Natural Forest Benefits and Economic Analysis of Natural Forest Conversion in Cambodia

Working Paper 33

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Cambodia Development Resource Institute

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Table of Contents

Foreword

I am pleased to introduce the final policy research working paper produced by the Cambodia Development Resource Institute (CDRI) as part of its 2002-2006 natural resources and environment (NRE) programme partnership with Danida. The first stage of this programme, from 2002-2004, produced a series of working papers, articles and conference and workshop presentations on Rural Livelihoods and Environment in Cambodia. This was followed by stage two, from 2004-2006, on Managing Natural Resources for Poverty Reduction: Policy Research on Resource Benefits and Management Options, some major outcomes of which are reflected in this working paper. For further details of these publications and presentations, which constitute a rich resource for government policy makers, international development agencies, civil society advocates, and researchers, on NRE issues in Cambodia, see CDRI's website at www.cdri.org.kh.

This working paper aims to support improved policy-making on sustainable development, natural resource management, and poverty reduction in Cambodia. The results presented in this working paper relate to important policy challenges and decisions currently facing the Royal Government of Cambodia (RGC) in relation to the future management of the large forest areas currently left in a post-concession management vacuum. The study analyses current policies promoting large scale conversion of natural forests for agricultural development, and discusses options for different forest management systems to meet the Cambodian Millennium Development Goals (CMDGs) on forest conservation and poverty reduction.

The study also introduces a framework and associated value flow model designed to analyse financial and economic aspects of forest conversion to assist land use planners in balancing environmental, social and financial aspects of land use changes in a more transparent way. An important message from the analysis is that sustainable management of high value natural forests has the potential to provide significant financial, social and environmental benefits, but in order to realise this potential, there is a need to improve the enabling environment for sustainable forest management, and focus on commercial partnership management models where significant benefits can be equitably distributed at the local level.

We hope that this working paper will make a valuable contribution to policy debate and action on this critical aspect of Cambodia's future sustainable development, and the achievement of both the NRE and poverty reduction objectives of Cambodia's National Strategic Development Plan 2006-10.

Larry Strange
Executive Director
Cambodia Development Resource Institute
Phnom Penh, December 2006

Acronyms and Abbreviations

ACI	Agrifood Consulting International
CBA	Cost-Benefit Analysis
CDRI	Cambodia Development Resource Institute
CIFOR	Centre for International Forestry Research
CF	Community Forestry
CSES	Cambodia Socio-Economic Survey
DBH	Diameter at Breast Height
FA	Forestry Administration
FAO	Food and Agriculture Organisation
IFSR	International Forest Sector Review
NC	Non-Commercial
NGO	Non-Government Organisation
NPV	Net Present Value
NTFP	Non-Timber Forest Product
MAFF	Ministry of Agriculture, Forestry and Fisheries
MAI	Mean Annual Increment
SFMP	Strategic Forest Management Plan
TEV	Total Economic Value

Exchange rate: 4200 riels per USD

Preface and Acknowledgments

This working paper presents the main research findings and lessons learned under CDRI's Managing Natural Resources for Poverty Reduction project under the Natural Resources and Environment Programme. Some findings have already been presented in research articles and CDRI policy briefs. This working paper is intended as the final report of the research project, and aims to disseminate more of the data behind some of the other publications and new results from a value flow model developed under this project.

The authors are very grateful to the many people who shared their knowledge on utilisation of natural forests and alternative land uses, including local people and plantation managers. We would like to bring a special thank to the former NRE team—Mr. Christian Sloth, technical adviser, Mr. Khlok Bottra, research associate, and Mr. Heov Kim Sreng, research associate, for designing the research methodology of the project and for compiling and collecting most of the data. Without their major contribution, this study would not have been possible. Also, thanks go to a number of enumerators for their work during household surveys as well as foresters from the Forest Administration and Wildlife Conservation Society, for their assistance with forest inventories. We gratefully acknowledge the support of Danida (Danish International Development Assistance) for CDRI's Managing Natural Resources for Poverty Reduction project under the Natural Resources and Environment Programme. We also extend our appreciation to Ms. Khiev Daravy, NRE research assistant for arranging data on land concessions and to Mr. Lic Vuthy, our fellow NRE researcher, for his comments and assistance in producing a brief Khmer version of this working paper. Finally, many thanks go to Dr. Brett Ballard, acting research director of CDRI, Dr. Michael Linddal, freelance consultant, Dr. Hermi Fransisco, deputy director of the Economy and Environment Programme Southeast Asia, Dr. Tom Evans, technical advisor of Wildlife Conservation Society, and Mr. Larry Strange, executive director of CDRI, for their valuable comments and support.

Phnom Penh, December 2006

Kasper K. Hansen and Neth Top
The Cambodia Development Resource Institute

Executive Summary

Cambodia is still a relatively richly forested country. It is mainly covered by state-owned natural forests, which provide a variety of local, national and global services and benefits. At the moment, around 2.7 million hectares of natural forests are in a post-concession management vacuum and under increasing threat of conversion to alternative land uses from an increasing rural population and large-scale land concessions. The government therefore faces important decisions on how future management of natural resources can balance the need for agricultural development with the need for forest conservation and the benefits and services they provide.

The aim of this working paper is to contribute to decision making related to natural forest conversion by valuing natural forests and examining financial and economic aspects of natural forest conversion to alternative land uses. The study focuses on three selected forest types (evergreen, semi-evergreen and deciduous) and nine alternative land uses (eucalyptus, acacia, oil palm, cashews, rubber, rice, soy beans, cassava and maize), which adds up to 27 different natural forest conversion scenarios.

The first part of the study assessed the total livelihood value[1] obtained locally from natural forests, based on 502 household interviews in four provinces (Kompong Thom, Kratie, Mondolkiri and Pursat) on consumption and sale of non-timber forest products (NTFPs) over the previous year. The annual total livelihood values obtained from forests in the four areas were: USD265/household in Kompong Thom, USD424/household in Kratie, USD167/household in Mondulkiri, and USD314/household in Pursat. Data were analysed separately for poor and medium households to identify linkages between poverty and the use of forest resources. The results were that poor households in the survey gained 42 percent of their livelihood value from forests, equal to USD280 per household annually. Medium households obtained on average 30 percent of their livelihood value from forests, or USD345 per household annually. In the present situation, natural forests must be considered a fundamental asset for the livelihoods of rural households living adjacent to forests in these provinces. The government should therefore recognise that centrally based decisions promoting conversion of natural forests without involvement of local people could potentially have significant negative economic impacts on communities living in or adjacent to natural forests. This is especially the case for poor households, which are less diversified in terms of income sources and more dependent on equitable access to forest resources.

The second part of the study examined forest values. To analyse economic aspects of natural forest conversion, the study developed a value flow model, in which the value of natural forests was compared with the value of alternative land uses. Main direct and indirect values of natural forests were assessed on a per hectare basis based on the household survey, forest inventories and environmental valuation studies conducted in other countries. The value of sustainable management of natural forests was estimated at USD1194/ha (USD112/ha/year) for deciduous forest, USD2445/ha (USD247/ha/year) for semi-evergreen forest and USD3721/ha (USD375/ha/year) for evergreen forest. The study found that natural forests may provide significant direct and indirect values, but also that these do not provide incentives for local people to utilise forests sustainably in the current forest management vacuum. Experiences with community-based forest management have slowly evolved in degraded forest areas, and local benefits have been limited to collection of NTFPs. The valuation of potential sustainable timber production showed that net returns from sustainable harvesting in such locations are financially questionable. It should therefore be a high government priority to consider if

[1] *Livelihood value in this paper is defined as the local value of consumption and sale of forest products.*

local involvement in management and sale of timber could be expanded to more commercially valuable forest types in order to determine whether joint forest management models can better contribute to national millennium development goals of poverty reduction and forest conservation.

The third part of the study analysed financial and economic aspects of natural forest conversion to alternative land uses. Data on expected financial and economic benefits from different alternative land uses were collected from interviews and secondary sources and entered into the value flow model. In the value flow model, the net present value (NPV) of different scenarios was assessed based on estimates of yields and environmental services incorporated in a cost-benefit analysis (CBA) framework. The study examined value flows of the 27 forest conversion scenarios over 50 years using real discount rates ranging from 8 to 12 percent. Due to limitations in data availability, the current value flow model does not include variations in productivity and market access from area to area, and this limits the scaling up of results.

The current experiences with wood plantations in Cambodia suggest that financial returns from fast-growing acacia and eucalyptus plantations are questionable. At a growth rate of 26 m3/ha/year, eucalyptus plantations may generate an annualised NPV of USD10/ha/year when using a 10 percent discount rate. This study found much lower growth rates, ranging from 9.0 to 19.5 m3/ha/year. When assuming a growth rate of 15 m3/ha/year, wood plantations generated an annualised NPV of –USD27/ha/year. Large-scale development of wood plantations is therefore not recommended at this point until more knowledge on realistic productivity and market opportunities is obtained. In the development of plantation forestry, it should be acknowledged that alternatives exist to large-scale production of pulp wood. Opportunities for smaller scale plantations with indigenous timber or NTFP species could be explored to try to enhance social and environmental benefits from plantation development.

In the analysis of perennial crops, rubber was the most financially profitable alternative land use. Investments in rubber had an internal rate of return of 20 percent and an annualised NPV of USD379/ha when using a 10 percent discount rate. In the value flow model, this value exceeded the values provided by natural forests, suggesting that converting natural forest to rubber may be an economically viable land use alternative under some circumstances. Cashews and oil palm plantations were not as profitable and could not generate a positive economic NPV when the baseline was natural forests. It is therefore recommended that for the time being, economic land concessions focusing on these crops should be targeted outside areas with natural forests until more knowledge is generated on what realistically can be expected from perennial crops at different locations.

This study's data collection was limited to a few well-established plantations. It is recommended that data from a wider range of plantations be collected in order to better analyse national variations in productivity and link the results in the model to national maps on soil quality and market accessibility. Also, economic CBA results do not ensure that benefits are distributed equally. A main challenge in the current agricultural development process will be to identify areas suitable for agricultural production and to mitigate local effects by integrating forest management for vulnerable households in the conversion process. A main question to clarify is if large centrally allocated economic land concessions are the best way to achieve rural development and poverty reduction. More focus could be on piloting more locally based management systems and enterprises for plantation crops to evaluate if this can make agricultural development more pro-poor.

The implication of the land use change findings for the current forest management situation is linked to the assumption in the model that sustainable management of natural forests can be implemented in the near future. If new management alternatives are not developed and the current management vacuum in post-concession areas continues, the values of these natural forests will keep declining and potential economic benefits from sustainable forest management will be reduced. It is therefore urgent that different sustainable forest management systems be analysed in a Cambodian context to identify management solutions that can mitigate the local and national impacts from deforestation and forest degradation.

A brief analysis of experiences with forest management in Cambodia over the last decade shows that concession forestry focused on short-term financial benefits and to a large extent neglected social and environmental aspects of forest management. Two or three of the "best" concessions demonstrated some efforts to include these aspects in their strategic forest management plans and may continue to do so in the future if they are allowed to continue. Concerns have been raised that the Forest Administration's new approach to forest management in annual bidding coupes is highly vulnerable to rent seeking and not compatible with sustainable forest management. It therefore seems urgent that the government strongly commit to creating an enabling environment for other forest management systems in which more accountability is shared between different participants. This process is currently evolving through expansion of community forestry activities. The experiences are, however, limited and need to be monitored continuously to find suitable local and national solutions. In the process, however, it will be important that not all focus is on forest management for subsistence use; much more effort should be allocated to exploring transparent and accountable commercial joint forest management models in more valuable post-concession forests to enhance local benefits from forests and meet the future demand for timber and fuel wood.

Chapter 1:
Introduction

This section presents a brief review of general knowledge on linkages between forests and rural development internationally and in Cambodia. It briefly outlines current threats to natural forests and trends in forest conversion and identifies gaps in the current knowledge of how forest conversion decisions in Cambodia are currently made.

1.1 Background on Forests and Rural Development

Those mainly involved in tropical forest management and conversion, such as state governments, private corporations and forest encroachers, have traditionally perceived the value of natural forests as the value of extractable timber and the alternative use of cleared land (Dove 1993; Gillis 1992; Godoy et al. 1993). Since the 1980s, it has been generally recognised that traditional forest industries focusing only on timber extraction have made little contribution to rural socio-economic development. As a result, the focus has slowly shifted towards people-oriented forestry, including improved management of common property resources (Westoby 1987; Chambers 1993; Arnold 1998a; Wollenberg and Ingles 1998; Ostrom 1999; Wunder 2001).

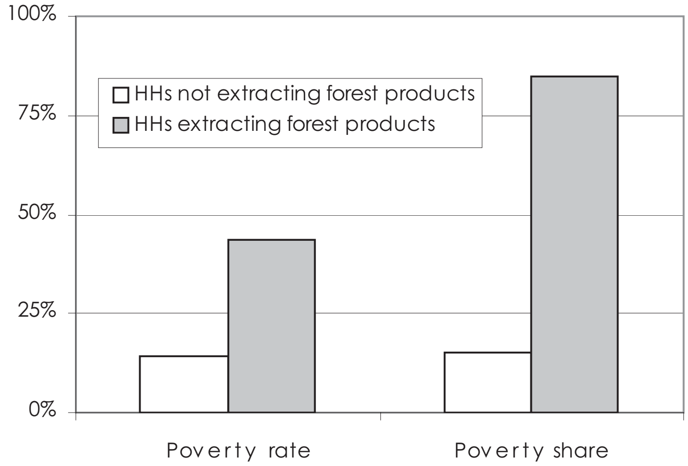
Rural people in developing countries living in or adjacent to tropical forests depend on forest resources for a wide range of products and services (Wollenberg and Ingles 1998; Byron and Arnold 1999). When forest-dependent people extract forest products, it is almost exclusively non-timber forest products (NTFPs) rather than timber extraction, which traditionally is the domain of outside corporations and concessionaries (Arnold and Pérez 2001; Wunder 2001). NTFPs are very important for forest-dependent people's livelihoods, and in many cases local people carry out a variety of practices to optimise benefits from the forest (Wiersum 1997; Arnold 1998b). NTFPs can generally be divided into two groups: those for subsistence and those for cash income. Subsistence NTFPs generally fill a supplementary or buffer role in rural livelihood systems by supplying food, medicine, agricultural inputs and fuel to the household (Arnold 1998b), whereas commercial NTFPs in some cases can be very important for the household income (Kusters and Belcher 2004). The commercialisation potential of NTFPs differs significantly from case to case, and current comparative international research has examined NTFP commercialisation to promote livelihood improvement (Perez and Byron 1999; Marshall et al. 2003; Kusters and Belcher 2004).

Both subsistence and commercial NTFPs are important for poverty reduction because the poorest segments of communities normally generate a larger share of their overall needs from NTFPs than do wealthier groups (Wiersum 1997; Byron and Arnold 1999; Neumann and Hirsch 2000; Arnold and Perez 2001; Kusters and Belcher 2004). Normally, NTFP extraction is characterised by low or medium returns to labour, low capital and skill requirements and open or semi-open access to resources (Angelsen and Wunder 2003). NTFP extraction can therefore be perceived as the easiest or perhaps the only activity that marginalised people can turn to when other possibilities are limited. Consequently, NTFP extraction as a main livelihood strategy can be interpreted as constituting either a "safety net" or a "poverty trap" for marginalised rural people (Angelsen and Wunder 2003). The poverty trap arises if poor people are kept impoverished by the low value generation potential of an NTFP-based livelihood strategy. The safety net function arises when NTFPs are relied upon for parts of the year or used as a risk-reducing buffer in times of hardship, while the main livelihood strategy is based on other activities. A main characteristic of the availability of forest resources for rural people is that NTFPs generally add diversification and resilience to rural people's livelihoods (Angelsen and Wunder 2003).

1.2 Forests and Rural Development in Cambodia

Poverty in Cambodia has recently been described in a comprehensive World Bank poverty assessment based on a national poverty line (WB 2006a). This analysis was partly based on data from the Cambodian Socio-Economic Survey (CSES) conducted in 2003/04. Based on these CSES data, the link between rural poverty and forest product extraction is illustrated in Figure 1.1 below.

Figure 1.1: Links between Poverty and Forest Product Extraction based on analysis of 2003/04 CSES data from NIS (2004).



The analysis showed that around 85 percent of the rural poor extract forest products to maintain their livelihoods, and that the rural poverty rate[2] of forest product extractors is 44 percent compared to 14 percent for rural households not extracting NTFPs. These figures show that there is currently a strong link between rural poverty and forest dependency in Cambodia. The World Bank assessment also found that even though poverty has decreased by around one percent per annum since 1998, inequality has increased over the same period. The gap between urban and rural areas is increasing, and poverty is more and more becoming a rural problem. As a result, pro-poor agricultural development and equitable access to common property resources are identified as key issues in poverty reduction strategies (WB 2006a).

