate the impact factor for each of the Kabupatens in Aceh.

Second, the actual affected kilometres of infrastructure, number of houses and number of deaths, have been estimated based on data on damages due to flooding in the period from 2005 to 2008, based mainly on the World Bank's assessment of damages during the 2006 flood (World Bank, 2007). Only houses and kilometres of infrastructure needing full replacement have been included.

Finally, it should be mentioned, that specific assumptions have been included to calculate the potential affected kilometres of infrastructure and number of deaths. Since a large proportion of infrastructure is situated in low-lying areas, close to rivers as well as coasts, it has been assumed that there is 10 times more infrastructure located in these areas. For the potential number of deaths, it has been assumed that there is a probability of 1.3% that a household member in a potential flood area will die. This number is based on the proportion of actual number of deaths to the actual number of affected households during floods from 2005 to 2008 (World Bank 2007, FAO 2005 and Fredriksson – personal communication 2008).

The individual values of impacts are estimated to be Rp.53 million (US$ 5,630) per residential house, Rp. 1,553 million (US$ 164,930) for one kilometre of road, and Rp. 365 million (US$ 38,760) in the case of mortality. The first value is based on the value reported by the World Bank (2007). For the derived value of constructing one kilometre of road, the distribution of dirt, gravel and asphalt roads in Aceh was obtained and priced using a weighted average with individual road type prices sourced from World Bank (2007) and Lebo & Schelling (2001). The value of a mortality case was derived though the benefit transfer of the value of mortality in Western Europe (US$ 3 million) corrected on the basis of the purchasing power parity difference between Western Europe and Indonesia.

Results

The annual value of flood prevention is presented in Figure 4.4, and is increasing in both the deforestation and the conservation scenario. In the deforestation scenario annual benefits from the forest equals US$ 90 million/year. The deforestation scenario is seeing a lower rate of increase than the conservation scenario due to the fact that the actual damage function is growing with 5 percent a year, while it remains constant in the conservation scenario. The increasing annual value in the deforestation scenario is due to a growth in potential damage (potential affected houses, infrastructure and mortality) as well. However, a continuous deforestation for several years longer would result in a decreasing value since the difference between potential and actual damage will be diminishing. The average annual economic value for flood prevention in the conservation scenario is estimated to be US$ 105 million/year.

In summary, floods result in huge damage, and preventing floods is therefore of high value. However, the relation between forest and floods remain a highly debated topic, and a conservative forest dependency rate of 14 % has therefore been included in this analysis, resulting in a limited value of the conservation scenario. Even though much of Aceh's forests are on highly erodible and steep slopes that can increase the risk of landslides significantly under deforestation, it has not been possible to include this in the current study. Thorough research in the Aceh region is demanded to determine how deforestation actually affects the frequency and magnitude of both floods and landslides.

Also, with improved research the dependency rate on forest could prove to be much higher and thereby also the benefits of conservation. The result of the valuation of the Aceh forests as preventing floods can be seen in Figure 4.4.

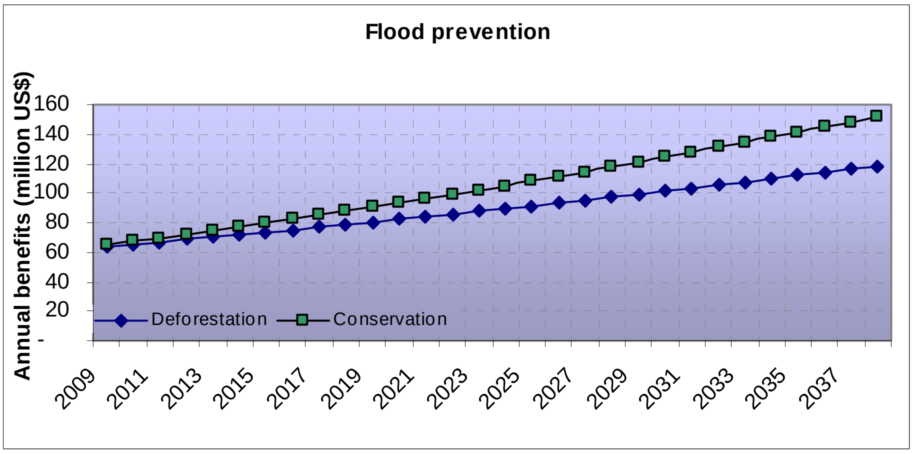


Figure 4.4 Annual benefits for flood prevention.

4.4 Agriculture and plantations

The impact occurring to agriculture and plantations caused by deforestation stems from several separate changes in functions described in Section 3.5. Erosion, water table changes, changes in flooding frequency and damage and, changes in pest and pollination services all affect agricultural productivity in unison. The intertwined mix of effects which deforestation has upon agriculture makes it a highly difficult area to value in relation to the forest ecosystem services provided to it. The ideal valuation technique is the production function approach where by each input into a production process is isolated so that the marginal contribution of the input, say groundwater recharge can be . If this input is derived from a natural ecosystem then it can be said that the value of the ecosystem function to agriculture is the marginal contribution to the total crop yield. However this becomes more complex when there are several inputs functioning at the same time as mentioned above. The complexity deepens when the exact science behind the ecological services is not in fact an exact science at all but depends on geographical characteristics of the land such as relief, soil composition, vegetation cover and converted vegetation cover type and so on. The value of the forest ecosystem to agriculture is therefore an agglomeration in varying proportions of all the above-mentioned services.

Literature

Extensive references have made connections between forest cover and agriculture (Ammour *et al.* 2000, Bann 1998, Ricketts *et al.* 2004, Pattanayak and Kramer 2001, Rosales *et al.* 2005). The common linkages are found to be; Bats controlling insects feeding on crops (pest control); bees and other pollinators ensuring pollination of fruit trees, vegetables and other crops; forest cover and soil composition reducing the erosion of valuable topsoil nutrients used by agriculture to ensure healthy yields and finally; the hydrological regulation provided by forests helping keep water tables stable, ensuring dry season flows and regulating climate and rainfall. Ricketts *et al.* (2004) found that a coffee plantation in Costa Rica benefited US$ 361 per hectare per year from the presence of a forest providing bee pollination services. This is to say that if the nearby forest were to be destroyed (destruction of bee habitat) the service provided by the bees would cease to exist requiring hand pollination or artificial bee farming resulting in extra per hectare costs of US$ 361 per year. Another study by Rosales *et al.* (2005) on the TEV of a forestry reserve in the Sekong Province of Lao valued the contribution of a tropical forest in a WWF priority conservation region to agricultural production. The study found the annual value to be US$ 2.5 per hectare, which translated into a benefit per household of US$ 150 in forest dependent revenue. Table 4.4 provides a summary of other valuation studies related to agriculture and forest.

Table 4.4 Valuation literature referring to the value of forests to agricultural activities.

What is being valued	Location	Value (US$ ha/year)	Reference
Cost of soil replacement and preventing soil loss	Guatemala	Negligible for soil loss; $12/ha for nutrient loss	Ammour *et al.* (2000)
Replacement cost of soil nutrients	Turkey	$46/há	Bann (1998)
Value of bee pollination for coffee plantations	Costa Rica	$361/ha/year	Ricketts *et al*. (2004)
Gain in profits to rice and coffee production	Eastern Indonesia	$3-35 per household	Pattanayak and Kramer (2001)
Protection of agricultural production	Sekong, Lao	$2.5/ha/year or $150/hh/year	Rosales *et al*. (2005)

The agricultural sector is a major source of production for the Province of Aceh (see table 4.6 on page 51). However, yield decline has been recorded in several districts in the Aceh region. This decline can be ascribed to the various changes in conditions related to deforestation, principally deterioration of the nutrient status of the soil, erosion of the top soil, deterioration of the physical condition of the soil, multiplication of pests and diseases, drought and floods, and increase of weeds including woody forest re-growth. Clearly, a link between these causes and the degradation of the forest ecosystem in Aceh can be assumed. For example, logging and deforestation of water catchments in the Aceh forest ecosystem is found to be responsible for taking 94 percent irrigation areas out of production (BZD 2000). Using a simplified productivity analysis, it is possible to use a dose-response effect to estimate agricultural losses due to flooding, reduced pest-control, erosion and droughts.

Methodology and data

In this study, the threats to agriculture and plantations caused by deforestation of the Aceh forest ecosystem are treated in a generic manner. In other words, the combination of increased flooding events, reduced pest-control and pollination, erosion and droughts, is assumed to have an overall negative impact on agricultural productivity. In determining the economic value for the agricultural sector of the Aceh forest ecosystem ($V_{agriculture}$), three types of crops are considered, including (1) rice, (2) fruit and vegetables, and (3) Palm Oil and derivatives. The total agriculture value of the Aceh forest ecosystem for each district is the sum of these values, to the extent that they depend on the Aceh forest ecosystem (see Equation 4.10).

$$V^{i}_{agriculture} = \sum_{C} A^{i}_{C} \qquad \text{for } i \in \{district\},\ C \in \{rice,\ vegetables,\ cash\ crops\} \qquad (4.10)$$

Again, deforestation is assumed to results in (1) a reduction in terms of quantity of produced outputs ($\Delta D_{crop}*Q_{crop}*p_{crop(t=0)}$) as well as (2) an increase in the cost of production (ΔP_{crop}). This is demonstrated for the Aceh value of rice crops (A_{rice}) in Equation 4.11:

$$A^{i}_{rice} = (D_{rice} \cdot Q^{i}_{rice}) \cdot (P_{rice(t=0)} + \Delta P_{rice(t)}) \qquad \text{for } i \in \{district\} \qquad (4.11)$$

Where as D_{rice} is the proportion of rice considered to be directly related (dependent) to the existence of the forest ecosystem, Q^{i}_{rice} is the total quantity of rice produced, P_{rice} is he price of rice and $\Delta P_{rice(t)}$ is the change of price over time as a result of deforestation and increased scarcity.

Since a proportion of deforested land is converted to agriculture, agricultural yields initially increase in the first years of the simulation as new land becomes converted to agriculture, however falling yields as a result of the various depleting forest services eventually takes its toll even in newly converted land, deforestation rates slow towards the second half of the simulation as the low lying land suitable for agriculture becomes fully used. Eventually net yields and thus revenue begins to fall and surpasses the growth in land available eventually causing a net reduction in yields. For the purpose of this study the dependency rates for (1) rice, (2) fruit and vegetables (3) palm oil have been carefully estimated using expert opinion at 14.8, 11.1 and 7.4 percent respectively.

Crop area and productivity data was obtained from the Provincial government statistic report for 2007 (BPS 2007). The yields are shown in Table 4.5 below. Fruit comprises of 16 different varieties including many local varieties and vegetables of 14 varieties. Under the rice category, maize, peanuts, cassava and soybeans have also been included although rice accounts for 89.6% of the total yield. For palm oil the statistics were reported as per smallholder and estate produced palm oil. However the values for each were reported differently. For small holders the yield data was reported in fresh fruit bunches which is sold to the processors, where as for the estate the values were in processed palm oil. In order to curb this problem it was decided to take the total area under production and multiply this by the average processed palm oil production per hectare for Indonesia (3.54 tons/ha). All agricultural prices except for palm oil were obtained from the FAO statistics database for Indonesia at 2005 prices. Palm oil price was reported in (Yusuf, 2004) at 2004 values. All prices were indexed to present day value. Weighted averages were taken for the fruit and vegetables category and for the rice category.

Table 4.5 Agricultural production of main crops in Aceh for 2006 (tons).

Regency/crop type	Rice production (tons)	Fruit and Vegetable production (tons)	Crude Palm Oil and Palm Kernel Oil production (tons)
Simeulue	543	28,169	0
Ache Singkil	7,222	21,822	166,821
Aceh Selatan	19,819	74,529	23,939
AcehTenggara	5,080	151,105	4,798
Aceh Timur	27,894	160,901	186,265
Aceh Tengah	20,036	46,803	0
Aceh Barat	13,658	100,779	58,139
Aceh Besar	42,782	182,858	4,365
Pidie	77,858	200,110	310
Bireuen	44,040	158,258	13,470
Aceh Utara	32,734	215,723	111,756
Aceh Barat Daya	84,281	50,857	23,832
Gayo Lues	4,757	64,173	0
Aceh Tamiang	16,940	90,294	176,187
Nagan Raya	10,044	113,355	190,059
Aceh Jaya	6,317	55,518	26,922
Bener Meriah	1,689	7,153	8
Kota Banda Aceh	3,382	1,293	0
Kota Sabang	620	567	0
Kota Langsa	1,910	6,955	509
Kota Lhokseumawe	0	6,011	345
Total	421,606	1,737,233	987,724

Source*:* BPS, 2007

Results

Under the agricultural valuation, the model assumes that both, the deforestation and conservation scenarios start at equal points in 2008. By 2009 conversion of forest to plantations generate their first yield under the deforestation scenario where as the conservation scenario there is no added agricultural activity. As a result there is a sharp increase in value between 2008 and 2009 under the deforestation scenario as newly converted lands become productive. The 2008 value for agriculture considered to be dependent on the Aceh forest ecosystem is US$ 205 million. This value encompasses all three crop categories mentioned above. Under the deforestation scenario agriculturalists enjoy high yields spanning large areas of newly converted land, however due to the typically low fertility levels of rainforest soils[5] plantations rapidly begin to suffer from decreasing yields. After a small and short-lived growth in the value of agriculture under the deforestation scenario resulting from increased area made available through

5 Rainforest soils are typically low in nutrients, most of the nutrients are found in the leaf litter or organic decomposing material which is rapidly decomposed and re-absorbed by trees. Once the trees are felled litter ceases to regenerate the soil becomes rapidly depleted of nutrients.

deforestation, the revenue begins to fall as yield falls, eventually crossing the constant value of agriculture in the conservation scenario in year 2020. Beyond which revenue from deforestation falls further as the depletion of certain ecological services begins to take its toll and land becomes abandoned. End of simulation values (2038) derived for agriculture from the model under the deforestation scenario is US$ 88 million where as for conservation the value stays constant at US$ 205 million. The average yearly benefit for agriculture is US$ 166 million for deforestation and US$ 206 million for conservation. Total benefits are US$ 5.1 billion for deforestation and US$ 6.4 billion for conservation. Figure 4.5 shows the yearly benefits from the agricultural sector.