Natural forests also provide potential benefits to a range of other local, national and international actors that are normally in conflict with local utilisation of forest resources. Different interests perceive the value of forests differently, and a main challenge for national forest management and forest conversion policies is balancing different interests while making decisions transparently. In Cambodia, the main non-government interest groups in forest management can roughly be divided into:

1. People living in or adjacent to forests who depend on forest resources to maintain their livelihoods.

2. Legal commercial timber interests seeking to capture timber rents, mainly represented by international concession companies.

3. Illegal commercial timber interests using weak law enforcement to capture timber rents, mainly represented by the military and powerful sub-contractors.

[2] *The poverty rate, also known as the poverty headcount, is defined as the percentage of people consuming less than the Cambodian poverty line.*

4. Environmental groups concerned about the conservation values of forests to future generations, mainly represented by international and local NGOs.
5. Agricultural expansionists interested in the land opportunity value, including both powerful large land concession holders and local farmers encroaching into forests to improve their livelihoods.

Over the last decade, central forest management in Cambodia has almost entirely focused on commercial timber interests through large-scale concession forestry. The system was implemented in high value natural forests country-wide covering around 7 million hectares, or almost 40 percent of the total land area of the country. The system largely ignored environmental and social aspects of sustainable forest management and was criticised for high levels of uncontrolled logging, conflicts over rights with local communities and limited contribution to national development and poverty alleviation (e.g., McKenney et al. 2004). A series of critical reviews (e.g., ADB 2000), social protests and donor pressure resulted in the suspension of all concessions, and the government enacted a moratorium on timber harvesting in December 2001 until concession companies revised their management plans and these were re-approved by the Forestry Administration (FA). As part of this process, a final independent review concluded in November 2005 that only two or three of the "best" concessions possibly could continue if management plans were further adjusted (GFA 2005). Donors, on the other hand, concluded that concession forestry should be terminated (WB 2005), and it has still not been decided by the FA whether some of the concessions should continue. As of November 2005, 13 forest concessions covering 2.7 million hectares still remained (WB 2006b).

Lately, forest management has slowly shifted towards more decentralised models aiming at improving local people's livelihoods. This has mainly been through community forestry approaches (CF); currently about 179,000 hectares have been allocated to community forests by the FA (MAFF 2006a). This system may involve commercial timber harvesting, but in practice it often focuses more on forest management for the benefit of local people rather than only optimising commercial timber production. In Cambodia, CF has mainly been implemented in degraded forest areas. So far, CF has been linked to the important role forests play in sustaining rural livelihoods, which has been described in several studies (e.g., McKenney and Tola 2002). CF covers only around one percent of Cambodia's land area and must still be considered as negligible compared to concession forestry.

In addition to timber and NTFPs, Cambodian forests are well known to provide a range of other indirect benefits nationally and globally. Forests have various positive impacts on their surroundings in terms of watershed protection, carbon storage, recreation and biodiversity conservation (Gregersen *et al.* 1995). Valuation of these forest services, however, has received only limited attention in Cambodia since the concept was pioneered in the late 1990s by Bann (1997; 1998). As a result, forest management outside protected areas has focused on indirect values only to a very limited extent.

Finally, some forests on good soils have a significant opportunity value of land for agricultural expansion. As mentioned above, the agricultural sector has been identified as one of the main areas for pro-poor development and this must be balanced with a need for forests to support rural livelihoods. The current expansion of agriculture involves local farmers extending their activities into forest areas as well as powerful large-scale agricultural concessions.

1.3 Current Trends in Forest Conversion

Forest cover in Cambodia has decreased significantly over the last decade, as shown in Table 1.1. According to the 2005 forest resource assessment by the Food and Agricultural Organisation (FAO) of the United Nations, Cambodia is still around 58 percent forested, but the deforestation rate has increased from one percent per annum between 1990 and 2002 to a current two percent per annum (FAO 2005).

Table 1.1: Area (in 1000 Ha) of Forest Cover and Percentage of Forest Cover Relative to Total Land Area of Cambodia.

Categories	1990	%	1992	%	1996	%	2000	%	2002	%	2005	%
Forests	12,946	71.5	12,769	70.5	12,415	68.6	11,540	63.7	11,103	61.3	10,447	57.7
Other wooded land	335	1.9	330	1.8	320	1.8	298	1.6	286	1.6	269	1.5
Total Other land	4,371	24.1	4,552	25.1	4,915	27.1	5,813	32.1	6,261	34.6	6,934	38.3
Inland water bodies	452	2.5	452	2.5	452	2.5	452	2.5	452	2.5	452	2.5
Total	18,104	100	18,104	100	18,104	100	18,104	100	18,104	100	18,104	100

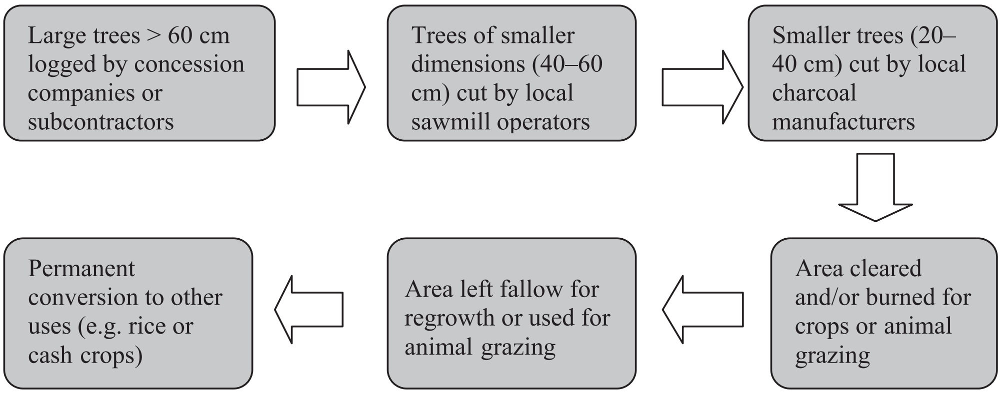
Source: FAO (2005)

The FAO assessment is based on forward predictions from previous data sets and should, as discussed in Heov *et al.* (2006a), be interpreted with caution. Still, the assessment shows that both number are high compared to other countries in the region, indicating that Cambodian forest resources currently are quite abundant but under increasing threat of conversion to alternative uses. It is also important to note that the numbers in the table reveal little about the level of forest degradation because the FAO uses a broad definition of forests, in which all land with more than 10 percent crown cover is defined as forest. Forests that are over-logged, but not converted, are not distinguished in the statistics and, as a result, the actual trend in forest degradation is not revealed. Based on these surveys, however, it can be noted that the forest cover already seems to be below the millennium development goal of maintaining a forest cover of 60 percent (RGC 2006).

Many factors have contributed to forest degradation and conversion. During the 1990s, they were closely associated with uncontrolled logging in areas opened up by large-scale forest concessions. Since 2002, official logging has declined, but the deforestation rate does not seem to have decreased. Since the moratorium on logging, forest conversion has mainly taken two roads: i) encroachment by local farmers and ii) large-scale conversion of forests through land concessions (Sloth *et al.* 2005).

The abandonment of the forest concession system and lack of alternative forest management systems have left Cambodia in a situation in which large areas of forests outside protected areas are in a management vacuum. A potential additional negative effect from concession forestry is that once concessions have harvested the largest commercial trees, the areas are more easily accessible for others. The post-concession areas are therefore at present unmanaged and at high risk of further degradation from sawmill operators, charcoal manufacturers and other users (IFSR 2004). While this situation continues, the value of forest resources will slowly decline and there will be an increasing risk of forest conversion by local encroachers, as illustrated in Figure 1.2.

Figure 1.2: Illustration of a Potential Forest Conversion Pattern in Post-Concession Areas



Such encroachment is linked to an increasing rural population and poor households that often have little alternative to collecting forest products and degrading forests to maintain their livelihoods. Given the current population growth rate of 2.5 percent, this process is unlikely to slow unless alternative income sources are available.

Another threat to forest resources has emerged through the development of large-scale economic land concessions. These are granted centrally and can come at any stage of the local forest conversion scenario in the figure above. In the 2001 Land Law, there is provision for land concessions for economic development on state private property. The law gives the concessionaire rights to an area of up to 10,000 ha for up to 99 years (RGC 2001). Land concessions for economic purposes have been generally characterised by a lack of transparency, unclear demarcation of boundaries, non-disclosure of benefits to the state treasury and non-conformity with legal frameworks (UNHCR 2004). Contracts signed before 2001 involve areas far exceeding the maximum 10,000 hectares stated in the 2001 Land Law. For example, the Preapimex concession in Pursat covers around 315,000 hectares. It has also been observed around the country that economic land concessions have often been granted on land with existing forest cover or on land used and cultivated by local people (UNHCR 2004; NGO Forum 2005; NGO Forum 2006).

A brief analysis of the location of eight land concessions compared with the 1997 forest cover in Table 1.2 shows that land concessions often have been established on land formerly classified as forest. The analysis is limited to a few concessions with a complete set of coordinates available from MAFF (2006b), which included three rubber concessions and five concessions with other crops.

Table 1.2: Percent of Concession Land Covered by Natural Forests in 1997

Type of concession	Percent of land that was natural forest in 1997			
	Evergreen	Semi-evergreen	Deciduous	Total
Rubber (n=3)	24	23	35	82
Other crops (n=5)	11	0	59	70

Based on UTM data from MAFF (2006b) and DFW (1998)

The table shows that a significant part of the areas allocated for land concessions used to be forested. This indicates that land concessions have expanded at the expense of natural forests.

Similarly to forest concessions, little consideration is given to local people in the development of economic land concessions, and this has often resulted in conflicts with local people who depend on forests and agricultural land for their livelihoods. Significant negative impacts on rural livelihoods have been recorded (UNHCR 2004). Barney (2005) found that in 2003, all 18 land concessions with signed contracts with the Ministry of Agriculture, Forestry and Fisheries (MAFF) that had demarcated their allocated land had noted problems with local communities. An additional six concessions without signed contracts had also noted conflicts.

Granting of economic land concessions is in general surrounded by a lack of transparency. As a result, it is very difficult to develop an exact picture of the distribution of land concessions as well as the actual use of land.

In 2005, the main crops to be planted in land concessions already signed include acacia, eucalyptus, rubber, oil palm, teak, cashews and cassava. Since then, it seems that some of the concessions have amended their plans. The available information from MAFF in August 2006 is shown in Appendix 1 (MAFF 2006a).

According to available official data, land concession companies have currently signed contracts with the MAFF for a total area of approximately 908,000 hectares (MAFF 2006a). How much of this area is actually planted is, however, uncertain. It has been observed that land allocated to economic land concessions often has been cleared but not cultivated, indicating that the process is driven by ulterior motives of land grabbing rather than productive investment (UNHCR 2004). Also, there is very little published information concerning the costs and benefits of the different land use systems, and decisions on allocating land to large concessions seem to be based on insufficient information.

An important question in natural forest conversion, therefore, concerns on what basis decisions allocating forest land to economic concessions are made. The large number of conflicts and the lack of published research on expected returns from different plantation crops under Cambodian conditions show that natural resource planners currently are making decisions concerning natural forest conversion based on insufficient information about potential economic costs and benefits. A main challenge facing land use planners is how land use change decisions can balance the local, national and global needs for forest products and services with the need for agricultural development in a transparent way.

The aim of this study is to inform current decision making on land use changes by introducing a framework and a value flow model to analyse whether a proposed land use change is economically viable. More specifically, the study will analyse the different types of forest benefits and assess economic consequences of natural forest conversion to provide information on the net effect of forest conversion decisions currently evolving in Cambodia.

1.4 Objectives of the Study

The above-mentioned issues point to the importance of generating more knowledge about the value of Cambodian forest resources and resource rents from alternative land uses in order to improve decision making on forest conversion and link forest conversion with national goals of forest conservation and poverty reduction. The overall goal of this study, therefore, is to contribute to an understanding of the economic value of natural forests and its implications for forest conversion in Cambodia.

To answer the overall objective, three specific objectives have been formulated:

- to assess the total livelihood value that households living adjacent to forests obtain in cash and non-cash income, and analyse differences between various socio-economic groups;
- to assess the total economic value (TEV) of selected forest types, including valuation of main direct and indirect values;
- to analyse the economic consequences of natural forest conversion by comparing the value of alternative land uses with the TEV of natural forests.

1.5 Limitations

The study was limited to the three main forest types in Cambodia: deciduous, semi-evergreen and evergreen. Other important forest types, such as mangroves and inundated forest, were not included since that would expand the valuation to include aquatic forest services as well. It is recommended that future research expands the analysis to these forest types.

The assessment of forest values was limited to the most well-described direct and indirect use values. The study was limited by the fact that studies on indirect economic values of natural forests in Cambodia are very scarce. Indirect values used in this study were therefore primarily based on valuations from other countries. Due to the large variations from site to site, this study was limited to values associated with watershed protection, soil erosion control and carbon storage. Uncertainties were also examined in a sensitivity analysis.

This study looked primarily at natural forests under threat of being converted to other land uses through large-scale agricultural development in areas under the jurisdiction of the MAFF. It therefore focused mainly on forests located outside protected areas. Forests inside protected areas under the jurisdiction of the Ministry of Environment face similar threats, but the fieldwork for this study focused on forests with a production purpose in order to relate the results to the large post-concession areas currently observed in Cambodia.

This study focused mainly on economic aspects of forest conversion scenarios. For planning and decision making, economic net present value (NPV) calculations should be supported by information on social and distributional effects of land use changes. Unfortunately, it was beyond the scope of this study to analyse distributional aspects of land use changes. It is recommended that future research look more deeply at these issues.

The comparative analysis of forests does not include variations in soil quality and production costs from area to area. Data covering site variations could not be obtained within this study, and the values presented are representative only for a given area. This limits the scaling up of results. It is recommended that future research on land use changes expands the analysis to include national variations and to better include economic CBA in overall land use planning.

1.6 Outline

The remainder of this paper presents the findings related to the three specific objectives. Chapter two introduces the two frameworks used to structure the analysis in this study: i) a total economic value framework to value natural forests and ii) a cost-benefit analysis to assess economic consequences of land use changes. Chapter three analyses the livelihood value obtained locally from forests, with specific focus on quantitative linkages between poverty and the use of forests and their implications for forest management. Chapter four examines the value of deciduous, semi-evergreen and evergreen forest types by valuing selected direct and indirect values provided by natural forests. Chapter five assesses economic consequences of forest conversion scenarios over a 50-year time frame based on a value flow model. Chapter six provides a brief discussion of the implications of results to the current forest management situation by examining Cambodian experiences with different forest management models. Finally, chapter seven provides main conclusions and recommendations of the study and some important lessons learned from working with value flow modelling at CDRI.

Chapter 2:
Frameworks and Methodology

Two frameworks structured the research in this study. The economic valuation of natural forest conversion was based on a TEV approach assessing the baseline value of three selected natural forest types, combined with a cost-benefit analysis (CBA) developed to assess the NPV of converting natural forests to alternative land uses.

2.1 Total Economic Value Framework

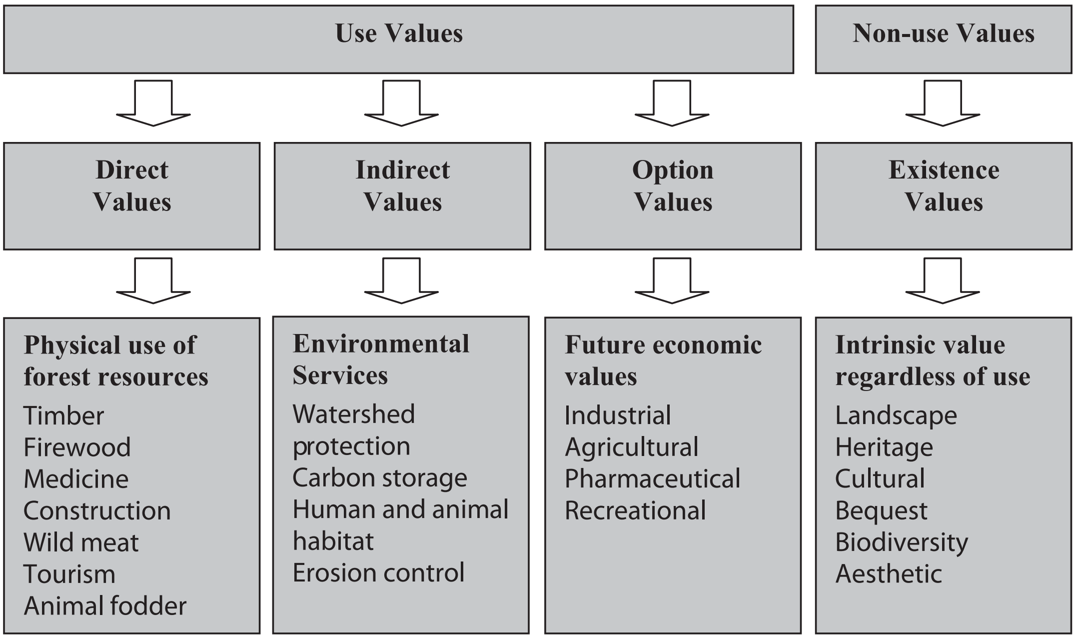
The value of forest resources has traditionally been measured in terms of direct financial benefits from extraction of timber. This value, however, does not reflect the true value of forest resources to society, since it excludes products collected for subsistence use, as well as externalities and non-tangible products. Natural forests have many positive externalities and non-tangible products, such as animal habitat, watershed protection and carbon sequestration. The value of timber extraction therefore represents an underestimation of forest values, and a TEV approach was adopted in this study to provide a more accurate valuation.