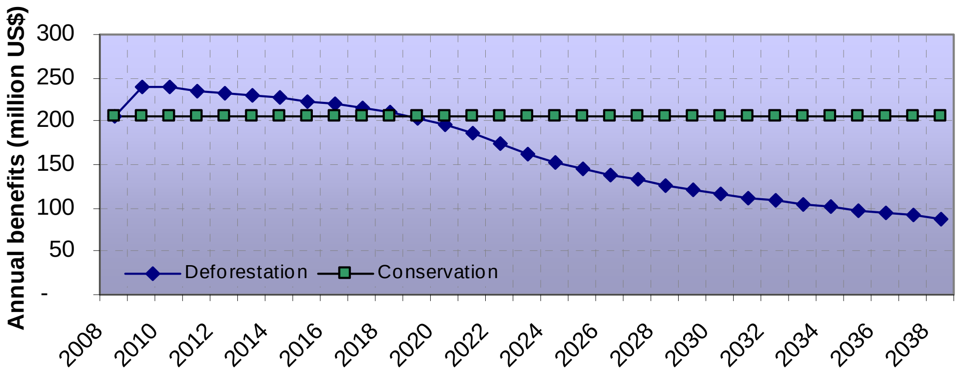


Figure 4.5 Annual benefits for agriculture.

4.5 Hydro-electricity

The accumulation of riverborne sediment deposited in dam reservoirs serves to reduce the life span of a dam. Sediment will accumulate in the reservoir serving to reduce the water storage potential, causing a reduction in water pressure at the turbines as well as a reduction in output water available for associated irrigation schemes. Silt and other courser sediment also damages the dams turbines requiring repair resulting in lost hydro-power generation due to down time during repairs. Removing sediment from dam reservoirs is possible but is very costly, an activity that not only requires the payment for dredging equipment but also involves lost generation during repairs. Sedimentation has already been discussed in section 3.5 as being a knock on effect of deforestation. Increased sedimentation of the waterways is seen at having a negative (cost) function for the regions hydro power plants.

Literature

Chunhong (1995) (cited in Chomitz 1998) reports that sedimentation reduces the storage capacity of Chinas reservoirs by 2.3% per year. The relevant question though, as Chomitz puts it knowing “the marginal effect of deforestation related sedimentation” (1998, pp 18) This question returns to the issue of sedimentation discussed in section 3.5. Sedimentation rates are related to catchment size, the converted land use type, geology, pedology and land gradient. Only by quantifying these on a case-by-case (micro) system will an accurate answer to the question be approached. Ultimately what this study seeks to apply is a dependency ratio of the value arising from hydro generated sales dependent on the forest ecosystem.

Erosion and sedimentation is not the only function that implies costs to hydropower facilities. Forests serve to regulate the hydrological cycle which in-turn, as has been reported by anectodal evidence from residents within the Aceh forest ecosystem, lowers water levels in rivers during certain times of the year. One plant in Aceh Tenggara closed down due to lack of water supplied to the turbines. The reduced flow of the rivers implies a loss in generation that can be directly ascribed to as the cost of deforestation. Again difficulties arise in quantifying the exact cost per hectare of forest lost.

A Payment for Environmental Services (PES) scheme in Costa Rica saw a hydropower dam offering US$ 10 payment per hectare of preserved forest (over an area of 3,000 hectares). The argument was that deforestation would cause temporal changes to the water availability and sedimentation of the storage area. Whilst an accurate scientific quantification of the likely reductions in cost in relation to lost forest cover (per ha) was not established, the operator of the dam opted for the precautionary principle and estimated a price that was deemed suitable (Rojas and Aylward, 2002).

Several districts, such as Aceh Tenggara, have built (micro) hydro-electricity plants. These plants use the water generated by the Aceh forest ecosystem to generate large amounts of electricity for the local communities. If these operations were conducted on a large scale, hydro-electricity would be a conflicting use of the rainforest, as large areas would become inundated by the reservoir. The plants operated in Aceh Tenggara and in other districts, however, are designed as small-scale economic activities, and may therefore be considered as supplementary to the conservation scenario.

Based on several interviews, it appeared that the operational conditions for the hydro-plants have worsened significantly in recent years. Increased erosion of the waterways forces the operators to remove the excessive sediments from their turbines. This leads to frequent interruption of the power supply to the region as well as higher operational costs. Moreover, the blades of the turbines are damaged regularly due to the rocks and stones coming down with floods. Most of these disturbances are considered abnormal and may therefore be attributed to deforestation of the Aceh forest ecosystem.

Methodology and data

Similar to the other benefits, the value of power generation dependent on the Aceh forest ecosystem consists of a ‘quantitative’ and a ‘cost’ component. The quantitative component is based on the amount of electricity that could potentially be produced through hydropower technologies. For the Aceh forest ecosystem as a whole, this percentage is assumed to be 22 percent. I.e., 22% of the generation value is derived from forest services like hydrological regulation and sedimentation control. In the conservation scenario, this share will be achieved throughout the period of 2008 to 2038. In the deforestation scenario, this share is assumed to decline from 22 to 12 percent as the ecological services become depleted. The ‘cost’ component represents the increased costs for electricity, caused by enhanced erosion and sedimentation. In the deforestation scenario, the cost of electricity generation is assumed to increase by 2 percent per year as a result of down time spent dredging and performing repairs. The consumption of energy also increases as the population of the area grows. A population growth function of 2% per annum is built into the model.

Data used

It was not possible to obtain the number, locations and capacity of all the (micro) hydro power plants operating within the whole of Aceh province. Instead the total kWh consumption of Aceh was available, broken down into user groups (residential, business, industry and public) for the province as a whole (see Table 4.6). The national energy company of Indonesia, Perusahaan Listrik Negara (PLN), reports that 10% of their generation capacity is derived from hydropower. Due to the non-availability of specific hydro generation capacity in Aceh province we were forced to make the assumption that the national average also applies to the province. Therefore the power generated by hydro is 10% of the total consumption reported in the table below. Weighted averages were taken for the prices.

Table 4.6 Total consumption/revenues of electricity (from all sources) for the Province of Aceh.

User groups	Number of costumers	KWH sold	Revenue millions/Rp	Cost p/ KWh Rp
Household	659,432	556,573,698	267,970	481
Bussines	41,718	123,859,946	83,901	677
Industries	897	34,996,169	27,545	787
Public	23,954	123,802,759	80,584	651
Total	**726,001**	**839,232,572**	**460,000**	**548**

Results

The value of hydropower dependent on the Aceh forest ecosystem in 2008 is US$ 1.08 million. Under the conservation scenario ecological services stay unchanged and growth in the demand for energy is met by increase in hydropower, therefore the value of hydropower dependent on Aceh's forest ecosystem gradually grows over the 30-year period to US$ 1.77 million in 2038. On the other hand the value of hydropower under the deforestation scenario declines from US$ 1.08 million to US$ 0.32 million in 2038 as a result of changing water availability and increased sedimentation and damage to the dams' infrastructure. The average yearly benefits from hydropower are US$ 0.68 million for deforestation and US$ 1.37 million for conservation. Total benefits accruing over the 30-year simulation are US$ 21 million and US$ 43 million for deforestation and conservation respectively. Figure 4.6 shows the yearly benefits for the hydropower sector.

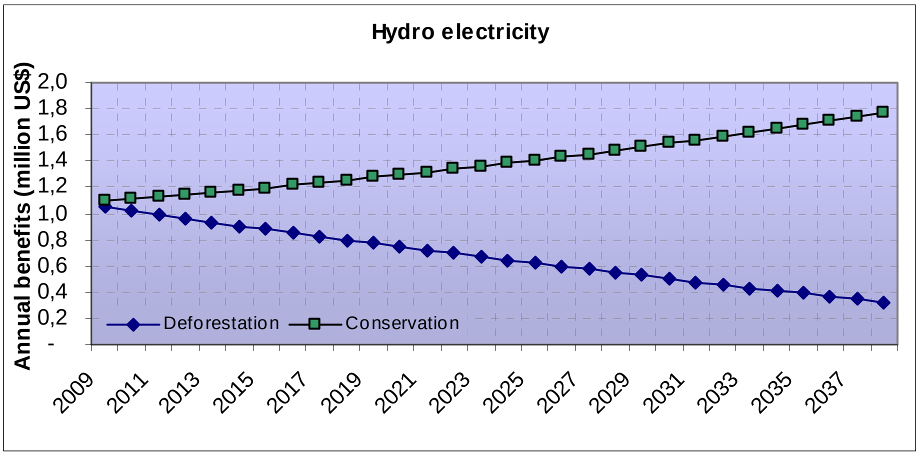


Figure 4.6 Annual benefits for hydropower.

4.6 Tourism

Tourism proves to be an important incentive for local communities to conserve the rainforest. The long-term income generated from tourism often exceeds the benefits of alternative sources of activities. At the same time, tourism may also form a threat to the rainforests due to unplanned expansion of facilities and accommodation for tourists. Ecotourism[6], however, if properly planned and implemented, can be one of the most important forms of sustainable, non-consumptive uses of conservation areas.

Globally, ecotourism has grown at 20-34 % a year since its origin in the 1990s. Tourism in and around the world's remaining natural areas has accounted for a substantial proportion of this expansion. While other types of tourism, such as sun-and-sand tourism, is stagnating in growth rate, ecotourism is expected to grow continuous and can within a few years take up 25 % of the world's travel market, equalling US$ 473.6 billion a year (International Ecotourism Society, 2006).

Due to a history of political unrest and several natural disasters, only a small fraction of tourists to Indonesia visit Aceh and its forests. The highest growth of tourism in the forest area has happened in Gunung Leuser around the orangutan rehabilitation project in Bukit Lawang, outside of Aceh (Unesco, 2004). Nevertheless, the potential for ecotourism in Aceh is believed to be substantial. In fact, given the unique chance to view wildlife such as orang-utans and elephants, eco-tourism possesses a major potential source of revenue for local communities living in the proximity of the Aceh forests. There is already evidence that tourism is starting to bloom in Aceh, with the forests and wildlife viewing opportunities being one of the main attractions (i.e. see The Rainforest Lodge - Gayo Lues, Aceh Explorer Tours, Ecotourism in Sumatra, Ecotourism Development in Southwest Aceh and Travellers Hub).

6 Eco-tourism is defined as tourism that depends critically on the natural values offered by the areas visited; hence it includes both nature tourism, where natural history is the focus, and more active forms of recreation, such as rafting, tubing and sports-fishing (Van Schaik 1999).

Literature

When environmental conservation projects increase tourism activities, economic valuation techniques can be used to measure the associated benefits. A wide range of literature exists on the value of tourism in tropical forests with values ranging from US$ 7 per visit to US$ 74.

Table 4.7 Value of tourists visiting forest.

Location	Value (US$/visit or US$/household)	Reference
Uganda	48 US$/foreign tourist	Naidoo and Adamowicz (2005)
Madagascar	27-74 US$/foreign tourist	Kramer *et al*. (1995)
Costa Rica	11-13 US$/local tourist 14-23 US$/foreign tourist	Shultz *et al*. (1998)
Indonesia	7 US$/local tourist 12 US$/foreign tourist	Van Beukering *et al.* (2003)

Van Beukering *et al*. (2003) estimated the value of tourists visiting the Leuser ecosystem. The valuation of tourism was done through a survey conducted in the Leuser Ecosystem in December 2000 and January 2001. In the survey special attention was paid to tourists spending patterns and their willingness to pay (WTP) for conservation of the Leuser Ecosystem. This data then served for a valuation based on the contingent valuation method (CVM) and the net factor income approach. Due to the area specification of the study of Van Beukering et al, it has been chosen to represent the basis of the tourism valuation of the Aceh forests.

Methodology and data

Three types of crucial economic estimates were retrieved from the respondents in the survey by Van Beukering *et al.* (2003). Due to differences in spending patterns and WTP, foreign and local tourist have been kept separate. The results of the survey are summarised in Table 4.8.

Table 4.8 Spending patterns of local and foreign tourists in WTP-survey (in Rp(year 2000)).

	Local tourists	Foreign tourists
Actual spending	68,030	72,206
WTP entrance fee	783	3,800
WTP donation	4,008	51,145

The first question, the actual spending pattern of tourist, shows that the difference between local and foreign tourists is relatively low. However, in the second and third question, willingness to pay additional entrance fee to the Leuser Ecosystem and to give donation regardless of whether the area would ever be visited, a large difference between local and foreign tourist can be observed. The latter value, the WTP to give donation, represents the non-use value of biodiversity, and will therefore only be used in the valuation of biodiversity. Since the values differ between local and foreign tourists, they have been kept separated during the calculations.

The value of tourism has been derived by the following equation:

$$V^{i}_{tourism} = N^{i}_{tourists} \cdot D^{i}_{tourists} \cdot \left(V_{spend} + V_{WTP-entrance}\right), \quad (4.12)$$

where the value of tourism equals number of tourists ($N_{tourists}$) multiplied by the number of days spend in the forest ($D_{tourists}$) and the sum of the actual amount of money spent (V_{spend}) and the WTP of additional entrance fee ($V_{WTP\text{-}entrance}$).

The number of tourists has been derived from recent information on the number of tourist visiting Aceh, as well as an assumption that 40 % of all tourists visit the forest. The length of stay in the forest, actual spending and WTP additional entrance fee is based on results from the survey in 2000/2001 by Van Beukering *et al.* (2003). All monetary values have been index corrected to 2008 values.

Based on these data, following estimates have been used in the valuation of tourism for the Aceh forests.

Table 4.9 Data on tourists visiting the forests of Aceh.

	Local tourists	Foreign tourists
Number of tourists	51,193	1,441
Average length of stay (# days)	1	5
Actual spending (Rp/day)	165,776	2,132,200
WTP additional entrance fee (Rp/day)	1,218	36,552

The main difference between the deforestation and conservation scenario is that the number of tourist-days are assumed to decline annually by 5 percent in the deforestation scenario. Also, the spending and the WTP for the entrance fee are assumed to decrease by 2 percent each year as a result of the reduced attractiveness of the forest. It is actually a genuine fear of the local tourist sector that the orang-utans will become extinct in the long run, resulting in a crash in tourist numbers. In the conservation scenario, tourist numbers are assumed to increase. Due to the current low number of tourists, the growth within the coming years is not considered to reach unsustainable heights. The WTP and the spending increase per tourist day are assumed to increase by 2 percent annually in the conservation scenario.

Results

The value of tourism will in the deforestation scenario decrease over the 30-year period from 3 to 0.3 million US$/yr, while in the conservation scenario the value will increase to US$ 20 million annually. Even though tourism is increasing, the annual value remains relatively low, which mainly is due to the fact that the current number of tourist visiting Aceh's forest areas is very low. However, if efforts are focussed on tourist development, a significant higher value could be expected in the future. The annual value of tourism in the deforestation and in the conservation scenario is depicted in Figure 4.7.

Figure 4.7 Annual benefits for the tourism sector.

4.7 Biodiversity

Biodiversity does not have any economic value unless if there is somebody willing to pay for it. Most people living in areas with a high biodiversity value normally are poorer and have less or no paying capacity. Therefore, the highest biodiversity values are likely to be found with people in industrialized countries, for example in the form of pharmaceutical sources and intrinsic non-use value.

In this study the value of biodiversity will be derived from the potential value of pharmaceutical sources, funds from international organisations aiming for conservation of biodiversity and tourists willingness to give donation for biodiversity conservation (the non-use value of biodiversity). Note that the recreational values of biodiversity for tourist have already been captured in the previous section.

Literature

There are a large number of studies that have aimed at estimating values related to biodiversity. Most studies have been undertaken in the UK and the US and utilise stated preference techniques. In these types of studies, biodiversity valuation can take place at four different levels: genetic diversity, species diversity, ecosystem diversity and functional diversity. Values highly vary, both within and between types of studies. For example, the existence value of tropical rainforests for US citizens has been valued at $4.6/ha/year (Pearce and Pearce, 2000), while the WTP of pharmaceutical companies for genetic material from specific biodiversity hotspots can be as high as $9,177 per hectare in Western Ecuador (Rausser and Small, 1998). It is clear that the assessment of biodiversity values does not lead to a univocal monetary indicator. Although the results from the different valuation studies are difficult to compare, the various results do underline the relatively high monetary values biodiversity conservation can hold.

The potential return from commercial drugs derived from plants species is one strong argument for identifying and preserving the world's biodiversity. About 25 percent of all Western prescription drugs and 75 percent of developing world drugs are based on plants extracts. The main difficulty in valuing the pharmaceutical value lies in quantifying the potential returns from species that have not yet been identified but which may have a potential medicinal value in the future. In order to estimate this as accurate as possible, an elaborate evaluation of the plant diversity as well as potential value of possible medicines should be conducted. As this is beyond the scope of this study, existing studies have been applied.

Table 4.10 Overview of valuation studies of bio-prospecting.

Study reference	Objective of study	Result
Pearce and Moran (1994)	Estimation of the value of land for medicinal plants	Between US$ 0.01 and US$ 21 per hectare in various forests
Simpson *et al*. (1996)	WTP of pharmaceutical companies for genetic material from specific biodiversity hotspots	Range from $ 0.2 per hectare in California Floristic Province to $ 20.6 per hectare in Western Ecuador
Simpson and Craft (1996)	'Social value' of genetic material from specific biodiversity hotspots	Range from $ 29 per hectare in California Floristic Province to $ 2,888 per hectare in Western Ecuador
Rausser and Small (1998)	WTP of pharmaceutical companies for genetic material from specific biodiversity hotspots	Range from $0 per hectare in California Floristic Province to $ 9177 per hectare in Western Ecuador
Kumari (1995)	To estimate the option value of biodiversity for pharmaceutical products	$ 0.52-695/ha/year in Malaysia

Source*:* Mostly adapted from Mullan & Kontoleon (2006)

In the end of the 1990s several bio-prospecting contracts between states and pharmaceutical industries were made for several million US$. Since then the number of agreements have not risen as expected, due to concern of the fairness of the agreements and critique from several environmental groups. Therefore, in the case of the rainforest in Aceh, a rather conservative pharmaceutical value has been assumed. The pharmaceutical potential together with conservation funding and the WTP a donation from tourists will make up the total biodiversity value.

Methodology and data

The first value that contributes to the valuation of biodiversity is the pharmaceutical potential. As mentioned above, we have assumed a conservative value of US$ 1 per hectare of primary forests. In relation to international funding for conservation of biodiversity in the forests of Aceh, there is currently the *Aceh Forest and Environment Program,* which is being implemented by the Leuser International Foundation and Fauna and Flora International (FFI). Funding is provided by the Multi Donor Fund (MDF) with a total of US$ 17.53 million allocated over the period from 2006 to 2010 (World Bank 2005). If deforestation occurs despite the presence of the programme, it is expected that the funding gradually will pull out, just as happened with the EU's funding of the Leuser Development Program. In contrast, if conservation is successful it is likely that either the current program will continue or other funding will become available. However, it is expected that the funding will be lower than during the set-up years from 2006 to 2010.

The final value that contributes to the valuation of biodiversity will be derived from the WTP of tourists to give donation for biodiversity conservation, which represent the non-use value of biodiversity. The value has been obtained from the survey conducted in the Leuser Ecosystem in December 2000 and January 2001 and indexed to 2008 values.

The total value of biodiversity is then calculated as the sum of the three obtained values:

$$V^{i}_{biodiversity} = \left(P_{ha-primary} \cdot P_{value/ha}\right) + \left(C_{Nr.funds} \cdot C_{donation}\right) + \left(T_{nr.tourist} \cdot T_{WTP-donation}\right) \quad (4.13)$$

where the value of the biodiversity is equal to the sum of:

- P: the number of hectares of primary forest and the pharmaceutical value per hectare,
- C: the number of conservation programs in the area and the size of donation, and
- T: the number of tourist and their WTP a donation for conserving biodiversity.

Results

While the value of biodiversity in the deforestation scenario gradually decrease from US$ 10 million per year to US$ 3 million per year, the value in the conservation scenario will be increasing from US$ 10 to US$ 108 per year. The steep increase in value under the conservation scenario is mainly due to an expected growth in the pharmaceutical potential. The annual benefits of biodiversity in the deforestation and the conservation scenario can be seen in Figure 4.8.

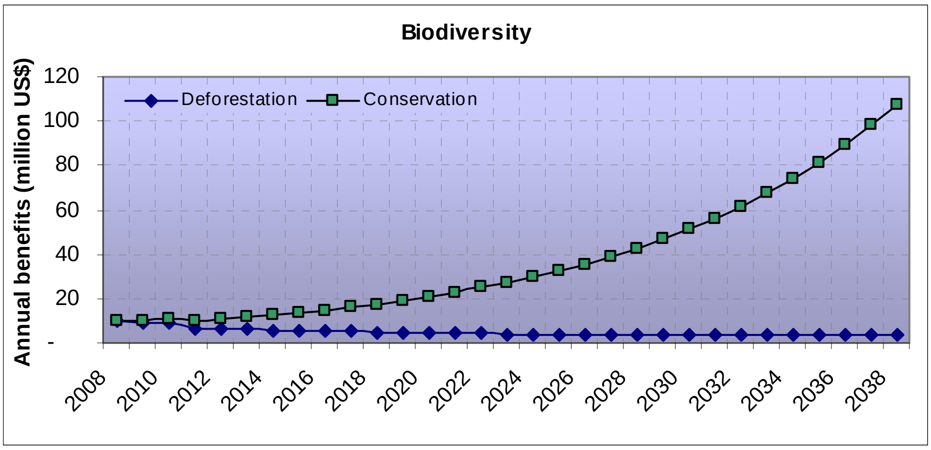


Figure 4.8 Annual benefits for the biodiversity sector.

4.8 Carbon sequestration

As an important element of the global carbon cycle, forest ecosystems are considered highly relevant components of the global debate on climate change. Forests act as a natural carbon sink, removing carbon dioxide (CO_2) from the atmosphere through photosynthesis and capturing it in forest biomass. But what happens when this natural cycle is disrupted by anthropogenic deforestation? It is estimated that tropical deforestation accounts for around 20 percent of the global CO_2 emissions (Chomitz 2006). With large profits to be made from agricultural plantations and commercial logging, there has been little to outweigh the opportunity costs of forest conservation in tropical countries. However recent developments in the international carbon market may offer an unprecedented opportunity to challenge the norm. The market mechanism by which this may be achieved is commonly referred to as avoided deforestation or Reduced Emissions from Deforestation and Degradation (REDD). Through this mechanism the carbon stored in the tropical forests of Indonesia may be monetized and may therefore hold significant potential for economic value.

Literature

Throughout the 1990s there were a number of economic valuation studies aiming to estimate the marginal damage costs of CO_2 emissions. Table 4-11 illustrates the results of these studies. The magnitude of these estimates varies greatly. The main parameters determining these variations are the level of the benchmark estimates of climate change, the time horizon and discount rate selected, and the vulnerability to climate change over time. Estimates of the marginal damage costs range between approximately US$ 6.0 and US$ 228 per tonne of carbon.

Other studies estimating the economic benefits of forest carbon compare the amount of carbon stored under various land uses and then place a monetary value on the amount of carbon stored under each land use scenario (Table 4.12). These studies are however highly dependent on their assumptions made about the carbon sequestration process, the damage costs per ton/C and the discount rate used. This gives a wide variance of values ranging from less than US$ 10/ha/year to US$ 400/ha/year.

Table 4.11 The marginal costs of CO_2 emissions (current (1990) value €^{1990} / tC) [a].

Valuation type [b]	Time of emission	1991-2000	2001-2010	2011-2020	2021-2030	Source
CBA		12.4	18.6	27.4	N.A.	Nordhaus (1994)
CBA		6.0-128	7.9-159	10.1-192	12.2-228	Cline (1992, 1993)
MC		11	13	15	19	Tol (1999)
MC		21.3	23.6	26.1	28.7	Fankhauser (1995)
MC		6.3	8.7	11.9	15.7	Maddison (1994)

[a] Exchange rate 1.0332$=1 €, net present values are discounted to the period of emission.
[b] MC = marginal cost study, i.e. estimate is based on slight perturbation of a baseline.
CBA = cost-benefit study, i.e. estimate is based on a shadow value.

Sources: Reported in Van Beukering, 2001, p. 68.

Table 4.12 Economic valuation of carbon sequestration in different countries.

Valuation	Location	Value US$/ha/year	Source
Value of carbon sequestration	USA	$58.8/ha/year	Loomis and Richardson (2000)
Value of carbon sequestration	Canada	$24-120/ha/year	van Kooten and Bulte (1999)
Value of carbon sequestration by US national forests	USA	$37/ha/year	Dunkiel and Sugarman (1998)
Value of carbon sequestration	UK	$280-413 per ha	Pearce (1994)
Carbon sequestration	Scandinavia	$10-15/ha/year	Turner *et al*. (2003)
Carbon sequestration	Uganda	$5.83/ha/year based on damage costs; $6.81/ha/year based on replacement costs	Howard (1995)
Carbon sequestration	Costa Rica	$105/ha/year	Bulte *et al*. (2002)

Besides using economic valuation studies, a value can be placed on forest carbon by observing the growing carbon markets. The dominant global carbon market is regulated by the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC). This regulatory carbon market has so far limited forest carbon offsets to Afforestation and Reforestation, not committing to a mechanism for REDD, at least for the first commitment period (2008-2012). However negotiations at the Conference of the Parties (COP) in Bali 2007 have deemed REDD suitable for inclusion in a post-Kyoto regime. For the moment, it is the voluntary carbon market that provides for REDD carbon trading.

To market carbon from avoided deforestation you must first estimate carbon emissions originating from deforestation activities. This is done by comparing carbon densities of forest with the carbon densities of the replacing land use after the forest is cleared. Table 4.13 provides a range of carbon density estimates made for forests and some other possible replacing land uses for Indonesia. Carbon revenues are then generated by comparing carbon emissions under the deforestation scenario, with carbon emissions under the conservation scenario.

Table 4.13 Carbon density estimates of forest and some alternative land uses for Indonesia.

Forest	Biomass C density (ton/ha)		Source
	Undisturbed	Logged	
Indonesia	390	148	Hairiah & Sitompul (2000) [a]
	254	150	Noorwijk et al. (2000) [b]
	325	245	Murdiyarso & Wasrin (1995) [c]
Asia (insular)	180-335		IPCC (2006) [a]
Other land uses			
Cultivated agricultural lands	5		Murdiyarso & Wasrin (1995) [c]
Shifting cultivation	15-50		
Grasslands	15-20		
Rubber monoculture	97		Noorwijk et al. (2000) [b]
Oil palm monoculture	91		

a above- and belowground biomass.
b aboveground biomass and upper 30cm of soil.
c aboveground biomass only.

Methodology and data

To estimate the economic value of carbon stored in the Aceh forests, the following procedure is used. First, an estimate of CO_2 emissions under the deforestation scenario must be made (equation 4.14).

$$E_{Carbon} = E_{Deforestation} - C_{\mathrm{Re}\,placingLU} \qquad (4.14)$$

This estimate consists of two carbon components; the carbon emissions from the forest lost to deforestation ($E_{Deforestation}$), and the carbon density of the replacing land use ($C_{\mathrm{Re}\,placingLU}$). For consistency and simplicity, similar assumptions made by the Ulu Massen REDD project (reference) will be adopted and applied to the forested area of Aceh province. This scenario will therefore assume that Primary and Secondary[7] forest have an average carbon density of 200 tC/ha and 150 tC/ha, respectively. The replacing land uses are assumed to be palm oil plantations (25 percent), mixed forest (20 percent), and scrub land (55 percent), with carbon density values of 76tC/ha, 85tC/ha and 55tC/ha respectively. Combining these conversion patterns and corresponding carbon densities with the rate forest loss in the deforestation scenario result in the net CO_2 emissions from deforestation. To estimate the economic value of carbon the following equation is used.

$$V_{Carbon} = \left(E_{Avoided} - E_{Leak-Perm}\right) \cdot P_{Carbon} \qquad (4.15)$$

Under the REDD mechanism, CO_2 is only of value when it prevented from being emitted to the atmosphere ($E_{Avoided}$). Under the conservation scenario, deforestation is assumed

7 In the Ulu Massen PDD they use the terms Undisturbed and Disturbed forest. In this report these terms will represent Primary and Secondary forest respectively.

to completely stop, i.e. all CO_2 emissions are avoided. Carbon revenues will be assumed to be limited to 50 percent in the first year due to project start-up, and leakage and permanence risk mitigation ($E_{Leak-Perm}$). By year five, 90 percent of reduced carbon emissions revenues will be captured with 10 percent lost to leakage and permanence.