TEV is a commonly used methodology to measure the value of the environment or natural resources. It is defined as the sum of all use and non-use values of a given good or service being measured. Use values (*UV*) cover all kinds of physical uses, environmental services and future options for economic gains, whereas non-use values (*NUV*) can be described as the value people experience by knowing that, for example, natural tropical forests exist. In the TEV framework, use values are further classified into direct (*DUV*), indirect (*IUV*) and option values (*OV*), while non-use values often are called existence value (*EV*). Thus:

$$TEV = UV + NUV = (DUV + IUV + OV) + EV$$

Forest resources provide a wide range of local, national and global values and services. Some of the most important services to include in a forest valuation are listed in Figure 2.1. *DUV* are mainly important to local communities and private companies since they relate to the physical use of forest resources (e.g., timber, fuel wood, food, construction materials, medicine, animal fodder and eco-tourism). Locally important *IUV* derived from forests include watershed protection, erosion control and animal habitat, while carbon storage is a good example of a globally important indirect use value of forests. *NUV* are mainly linked to the global community and represent the value that people around the world experience by knowing that tropical forests exist. From a local point of view, non-use values may have limited importance unless local people are compensated for preserving forest resources.

Figure 2.1: TEV framework and examples of use and non-use values of forest resources. Adapted from Gregersen et al. 1995 and Emerton and Karanjan 2004



The TEV framework has been applied to identify main values from natural forests to be included in the valuation of natural forests in this study.

2.2 Cost-Benefit Analysis Framework and Value Flow Model

To evaluate economic benefits and costs of converting natural forests to other land uses, alternative scenarios have been compared with a baseline natural forest situation, including sustainable harvesting. For this analysis, a value flow model was developed to compare different scenarios in a consistent manner.

The main analytical tool used in the value flow model was cost-benefit analysis. CBA is one of the most commonly used tools in environmental economics and for evaluating the economic viability of investments. It calculates the present value of a stream of costs and benefits in a project, and computes flows to a total net present value. The NPV can be described as the difference between the present (discounted) value of benefits and the present (discounted) value of costs. A project is generally considered beneficial if the NPV is positive. An important factor in the analysis is the discount rate, which is used to convert all costs and benefits to a comparable present value. Discounting incorporates the time value of money into the analysis. It assumes that a person would rather have one dollar today than one dollar in one year since today's dollar can be invested into an alternative project and hence be worth a multiple of one plus the interest rate of that project in one year. Choosing a discount rate is therefore one of the most important factors in the CBA. The general formula for the NPV is:

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

where n is life span of the project, t is the time in years, Bt is benefit at time t, Ct is cost at time t, r is the discount rate, 1/(1 + r)t is the discount factor at time t, and ∑ is the sum of flows.

2.2.1 Baseline, Time Frame and Discounting

The baseline chosen for this study covers natural forests, including evergreen, semi-evergreen and deciduous types. Within each of the three forest types, the following direct and indirect values from Figure 2.1 have been selected for valuation.

Direct values: The study included potential values from sustainable timber and NTFP harvesting. NTFPs were assessed in market prices based on recall of consumption in household surveys, converted to per hectare values. Sustainable timber harvesting was based on a simple forest growth model and expected timber prices and production costs.

Indirect values: Carbon sequestration was valued based on forest volumes converted to above ground biomass in the forest growth model. Watershed protection, including soil conservation, was valued based on studies elsewhere in the region.

Time frame and discount rate: A real discount rate of 10 percent was used as a baseline, together with a 50-year time frame when calculating the NPV for each forest type. In the analysis, it was assumed that future costs and prices increase at the same inflation rate. Hence, different costs and benefits remain the same in real terms over the time frame. With a current inflation rate of around 5 percent (NIS 2006), the 10 percent real discount rate equals a nominal interest rate of around 15 percent. All prices are based on 2004/2005 prices, except indirect values, which were valued based on benefit transfer from other countries.

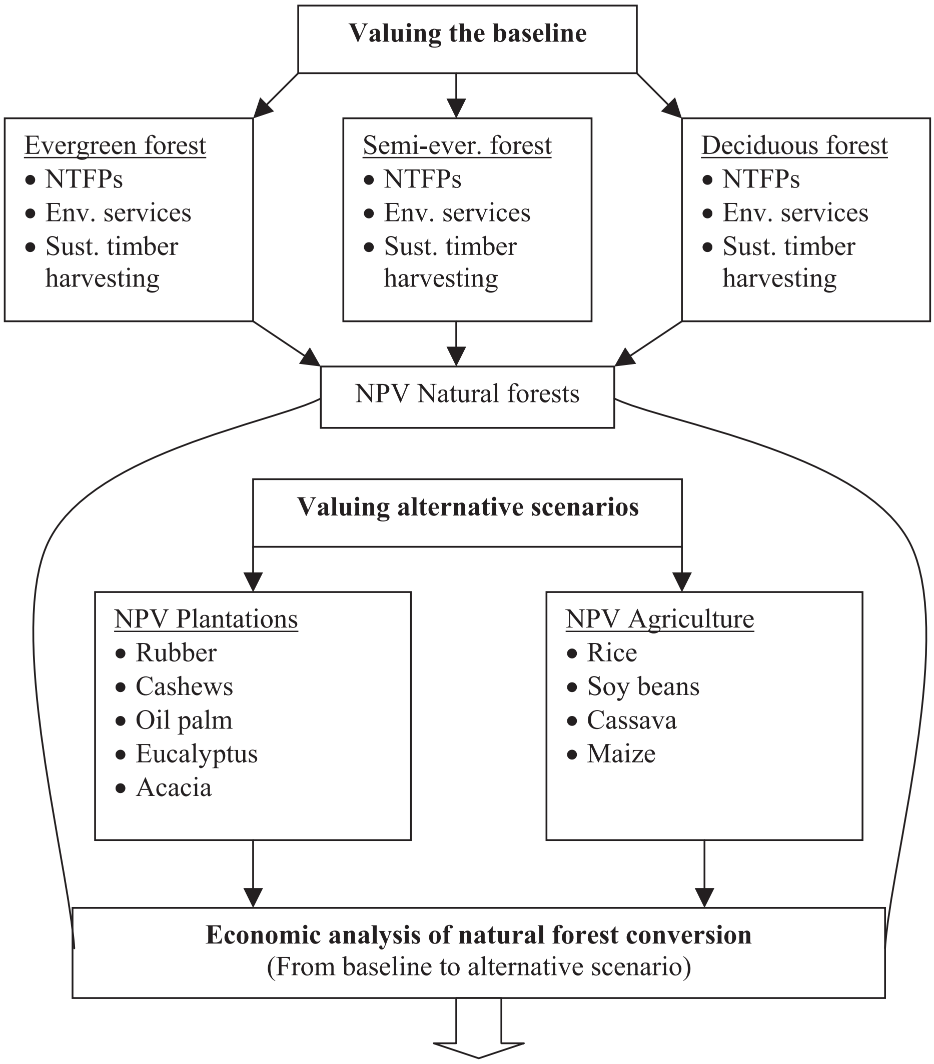
2.2.2 Analysis of Natural Forest Conversion Scenarios

Different types of plantation forest (acacia and eucalyptus), perennial crop plantation (rubber, cashews, oil palm) and agriculture (rice, soy beans, cassava, maize) were the alternative land uses compared to the baseline.

The resource rent of each of these nine scenarios was calculated using the same discount rate and time frame. The NPVs were calculated for evergreen, semi-evergreen and deciduous forest types and the nine alternative scenarios. CBA was applied in the comparative analysis. A total of 27 combinations exist.

As illustrated in Figure 2.3, the CBA for each possible conversion scenario included benefits from an alternative land use (represented by the calculated NPV) and costs in terms of lost natural forest values and services. To what extent baseline values such as NTFP collection, carbon sequestration, watershed protection and sustainable logging are affected by the conversion will depend on the alternative land use. The value of carbon sequestration lost, for example, will be different if the alternative land use is a soy bean field or a forest plantation, where large amounts of carbon are stored in the growing trees. In order to assess the net benefits, it has been attempted to include main indirect values of alternative uses.

Figure 2.2: Framework developed to analyse economic consequences of forest conversion in this study.



Conversion example: Evergreen forests (baseline) to acacia plantation (alternative)			
	Net Present Value		
	8 %	10 %	12 %
Benefits from alternative			
net value from land clearance (timber)			
net production value			
Costs from alternative			
loss of baseline NTFP collection			
loss of sustainable timber harvest			
loss of baseline indirect values (environmental services)			
Net present value (USD/ha)			

2.2.3 Sensitivity Analysis

The analysis of land conversion scenarios was based on a number of assumptions related to different parameters. Indirect values, for example, were assessed under the assumption that experiences from other countries are similarly appliable to Cambodia, and it was assumed that prices of products in relative terms are constant when predicting future cash flows. A sensitivity analysis was conducted in order to examine how changes in the main parameters of the model influenced the total NPV of land conversion scenarios. The parameters included in the sensitivity analysis were:

- Discount rate

  NPV at 8, 10, and 12 percent

- Prices of products in baseline and alternative land uses

  +/- 10 percent

  +/- 20 percent

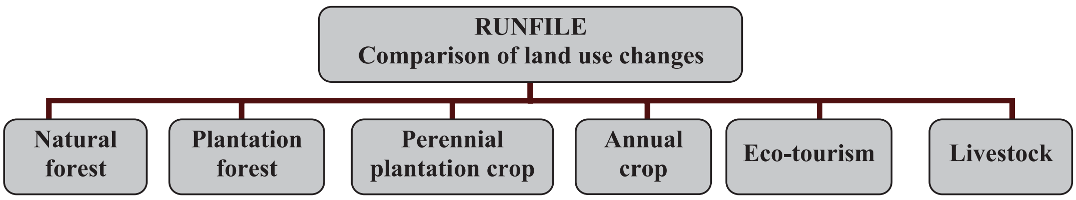
- Indirect values in baseline and alternative land uses

  -10, -20, -50, -90 and -100 percent

2.3 Value Flow Model and Valuation Methodology

The value flow model was developed based on the framework shown in Figure 2.2. The value flow model is basically a collection of connected spreadsheets in MS Excel 2003. The model has six different land use categories that the user can choose (natural forest, plantation forest, perennial plantation crop, annual crop, eco-tourism and livestock). Each land use category has a template in which data can be entered and in which yields are modelled based on the characteristics of a given land use system (See Figure 2.3).

Figure 2.3: Different components in the model are linked to a central RUNFILE, in which different land use scenarios can be defined and analysed.



In other sheets of the template, costs of inputs and prices of products and by-products (including indirect values) can be entered, and the output in terms of flows of costs and benefits over a defined period are summarised for each land use. Each summary sheet is then linked to a central RUNFILE in which different land use scenarios can be defined and in which the associated NPV is calculated based on the data from the land use sheets. The analysis of net effects of different scenarios in the RUNFILE is based on a comparison of a user-defined baseline and a user-defined alternative land use. The analysis presented in this study focuses on natural forests, plantation forests, perennial plantation crops and annual crops.

2.3.1 Valuation of Local Use of Non-Timber Forest Products

Local people have customary user rights to collect forests products from natural forests according to Article 40 of the 2002 Forestry Law (RGC 2002). The valuation of this direct use value involves tangible products that can be valued from household surveys, inventories and market surveys. An important characteristic of NTFPs is that they are not used only for sale. Valuation of NTFPs in this study included NTFPs collected by households for cash income as well as consumption, and was simply based on data on quantities collected by households and market prices of these products. When applying this technique, it is important to ensure that data collection covers an adequate period of time and sample of households to avoid biases from seasonality and fluctuating market prices. In order to minimise such bias, the valuation of forest products was based on seasonal calendars in which household members were asked to recall their collection of NTFPs for consumption and sale over the previous year. The value of NTFP collection can be described in the equation below:

$$NPV = \sum_{t=0}^{n} \frac{\sum (NTFP_1 * p_1 + NTFP_2 * p_2 .....NTFP_x * p_x)_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

where NTFP is the amount consumed and sold over a year, p is the market or forest gate price of the product over a year and Ct is the cost of collection.

NTFP value estimates must be net of harvesting costs. The main harvesting cost is the opportunity cost of labour. This can often be taken as a wage rate in an alternative form of employment. In rural areas, however, it is common for households to use surplus family labour with no other employment opportunities than NTFP collection. For these reasons, the opportunity cost of labour is expected to be very low, and for the purpose of this study, the opportunity cost of labour is assumed to be zero.

In the value flow model, the value of NTFP collection over the previous year (2004/2005) is used as a baseline value that varies over the years relatively to the standing volume of trees. The value will therefore be slightly different from an annuity over the time frame.

2.3.2 Valuation of Sustainable Timber Production

As mentioned in the introduction, a large part of natural forests has been left unmanaged since the moratorium on logging by concession companies was enacted. The value of sustainable timber harvesting is therefore an option that can be pursued in the future if forests are not converted. In this study, it is assumed that some kind of sustainable forestry is implemented, with the first harvesting in five years according to Article 12 in the 2003 sub-decree on community forest management (RGC 2003).

In Cambodia, commercial tree species are divided into different royalty classes according to their expected commercial value. In *Prakas* No. 089, these are divided into four classes: luxury, I, II and III. Tree species not listed under any royalty class in the *prakas* are defined as non-commercial (NC) (RGC 2005).

Valuation of sustainable timber extraction was based on forest inventories assessing standing timber volumes (see section 4.1) and stumpage value estimations for the different royalty classes. Stumpage value estimates were defined as timber sales prices minus production cost. Reliable data, however, have been difficult to acquire since there has been a moratorium on logging since December 2001. Timber sales prices and production costs, including informal and formal fees, were therefore based on informal interviews and estimates in secondary sources.

The *prakas* states that it is illegal to harvest luxury tree species and trees used by local communities for resin tapping. Royalty class II was therefore subdivided into resin and non-resin trees (II [resin] and II) in order to exclude resin trees from the assessment of sustainable harvesting volumes. The value of sustainable timber harvest is:

$$NPV_{sustainable} = \sum_{t=0}^{n} \frac{\sum (V_{lux} * p_{lux} + V_{I} * p_{I} + V_{I} * p_{I} + \ldots + V_{N} * p_{N})_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

where n is the time frame, t is the time in years, V is sustainable harvested volume (m3/ha) in royalty classes at year t, *p* is sales price of each royalty class ($\$/m^3$) in year t, Ct is production cost in year *t* and *r* is the discount rate.

In the value flow model, potential timber flows from sustainable partial cuts in 2011 and 2036 were valued. It should be noted that this valuation ignores the value accumulated in the standing trees at the end of the time frame. The valuation is therefore an underestimation of the value of sustainable timber harvesting.

2.3.3 Valuation of Indirect Values

As illustrated in Figure 2.1, natural forests provide a number of indirect benefits. The estimation of indirect values in this study was limited to carbon sequestration, watershed protection and soil conservation. The following sections provide a brief overview of the main methods used for valuation.

2.3.3.1 Watershed Protection and Soil Conservation

One of the most commonly described indirect forest values is watershed protection. Forest cover, if it is maintained in a good state, helps to regulate water flow and prevent soil erosion. As a result, downstream water users benefit from less silting and more assured water flows (i.e. reduced flooding in the wet season and more reliable flows in the dry season). If forest is converted to agriculture, it is likely to mean a loss of catchment protection, resulting in higher downstream silting and sedimentation, and a greater likelihood of wet season floods and dry season water shortages.

For major downstream water-based economic activities, such as hydropower, urban water supplies, irrigated agriculture and fisheries, there are two main ways of calculating the catchment protection benefits of forest cover: i) the effect on production or damage avoided and ii) expenditures to mitigate/avert downstream impacts. The main constraint on valuing these benefits, using either method, is the extent to which it is possible to predict a clear and quantifiable link between deforestation and water quality/flow—in effect to predict the likely impacts of changes in forest cover. Unfortunately, no studies on this have been conducted in Cambodia. As a result, the valuation of watershed protection and soil erosion control was based on benefit transfer from other studies in the region.

In the value flow model, the values obtained from other studies were used as a baseline value that varies over the years relative to the standing volume of trees. The values presented will therefore be slightly different from an annuity over the time frame.

2.3.3.2 Carbon Sequestration

Forests have economic value in terms of the atmospheric regulation they provide. Of these services, the easiest to predict and value is carbon sequestration, since growing natural vegetation stores carbon.

There are two ways in which the carbon sequestration functions of forests can be valued: i) market prices/replacement costs and ii) damage/economic losses avoided. Both rely to some extent on the use of generic data, or data generated in other countries.

The valuation in this study was based on carbon models developed to predict the annual carbon increment in different land uses, as well as current market prices in international carbon trading.

In the value flow model, the value of carbon sequestration varies from year to year depending on estimated increments and silvicultural interventions.

2.3.4 Valuation of Alternative Land Uses

The value of alternative land was calculated as the NPV of expected flows of costs and benefits:

$$NPV = \sum_{t=0}^{n} \frac{Y_t * p_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

where n is life span of the project, t is the time in years, Y_t is yield from plantation at time t, p_t is price of product at time t, C_t is production cost at time t, r is the discount rate, $1/(1 + r)^t$ is the discount factor at time t.

In this study, the value of alternative land uses has been valued based on data collected from interviews with plantations and from secondary sources.

It should be noted that the value of annual crops in the model does not include yearly variations and is basically just an annuity over the time frame.

2.4 Overview of Data Collection

Data for the analysis of forest benefits and the comparative analysis were collected from household surveys, forest inventories, interviews and secondary sources.

Data from the household surveys and forest inventories and secondary literature were used in analysing local benefits and in estimating the TEV of baseline forests, while secondary sources and interviews were used in the analysis of alternative land uses. For a discussion of methodology, see Appendix 7. Natural forests in Mondolkiri, Kratie, Kompong Thom and Pursat were chosen as baselines to cover main ecological regions in Cambodia. Alternative land uses were not present in the baseline survey areas, so data on alternative land uses were collected from other provinces and secondary sources. The sources of data on different land uses are presented in Table 2.1. The specific methodology is described in each section.

Table 2.1: Overview of Data Collection Methodology and Study Areas

Land use	Methodology	Area
Natural forests (baseline)	Household survey Forest inventories	Mondolkiri, Kratie, Kompong Thom and Pursat
	Literature review	Not specific
Plantation forests	Literature review	Not specific
	Plantation inventories	Takeo and Kompong Chhnang
Perennial crops	Interviews	Sihanoukville (oil palm), Kompong Cham (cashews) and Kompong Thom (rubber)
Annual crops	Literature review	Not specific

Chapter 3:

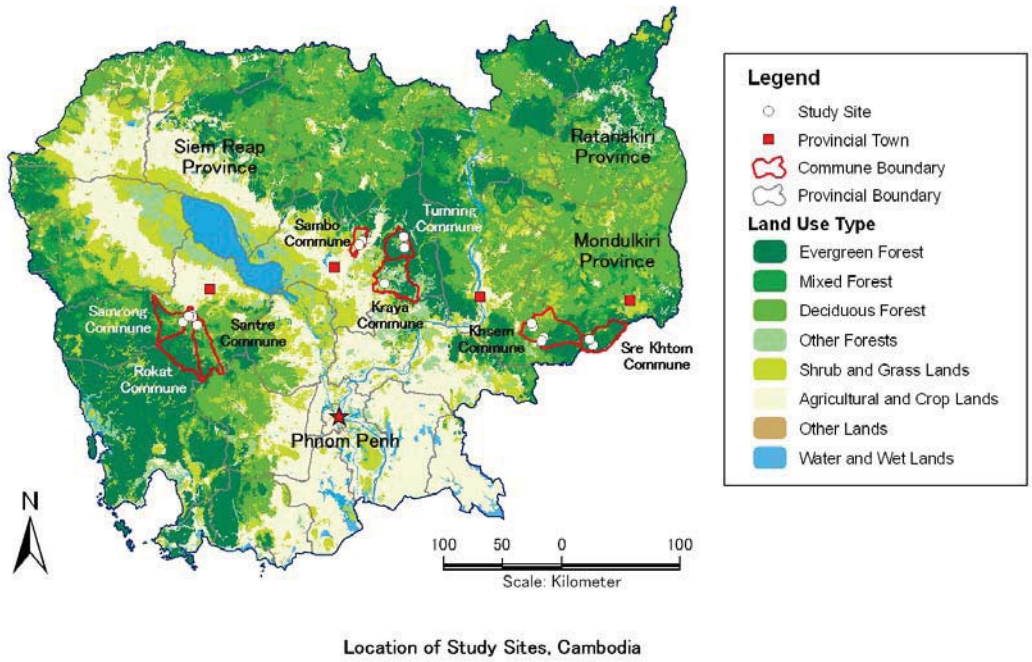
Livelihood Value Obtained from Natural Forests

This section presents the findings on the livelihood value of forest resources for rural households. The findings illustrate how the baseline forest situation is linked to rural livelihoods and poverty in order to assess and discuss the local socio-economic consequences of forest conversion.

3.1 Study Area and Data Collection

The data collection for this study focused on household interviews in 16 villages in four provinces covering the main forest zones of Cambodia. These were Ou Am and Ou Rona in Mondolkiri, Mil, Doung, Srae Roneam and Samrang in Kratie, Dang Kdar, Tum Ar, Ronteah, Samret and Chramas in Kompong Thom and Ksetr Bourei, Kol Totueng, Srae Popeay, Veal and Veal Vong in Pursat. The location of villages is shown in the study area map below.

Figure 3.1: Map of study sites for household survey covering 16 villages in eight communes of Kompong Thom, Pursat, Mondolkiri and Kratie provinces.



The surveyed villages were all located adjacent to natural forests. They were grouped according to the main forest type accessible from the villages: six villages located near evergreen forests, four near semi-evergreen forests and six near deciduous forests. The 16 villages were quite different in population, distance to main markets, and available collection areas. The main characteristics of the villages in the survey are listed in Appendix 2.

A total of five hundred and two households was randomly selected in all villages for semi-structured interviews on forest use and other livelihood activities. The sample design is shown in Appendix 2, and the main methodology used in data collection is described below:

Questionnaire design and pre-testing: The questionnaire was designed based on information gathered during focus group discussions on main NTFPs collected and main income categories. The questionnaire was pre-tested in 20 households in Kratie. The household surveys in the four provinces were conducted from July to September 2005. The final questionnaire used for the data collection is in Appendix 3.

Seasonal calendars: Seasonal calendars were used in the individual household interviews to include the seasonality of NTFP collection. The standard seasonal calendar matrix is shown as part of the questionnaire in Appendix 3. During the exercise, all household members were encouraged to participate in order to include the main collectors of a given NTFP and to minimise gender biases.

Wealth rankings: In order to analyse different patterns of use according to socio-economic status, households were divided into wealth categories based on local indicators of wealth, such as type of house and number of livestock. Local indicators of wealth were defined in focus group interviews in the villages. The characteristics of different wealth groups are listed in Appendix 4.

Comparison of socio-economic groups: Before the comparative analysis between different socio-economic groups was conducted, differences in household size were compared in order to assess whether it was necessary to convert results to adult equivalent units (Cavendish 2002). No significant difference was found, and the comparative analysis was therefore structured at the household level.

Before the results are presented, it should be noted that this section looks at differences between socio-economic groups. There will be local variations in collection of products as well as main income activities, and these are not reflected in the following analysis. The sample frame is not representative for the whole country as it only covers households living adjacent to forests in these four provinces.

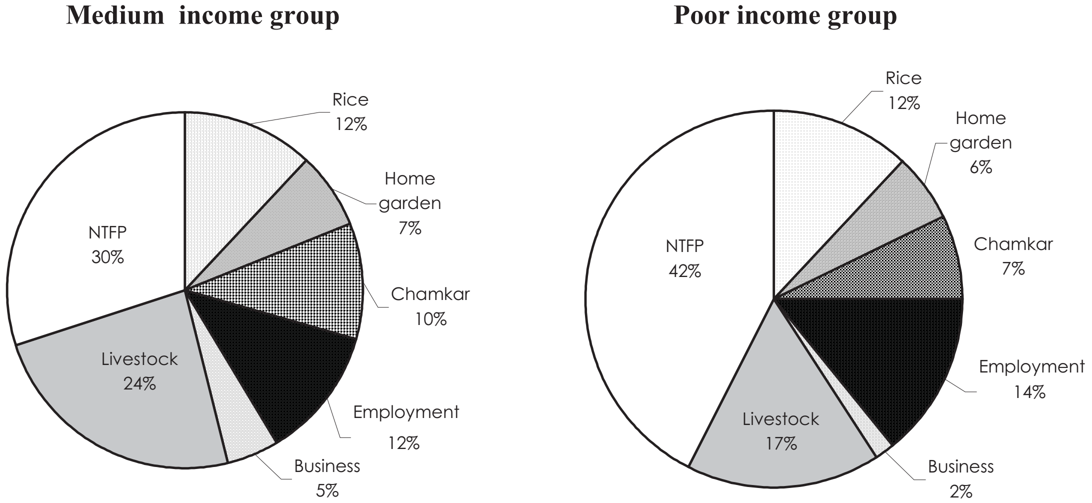
3.2 The Importance of Forest Resources for Household Income

Rural livelihoods are in general very diverse, and households pursued a wide range of activities to support themselves. The livelihood activities of households in the study areas were divided into seven main categories:

1. **Rice farming,** including upland and paddy rice.
2. **Home garden,** defined as the garden surrounding the house or residential area. The main crops of home gardens include fruits, vegetables and spices used day to day, such as lemons, papayas, mangoes, coconuts, pineapples, jackfruit and lemongrass.
3. **Chamkar farming** is loosely defined as farming other than wet rice cultivation. It is usually found in more hilly locations and can involve either permanent cropping or shifting cultivation. Some main crops of chamkar include soybeans, maize, cashews and cassava.
4. **Employment,** defined as off-farm work, including seasonal and full-time employment.
5. **Private business,** referring to small-scale home-based businesses such as retail stores and food stalls.
6. **Livestock,** which includes all animals kept and consumed or sold by the household or kept as savings: chickens, cattle, buffaloes, ducks etc.
7. **NTFP collection,** for either consumption or sale.

All categories were valued in terms of consumption and sale, and the total of this was defined as the total livelihood value of each activity. The relative shares of the livelihood value of the seven activities are shown in Figure 3.2 below.

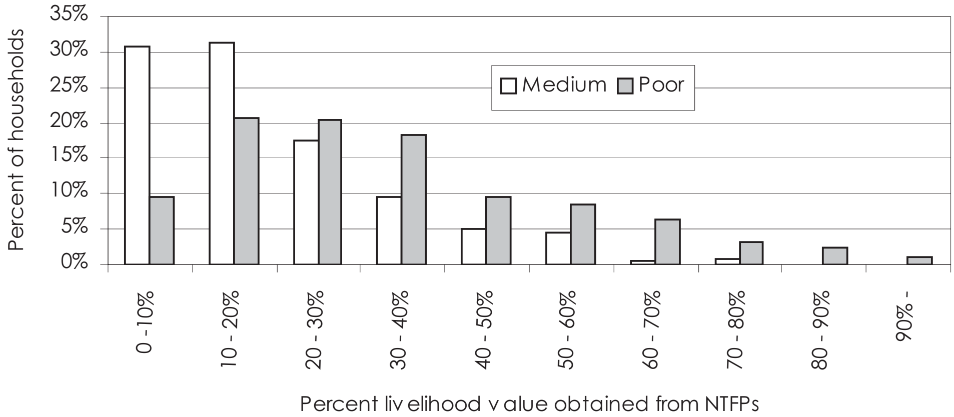
Figure 3.2: Relative total livelihood value of different activities for different socio-economic groups. Based on recall data of income and consumption in household interviews. Seasonality of NTFP use was captured in seasonal calendar exercises during household interviews (n=218 for medium and n=284 for poor households).



The analysis found that when both income and consumption are valued, NTFP collection is one of the most important livelihood activities for both socio-economic groups in the study areas. The study found that medium households generated about 30 percent of their livelihood value from NTFPs, while poor households averaged 42 percent. This must be considered as a high average for both socio-economic groups. To get a better idea about who are the main local beneficiaries, the distribution of value among households was analysed.

The livelihood value obtained from NTFPs was distributed differently among surveyed households, as shown in Figure 3.3. For both groups, it was most common for households to obtain between 10 and 20 percent of their livelihood value from NTFPs. Among medium households, about 62 percent derived less than 20 percent of their livelihood value from NTFPs, while 37 percent derived between 20 and 60 percent. Only around 1 percent obtained more than 60 percent of their livelihood value from NTFPs. Households in the poor group generally obtained a larger share of their livelihood value from NTFPs: around 57 percent of obtained between 20 and 60 percent from NTFPs, and 13 percent derived more than 60 percent from them. Around 2 percent obtained more than 80 percent of their livelihood value and must be considered fully dependent on forest resources.

Figure 3.3: Distribution of households based on the percentage of livelihood value that originates from consumption and sale of NTFPs. Based on household interviews (n=218 for medium and n=284 for poor households).



These figures clearly underline the importance of NTFPs to local livelihoods, especially for the poorest segment of the communities in the study areas, and show that decisions on allocating more land to forest conversion potentially will have significant negative economic impacts on a large proportion of the households.

3.3 Main NTFPs Collected by Households and Their Value

A large number of NTFPs were collected in the study areas. The large number of different products and species called for a classification. The following six categories of NTFPs were identified during the data analysis as major contributors to rural livelihoods. The classification is based on the functional role and origin of the products:

1. **Fuel wood (firewood and charcoal)** are the most important sources of fuel for cooking in Cambodia. In rural areas, approximately 97 percent of all households use firewood or charcoal for cooking, and in urban areas the figure is 78 percent. This large-scale use of fuel wood in rural areas makes firewood and charcoal an important energy resource and income source for rural and peri-urban households with few alternatives for cash income (FAO 1998; Heng 2002). As shown in the following, the data collected in the current study clearly support these findings, both in regard to the percentage of people using wood as fuel and the value of wood as a source of energy.

2. **Resin collection** provides a significant income to many Cambodian households, particularly in the eastern region and in other areas with forests containing resin trees. Two main types of resin are collected: i) solid resin from Shorea species and ii) oleoresin[3] from species of *Dipterocarp* trees. Oleoresin is the most collected resin in Cambodia, and this was also the case in areas surveyed in this study. *Dipterocarpacea* is a family of trees most commonly found in evergreen forests in this study. The resin is primarily collected for cash income and is mostly sold directly to visiting traders, who transport and resell it for processing (Meng and Martin 2002; Evans et al. 2003; Prom and McKenney, 2003). A smaller quantity of resin is also used by the households themselves for lighting, caulking boats, paint and varnishes.

[3] *Oleoresin is liquid resin tapped by cutting a hole into the tree trunk and using fire as a stimulant for natural production of the sap. Overnight the oleoresin flows into the hole and the collector can come back the next day to collect it. The same hole can be burned for many years depending on methods and the age of the tree, which can be tapped for decades.*

3. **Wild meat (including fish)** represents a substantial value to rural households for both consumption and cash income. Other studies also mention the importance of wild game and fish (e.g. Desai and Lic 1996; Lic and Martin 2002). Protection of endangered species is a serious concern in connection with hunting wild animals.

4. **Wild plants for food and medicinal purposes** are valued in most Cambodian communities as an important supplement to the daily diet and as an alternative or supplement to the official health care system. The reliance on medicinal plants by local communities may be far more important than is generally believed. Approximately 600 different species are reported to be used for medical purposes, including epiphytes, ferns, herbs, grasses, sedges and vines (Meng and Martin 2002; Kham 2004; Linddal and Outey 2004). Wild plants include vegetables, such as rattan shoots, nuts, roots, tubers, perennial herbs, ferns, palm core, mushrooms, bamboo shoots, nuts and young leaves of woody vines and trees and a range of edible fruits. They are collected and consumed daily and provide an important supplement to villagers' diets.

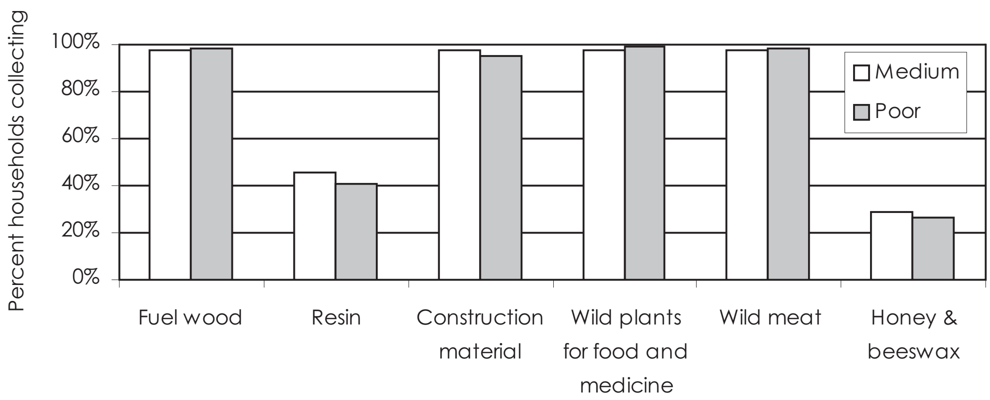
5. **Construction materials**—bamboo and wooden poles, small timber, leaves, grass and vines are important to many rural people's lives, supplying cheap and easily available building materials. Species of bamboo that are often used for construction include *Dendrocalamus giganteus, Dendrocalamus membranacceus, Bambusa vulgaris, Bambusa bambos* and *Bambusa arumdicacea*. Bamboo is also used for making utensils, such as farming and fishing tools, baskets, chopsticks, floor gratings and columns of cottages and carrying poles. Wooden poles are very commonly used to make gates and livestock cages, and are traded in many provinces. Building timber is used to make plywood for house walls and doors, while leaves and thatch are used to make roofs.