The next step is to attribute a monetary value to the avoided CO_2 emissions. This can be done in two ways; (1) by using economic valuation studies based on the actual damage caused by carbon emissions and (2) by observing current market prices. The economic valuation estimates presented in table 1 above are representative of the marginal cost of carbon emissions to global society, and do not necessarily reflect the current market price. For this study it is more fitting to value the forest carbon according to the observed market price. The average price for one tonne of CO_2 offset from avoided deforestation in 2007 was $US 4.80 (Hamilton *et al.* 2008). This price can then be applied to the quantity of emissions avoided to give the gross market value.

Finally, the cost of implementing and sustaining a carbon conservation project must be considered. A number of studies have estimated the costs of conserving forest carbon. Kremen *et al.* (2000) reported costs of between US$ 0.23 and US$ 4.34 per ton of CO_2 generated from forest conservation in Madagascar. This range is comparable to the figure of Schwarze (2000) estimating costs of land use change and forestry projects to be US$ 2.80 per ton CO_2. For this study, the costs associated with carbon emission reducetions will be related to estimated costs of the Ulu Massen REDD project. During the first five years of the project costs are high due to project start-up and implementation. After this period costs are assumed to reduce by 50 percent, accounting only for monitoring and verification of emission reductions and forest conservation activities. Using the above assumptions and the budgetary information provided by the Ulu Massen PDD, the average cost over the 30-year period is assumed to be US$ 1.70 per ton of CO_2. When costs are included, the net benefit value is US$ 3.10 per ton of CO_2.

Results

The results of the annual benefits for carbon sequestration are illustrated in Figure 4.9. In the deforestation scenario, the deforestation rate is not reduced. This means no carbon emissions are avoided and therefore, no carbon revenues are generated. In the conservation scenario deforestation is assumed to completely stop. The carbon benefits from avoided deforestation quickly become realised resulting in a substantial amount of revenues generated over the first 10 years. The trend of carbon benefits in the conservation scenario is purely dependent on the alternative deforestation rate in the deforestation scenario that explains the correlation between the two. The average annual benefit from carbon sequestration is US$ 56 million/year, totalling US$ 1749 million over the given timeframe.

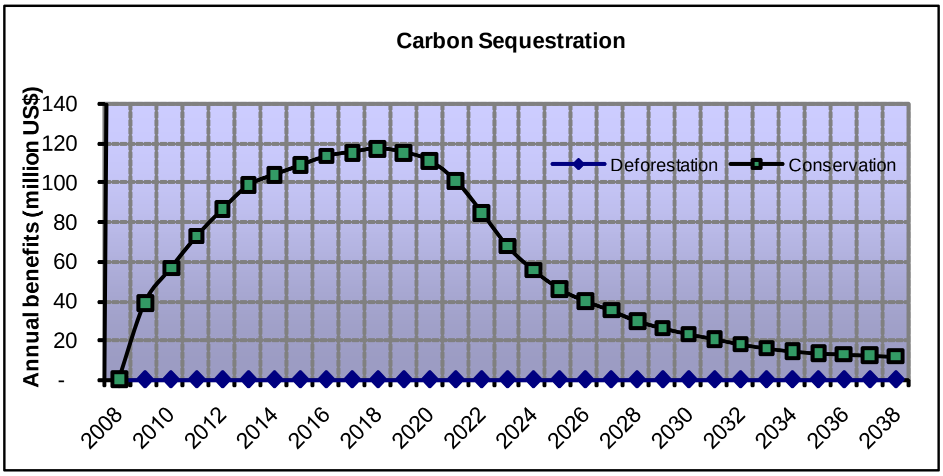


Figure 4.9 Annual benefits for the sequestration sector.

4.9 Fire prevention

Forest fires are common in Indonesia, destroying thousands of hectares of forest every year. Most fires are ignited deliberately by people attempting to clear the forest as rapidly and cheaply as possible for plantations. The lucrative oil palm industry has often been cited as one of the primary culprits on Sumatra (Sargeant 2001, Global Forest Watch 2002). The problem is compounded during the dry season when hot and dry winds blowing from the southwest result in an explosion of fires throughout Indonesia. Intact forest provide greater resistance to fire, while more open forest, degraded land, and plantations remain highly susceptible to fire, especially in dry periods. Thus, quality and quantity of forest in Aceh holds an economic value in terms of fire prevention.

Literature

Fires are a potential threat to sustainable development, due to their direct effect on ecosystems, contribution to GHG emission, impact on biodiversity and polluting smoke haze (Tacconi 2003). A devastating fire engulfed vast areas in Indonesia in 1997 and 1998. A prolonged dry season caused by the El Niňo phenomenon created the conditions for uncontrollable forest fires. Nearly 10 million hectares burned, exposing some 20 million people across Southeast Asia to harmful smoke-borne pollutants for long periods.

Since then there have been a number of studies aiming to estimate the total economic damage caused by these fires. Barber and Schweithelm (2000) estimated the damage caused to be US$ 9.3 billion. Tacconi (2003) updated and compared two other studies by Glover and Gessup (1999) and BAPPENAS-ADB (1999) that produced more conservative estimates of between US$ 3.5 and 6.3 billion respectively. Table 4.14 provides a summary of the estimated economic damages from the resultant breakdown of transportation, destruction of crops and timber, precipitous decline in tourism, additional health care costs, and other costs.

Methodology and data

To what extent can intact rainforest be considered to have a fire prevention function, and thus an additional value for preventing economic damage? Uhl (1990) describes how disturbed for is much more prone to fires than primary forests. The danger 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.

To estimate the economic value of the forest in Aceh for fire prevention, a similar approach as had been applied for flood prevention has been followed. The main question is what the damage from fires would be if the forest in Aceh were degraded. Similar to the issue of flooding, the value for fire prevention is expressed in terms of avoided damage. As shown in equation 4.15, the avoided fire damage (V_{fire}) equals the product of the damage of a fire event ($L_{potential}$) with the probability that fire will occur (P_{fire}).

$$V^i_{fire} = L^i_{potential} \cdot P^i_{fire} \qquad \text{for } i \in \{\text{district}\} \qquad (4.15)$$

The average damage is assumed to be growing proportional with the local economy for each district. The potential economic damage is primarily based on the average estimated damage caused by the 1997/98 fires from the two studies reported by Tacconi (2003). Sumatra accounted for almost 18 percent of the area burned in these fires. This means that 18 percent of the total damages can be attributed to Sumatra. A fraction of this percentage can be then attributed to the burnable area of Aceh.

Table 4.14 Summary of economic damages related to fire across various sectors.

Cost Item	Indonesia		Other Countries		**Total**
	Tangible	Intangible	Tangible	Intangible	
1. Fire-related costs					
• Timber	1,461				
• Lost growth of timber	287				
• Timber plantation	91				
• Estate crops	319				
• NTFPs		631			
Indirect forest benefits					
• Flood protection		413			
• Erosion and siltation		1,354			
• Fire fighting costs	12				
• Carbon emissions				1,446	
• Building and property	1				
Sub-total	2,171	2,398		1,446	
2. Smoke haze-related costs					
• Health		148			
• Tourism	111				
• Transportation	33				
Sub-total	144	148			
Total costs	**2,315**	**2,546**		**1,446**	**6,307**

The probability of a fire occurring in the area due to deforestation (P_{fire}) is determined by the current probability of fire events in different forms of land use ($P_{fire\_landuse}$) multiplied by an indicator of the current composition of land uses ($L_{landuse}$). For example, a fire event in a primary forest is assumed to occur once in 50 years. In contrast, fire events in grasslands are assumed to occur every 7 years.

$$P^{i}_{fire} = \sum_{landuse} (P_{fire\_landuse} \cdot L^{i}_{landuse}) \quad \text{for } i \in \{\text{district}\}, \text{and "landuse"} \in \{\text{primary forest, secondary forest, plantation, grasslands}\} \qquad (4.16)$$

Results

The results of the annual benefits of forest for fire prevention are illustrated in Figure 4.10. There are two components that influence the value of fire prevention; the composition of land cover, and the growth in the economy. In the deforestation scenario, more primary and secondary forest is converted to alternative land uses that have higher fire risk. This means that the fire prevention potential that could be attributed to forests is reduced resulting in a higher likelihood of fire occurrence and a corresponding decrease in avoided damages. However, as can be seen in figure xx, there comes a point in time in the deforestation scenario where the value of fire prevention begins to increase again. This can be explained by the combination is of two factors.

1. The value of avoided damages increase with growth in the economy and,
2. The deforestation rate begins to decrease after year 2020.

The combination of these two factors means there comes a point in time where the increasing value of avoided damage from remaining forest cover outweighs the reduction in avoided damages from the reduced forest cover.

In the conservation scenario no change in forest cover and alternative land uses mean that the probability of fire occurrence does not change over time. The increase in economic value seen in figure xx is solely attributable to the growth in economy. The average value for fire prevention in the conservation scenario is US$ 12 million/year, totalling US$ 370 over the given timeframe.

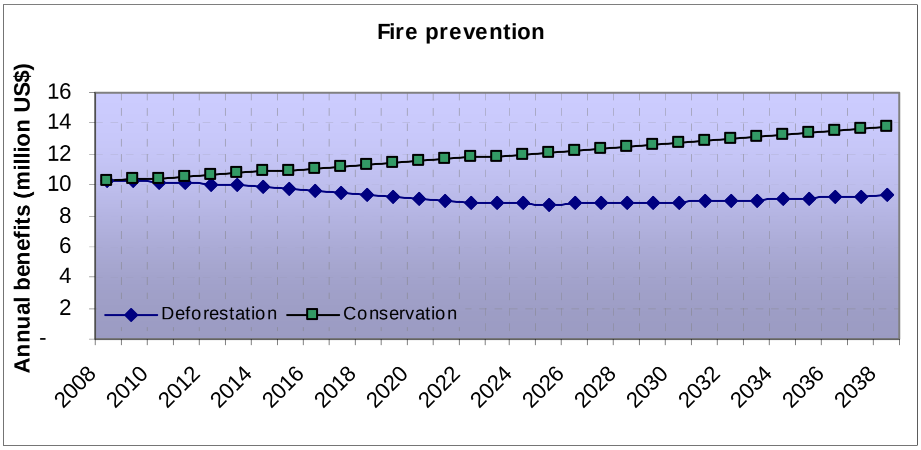


Figure 4.10 Annual benefits for fire prevention sector.

4.10 Non-timber forest products

Forests provide a wide range of products other than timber, such as firewood, food and medicines. These are referred to as non-timber-forest-products (NTFPs) and are often harvested on a small scale from wild sources and can be an important asset to local livelihood.

Non-timber forest products (NTFP) have a rather ambiguous status as an economic value. Similar to timber, the exploitation of NTFP is limited to a certain threshold level. If too much is harvested, future benefits will be lost. At the same time, withholding local people from access to NTFP also avoids the potential benefits to be realised. Therefore, in the deforestation scenario a short-term increase in harvested NTFP will be observed in the first decade after which this sector becomes practically non-active due to over-exploitation.

The economic value of NTFPs can be elicited directly when a market exist for the collected products. However, it is not always easy to retrieve market prices for some NTFP as certain goods are predominantly exchanged in barter trade. When a market price for NTFP is determined, the costs of harvest need to be estimated in order to obtain the net value.

Literature

A wide range of estimates of the value of NTFP is available in the literature. Bann (1998) and CBD (2001) provide an overview of studies with values ranging from a few dollars per hectare to several hundreds. In the table below, an overview of studies on valuation of NTFP's in forest in Southeast Asia can be seen.

Values range from 8 US$/ha to 55 US$/ha in the Southeast Asian forests. The higher values relate to readily accessible forest and values for non-accessible forest would be close to zero in net terms due to the costs of access and extraction.

Since specific data for local NTFP production and prices are available for the Aceh area in Van Beukering *et al*. (2000), these will be used to estimate the value of NTFP's in the forests of Aceh. However, the derived value will at the end of this section be compared with the values presented in Table 4.15.

Table 4.15 Overview of studies valuing NTFPs in Southeast Asia.

Source	Products	Site	Net Value (US$/ha)
Mai *et al*., 1999	Bamboo, medicinal plants, fuelwood, fodder, rattan, food plants	Vietnam	27-55
Bann, 1997	Nuts, wildmeat, rattan etc.	Ratanakiri, Cambodia	19
Caldecott, 1988	Fauna (wildlife)	Sarawak, Malaysia	8
Godoy and Feaw, 1989	Rattan	Kalimantan, Indonesia	53

Methodology and data

Three types of products are considered in estimating the total value (V_{NFTP}), categorized according to the value of the product. Low value products include cotton tree, rattan, resin, rumbia/nipah/sagu, and gum benzoin. Medium value products consist of nutmeg, aromatic oil, candlenut, cinnamon, and palm sugar. High value products include honey, vanilla, and bird nests. The total NTFP value of the forest in Aceh for each district is the sum of these values, (see equation 4.17).

$$V^i_{NTFP} = \sum_P A^i_P \qquad \text{for } i \in \{district\},\ P \in \{low\ value,\ medium\ value,\ high\ value\}$$

(4.17)

The value for NTFP is demonstrated for low-value products (A_{NTFP_low}). It consists of two components: (1) a value based on the collected quantity, and (2) a value based on the price advantage compared to its substitutes.

$$A^i_{NTFP\_low} = Q^i_{NTFP\_low} \cdot p^i_{NTFP\_low} + Q_{shortage} \cdot (p_{NTFP\_low} - p_{substitute}) \qquad \text{for } i \in \{district\} \qquad (4.18)$$

As shown in equation 4.18, the calculation of the first component ($Q_{NTFP\_low} * p_{NTFP\_low}$), the total revenues or private benefits generated from the collected NTFP, seems rather straightforward. However, it is not always easy to retrieve market prices for some NTFP as was mentioned above. The second component is based on the reasoning that substitutes are often more expensive. $Q_{Shortage}$ is an indication of the relation between what is demanded and the quantity that the forest can supply.

$$Q_{shortage} = Q_{demand} - (Q_{\sup ply} + Q_{additional}) \qquad (4.19)$$

In the deforestation scenario the supply will be increasing in short term, as additional extraction becomes possible. However, this additional supply will fast be overcome by overexploitation, and the total extraction that is possible from the forest will decline. The overexploitation necessitates the local community to purchase more costly substitutes in the long run. Therefore, the value for NTFP in the deforestation scenario may not only become very small, in fact, the value may even turn negative because the local demand will now have to be met by more expensive substitutes.