6. **Honey and beeswax** were identified as a small but distinctive category used by a significant proportion of households.

It should be noted that NTFP collection normally is very area-specific, depending on availability of products and markets. The categories in this study represent the areas surveyed. Other categories, for example malva nuts from *Sterculia lychnophora*, may be important in other areas.

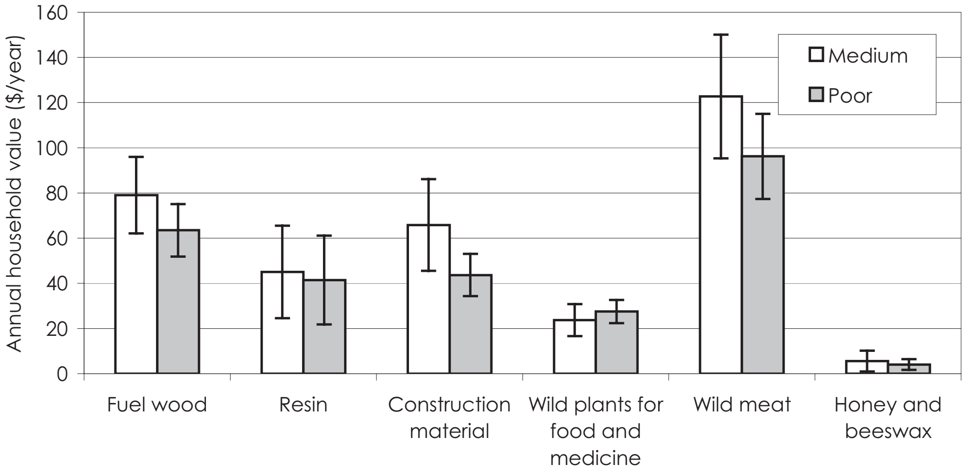
The importance of each category in the study areas is illustrated by the proportion of households collecting each category, as shown in Figure 3.4.

Figure 3.4: Percent of households in the survey collecting different NTFPs, by socio-economic group.



The analysis shows that over the previous year, almost all households in the survey were engaged in collection of fuel wood, building materials, wild plants and wild meat. Resin and honey and beeswax were important only in some areas, but still they were collected by around 40 and 30 percent of the households, respectively. There was no significant difference between the socio-economic groups in terms of the percentage of households collecting different products. In order to determine the economic importance of each category, the average livelihood value derived from these activities was analysed, as shown in Figure 3.5.

Figure 3.5: Total value of different forest products for different socio-economic groups. Confidence levels calculated as 2*standard error for a given strata (n=218 for medium and n=284 for poor)



The most valuable products for both socio-economic groups were wild meat (the share of fish was 26 percent for medium and 28 percent for poor), fuel wood, building materials and resin. The relative importance of products was similar between socio-economic groups. Medium households, however, generally obtained more livelihood value from all NTFP categories, except for wild plants. This difference for wild plants may be explained by the fact that poor households have less cash income to buy pharmaceuticals and therefore are more dependent on medicine from the forests.

If the percentage of cash and non-cash value is analysed for each NTFP category (Figure 3.6 and Figure 3.7), the analysis shows that approximately 50 percent of the NTFP collection is for subsistence. Only resin was collected mainly for sale. This underlines the importance of including consumption in valuation of livelihood activities in socio-economic surveys.

Figure 3.6: Percentage of value obtained from cash or non-cash activities for medium households (n=218)

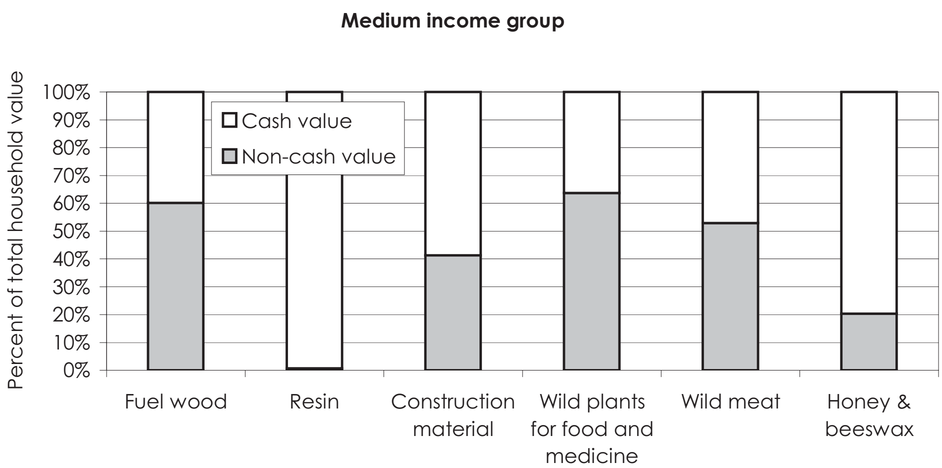
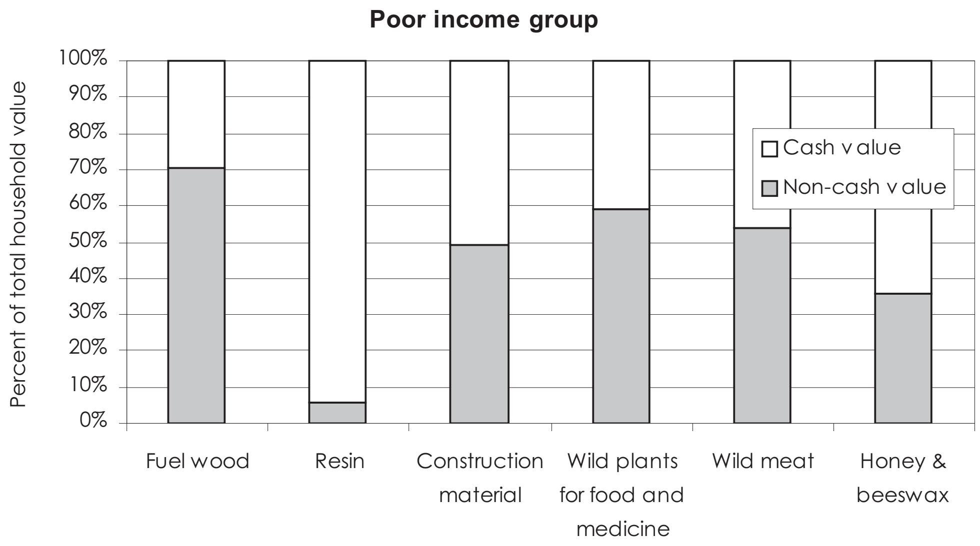


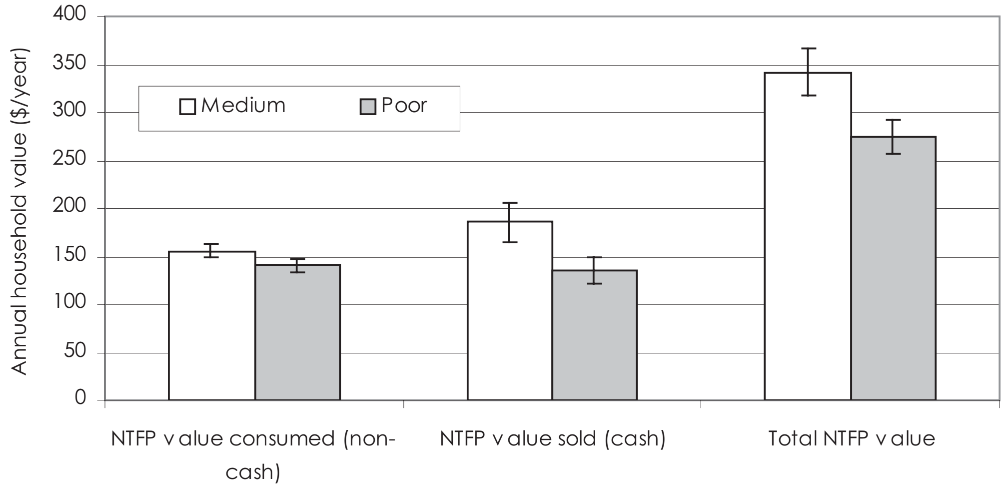
Figure 3.7: Percentage of value obtained from cash or non-cash activities for poor households (n=284)



3.4 Cash and Non-Cash Income from Forest Resources

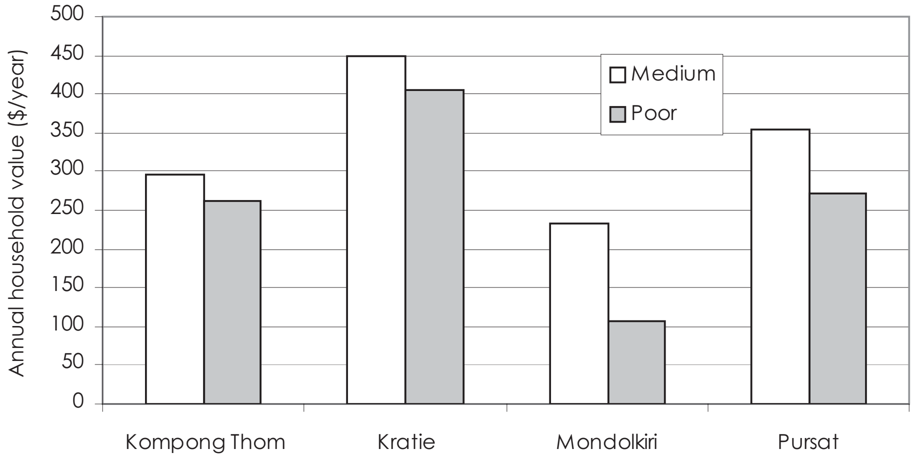
Another interesting analysis is shown in Figure 3.8, where the total value of NTFP collection is divided into cash and non-cash values for poor and medium households. The analysis reveals some interesting differences between the two groups. The average total livelihood value obtained from NTFPs in the survey is USD345/year for medium households and USD280/year for poor households. It is interesting that this difference is related to the sale of NTFPs, since the consumption values are about the same for the two groups. Average numbers of members of households of the two socio-economic groups were compared to test if the difference could be explained by a larger household size in the medium group. The study found no significant difference in household size between the two groups. The differences in total NTFP income could therefore not be explained by this factor. This suggests that this difference more likely is rooted in poor households' lack of capacity to collect high-value NTFPs and seize market opportunities as described in CDRI (forthcoming).

Figure 3.8: Total value of cash and non-cash income from NTFPs for different socio-economic groups. Confidence levels calculated as 2*standard error for a given stratum (n = 284 for poor and n = 218 for medium).



The total livelihood value derived from NTFPs varied between the four areas as shown in Figure 3.9 below. The average values for households in the survey were: USD265/household in Kompong Thom, USD424/household in Kratie, USD167/household in Mondulkiri, and USD314/household in Pursat. The trend that better-off households tend to derive more value from forests, however, was the same and did not depend on the areas.

Figure 3.9: Variations in total NTFP value for households in the four provinces.



3.5 Local Management and Trends in Availability of Forest Products

Another characteristic of NTFP use is that most products are collected from common property resources near the villages. These areas are practically open access, and the collection is almost uncontrolled and often destructive, with few rules to support sustainable use. Local people perceive the availability of forest products as declining, and all villages report that collection of NTFPs is becoming more and more labour intensive. This trend points to the importance of assisting local communities to implement more sustainable management systems. At the moment, such initiatives are highly constrained by lack of local incentives to engage in long-term forest management. Incentives for local people to invest labour or money into intensified use of forests is often linked to secure tenure or user rights, as well as a resource base that is not too degraded to supply benefits in the near future (IFSR 2004).

3.6 Trade and Marketing of Non-Timber Forest Products

The findings underline the importance of forest products in the rural economy as a commodity group that is not only used as a safety net, as often mentioned, but also as a very important resource in the overall livelihood of a majority of rural people living in or adjacent to forest resources. This indicates a potential link between livelihood improvements and commercialisation and/or domestication of NTFPs, but this has to be evaluated on a case-by-case basis.

Despite the importance of NTFPs in the rural economy, the existing data on trade and marketing of NTFPs are scarce, basically consisting of isolated case studies or limited statistics. The most recent official statistics on international trade of NTFPs, from 2002, mention small amounts of mushrooms and rattan (DFW 2003). Other products, such as resin, bamboo and medicinal plants, are known to be traded both domestically and internationally, but the actual size and potential of trade are still unknown (Prom and McKenney, 2003). Linddal and Outey (2004) suggest that exports of medicinal plants from Cambodia are significant, but no information is available on their size and character.

Commercialisation of NTFPs has often been associated with unrealistic development and conservation expectations. Over the last decade, international research has focused on what factors affect the potential for increasing the commercial value of NTFPs. A comprehensive study by the Centre for International Forestry Research (CIFOR) comparing 24 NTFP case studies from the region shows that commercialisation of NTFPs in some cases can contribute significantly to rural development if the right tenure and marketing attributes are in place to support local trade (Kusters and Belcher 2004). Marketing of NTFPs is not well described in Cambodia, except for a few studies on resin by, for example, Prom and McKenney 2003. This study found that resin trade generally is restricted by informal fee collections at different points in the market chain. Despite this, oleoresin still plays an important role in many rural people's livelihoods, and the lack of studies on commercialisation and domestication of NTFPs indicates that there is a need for research to look more deeply at the potential role of small and medium NTFP enterprises in rural development strategies.

3.7 Summary of Results

The total livelihood value of forests in this study was on average USD280 and USD345 per year for poor and medium households, respectively. In relative terms, this NTFP collection represents 42 and 30 percent of the total livelihood value for an average poor and medium household in the survey. NTFP collection must therefore be considered as a fundamental activity for a large proportion of people living adjacent to forests. Changes in access to forest resources will therefore have serious impacts, especially on poor households, unless alternative activities are available to compensate for the livelihood values lost.

The significant income that households derive from NTFP collection shows that there may be potential for improving income through commercialisation and domestication of NTFPs. The current uncontrolled collection from common property resources and the negative trend in availability of NTFPs point to a need for piloting and implementing new sustainable natural resource management models to enhance the contribution of natural forests to rural development and poverty alleviation. This needs to be aided by a consistent legal framework to support local management against external interests. Also, the trade and marketing structure for forest products needs to be adjusted through removal of restrictive licence and fee systems in order to encourage pro-poor trade and rural development.

Chapter 4:

The Total Economic Value of Baseline Forests

This section presents the findings of the total economic value (TEV) of different types of natural forests in the value flow model. The analysis includes main direct and indirect use values as described earlier in the methodology chapter. The analysis is structured on a per hectare basis in order to compare economic consequences of natural forest conversion scenarios in the next chapter.

4.1 Forest Types and Data Collection

The TEV of forests will vary significantly depending on a number of parameters, such as the density and distribution of tree species and NTFPs, location (near streams or on erosion-prone land), biodiversity (habitat for endangered species) and potential for carbon storage. These values are often very site-specific, and in order to cover some of the variations this study has focused on the three main forest types reflected in national statistics: evergreen, semi-evergreen and deciduous forests.

4.1.1 Evergreen Forest

Evergreen forests are usually multi-storeyed. They are often found on hills and along streams and rivers. They are composed of lowland tropical rain forests, hill evergreen forests and dry evergreen forests. A certain percentage of deciduous trees may be included, and most moist deciduous forests may not be distinguishable from evergreen forests. In this study, evergreen forest was observed in Ou Am and Ou Rona in Mondolkiri, Tum Ar and Ronteah in Kompong Thom and Ksetr Bourei and Veal in Pursat.

4.1.2 Semi-Evergreen Forest

Semi-evergreen forests contain both deciduous and evergreen tree species. The percentage of evergreen trees varies from 30 to 70 percent. Semi-evergreen forests can be quite similar to evergreen forests, although they appear more brownish or greyish in the dry season. In this study, semi-evergreen forest was observed around Mil and Doung in Kratie, Kang Kdar in Kompong Thom and Veal Vong in Pursat.

4.1.3 Deciduous Forest

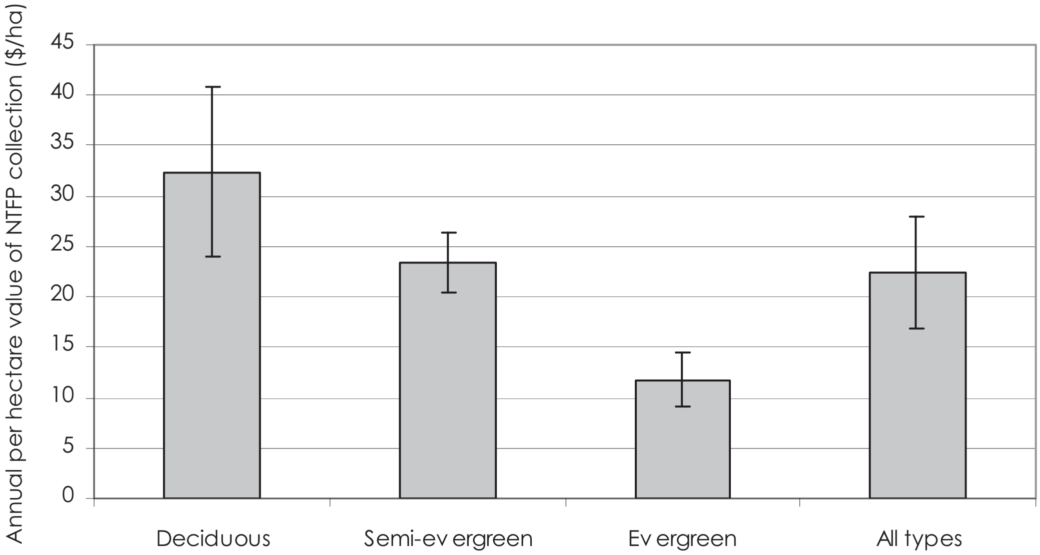
Deciduous forests contain mixed deciduous and dry ipterocarp trees. Deciduous forests drop their leaves more or less completely during the dry season. Their appearance varies from reddish violet to yellowish brown at the end of the wet season, and from brownish green to bluish grey during the dry season. Dry forests naturally have an open character. Fires usually occur in deciduous forests. Undisturbed deciduous forest may have crown cover of up to 40 percent. In this study, deciduous forest was observed in Srae Roneam and Samrang in Kratie, Samret and Chramas in Kompong Thom and Kol Totueng and Srae Popeay in Pursat.

4.2 Value of NTFP Collection

Based on household interviews and participatory village forest resource mapping sessions, the direct value of NTFP collection was converted to per hectare values. Main findings are presented in Figure

4.1, which shows that the average direct value of NTFP use is USD32 per hectare in deciduous, USD23 in semi-evergreen and USD12 in evergreen forests. The average value for all the forests in the 16 villages surveyed was USD22 per hectare.

Figure 4.1: Per hectare direct values of NTFP use in selected forest types. Based on household interviews (n=502) and forest resource mapping exercises in each village (n=16). Confidence levels based on village averages (n=6 for deciduous, n=4 for semi-evergreen and n=6 for evergreen).



It is interesting that deciduous forest has the highest direct use value. This is most likely due to the fact that NTFP values are based on actual NTFP flows. In general, the use of NTFPs can be valued in two ways: (i) based on actual flows, as in this study, or (ii) based on NTFP inventories. The latter method increases the value of NTFP use since all potential products are valued. This is especially so for dense evergreen forests. The approach should, however, be used with caution because it is difficult to predict market price changes derived from a hypothetical extra supply, as well as to assess if or when opportunity costs of production exceed benefits from sale of products. Methodologically it is considered most appropriate to use the actual NTFP flow when considering valuation of NTFP use from the local extractors' point of view (e.g. Godoy et al. 1993; Tewari 2000). Using a TEV approach, however, it could be argued that the stock value could be used to some extent because there is a possibility that improved market access in the future will make collection more profitable. This is a speculative argument though, that relies on the elasticity of demand and consumers' preference for different NTFPs. The NTFP value in this study was therefore valued based on actual NTFP flows.

The higher per hectare value of deciduous forests found in this study is most likely due to their location closer to the villages as well as the fact that village collection areas on average were smaller in deciduous forest areas (see Table 4.1).

Table 4.1: Average Collection Area in Forests

Forest type	Average size (ha)
Deciduous	1640
Semi-evergreen	5190
Evergreen	5330

Field survey (2005)

Deciduous forests in this study could be more intensively used because they were easier to access and the transport costs were lower. Evergreen forests, on the other hand, were in general located further from the villages, and NTFP use was limited to the most valuable products, the profits of which could cover transport costs and the opportunity costs of labour. Forests located near the villages were of special importance to poor households, and it could be argued that these forests are of greater social value since they support the most vulnerable households and contribute more to equitable access to natural resources.

For the overall analysis, the direct NTFP use values for selected forest types were entered into the value flow analysis model as part of the TEV of baseline forests. As mentioned in chapter 2, the annual NTFP values vary according to the standing volumes in the model. Therefore, they will be slightly different from the value of a 50-year annuity presented in Figure 4.1. The total value of NTFP collection at different discount rates over 50 years from the model is given in Table 4.2.

Table 4.2: NPV of NTFP Collection (USD/ha) Over 50 Years in Forest Types at Different Discount Rates

Forest type	NPV @ 8 percent	NPV @ 10 percent	NPV @ 12 percent
Deciduous	459	365	266
Semi-evergreen	285	228	191
Evergreen	149	119	100

Based on model estimates

The NPV of NTFP collection at a 10 percent discount rate over a 50-year period ranges from USD119 to USD365 depending on forest type. These values are based on the assumption that current collection levels can be maintained for 50 years under sustainable management regimes. This value is quite low on a per hectare basis, even though the livelihood value per household presented in Chapter 3 was high. This illustrates that NTFP collection from common property areas is quite land intensive and that it needs to be intensified if it is to keep up with an increasing population.

4.3 Value of Sustainable Timber Harvesting

The potential value of sustainable timber harvesting in baseline forests was assessed based on inventories of standing timber volumes and estimates of timber sales prices and production costs. In the valuation, it was assumed that future commercial timber harvesting could involve local communities and that commercial harvesting will start in five years, as stated in the current legislation on implementation of community forestry (RGC 2003).

4.3.1 Inventories in Natural Forests

Forest inventories were conducted in the three selected forest types in Mondolkiri, Kratie, Pursat and Kompong Thom Provinces. The total number of plots inventoried in each forest type is shown in Table 4.3.

Table 4.3: Number of Plots Inventoried in Selected Forest Types

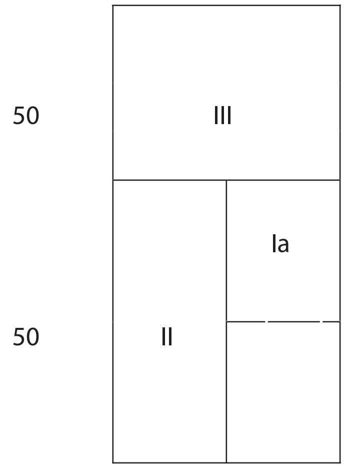
Provinces	Number of plots Evergreen	Number of plots Semi-evergreen	Number of plots Deciduous	Total plots
Mondolkiri		8		8
Kratie	8		11	19
Pursat	2	2	2	6
Kompong Thom	2	2	2	6
Total	12	12	15	39

Field survey (2005)

The plot design used in forest inventories was based on national guidelines developed for community forestry (RGC 2006). In evergreen and semi-evergreen forests, a plot of 50 x 100 m (0.5 ha) was demarcated and divided into four sub-plots, while in deciduous forests a plot of 50 x 50m (0.25 ha) was demarcated and divided into three sub-plots as illustrated in Figure 4.2.

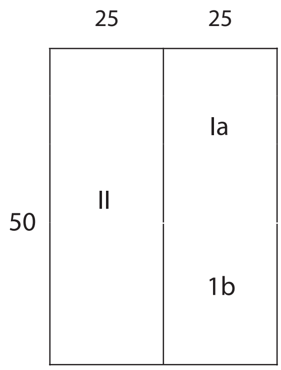
Figure 4.2: Plot design for natural forest inventories in selected forest types.

Plot /sub-plot	Size of plot Or sub-plot	Trees and saplings inventoried
All	50 X 100 m	Trees ≥ 30 cm
III	50 X 50 m	Trees 10-29 cm
II	25 X 50 m	Saplings <10 cm (height>1 m)
Ia	25 X 25 m	Bamboo and main NTFPs



Plot Description for Deciduous Forest

Plot / sub-plot	Size of plot Or sub-plot	Trees and saplings inventoried
All	50 X 50 m	Trees ≥ 30 cm
Ia+Ib	25 X 50 m	Trees 10-29 cm
Ia	25 X 25 m	Saplings <10 cm (height>1 m)
II	25 X 50 m	Bamboo and main NTFPs



Within the plot design, species of individual trees were identified and trees were measured for a number of parameters, including diameter at breast height (DBH), tree height and log height. For all plots, densities and volumes of trees in DBH classes of different royalty classes were calculated in order to assess the average standing volume of commercial and non-commercial species in the selected forest types.

4.3.2 Data on Productivity of Natural Forests

Data from permanent sample plots as well as inventory data were used to simulate natural forest growth in the value flow model. The growth in the model is based on average diameter increment data from permanent sample plots (MAFF 2003; Boscolo 2004) simulating the probability that a tree would move up to a higher DBH class.

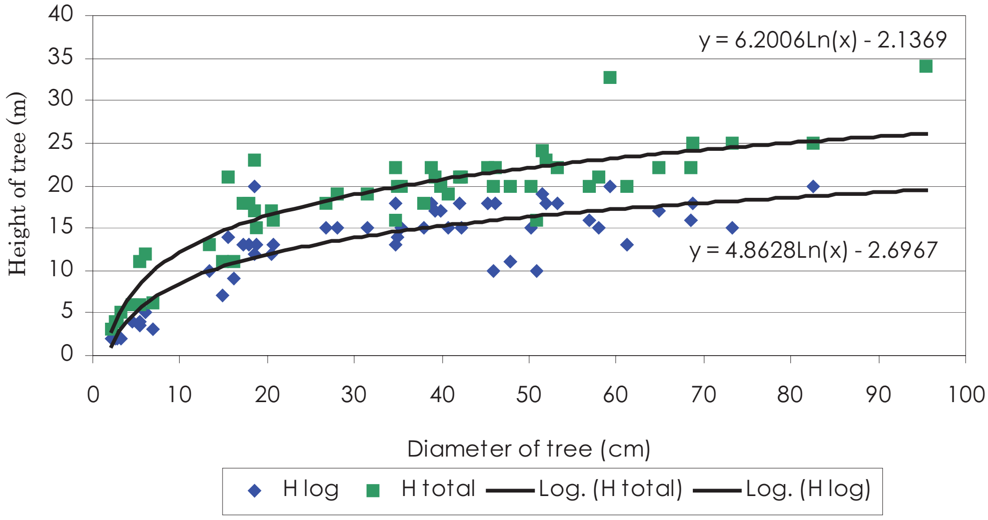
Harvested trees are converted into saleable volumes based on average diameters (Dg) and heights (Hg) for different DBH classes and a form factor[4] of 0.65. For this purpose, diameter-height regressions have been developed for different royalty classes based on data from the inventories. The basic formula used is:

[4] *In general terms, the form factor of a tree is the ratio of its volume to the volume of a specified geometric solid of similar basal diameter and height. Most commonly, the form factor of trees is based on a cylinder. Thus, the product of tree basal area, tree height and cylindrical form factor should give tree volume.*

$$h = \alpha + \beta \cdot \ln(d)$$

where *h* donates total log height or tree height in metres, *d* denotes diameter in cm, and α and β are constants (see Figure 4.3 for an illustration). The commercial volume is calculated as the share of log volume to tree volume.

Figure 4.3: Example of diameter height regression for royalty class II resin in evergreen forests. H log is commercial log height and H total is tree height.



The regressions developed for this study should be interpreted only as indicative due to large variations between areas and within royalty classes. For the purpose of this economic valuation, however, it was assumed appropriate to convert tree volumes to saleable volume based on these regressions.

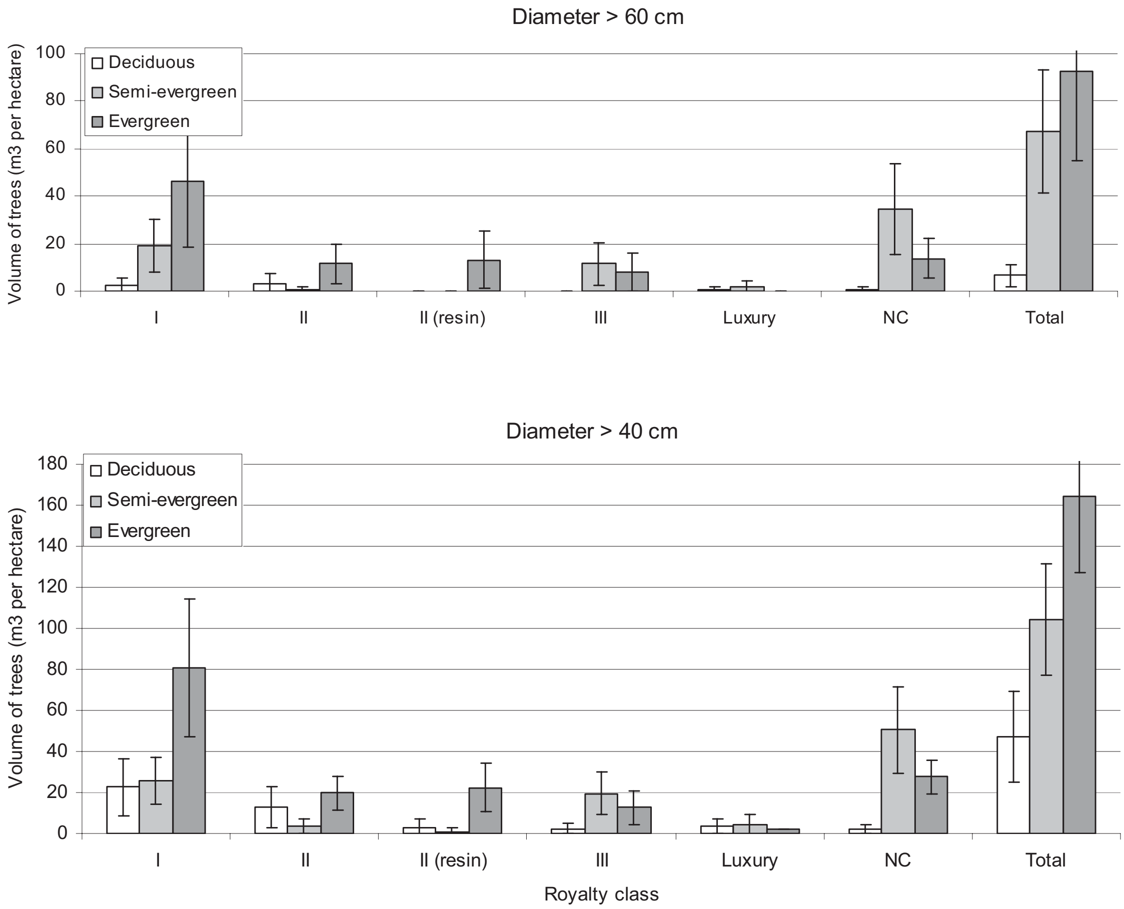
In order to convert yields to cash flows, profit margins were estimated based on information on production costs and sales prices obtained from informal interviews and estimates in IFSR (2004) and McKenney *et al.* (2004), and then entered into the value flow model. Taxation of harvested timber was based on potential log volumes. See Appendix 5 for more information on productivity data applied in the model.

4.3.3 Standing Tree Volumes in Baseline Forest Types

The categorisation of forests is also linked to the economic value of standing timber in terms of densities and distribution of different tree species. Deciduous forests are the most open forest type with less timber value, while evergreen forests are the densest and most valuable in standing timber volumes.

The distribution of standing tree volumes in the royalty classes is illustrated in Figure 4.4 to provide a sense of the tree distribution in the three forest types. The figure shows that the standing volume varies significantly among forest types. At the same time, the confidence levels for royalty class volume estimates in the figure show that there is high variation within each forest type. The volumes and densities found in this study were compared with data from other inventories conducted by CDRI and the Wildlife Conservation Society in McKenney *et al.* (2004), as well as data from the Independent Forest Sector Review (Boscolo 2004) and the most reliable Strategic Forest Management Plans (see Heov *et al.* 2006b). The densities and volumes found in this study were similar to the other studies. Based on these comparisons, it is assumed that they are representative for the selected forest types. It is, however, important to note that there is large variation both between and within forest types and that the values should by no means be considered as national averages.

Figure 4.4. Standing volume of trees with DBH > 40 cm and DBH > 60 cm in different forest types. Based on forest inventories (n= 39) conducted in this study. Note that figures are standing tree volumes, not commercial log volumes. See Appendix 5 for volume and density tables of selected forest types.



The density and volume of standing trees in different DBH classes were entered into a forest growth model. Sustainable harvesting levels were estimated based on diameter growth data from permanent sample plots, assuming that sustainable harvesting interventions damage 40 percent of the residual stand (FAO 2003).

4.3.4 NPV of Sustainable Timber Harvesting

The NPV of sustainable timber harvesting over 50 years in a 25-year harvesting cycle starting in 2011 for one hectare of baseline forest is summarised in the Table 4.4.

Table 4.4: Timber Values from Sustainable Harvesting in Selected Forest Types over 50 Years

Forest type	NPV @ 8 percent	NPV @ 10 percent	NPV @ 12 percent
Deciduous	-306	-248	-207
Semi-evergreen	403	516	461
Evergreen	1931	1691	1497

Based on model estimates

These values illustrate that the per hectare value of potential sustainable timber harvesting is much larger in evergreen forests. The figures also indicate that there is limited potential for sustainable timber harvesting in deciduous forests because they are so degraded that future timber flows cannot cover production and protection costs. This supports the general impression that community forestry initiatives in degraded deciduous forests are questionable in terms of economic incentives to engage in sustainable harvesting of timber. The successful development of local community forestry is therefore most likely linked to securing rights over land rather than an investment in the production of these forests, as is also stated in, for example, IFSR (2004). On the other hand, the results suggest that benefits from sustainable production of timber in semi-evergreen and evergreen forests could provide significant benefits for local people in some kind of joint management system in which benefits are shared among companies, local people and the state.