The current production of NTFP's in the Aceh forest has been determined on the basis of data from Van Beukering *et al*. (2003). As shown in Figure 4.11, a relationship between production of NTFP and the area of primary forest per capita were found. The production of NTFP will increase until a level of 2 hectares of primary forest per capita is reached, and thereafter level off. On the basis of the polynomial function, the production of NTFP in each of the kabupatens of Aceh has been calculated. Table 4.16 shows the overall production and prices for the three categories of NTFPs.

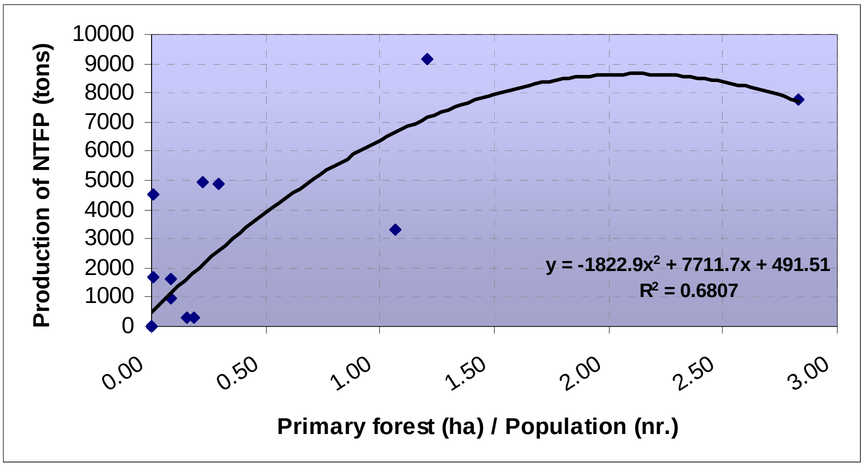


Figure 4.11 Relationship between production of NTFP and the area of primary forest per capita.

The production of NTFP will increase until a level of 2 hectares of primary forest per capita is reached, and thereafter level off. On the basis of the given polynomial function, the production of NTFP in each of the kabupatens of Aceh has been calculated. In the table below the overall production, as well as prices can be seen for the three categories of NTFPs.

Table 4.16 Overall production and market prices for NTFP in Aceh.

NTFP	Production (ton)	Price in Banda Aceh (million RP/ton)
Low value NTFP	23,539	1,399,264
Medium value NTFP	50,733	2,162,974
High value NTFP	532	7,005,800

Source: Extrapolated from data given in Van Beukering *et al.* (2000).

Results

Figure 4.12 shows the annual benefits of NTFPs in the two scenarios. In the deforestation scenario the average annual value of NTFPs is decreasing from US$ 16 million/year to US$ 1 million/year. In contrast, the benefits of NTFPs in the conservation scenario are increasing gradually, leading to an average annual value of US$ 21 million/year. Is these estimates converted to a value per hectare, we get an initial value of NTFPs of almost 7 US$/ha of primary forest. This value is decreasing in the deforestation scenario, while it is increasing to 12 US$/ha over the 30-year period in the conservation scenario. The estimated NTFP values seem comparable to those of other literature on NTFPs in Southeast Asia, but can also be concluded to be relatively conservative. The annual value of NTFPs is illustrated in Figure 4.12.

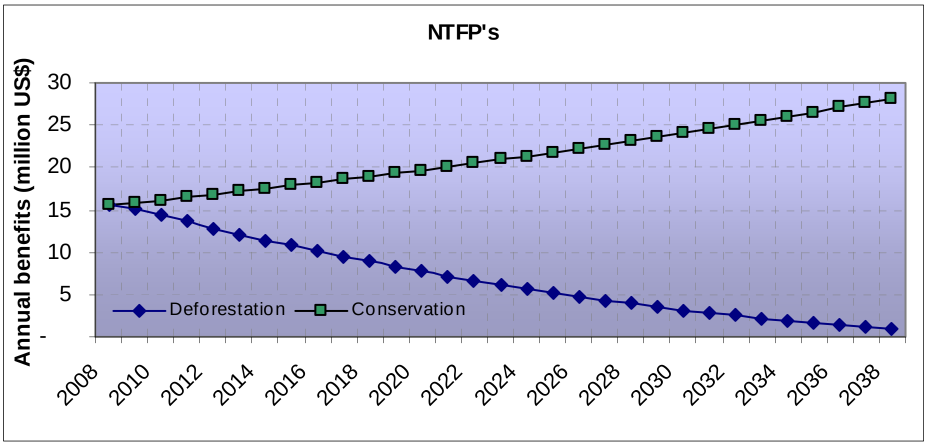


Figure 4.12 Shows TEV for the NTFP sector.

4.11 Timber

As one of the most abundant natural resources in Aceh, timber production has for long been an important provisioning service of the Aceh forest. Despite the efforts of recent years this industry is characterized by turbulence and illegal activities. In 2001 forest concessions were closed in an effort to gain control over the rampant exploitation of Aceh's timber reserves. Following the 2004 tsunami, local demand of timber rose dramatically as reconstruction began, initiating the resumption of earlier logging practices. As reconstruction neared completion, concerns were again expressed about the long-term sustainability of the logging practices leading to a logging moratorium re-imposed in 2007 pending the preparation of a master plan (Blackett and Irianto 2007). With dense stands of tropical forests holding vast quantities of valuable timber, the forests of Aceh hold significant economic value in terms of timber extraction.

Literature

If the forests of Aceh are to be completely conserved it means that a significant financial loss is incurred representing the opportunity cost of forest conversion. There have been a number of studies attempting to estimate these costs. The majority of this opportunity cost is composed timber extraction and the profits to be made from lucrative alternative land uses. Greg-Gran (2006) reports estimates the opportunity costs of foregone timber extraction in three developing countries. Of the three countries included, Indonesia presents the highest opportunity costs of foregone timber extraction of US$ 1,130[8]. However this estimate was described by Tomich *et al.* (2002) as a rather conservative estimate. Another fraction of the opportunity cost of conservation will include a cost to local households who are employed directly or indirectly through the logging industry. Butry and Pattanayak (2001) estimated the total losses to households supported through logging activities in Indonesia to be over US$ 24 /ha/yr.

Since timber is marketed, its economic value should, in principle, be easy to derive. However, in practice there are several problems involved in estimating this value such as determining the 'ex forest price' (the price received on sale to either a processor or an exporter) and the costs of transaction and transportation (Secretariat of the CBD, 2001). Gregersen *et al.* (1995) give insight into the methods that can generally be applied to derive timber values. Market prices are usually available for round wood delivered at the processing plant or point of export. Costs of harvesting, extraction, and transport have to be deducted to arrive at a residual price for standing timber in the forest. Total values are derived by applying these unit prices to the estimated quantities that could be harvested as sustainable annual flows of timber from the available standing stock.

Table 4.17 Opportunity costs of foregone timber harvesting.

Source	Location	Opportunity costs ($/ha/year)
Grieg-Gran (2006)*	Various	Opportunity costs of foregone timber harvesting: Ghana: $830/ha Brazil: $236/ha Indonesian: $1035/ha/year
Butry and Pattanayak (2001)	Indonesia	Total losses to logging households: $24.23/ha/year

* Prices shown in table were reported by Grieg-Gran in 2005 US$.

Indonesia is known for high yielding timber harvests. Most studies report the average amount of commercial timber harvested in Southeast Asia and Indonesia to be around 30 m^3 of logwood per hectare (FAO 1990, Kartodihardjo 2002, Tacconi 2003). Much of the timber harvested is processed in one of the many sawmills or plywood mills. Timber processing industries in Aceh commonly use old machinery and dated technology resulting in low recovery efficiencies of only 50 percent (Blackett and Irianto 2007).
Table 4.18 depicts historical production volumes in Aceh in log- and sawn wood.

8 This price is corrected from US$2005 (1035) to US$2008 (1130).

Table 4.18 Log and sawn timber production in Aceh. FAO(2007).

Year	Log production (m^3)	Sawn timber production (m^3)*
2001	92,245	58,266
2002	163,232	112,856
2003	64,233	35,505
2004	44,171	39,082
2005	37,490	27,432
2006	54,450	11,738

* FAO (2007) reported two different totals for sawn timber in Aceh. Only one of is shown here.
Source: Blackett and Irianto (2007).

Methodology and data

Timber extracted from the forest is typically marketed, and therefore market prices can be used for its valuation. Market prices are available for sawn wood in Aceh. Total value is then derived by applying the price for a unit of timber to the estimated quantities that could be harvested from the area of forest under sustainable harvesting (Bann 1998). In the case of the forests in Aceh, this latter condition does not necessarily hold because it is in fact the purpose of this study to determine the costs and benefits of unsustainable logging (clear-cut) practices. The conservation scenario assumes a strict ban on logging.

In valuing the economic value of timber of the forests in Aceh (V_{timber}), a comparable approach is followed as has been applied to NTFP. Three types of timber products are considered categorised according to the value of the product. The total timber value of the Aceh forests is the sum of these values, (see equation 4.20).

$$V^i_{timber} = \sum_T A^i_T \quad \text{for } i \in \{\text{regency}\},\ T \in \{\text{low value, medium value, high value}\} \tag{4.20}$$

Similar to NTFP, the timber value consists of two components: (1) a value based on the logged quantity, and (2) a value based on the price difference compared to its future substitutes (see explanation for NTFP). It should be noted that the second component, the increased costs of wood in the future, is a very real threat for Indonesia. In 1995, the first signs of a wood shortage in Indonesia had already been noticed. A study by the World Bank (1995) stressed that the remaining virgin forest in the company's concession would last no more than 10 to 15 years, and there appear strong doubts that the conditions for regenerating forests will allow adequate supply beyond that period. This certainly implies that domestic supply shortage will become real in the near future.

The pattern of logging in the 'deforestation' scenario has been shown in Figure 3.1. We assume a harvesting efficiency of 30 m^3 of logwood per hectare of primary forest cleared and half of this amount for secondary forest. To determine the value of the harvested timber we further assume a round-wood/sawn-wood ratio of 50 percent. The different categories of timber used for the valuation are meranti, other hardwood and other wood. For primary forest the volume commercialised is assumed to be 1, 10 and 4 m^3/ha, respectively. For secondary forest this volume is much lower at 0.5, 5 and 2 m^3/ha, respectively. Once a gross valuation of the timber is established the value must be corrected for harvesting, processing and transportation costs. Blackett and Irianto (2007) report costs of US$ 42.50 per m^3 for logwood. As the recovery efficiency of log wood to sawn wood is 50 percent these costs are doubled for total costs attributed to sawn wood.

Results

The results of the annual benefits for timber are illustrated in Figure 4.13. In the deforestation scenario, timber harvesting is assumed to quickly resume to similar levels before the logging moratorium, representing the sharp rise in revenues captured from sales in timber in the first year. From there on timber revenues are directly dependent on the deforestation rate, i.e. the amount of timber harvested per hectare of forest cleared. The average annual benefits from timber is estimated to be US$ 149 million/year, totalling US$ 4,634 million over the given time period. In the conservation scenario all deforestation and logging is assumed to stop. This means even local demand for timber cannot be met and therefore timber must be imported into the region, resulting in negative benefits.

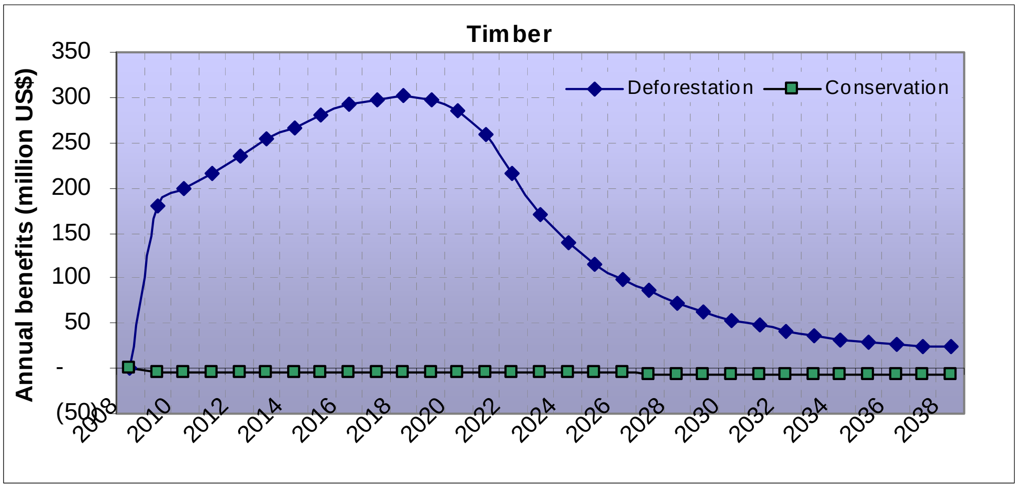


Figure 4.13 Annual benefits for the timber sector.

5. Results

By combining the individual benefits discussed in Chapter 4, the results of the economic valuation exercise are presented as the Total Economic Value (TEV). Several perspectives will be addressed: (1) Overall TEV; (2) Different sectors; and (3) Sensitivity Analysis.

5.1 Overall TEV

By aggregating the net benefits over time, the TEV for the 'deforestation' and 'conservation' scenarios can be determined. Figure 5.1 shows the annual net benefits for both scenarios over the period 2009-2038.

Until 2020, the deforestation scenario generates higher socio-economic benefits than the conservation scenario. This development is the result of two underlying mechanisms: (1) large revenues result from increased logging and harvesting of NTFP, and (2) the negative impacts of deforestation are still within manageable dimensions. After 2020, however, the net annual benefits of conservation outweigh the benefits from increased logging. The 'low-hanging-fruits' have been picked and its branches destroyed. The forest that is left is difficult to reach and therefore less attractive to log. Moreover, the negative effects of declining water retention, reduced pest control, increased erosion, and more frequent events of floods and droughts, now starts to take its toll.

The net annual benefits of the conservation scenario, on the other hand, increases as the growing economy becomes more efficient in utilising the 'goods and services' of the forest ecosystem. Various sectors, such as the tourist industry, agriculture, and hydroelectricity, gain from the existence of the rainforest. They both expand their activities and generate higher per unit benefits.

Based on the annual figures presented in Figure 5.1, the TEV can be calculated by aggregating the discounted values of the net annual benefits over time. As discussed in Section 2.3, the choice of the discount rate is crucially important for the calculation of the net present value and hence for the TEV. Someone with a short-term perspective will tend to use a relatively high discount rate. For environmental goods, however, a discount rate between 3 and 5 percent is generally used (Pearce and Ulph 1995). Some economists argue, however, that a zero percent discount rate is fairer for environmental goods with irreversible effects where future generations will still be impacted by decisions made now. Others argue that in developing countries, given capital scarcity, relatively high discount rates are more appropriate.

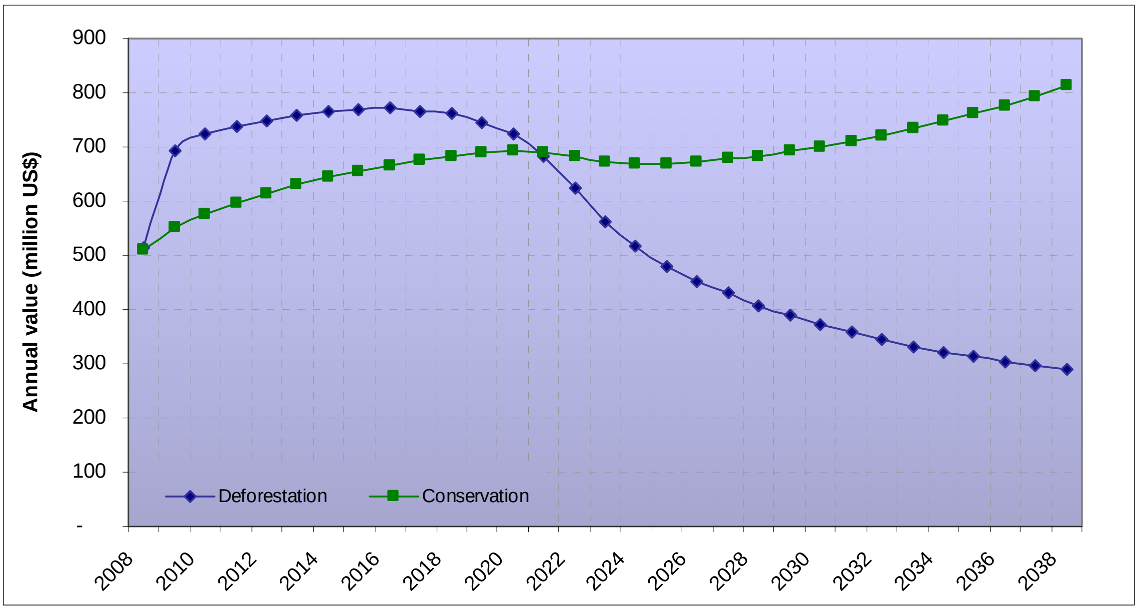


Figure 5.1 Net annual benefits over time.

Table 5.1 presents the NPV per hectare for the average forest in Aceh for 0%, 5%, 10% and 15% discount rates. In addition, Figure 5.2 presents the TEV for the two scenarios as a function of the discount rate. Discount rates ranging from 0 to 15 percent have been used. The higher this rate, the more future benefits will be discounted away. The figure shows the converging TEV of the deforestation, and conservation 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 especially in the longer run. Although the curves converge, it only occurs at a discount rate of +- 8% following which the divergence between both scenarios is very shallow and slow. At discount rates <8% the conservation scenario is superior to the deforestation scenario after which the deforestation scenario, given its short term profitability characteristics becomes superior to the conservation scenario, however only marginally.

Table 5.1 TEV under varying discount rates (millions of US$).

Scenario	Discount rate 0%	Discount rate 5%	Discount rate 10%	Discount rate 15%
Deforestation	17,716	10,368	7,016	5,237
Conservation	21,909	11,107	6,825	4,813

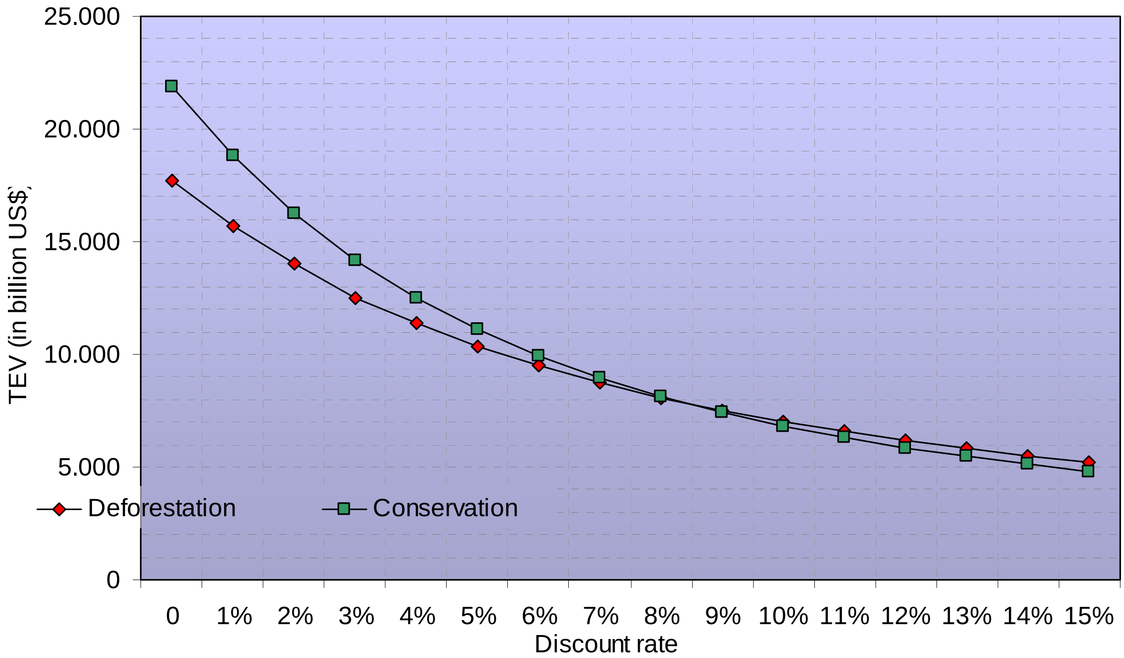


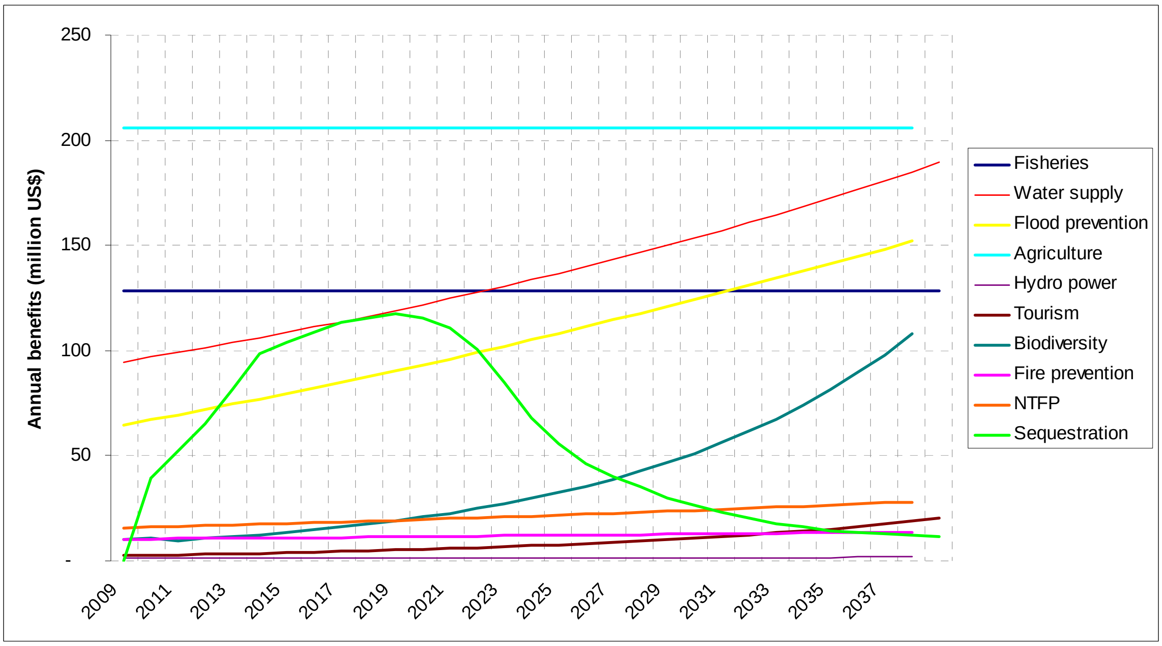
Figure 5.2 TEV of the Aceh Forestry Ecosystem at varying discount rates.

5.2 Sectors

The TEV is comprised of the numerous benefits of ecosystem goods and services provided by the forests ecosystem in Aceh. The Figures below show the development of benefits to the different sectors for the two scenarios. Note that some sectors yield much higher benefits than others and subsequently when displaying all sectors on one graph the smaller yielding sectors have become crowded towards the X-axis (especially in the deforestation scenario where small benefit yielding sectors such as hydro-power and fire prevention become even smaller as the time moves on). Individual sector graphs can be found in the results section of each sector (section 4.1-4.11).

The figure below shows the distribution of benefits across the sectors for both the deforestation and the conservation scenarios. Again there are clear big sectors such as agriculture, fisheries and water supply that shadow the smaller yielding sectors like tourism, hydropower and fire prevention. What can be seen from the figure is the disappearance of sequestration in the deforestation scenario replaced by timber.

Conservation scenario



Deforestation scenario

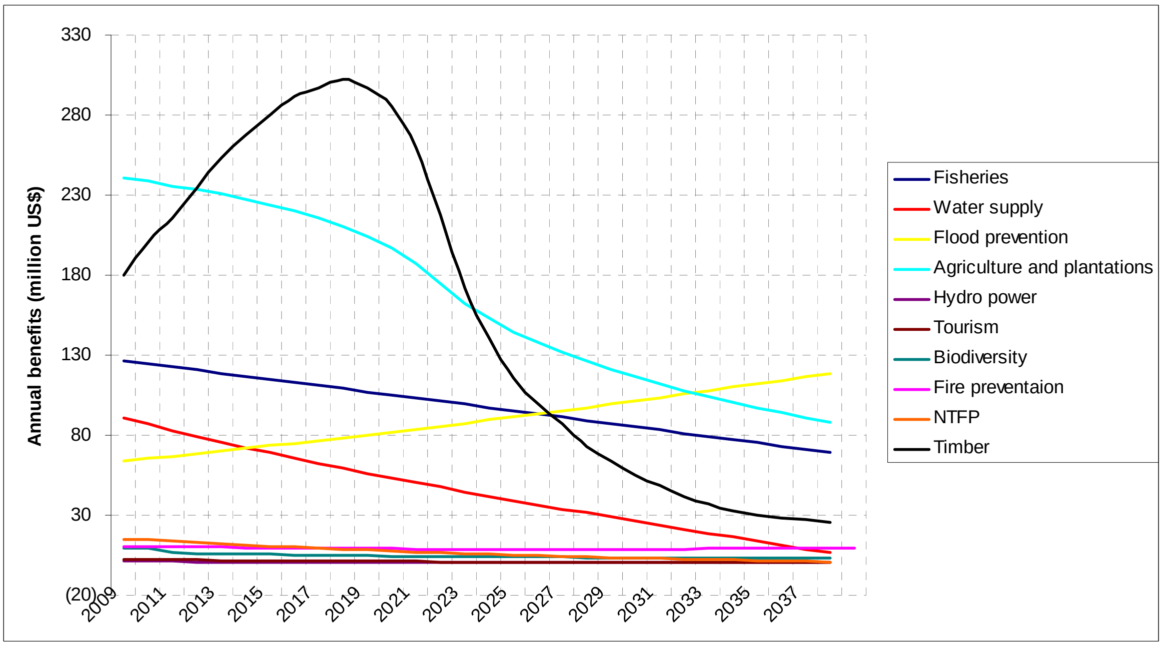


Figure 5.3 Development of benefits to different sectors over the period 2009-2038.

Table 5.2 Total value and distribution of benefits amongst sectors for both scenarios (at 3.5% discounting).

Sector	Deforestation Value (in million US$)	Proportion (%)	Conservation Value (in million US$)	Proportion (%)
Water supply	1,059	8.8	2,487	18.5
Fishery	2,025	16.9	2,490	18.6
Flood prevention	1,622	13.5	1,860	13.9
Agriculture	3,512	29.2	3,991	29.8
Hydro-electricity	15	0.1	26	0.2
Tourism	25	0.2	139	1.0
Biodiversity	103	0.9	582	4.3
Sequestration	-	0.0	1,217	9.1
Fire prevention	183	1.5	225	1.7
Non-timber forest products	161	1.3	391	2.9
Timber	3,308	27.5	0	0.0
Total	**12,011**	**100.0**	**13,408**	**100.0**

5.3 Sensitivity analysis

A large number of assumptions have been made to be able to generate the results. This was necessary, given the constraints of data, budget and time for this research. These assumptions need not to be problematic as long as the results are relatively robust vis-à-vis changes in the assumed parameter values. In the following, four crucial parameters are tested for robustness: population growth and the value of water, timber and carbon.

Population growth

The scenarios presented above are calculated at an annual population growth of 2 percent. Depending on economic and political conditions, this growth rate is likely to vary. Many of the above benefits, such as water supply, flooding and NTFP, depend strongly on the number of people that use the goods and services of the forest. Therefore, a change in population growth will have a significant impact on the benefits of the Aceh forests. Figure 5.4 shows the outcome of the sensitivity analysis for the growth rate of population.

Benefits in the conservation are more sensitive to population growth than deforestation, because the former benefits are more directly attributed to the local population. This implies that at a population growth higher than 2%, the positive difference in benefits between the conservation and the deforestation scenarios are even higher. The opposite holds for a population growth lower than 2%, but that seems less likely to occur in the short run. It is also clear from Figure 5.4 that the changes in TEV due to differences in population growth rates are rather small. Therefore, the model outcomes are robust for changes in population growth.