4.4 Indirect Values of Natural Forests

Since there are no studies of indirect values of forest resources in Cambodia, this section will provide a brief description of potential benefits from forest resources as well as a presentation of a selected number of case studies used in this study to assess indirect values.

4.4.1 Biophysical Relationships

Forests provide a variety of ecosystem services, such as watershed protection, soil and biodiversity conservation and carbon sequestration (Botkin and Talbot 1992; Myers 1995). The biophysical relationships between forests and these services are highly variable from one location to another according to climate, soils and vegetation types. As a result, there is no direct substitute for site-specific information. Nevertheless, in the following sections basic information on relationships between forests and environmental services are summarised based on Calder (1998), Falkenmark *et al.* (1999), Pattanayak (2004) and Johnson (2000). In the end, some results from valuation studies, which have been selected as appropriate for valuing baseline forests based on benefit transfer, are presented.

Forests and Soils

A well-developed understorey or litter layer, typically found under forests, minimises surface erosion. Extensive root systems help hold soil more firmly in place and resist landslides, as compared to clear-cut or heavily disturbed forests. By reducing soil erosion, forest cover decreases the sedimentation and dissolved load in surface run-off and inter-flow. Due to the complex trapping and storage process for sediments, there may be significant time lags before downstream sediment loads are noticeably lower in the basin. The forest canopy and the litter layer protect the soil from the damaging influence of solar radiation and rainfall. As a result, forest soils usually have very open structure and higher concentrations of organic matter and faunal activity, thereby improving access to nutrients and water for trees, plants and other flora.

Forests and Water Flow

Forests generally reduce the total annual stream flow. This is because trees absorb water, some of which is then evaporated back into the atmosphere. In general, trees consume more water than other types of vegetation, including grasses and annual crops. The degree to which forests reduce stream flow, however, depends on various factors. For example, shallow-rooted trees tend to use less water than deep-rooted trees, and young regenerating forests tend to use much more water than mature and old growth forests. Even though both natural and planted forests use more water than most agricultural crops and grasslands, the better infiltration and water storage capacity of the surface layers of forest soils may result in different levels of flow during different seasons.

By slowing the rate of run-off, forests can help minimise flooding in smaller watersheds, although they may not influence large-scale flooding. By slowing the run-off rate, forests may also increase minimum stream flows during the dry season. Forested areas usually register a lower frequency and rate of peak flow for small and medium storms. For larger river basins and big storms, however, other geological and climatic factors are more important than the presence of forests. Forests serve to protect against storm damage, acting as windbreaks and creating roughness effects, diminishing storm intensities

Forests have two opposing impacts on groundwater levels: i) they tend to increase infiltration and soil retention, promoting groundwater recharge and reducing run-off, and ii) they use water in evapotranspiration, thereby reducing groundwater recharge. Trees play important roles in water storage, including storing water themselves, playing a critical role in evapotranspiration and providing pathways for water retention in subsurface reservoirs. In some cases, forest cover can lower groundwater recharge because more precipitation is intercepted by vegetation and returned to the atmosphere. In other cases, the removal of forest cover can result in a crusting of the soil surface that reduces or prevents water infiltration and groundwater recharge.

Forests and Climate

Forests may influence precipitation at a large regional scale, but the effect of forest cover on rainfall in most areas is limited. The distribution of forests is a consequence of climate and soil conditions, not the reverse. On the other hand, forests provide important local to global climate regulation services. These services are a result of transpiration and carbon cycling. Reducing the forest cover and forests' capacity to store carbon can therefore potentially add to global warming.

4.4.2 The Value of Watershed Protection and Soil Conservation

The literature review for appropriate valuation studies to help reveal the economic value of forest services found that the quantifiable benefits of forest hydrological services are highly variable. Furthermore, the literature tends to treat the service values as absolute numbers regardless of alternative land uses. This is ecologically and economically invalid. Hydrological functions of the land are strongly related to ground cover and, hence, the hydrological impact of converting a natural forest to, say, a plantation might be quite different from converting it to annual cropping. This in turn will affect the value of maintaining the land as natural forest. In other words, it is necessary to compute the net benefits of forest conservation: the gross benefits under sustainable use less the benefits from the alternative use. The opportunity costs of forest conservation also depend on how accessible the land is to markets and the suitability of the soil for crops, whereas the hydrological value often depends on the slope, rainfall, type of soil, position in the watershed and proximity to dams, fisheries and irrigation systems. Moreover, several hydrological processes are scale-dependent. The dynamics of erosion and run-off, for instance, are quite different in 100, 10,000 and 1,000,000 hectare watersheds.

To give an indication of forest ecosystem values in the region, the valuation of indirect values is based on three recent case studies from the region.

Guo et al. (2001): ***Ecosystem functions, services, and their values—a case study in Xingshan County.***

The annual economic value of some ecosystem services was estimated for forest ecosystems in Xingshan county of Hubei province of China, using both simulation models and a geographic information system to analyse the effect of ecological factors (vegetation, soil and slope) on ecosystem functions.

Xingshan is rich in forest resources (107,000 ha of forest), covering around 51 percent of the total land area of the county. The ecosystem services assessed relate to water conservation, soil conservation and gas regulation. Water conservation includes hydrological flow regulation and water retention and storage. Soil conservation relates to the reduction of land disuse, prevention of silt accretion, decrease of soil deposit and protection of soil fertility. Gas regulation includes both carbon fixation and oxygen supply. These services were estimated to provide an indirect economic value of 528.73 million RMB (8.3 RMB = 1 USD) per year. Thus, the total economic value of forest ecosystem services in Xingshan County is estimated to be USD63.70 million per year.

Table 4.5: Annual Indirect Values Provided by Natural Forests in Xingshan County, China

Type	Ecosystem service	Value (Million RMB)	Value (Million USD)	Value (USD per hectare)
Water conservation	Hydrological flow regulation	59.78	7.20	67
	Water retention and storage	3.59	0.43	4
Soil conservation	Reduction of land disuse	2.94	0.35	3
	Prevention of silt accretion	78.02	9.40	88
	Decrease of soil deposit	50.38	6.07	57
	Protection of soil fertility	241.30	29.07	272
Gas regulation	Carbon fixation	46.45	5.60	52
	Oxygen supply	46.27	5.57	52
Total		528.73	63.70	595

Total forest area 107,000 hectares. Source: Gou et al. (2001)

The (2001): ***Economics of Soil Erosion and the Choice of Land Use Systems by Upland Farmers in Central Vietnam.***

This study measured the on-site cost of soil erosion and analysed the choice of land use alternatives by upland farmers in central Vietnam. An assessment was undertaken of the erosion potential and financial profitability of typical land use systems in the area, namely the upland rice-based system, sugar cane system, fruit tree-based agroforestry and eucalyptus-based system. The descriptive analysis of data from interviews of 260 farmers in Xuanloc, a typical upland commune in Thua Thien Hue province, indicates that soil erosion is a significant problem in the region. Soil erosion has adversely affected the livelihood of upland farmers and presents a real hindrance to long-term economic development efforts.

Results from the model simulations[5] indicated that among the four typical land use systems, fruit tree agroforestry is the least erosive and the upland rice-based system the most erosive. Although less erosive than the upland rice system, sugar cane, the most recently introduced land use option, has an annual soil loss much higher than the soil loss tolerance value. A CBA with a time frame of 30 years showed that among the four typical land uses, agroforestry was the most financially profitable and upland rice and eucalyptus the least profitable. Table 4.6 shows the net on-site costs of soil erosion under the three land use systems compared to agroforestry.

Table 4.6: Annual On-Site Costs of Soil Erosion under Different Land Use Options Compared to Agroforestry

Alternative land use	Value VND (Per hectare)	Value USD (Per hectare)
Upland rice	1,022,000	68
Eucalyptus	1,019,000	68
Sugar cane	635,000	42

Exchange rate: 15,000VND=USD1. Source: The (2001)

5 *Based on a SCUAF (Soil Change Under Agro-Forestry) computer model, which is designed to predict specified land uses effect on soil conditions and productivity.*

Emerton et al. (2002): ***Nam Et-Phou Loei National Biodiversity Conservation Area, Lao PDR: A Case Study of Economic and Development Linkages.***

This study concentrates on the economic benefits from two national biodiversity conservation areas (NBCAs): Nam Et and Phou Loei. The study investigates the contribution of these two protected areas to economic activities in surrounding provinces, districts and villages. One of the indirect benefits is hydropower.

Hydropower facilities utilise water resources coming from inside the NBCA. These facilities supply villages in and around the NBCA and downstream urban settlements. There is a 60 kW scheme on the Nam Et near Xon Neua that supplies nine villages and a 250 kW dam on the Nam Sat that supplies Viengthong district centre and 10 villages. There is also a medium-scale hydropower scheme on the Nam Peun, with an installed capacity of 36 kW. At least 1000 households in Houaphan province are known to rely on more than 850 micro-hydropower units that use water originating in Nam Et and Phou Loei. In Houaphan alone, the Nam Et and Phou Loei rivers and their tributaries are known to provide at least three medium-scale hydroelectric schemes with a combined installed capacity of more than 360 kW, and at a total investment cost of more than USD2 million. An 80 kW scheme on the Nam Et supplies power to at least nine villages, a 250 kW scheme on the Nam Sat supplies power to the Viengthong district centre and at least 10 villages, and a 36 kW scheme on the Nam Peun supplies power to at least five villages. The main findings are shown in the Table 4.7. The findings are presented for the area as a whole, and translate into 20,625 kip/ha/year or approximately USD2/ha/year.

Table 4.7: Value of Production in Houaphan Province Supported by Nam Et and Phou Loei Watersheds

Economic activity	Direct beneficiary population	Gross value of output (million kip/year)	
Medium hydro Micro-hydro	24 villages, 1 district centre > 1000 households	235 410	Traded value of electricity[6]
Irrigated agriculture	1,000 ha of paddy rice	5130	Gross returns to production
TOTAL	5775		

Source: Emerton et al. (2002)

The numbers presented show that there is wide variation in the values found in different case studies. Water conservation and soil conservation have been used to predict indirect values in the model based on relative changes in standing tree volumes. It was assumed that under sustainable forest management, semi-evergreen and evergreen forests will have a significant forest cover during the entire period and thereby maintain soil and watershed functions. The value of water conservation in Gou *et al.* (2001) of around USD70/ha/year is assumed appropriate. The average value of soil conservation of approximately USD60/ha/year in The (2001) is also assumed appropriate. Deciduous forests, on the other hand, are more degraded and cannot be expected to provide the same benefits until a constant crown cover is established. The annual value in deciduous forests is therefore assumed to be half of the value in the two other forest types.

This leads to a value of watershed protection and soil protection over 50 years as shown in Table 4.8

[6] *Although this hydropower is currently provided without charge, or at minimal cost, electricity originating from other parts of the country is traded domestically and exported. Power is also imported into the Lao PDR from Thailand and Vietnam at a cost of between $0.03 and $0.06 per kwh. This traded value is taken as the cost avoided of providing electricity from imported sources.*

Table 4.8: NPV of Watershed Protection and Soil Conservation (USD/ha) over 50 Years in Selected Forest Types

Forest type	Indirect values	NPV @ 8 percent	NPV @ 10 percent	NPV @ 12 percent
Deciduous	Watershed protection	502	399	329
	Soil erosion control	430	342	282
Semi-evergreen	Watershed protection	867	700	585
	Soil erosion control	743	600	502
Evergreen	Watershed protection	867	700	586
	Soil erosion control	743	600	502

Based on model estimates

4.4.3 The Value of Carbon Sequestration

In order to value carbon sequestration, it is necessary to estimate how much carbon is actually stored in the forest. This has been done based on a biomass expansion factor (*BEF*) developed by Brown (1997). The *BEF* converts the standing volume of all trees in natural forests to above ground biomass (*AGB*) in the equation:

$$AGB = SV * WD * BEF,$$

where *SV* donates total stem volume (m^3/ha) and *WD* donates the average wood density for natural forests in Asia (0.57 tonne/m^3).

The value of *BEF* in the formula depends on the magnitude of SV*WD:

$$SV * WD < 190 \Rightarrow BEF = 1.74$$
$$SV * WD > 190 \Rightarrow BEF = e^{3.213-0.506*\ln(SV*WD)}$$

The *AGB* value was then converted to tonnes of carbon by using a general assumption that the carbon content of tree biomass is 50 percent. Incremental carbon (IC) stored was then calculated as:

$$IC = C_t - C_{t-1},$$

where C_t is tonne of carbon stored per hectare in year t and C_{t-1} the carbon stored per hectare the year before.

The value of carbon sequestration depends on the alternative land use. Annual carbon sequestration may be negative if the alternative is fast growing plantations. In order to incorporate this into the model, mean annual biomass carbon (MABC) was assessed for plantations based on mean annual growth and the following formula:

$$MABC = MAI * WD * F * 0.5$$

where MAI is mean annual increment (m^3/ha/year), WD is wood density (tonne/m^3), F is the expansion factor and 0.5 represents the carbon content.

The value of carbon sequestration in the study depends on the alternative land use. Fast growing plantations, for example, have a significant annual carbon increment and the net difference in carbon storage will mainly be in the establishment phase of plantations. On the other hand, natural forests store much more carbon than crops, where most of the biomass is removed every year. The value of carbon sequestration in selected forest types is:

Table 4.9: NPV of Carbon (USD/ha) over 50 Years from Selected Forest Types Compared to Annual Crops

Forest type	NPV @ 8 percent	NPV @ 10 percent	NPV @ 12 percent
Deciduous	355	336	319
Semi-evergreen	412	401	389
Evergreen	636	610	588

Based on carbon price of $5/tonne in model estimates

4.5 Total Economic Value of Baseline Forests

With the above values included in this study, the TEV of selected forest types over 50 years adds up to the amounts shown in Table 4.10.

Table 4.10: Summary of TEV Results of Baseline Forest Scenarios at Different Discount Rates over 50 Years (USD/ha)

Forest type	Values	NPV @ 8 percent	NPV @ 10 percent	NPV @ 12 percent	Annualised NPV @ 10 percent
Deciduous	NTFP	459	365	301	37
	Sustainable timber	-306	-248	-207	-25
	Carbon sequestration	355	336	319	34
	Soil and water protection	932	741	612	75
	Total	**1441**	**1194**	**1025**	**120**
Semi-evergreen	NTFP	285	230	192	23
	Sustainable timber	403	367	333	37
	Carbon sequestration	412	401	389	40
	Soil and water protection	1611	1300	1087	131
	Total	**2299**	**2445**	**2128**	**247**
Evergreen	NTFP	149	119	100	12
	Sustainable timber	1931	1691	1497	171
	Carbon sequestration	636	610	588	62
	Soil and water protection	2245	1300	1088	131
	Total	**4325**	**3721**	**3273**	**375**

Based on model estimates

These numbers suggest that indirect values from natural forests may be significant. At the same time, they must be interpreted with caution due to data limitations and lack of empirical studies on environmental values in Cambodia. The value of soil and water protection will be highly site specific, depending on the proximity to water resources and the topography of a given area. The indirect values used in this study are therefore most likely higher than average. On the other hand, this valuation includes only a few indirect values, such as carbon sequestration and soil and watershed protection, and this may balance a potential overestimation. As mentioned before, forests also provide values in terms of biodiversity conservation for future generations. These values include recreation (e.g., eco-tourism), habitat for endangered plants and animal species, conservation of valuable genetic information with potential use in the pharmacy industry (bio-prospecting) and conservation of indigenous tree seeds for future timber production, just to mention a few examples. To compare with other countries in the region, a CIFOR study from Indonesia by Matura (2005) uses a TEV value of forests of USD1283/ha/year. The annualised NPV of sustainable management of natural forests at a 10 percent discount rate was USD375/ha/year for evergreen forests, USD247/ha/year for semi-evergreen forests and USD120/ha/year for deciduous forests.

In relation to forest values, it is more important to note that the distribution of indirect and direct values indicates that currently there are few local economic incentives to encourage sustainable forest management unless local people are paid to conserve forests or empowered to participate in the management and sale of timber.

4.6 Summary of Results

This chapter expands the concept of forest valuation in Cambodia to include more than timber by using a TEV approach to value baseline forests on a per hectare basis. The analysis showed that natural forests provide various local, national and global benefits. Some of these benefits are directly measurable in terms of potential timber production and consumption and sale of NTFPs, whereas the valuation of indirect benefits, such as carbon sequestration and watershed protection, depends on complex biophysical relationships and alternative land uses. This complicates the valuation of some services, and as a result this study was limited to a few well-described values based on experiences in other countries. The analysis found that by including these values, the NPV of selected forest types at a 10 percent discount rate over 50 years was USD1194/ha (USD120/ha/year) for deciduous, USD2445/ha (USD247/ha/year) for semi-evergreen, and USD3721/ha (USD375/ha/year) for evergreen forests.