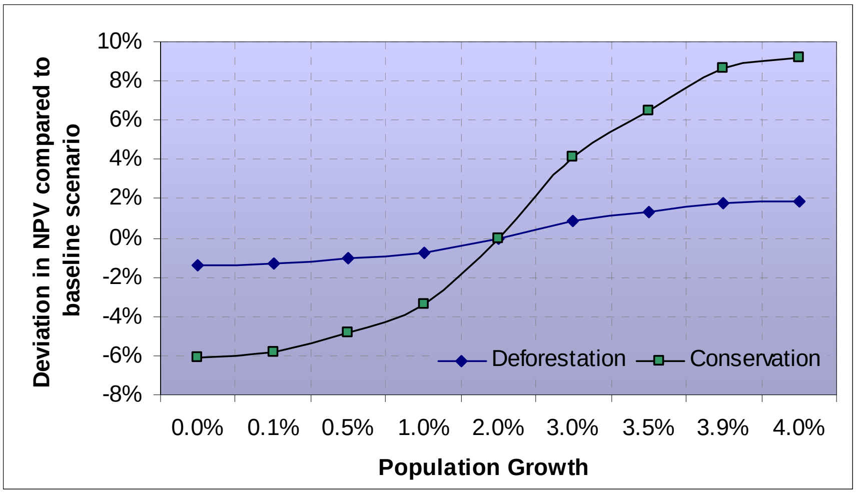


Figure 5.4 Change in Net Present Value for different population growth rates.

Value of water

In calculating the benefits of water supply, a price of water of 0.6 US$/m^3 and 1 US$/m^3 for respectively households and industries have been assumed. Figure 5.5 shows the sensitivity of the deforestation and the conservation scenario for different price levels. The conservation scenario is relatively robust to changes in water price, while the deforestation scenario is influenced significantly. With small price increases/decreases the benefits of the deforestation scenario accordingly increase or decrease with a high rate, but the relative changes level off when prices further change. However, even with a price of water at 0 US$/m^3 (-100 %) the conservation scenario still generates more benefits than the deforestation scenario. Therefore, the result of the conservation scenario generating the highest benefits is robust to changes in water prices.

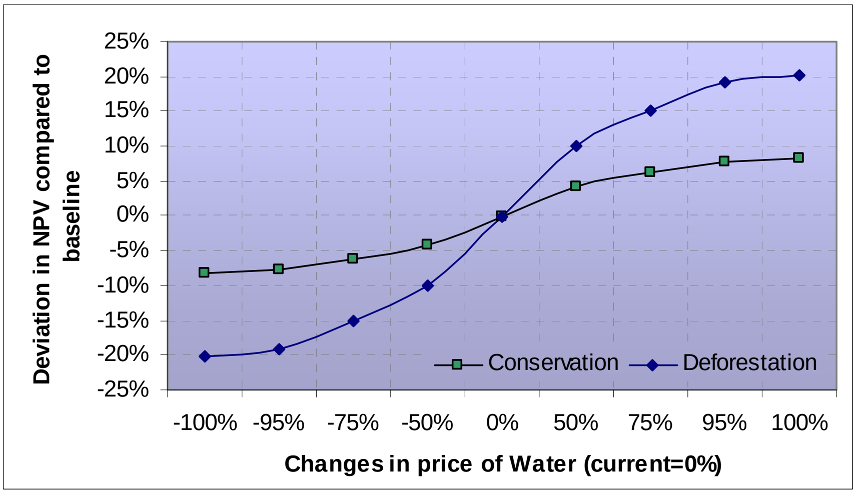


Figure 5.5 Change in Net Present Value for different water prices.

Value of timber

Figure 5.6 shows the sensitivity of the value of timber. Only the deforestation scenario is shown, since the conservation scenario is not responsive to changes in the price of timber. For the deforestation scenario the total benefits change significantly with timber prices. At a price increase of about 90 % the deforestation scenario will even result in higher total benefits than in the conservation scenario. Even though such a high increase in price does not seem likely within the near future, it indicates the huge effect timber prices will have on the optimal logging regime. However, price increases depends very much on international timber markets and a single region or country is unable to dictate the international market. Therefore, the timber price remains a crucial but uncertain factor.

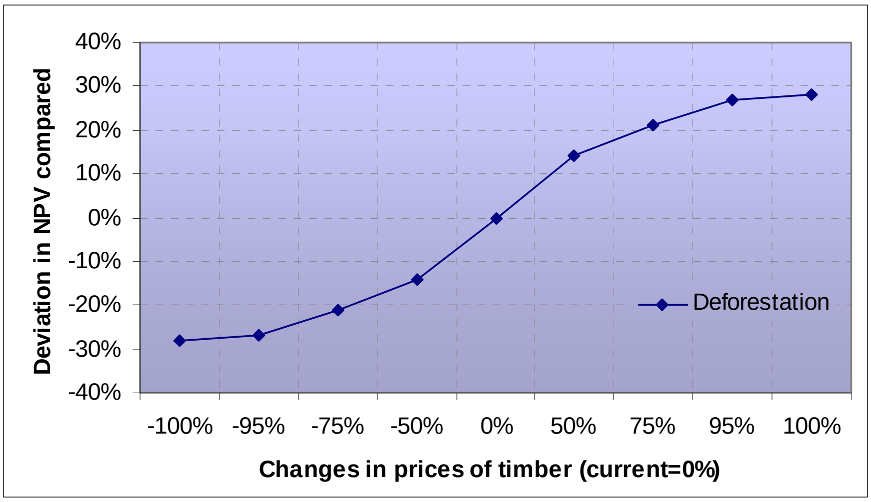


Figure 5.6 Change in Net Present Value for different timber prices.

Value of carbon credits

Figure 5.7 shows the sensitivity of the price of carbon credits for the conservation scenario. Since no carbon credits will be generated in the deforestation scenario, this has been left out of the figure. The benefits of the conservation scenario are relatively robust to changes in carbon prices. Even with no benefits generated from carbon credits, the conservation scenario is preferred to the deforestation scenario. The current net benefits of carbon credits generated from REDD is 2.8 US$/credit (a market price of 4.8 US$/credits and costs of 2 US$/credit). These net benefits are very likely to increase rather than the opposite. Not only has the voluntary market seen a rapid expansion between 2006 and 2007 of 165 percent, but it is also set to further increase in the coming years (Carbon Trust 2006, Hamilton *et al.* 2007, Hamilton *et al.* 2008). This together with recent developments concerning the regulatory market, have sparked major interest in REDD activities, and the prices of REDD carbon credits are therefore very likely to increase.

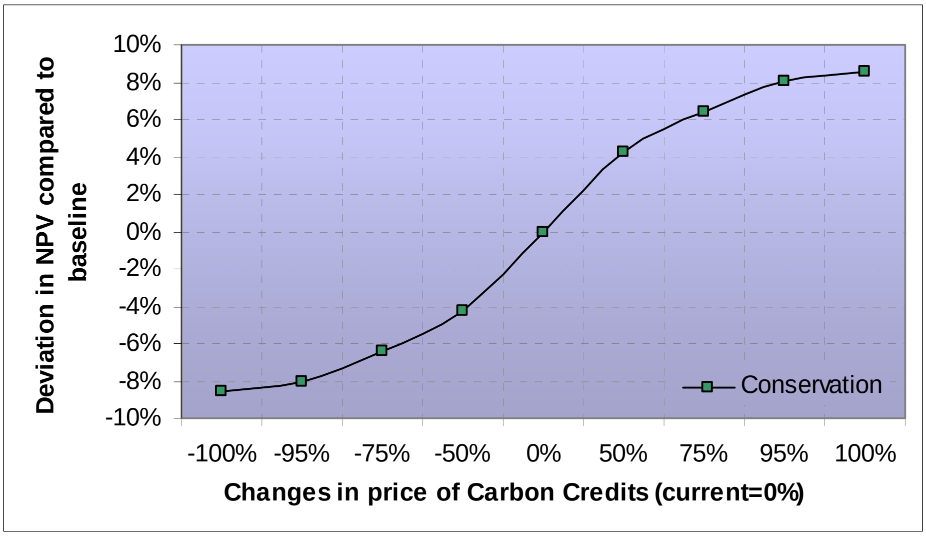


Figure 5.7 Change in Net Present Value for different prices of carbon credits.

6. Lessons learned

Despite the slow deforestation rate during the last decade, the forest ecosystem of Aceh Province has come under new pressures by the various actors involved in deforestation activities. This has been brought about by an array of socio-political and economic changes. The recent tsunami followed by the Aceh peace accord has generated a explosive increase in demand for timber and agricultural expansion. Moreover, the demand for palm oil is generating great interest at the national government level leading to tendency in policies to promote the expansion of this vast market in Aceh. These trends are putting the forest ecosystem under severe pressure.

These new developments are expected to destroy vast areas of largely intact forest that in turn is likely to lead to losses of valuable ecosystem services that these forests provide. The decline of several crucial ecological functions of the rainforest may have serious consequences for numerous economic activities in and around the province. The objecttive of this report was to quantify the economic importance of the forest ecosystem in the province of Aceh by evaluating the changes in economic benefits across two contrasting scenarios (deforestation and conservation).

6.1 Approach

Valuing the environment is becoming widely accepted as a new form of achieving holistic decision-making when it comes to concern areas of nature. The often hidden benefits attributed to natural ecosystems is the barrier to implementing this type of decision making into all important decisions over the level of natural resource extraction. Before the emergence of environmental valuation the trade-offs between such services and the commercial resources they potentially provided was more difficult to make. However techniques are constantly being developed and improved which aim at capturing and quantifying the value of services provided by nature. In this study, economic valuation is used as the main analytical tool to compare the advantages and disadvantages of certain scenarios for the forest ecosystem of Aceh.

Nowadays, most economists agree that the value of natural resources depends not only on the market prices of its direct uses, but also on all other functions of the natural resources that generate value in its broadest sense. This is reflected in the concept of the so-called Total Economic Value (TEV). In determining the TEV of tropical rainforest, a distinction is often made between direct use values, indirect use values and non-use values. The former relates to the values derived from direct use or interaction with rainforest resources and services, whereas the second stems from the indirect support and protection provided to economic activity and property by the rainforests' natural functions, or regulatory 'environmental' services. Non-use values, amongst others, refers to an individual's willingness to pay (WTP) to secure the continued existence of, for example endangered wildlife species, without ever actually seeing it in the wild.

A common way to determine the use and non-use values is to pursue the sequence of underlying processes, starting with the cause of an impact, on to the physical impact and ending with the social and economic effects. The approach followed in this study proceeds in such a manner adhering to the impact pathway approach.

Economic valuation has been applied to evaluate the TEV of the forest ecosystem of the province of Aceh under two possible future scenarios: (1) the 'conservation' scenario, implying that protection of the rainforest is strictly enforced and thus logging will be excluded as an economic activity; (2) the 'deforestation' scenario, implying a continuation of the current trend of clear-cutting. The benefits included in this study are water supply; fisheries; flood and drought prevention; agriculture and plantations; hydro-electricity; tourism; biodiversity; carbon sequestration; fire prevention; non-timber forest products; and timber.

6.2 Conclusions

Economic valuation has proved to be a strong and useful tool in analysing welfare changes for the different scenarios in the Aceh forest ecosystem. Several lessons can be learned from the analysis: Conservation of the forest under the conservation scenario benefits society in Aceh by avoiding damages and loss of income in the coming 30 years by US$ 4.2 billion. The conservation yields total benefits in the region of US$ 22 billion whilst the deforestation scenario yields benefits of US$ 17.8 billion (at 0% discounting). The benefits under the deforestation scenario accrue mostly within the first 10-12 years where as the benefits accruing from the conservation scenario are long term.

It was found that the conservation scenario does not yield vastly higher benefits than the deforestation scenario. Many short-term return investment seekers would likely advocate the case for deforestation. It must be stressed however that firstly deforestation is not something that one can go back on. With its irreversible nature comes uncertain impacts. The truth is: no one really knows the exact extent to which forests interact with our day-to-day lives. Removing the forests certainly means a reduction in services perhaps even to an extent greater to our predictions. Furthermore the impacts of deforestation rarely manifest themselves in a linear manner. Perhaps thresholds exist beyond which impacts and damages are amplified. When dealing with such uncertainties over irreversible decisions it is best to adopt the precautionary principle similar to the dam managers in Costa Rica. Furthermore opting for conservation of forest resources is development along sustainable lines thus ensuring their availability for future generations.

The conducted valuation can be considered to be a conservative estimate of the total values potentially derived from the forest under the conservation scenario. A number of prices that have been used in the study may well rise in the future. For example, carbon sequestration and carbon trading is still in its infancy. The price used for carbon in this study is the present value of carbon. As the world heats and more concern is raised for global warming these prices are likely to increase. Furthermore new conventions and protocols may well assert increased pressures on the worlds' nations to prevent and mitigate the release of GHG's, an action that will inevitably generate increased interest and benefits for conserved forests.

This study was conducted using an array of carefully thought out yet often still crude assumptions. Some of the most crucial assumptions and indeed the most uncertain ones were tested under the sensitivity analysis to understand better their impact on the outcome of the valuation exercise. It was found that the benefits derived from the conservation scenario are robust in terms of changes in population growth and in changing prices of water and carbon. The deforestation scenario only becomes more beneficial once the price of timber is increased by 95%, an increase that is not likely to occur over the coming 30 years.

Finally, it must be stressed that the above-presented results should be considered as a tentative outcome of the economic valuation in the context of the management of the forestry resources of Aceh. These results should be treated as indicative of the likely values under both scenarios. More ground work is required in the area of data collection, socio-economic trends regarding forest - people interactions and ultimately improvements in the knowledge of ecosystem services tailored to the specific location need to be advanced.

6.3 Policy recommendations

This report is by no means a standalone and authoritative report of what can be earned in two contrasting forest management strategies (scenarios). An array of activities and uncertainties lie in the way to eventually realising benefits close to, or beyond the findings of this report. The current management practices of the natural resources in Aceh province are not likely to change from one day to another. Making this transition possible is a whole new subject in itself.

There are a number of ways to bridge the gap between current management practices to *ideal* conservation practices. The conventional 'command and control' approach has proven ineffective in reducing ecosystem degradation and in allocation of costs and benefits. During the last decade the market approach has emerged as an efficient mechanism to address ecosystem degradation in the form of 'Payment for Environmental Services' (PES). This approach seeks to attribute a value to certain ecosystem services and establish appropriate pricing, institutional and redistribution systems that will ultimately lead to sustainable and socially optimal land use practices.

Development of markets

To derive the potential financial benefits from conservation, development of PES markets are essential. At current state, there are three specific ecosystem services that we feel offer the greatest market development potential: water, ecotourism and carbon.

Water supply

This study indicates that water supply is a highly important ecological function that contributed substantially to the local economy. Not only does the standing rainforest regulate the annual flow of water, but it also ensures a clean and accessible source to society. A service, without which, would require expensive infrastructure to replace the ecological function. The realisation of the benefits of this service has seen the emergence of several pioneering PES water schemes. In Costa Rica, for example, a government agency is making payments to landowners for protecting a forest to ensure regulated clean water to downstream users with funding from national tax on fuel, income from donors, and public and private companies. In Ecuador a municipality has established a surcharge into which domestic water users in the town pay a fee for water provision. The funds raised are used to make monthly payments in the range of US$ 0.5-1/ha to upstream landowners for managing forestland. In the Philippines, another PES scheme exists where local resident within the forested area gain compensation for conservation activities in the name of watershed management.

Eco-tourism

Although the tourism sector in Aceh remains largely under-established, the province offers a high potential for ecotourism development. Not only does the province boast one of the largest remaining continuous areas of forest in Indonesia, it also hosts an array of appealing charismatic species such as the orang-utan and the Sumatran tiger. These appeals, combined with the fact that ecotourism is the fastest growing sector within the tourism industry represent a high potential for ecotourism development in the area. Large competition exists between countries and indeed between eco-resorts. In order to fully capture the potential benefits that would go hand in hand with forest conservation an appropriate governing body should be implemented which is involved with all aspects of the sectors development. This body should be responsible for: stimulating investments, regulating operators, ensuring appropriate land allocation, ensuring minimal impacts, certification procedures marketing of ecotourism and accounting of tourist numbers.

Carbon

The carbon stored in Aceh's forest holds significant global interest. Dense forest carbon reserves coupled with a relatively high deforestation rate means that Aceh holds considerable physical potential to gain revenues from avoided carbon emissions. Development of this market in Aceh should be seen as priority as the markets are already established and revenues can be realised almost immediately. The International regulatory carbon market remains promising for the future, however until this market becomes a reality, the voluntary carbon market provides early opportunities to be rewarded for forest conservation. Support for this form of market development in Aceh has not gone unnoticed throughout the world. The Ulu Massen REDD project serves as a fine example of how this market can be accessed and proves that despite obvious barriers to progress, goals can be achieved. It is recommended that the carbon potential for the entire province of Aceh be fully exploited, a view that is also supported by the Aceh Master Plan. While REDD may provide the most immediate carbon benefits, other carbon mitigation projects should certainly be explored. Much of the idle land in Aceh may qualify for Afforestation and Reforestation that again holds significant potential, especially considering the tropical climate. Improved forest management (e.g. conventional to reduced impact logging) may also hold significant potential and provide flexibility to the design of an integrated carbon development plan for the entire province.

In order to fully develop markets for the above-mentioned services and potential PES schemes it is firstly necessary to determine the main driving forces behind deforestation. Once these are determined the likely impacts to the actors involved must be quantified in order to gain an understanding as to what is required to prevent their degrading actions. Ultimately this is a methodological exercise that aims at arriving at suitable alternatives or payments to prevent deforestation with sustainable alternative livelihood.

Institutions – stakeholders – distribution of benefits

Institutional and social aspects are important. On the institutional side, legal aspects such as land tenure, monitoring and allocation of benefits are important. If the establishment of properly mandated institutions to manage the conservation strategies mentioned above does not take place, then the costs of reducing deforestation could get unfairly divided among stakeholders, and reducing deforestation would thereby be more difficult and prone to failure.

On the social side, the distributional aspects of a conservation strategy must be addressed. If timber extraction is to be banned there will be clear losers. People will have to seek alternative livelihoods, perhaps be compensated for their lost livelihood. Ultimately the same institutions must address these distributional issues and arrive at robust solutions that encompass the interest of all stakeholders equally. Arriving at such solutions is a whole new subject within itself which is elementary to the process of changing directions in natural resource policy and studies into the stakeholders and distributional issues must be adequately studied before drastic policy is passed.

6.4 Future research

This research was performed in a limited time frame. Whilst utmost care has been taken throughout to calculate and portray an accurate as possible picture of the benefits and costs involved in both presented scenarios, the authors identify several potential improvements to this study which would benefit the final outcome and certainty of results, and thus better support decision makers in their investment and policy decisions.

- This report has chosen to focus on two highly contrasting scenarios of complete conservation and drastic levels of deforestation. In reality, such extreme scenarios are unlikely to materialise. In the real world, some levels of selective logging and other forms of sustainable extraction are inevitable. The authors therefore advocate the development of several *"in-between" scenarios* as being beneficial for a more "middle of the road" projection on forest management.
- Before any new product is introduced to a market, its market potential must be elaborately explored including identification of possible barriers and limitations. In this respect the market for ecosystem services is no exception. Prior to project implementation a thorough *market assessment* is needed so that *all* relevant factors that influence the sustained marketability of the service are encompassed early in the project design phase. This market assessment must explicitly address the core dimensions of the service and can be tackled using a three pronged approach: (a) 'Technical assessment' examining bio-physical relationship between the ecosystem and the service provision; (b) 'Institutional assessment' exploring the current governance practice and identify the optimum setting for the function of the PES; and (c) 'Socio-economic assessment' addressing the demand and supply of the ecosystem service. These overarching assessments will ensure that the project is robust and contribute to the long-term sustainability of the service.
- An array of technical tools is recommended in the data collection phase of the project. Specifically, elaboration on the spatial application through remote sensing data and *Geographic Information Systems (GIS)* would serve to improve the

accuracy of the value estimates. This would involve spatial data regarding land use, soil science, extent and quality of forest cover, gradient and hydrology. This spatial information is particularly useful in refining certain assumptions made in regards to benefits accruing through avoided deforestation and thus the carbon sequestration potential. These potential improvements also hold for water supply, agriculture and flood damage sectors.

- Due to the fact that the costs and benefits will likely accrue to varying stakeholders a pressing inclusion into this study is a complete *stakeholder analysis*. This is pivotal in the process of establishing a conservation scenario on the socio-political side. Only with a proper understanding of the distribution of benefits from the various ecosystem services can a successful conservation plan be established.

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Appendix I.

Types of valuation techniques

(Surrogate) market price methods

These methods use the market price of a good as a measure of its value. Market price of a good times the quantity traded yields a measure of the total WTP for a good. When no market prices are available, one could use *surrogate price methods*. These methods use the prices of goods that are substitutes for the goods from rainforest ecosystems, or use the value of the resources used to produce these substitutes. The *substitute price* is the most direct of these methods. It uses the price of a good that can substitute for a good from a rainforest to value this good. This substitute should resemble the good from the rainforest as close as possible in all its characteristics. There may, for example, be considerable differences in quality between the good that is obtained directly from the rainforest, and its marketed substitute. For example, the durability of wood collected from a rainforest for housing purposes may differ from that of wood that is sold on the market.

If there is no market price for the substitute, the *indirect substitute price* could be used. This method uses the opportunity costs of using some good as a substitute for a rainforest related good instead of for its original use. For example Fleming (1983; cited in James 1991) valued firewood by the benefits forgone (opportunity costs) of using dung as a substitute for firewood rather than use it as a fertiliser.

The *indirect opportunity costs* values a rainforest-related good using the opportunity costs of the inputs used to produce or collect it. For example, the value of firewood can be measured by the opportunity costs of the labour used to collect it as measured; for example, by the market wage rate or some estimated shadow wage rate. For example, Gammage (1994) estimated a shadow wage rate for firewood collection by using discrete choice theory. Households are assumed to have the choice between two different sources of firewood: either to buy it on the market, or to collect it themselves. If the household is assumed to maximise utility given these two opportunities for firewood supply this model can be used to value the time used in gathering firewood.

How good these surrogate price methods are depends on how good the substitute actually substitutes for the rainforest-related good. But even in the case of perfect substitutes, the price of a marketed substitute is not automatically a correct indicator of the value of an un-marketed good. This has to do with the so-called income effects that are ignored in this approach. Suppose, for example, that a household that previously used some rainforest forest for firewood collection now has to buy its firewood on the market because the forest is put to some other use. If it concerns a low household income, buying firewood on the market would probably consume a considerable part of their income, which means there is a considerable income effect. If the lost firewood is valued by its market price, this might lead to a serious underestimate of the true value of the lost firewood to the household because this income effect is ignored. These matters can be studied by using the framework of the so-called household production function (see Smith, 1991).

Hedonic pricing method

The idea behind this method is that the price of a good can be seen as a function of a number of its characteristics, including some environmental characteristics. The Hedonic Pricing Method (HPM) has been used mainly to analyse house prices. House prices are seen as a function of such characteristics as number of rooms, neighbourhood characteristics etc., but also environmental variables such as air quality, or having a nice view from the house. The HPM proceeds by estimating a so-called hedonic price function by regressing house price on the relevant characteristics. In the simplest form of the method, a measure of the value of an environmental characteristic of interest can be deduced by differentiating the hedonic price function with respect to the characteristic of interest, for example air quality. This gives the so-called implicit price function which can be interpreted as a demand function for air quality and can be used to value a change in air quality.

To give a valid measure of the value of environmental quality some crucial assumptions have to be fulfilled. The households have to be aware of differences in environmental quality between different houses and perceive them in the same way. Furthermore, the housing market has to fulfil certain restrictions. See Palmquist (1991) for an in depth treatment of the economic and econometric aspects of the hedonic prices methods.

We know of no studies that have used this method for estimating the value of certain rainforest characteristics. A possible application might be the valuation of the protective function of rainforests. For example, differences in the risk of flooding between areas with undisturbed and those with degraded rainforests could be used to derive a measure of the WTP for these protective functions. Differences in land prices could also be used to derive a measure of the WTP for the protection provided by rainforests to agricultural practices (hedonic land prices). A problem might be the absence of a fully developed market for housing and land. Also, the extent to which areas with different degrees of protection could be seen as one market might be a problem. If there is very low mobility between these areas they should probably be seen as segregated markets, making a study with hedonic prices difficult.

Travel cost method

This method is used mainly for estimating the recreational value of an area. If there are no entrance fees attached to visiting a rainforest area, no direct measure of the WTP for this recreational service is available. The intuition behind the Travel Cost Method (TCM) is that the travel costs incurred in visiting the area give an indication of the WTP to visit the area. The household production function framework can again be used to provide a theoretical background for the method. Application of the TCM involves gathering data from visitors of an area on their travel costs, travel time, income, and any variables that are expected to influence individuals' preferences regarding visits to the area. With this information, a demand equation can be estimated relating the number of visits to an area with the total costs of visiting the area, income and any other relevant variables.

Contingent valuation method

The Contingent Valuation Method (CVM) estimates the WTP for a change in the quantity and/or quality of an environmental good by using survey techniques (Mitchell and Carson, 1989; Hoevenagel, 1994). Using a questionnaire, a hypothetical change is described and the respondent is asked for his/her WTP for this change. For example, we might ask respondents what would be their WTP to preserve a pristine rainforest area in its current state instead of being logged over. These valuation questions are usually supplemented by some questions on relevant attitudes and preferences regarding the good in question and some socio-economic variables. This information is used to estimate a bid function, relating WTP to these variables. The bid function can be used for validity checks (for example, testing whether WTP is positively related with income, as theory predicts) and for correcting average WTP in the case of certain response biases (for example, an over-representation of high income groups). In order to obtain a valid response it is crucial to provide an accurate and meaningful description of the change that is valued, and further that all relevant characteristics of the hypothetical market are described (for example, how and how frequently the respondent is expected to pay).

In recent years, the CVM has attracted much attention and is regarded by many as one of the most promising valuation methods. This has to do with two important characteristics of the methods: (i) it is the only method capable of estimating non-use value and/or option value; and (ii) it can be used for valuing hypothetical changes in environmental quality. Critics of the CVM question the reliability and validity of answers to hypothetical WTP questions, and point to biases the method seems to be vulnerable to. A great deal of research has been done to detect such biases and on how to prevent them. This has resulted in the setting up of guidelines for conducting good CVM research (Arrow *et al*, 1993) following CVM estimates of damages in the Exxon Valdiz oil spill.

Methods for valuing protective functions

Rainforests provide protection against floods and fires by dissipating the energy of floodwaters and providing wet conditions. A number of methods can be used to value this protective function. These are all based on some measure of the (expected) damages that would be incurred if the protective function is impaired. If the loss of the protective function is thought to lead to a sure loss of assets (for example houses), the *cost of replacement method* can be used. This method values the protective function by the full cost of replacing the assets that are lost if the protective function is lost. The *rehabilitation method* differs from this method because (i) it takes the costs of restoring assets to their current state as a base for damages, and (ii) it takes into account the probability of a damaging event. For example, if the probability of a flood increases from 0.1 to 0.2 because of cutting down a strip of rainforest and the restoration costs would be $ x, the estimate of the value of this change in the probability of flooding is (0.2-0.1)∗$x.

The *value of lost production method* can be used if the rainforests provide protection to some productive activity, for example agriculture. It is essentially the same as the rehabilitation cost method, instead that it uses the expected damage to production as its base. With the *additional establishment cost method*, the costs that would have to be made when establishing the protected assets at an alternative location providing the same level of protection as the rainforest ecosystem are used as a measure of the value of the protective function. Finally, the *cost of relocation method* uses the costs that would have to be made to relocate the protected assets to an alternative location providing the same level of protection as the rainforest ecosystem as a measure of the protective function. The cost of relocation method differs from the additional establishment cost method in that the latter uses the extra costs that are needed to establish the same level of protection at a different location, whereas the latter uses the full cost of relocating the assets to another location.

Production function approach and valuation of off-site services

This approach to valuing environmental functions is applicable whenever an environmental resource serves as an input in the production of some marketed good. The value of a change in quantity and/or quality of the resource is equal to the value of the lost production resulting from this change, more precisely, the change in consumers' and producers' surplus resulting from the change.

In principle, the production function method (PFM) is applicable whenever (parts of) a rainforest ecosystem contribute, either directly or indirectly, to the production of some marketed good. In the case of rainforest valuation the PFM has been proposed mainly as a promising method for valuing the services provided by rainforest ecosystems to off-site fisheries and agriculture. Rainforests serve as breeding, nursery and feeding ground for many bird species, thereby supporting the adjacent agriculture in terms of pest control and pollination. Therefore, any disturbance to a rainforest can lead to a loss of this function and can thereby ultimately affecting crop yields.

The essential element in such an analysis is to quantify the impact of a disturbance of the rainforest on offsite benefits. This can be done by estimating the production function, though this is often a very difficult task. The relationship is indirect and it often involves many unknown, very complex ecological interrelationships. We know of no studies that have tried to quantify these effects. As we will see, valuation of the impacts of rainforest destruction on fire and flood prevention, agriculture and fisheries is usually based on rather heroic assumptions.