The distribution of direct and indirect forest values reveals that at the moment there are limited economic incentives for sustainable local management. Only NTFP collection is providing local benefits, and these benefits, because of insecure user rights and other factors, seem too low to provide incentives for local people to engage in sustainable use of forest resources compared to alternative land uses. A main challenge facing decision makers in the forest sector is how to incorporate externalities in the management of forest resources at the local level.

The results also show that NTFP values may exceed potential timber values in some forests, typically deciduous forests. Traditional management systems entirely focused on financial benefits from commercial timber production are likely to exclude the locally most valuable products and services provided by these forests. In more valuable forest types (semi-evergreen and evergreen), on the other hand, there may be a potential win-win situation if local people can be involved in the management and sale of timber.

Chapter 5:

Findings on Natural Forest Conversion Scenarios

This section presents findings of the comparative analysis assessing the economic consequences of forest conversion. A sensitivity analysis is conducted in order to assess the importance of different parameters in the model. Management aspects of alternative land uses are also discussed briefly.

5.1 Data Sources and Main Assumptions of the Analysis

Data on the productivity of alternative land uses were collected in interviews and from available data in Cambodia-specific literature. These data were entered into different templates of the value flow model and analysed on a per hectare basis compared to the per hectare value of baseline forests.

Wood plantations: Data on wood plantations were primarily based on MacMillan (2004). In order to evaluate the degree to which yield expectations in the study are in line with what can be expected from a plantation, additional inventory data were collected from acacia and eucalyptus plantations in Kompong Chhnang and Takeo (see Appendix 6 for a description of production data and inventories).

Perennial crop plantations: Data were collected in formal interviews with informants engaged in large-scale farming of oil palms, cashews and rubber. Data collection was limited to one plantation of each type (see Appendix 6 for a description of production data).

Annual crops: Data used in the model were based on CDRI's own research on soy beans, maize and cassava by Nou (2005), and rice data were extracted from MAFF (2003) and discussed with agricultural experts at CDRI.

The estimation of value flows in the comparative analysis was based on a number of assumptions. The main assumptions were:

Baseline Forests

- NTFP collection is carried out during the entire time frame, because a constant forest cover is maintained. The net effect of NTFP collection compared to alternative land uses begins in 2007 when forests are converted to other land uses. Current collection levels are sustainable.
- The potential value of sustainable timber harvesting is based on a 25-year cycle beginning after five years. This represents a partial cut of approximately 50 percent of trees over 60 cm in 2011 and 2036.
- Carbon sequestration is valued from year to year compared to the alternative land use starting from 2007 where natural forests are converted to alternative land uses. In 2007, the net changes equal the standing volume as the entire area is cleared. The rest of the year, the net value equals the incremental carbon value in natural forest minus the incremental carbon value of alternative land uses.

- Natural forests maintain a constant forest cover, and the value of watershed protection and soil erosion control is maintained over the 50 years. The net effect in the comparative analysis begins in 2007 when forests are converted to other land uses.

Alternative Land Uses

- Alternative land uses are established in 2007 and the products harvested according to the characteristics of a given land use system (see Appendix 6).
- NTFP collection is the same as the baseline in year 2006 and thereafter zero.
- To some extent, profitable timber harvesting is carried out during forest clearings in 2007 in evergreen forests. A net return of USD1000/ha is assumed in evergreen forest based on Agrifood Consulting International (ACI 2005). Timber harvesting in deciduous and semi-evergreen forests is unprofitable because too few commercial trees per hectare are present to cover harvesting and clearing costs of the entire area. In these forest types, net timber profits cover for site clearing costs.
- Carbon sequestration is valued according to the increment of carbon stored from year to year. The incremental carbon sequestration in annual and perennial crops is insignificant compared to natural forests. For fast-growing wood species, the incremental value is estimated based on the mean annual increment.
- Crown cover in the alternative land uses is not maintained because the area will be cleared for every rotation. Soil erosion is periodic during the entire time frame, especially in the establishment phase. Indirect values from watershed protection and soil erosion are therefore limited compared to natural forests.

Before the results of the comparative analysis are presented some extra words of caution are in order. As mentioned before, the comparative analysis was built on a limited data set collected from different areas. These numbers will therefore not be representative for Cambodia as a whole, although they still give an indication of what currently can be reasonably expected. The reliability of the comparative analysis depends on the sources of information and the assumptions made in this study, as well as in others. To the greatest possible extent, information has been triangulated with other studies to increase its reliability. Due to the very limited information available, however, this has not always been possible. Some of the main limitations with the data are as follows:

Production data: Yields, prices and transport costs differ from area to area, and such fluctuations could not be included in the comparative analysis due to data limitations. The NPV calculation for each land use was based on limited data and should therefore be used only as indicative for an average plantation or crop. Local conditions may affect the results in either direction, and more data need to be collected to include such variations in the analysis. Similarly, timber production costs and sales prices have been very difficult to estimate because limited data are published and markets are highly distorted by the current moratorium on logging.

Growth in natural forest: Natural forest growth is based on limited published data from permanent sample plots. It was not possible to obtain primary data from the plots. Published data are based on measurements in 1998 and 2000, and incremental data are therefore still uncertain. The study assumed that published diameter increment data in the selected forest types from the plots are the best representation of forest growth under Cambodian conditions available at present. The growth model is designed so that the reliability of natural forest growth can be improved over the years.

Indirect values: Studies on indirect values are very scarce in Cambodia. Including indirect values in the analysis therefore depends on how appropriate it is to assume that a forest in Cambodia will have similar indirect value as in other studies in the region. It was beyond the scope of this study to value these indirect values and, due to lack of empirical studies in Cambodia, the study had to assume that values from other countries are valid as an indication for Cambodia. The analysis also assumed that it is possible to maintain a constant forest cover under the sustainable harvesting scenario and thereby maintain environmental values. This may not be valid given the current management situation, but it still illustrates what kinds of values are lost when natural forests are converted to other land uses.

5.2 Financial Returns from Alternative Uses and Results of Conversion Scenarios

Table 5.1 presents the main results of the analysis using a 10 percent real discount rate. The financial NPV for each alternative land use option is presented together with economic NPV for conversion of each of the three forest types. The results from the value flow model show that there are often significant differences between financial and economic NPVs for a given land use change scenario. Some land uses may be financially, but not economically, viable and by focusing only on financial aspects, land will not always be used in an optimal way. The results of this analysis show that conversion of natural forests often has negative economic consequences, especially in areas of more valuable semi-evergreen and evergreen forests.

Table 5.1: NPV for Alternative Land Uses and Natural Forest Conversion Scenarios (USD/ha) at 10 Percent Discount Rate

Category	Alternative	Financial NPV	Annualised NPV @ 10 percent	Baseline	Economic NPV
Forest plantations	Eucalyptus	100	10	Deciduous	-889
				Semi-evergreen	-1943
				Evergreen	-2541
	Acacia	-323	-33	Deciduous	-1359
				Semi-evergreen	-2414
				Evergreen	-3012
Perennial crop plantations	Oil Palm	303	31	Deciduous	-808
				Semi-evergreen	-1.863
				Evergreen	-2.461
	Cashews	451	45	Deciduous	-660
				Semi-evergreen	-1.715
				Evergreen	-2.313
	Rubber	3756	379	Deciduous	(2724)
				Semi-evergreen	1.670
				Evergreen	1072
Annual crops	Rice	289	29	Deciduous	-848
				Semi-evergreen	-1.903
				Evergreen	-3.327
	Soybean	1330	134	Deciduous	97
				Semi-evergreen	-958
				Evergreen	-2.382
	Cassava	1022	103	Deciduous	-183
				Semi-evergreen	-1.238
				Evergreen	-2.662
	Maize	691	70	Deciduous	-483
				Semi-evergreen	-1.538
				Evergreen	-2.962

Based on model estimates

These results are based on a 10 percent discount rate as well as various assumptions on productivity, prices, transportation costs and indirect values. The values presented, however, do not include variations from area to area. This limits the potential for scaling up the results. That being said, the negative financial returns of some crops suggest that current plantation development involving these crops under similar conditions is not financially viable, indicating that conversions sometimes are based on other motives. As mentioned, there are various uncertainties about the results, and the following section takes a closer look at economic and financial aspects of natural forest conversion to different land use systems by conducting sensitivity analysis as well as briefly analysing different management aspects.

5.3 Conversion of Natural Forests to Wood Plantations

The first scenario analysed concerns the economic consequences of converting natural forests to forest plantations. The current development of plantation forestry in Cambodia involves mainly fast-growing eucalyptus and acacia for pulp wood. These plantation systems are monocultures, and the stands normally are clear cut every five to 15 years depending on local growth conditions. This study used an eight-year rotation. The environmental services provided by this kind of plantation, however, are limited because it is a monoculture and clear cut at short intervals without a stable forest cover. Compared to natural forests, wood plantations have low biodiversity, and significant soil erosion must also be expected, especially during the establishment phase (Cossalter and Pye-Smith 2003). Since the main purpose of these plantations is to produce wood for pulp, plantations provide very few benefits from collection of NTFPs. One of the few indirect values that can be expected from fast-growing wood-pulp plantation is carbon storage. In this study, however, plantations replace an already forested area, and carbon storage in plantations would in principle therefore not qualify for carbon credit. Carbon values included in the model are therefore used only to predict the net effects of changes compared to natural forests.

5.3.1 NPV of Converting Natural Forests to Plantations

The financial NPVs of wood plantations are shown in Table 5.2 and the economic NPVs of establishing these plantations on land occupied by natural forests are presented in Table 5.3. In the economic analysis, the study assumes that clear cutting deciduous and semi-evergreen forest can cover for the site preparation costs. For evergreen forest, the study assumes an initial net benefit from timber in the clearing and site preparation phase.

Table 5.2: Financial NPV (USD/ha) for Plantation Forests over 50 years

Alternative	Financial NPV (USD/ha) at different discount rates			Annualised NPV @ 10 percent
	8%	10%	12%	
Eucalyptus	380	100	-85	10
Acacia	-150	-323	-426	-33

Based on model estimates (plantation established after one year in 2007)

These figures suggest that converting natural forests to fast-growing wood plantations has a negative economic NPV for all forest types. Based on average values, conversion of large areas of natural forests to acacia and eucalyptus plantations through large-scale land concessions does not seem economically viable given the opportunity cost of NTFP collection and sustainable forest management, as well as lost indirect values.

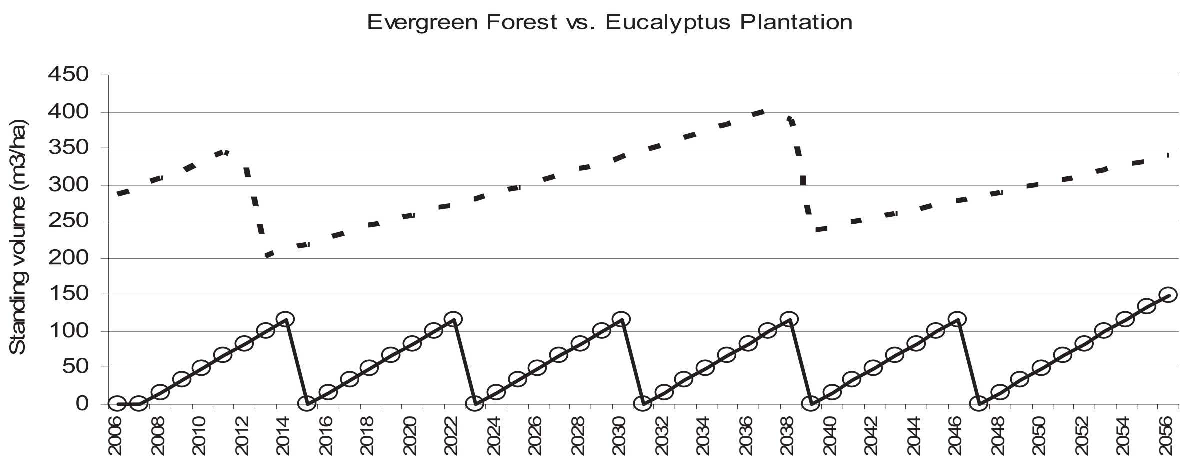
Table 5.3: Economic NPV of Converting Baseline Natural Forests to Plantations (USD/ha) over 50 years

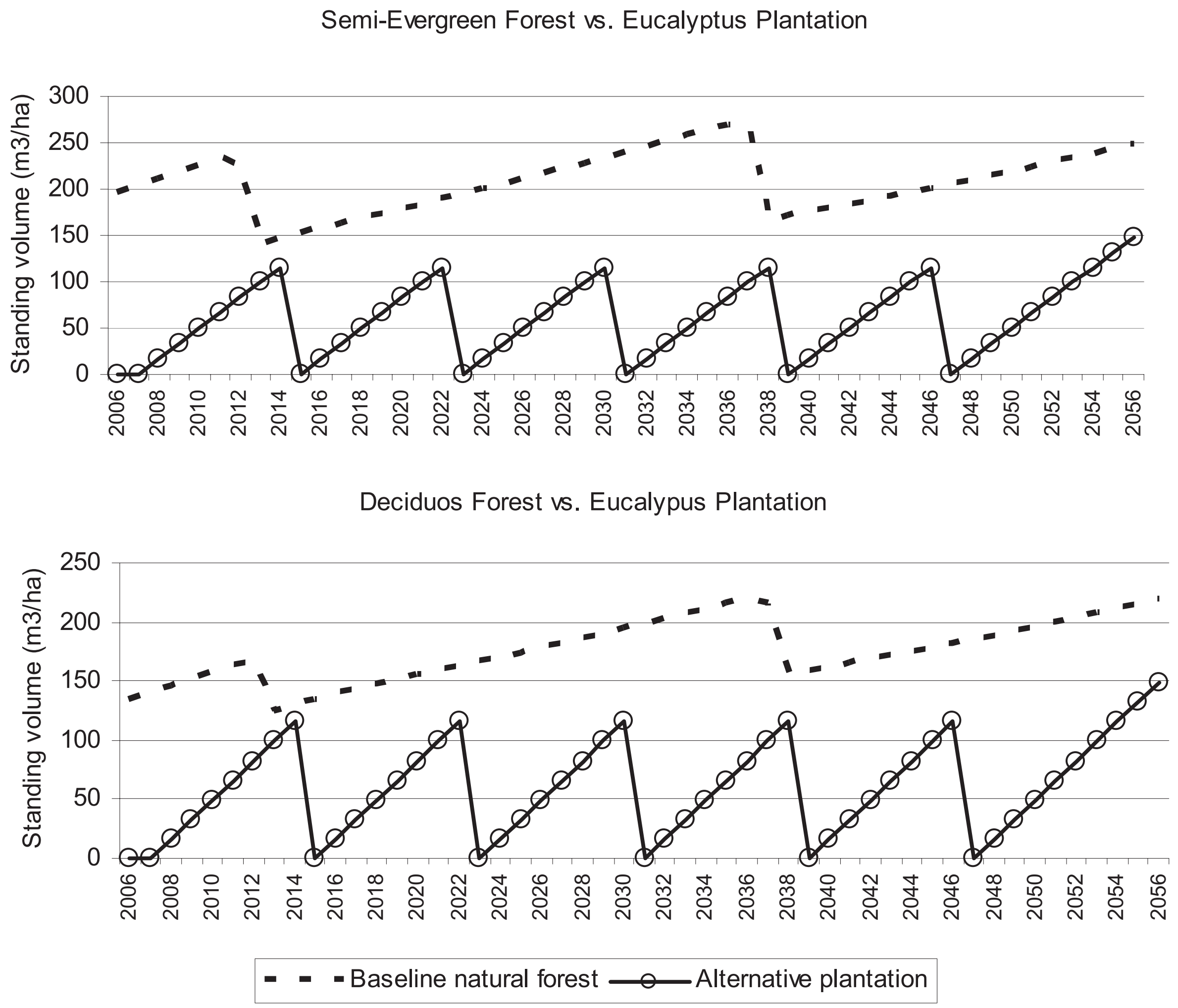
Alternative	Baseline	Economic NPV at different discount rates (USD/ha) 8%	10%	12%
Eucalyptus	Deciduous	-843	-889	-914
	Semi-evergreen	-2063	-1943	-1841
	Evergreen	-2821	-2541	-2318
Acacia	Deciduous	-1427	-1359	-1299
	Semi-evergreen	-2647	-2414	-2227
	Evergreen	-3405	-3012	-2703

Based on model estimates (plantation established after one year in 2007)

To illustrate the differences in forest volumes and carbon storage between natural forests and plantations, the average standing forest volume (m3/ha) over the 50-year time frame is illustrated in Figure 5.1 below. It should be noted that the plantation scenario included only commercial trees, whereas natural forests include both commercial and non-commercial trees. In natural forests, the non-commercial part has a value in terms of the environmental services it provides. The figure illustrates that a significant part of the volume is left standing on the area to support future production and maintain environmental services. At the same time, the steepness of the graphs shows that plantations grow much faster, but since they are clear cut at such short intervals, they do not provide a constant crown cover and can not be assumed to maintain watershed protection and soil erosion services like natural forests.

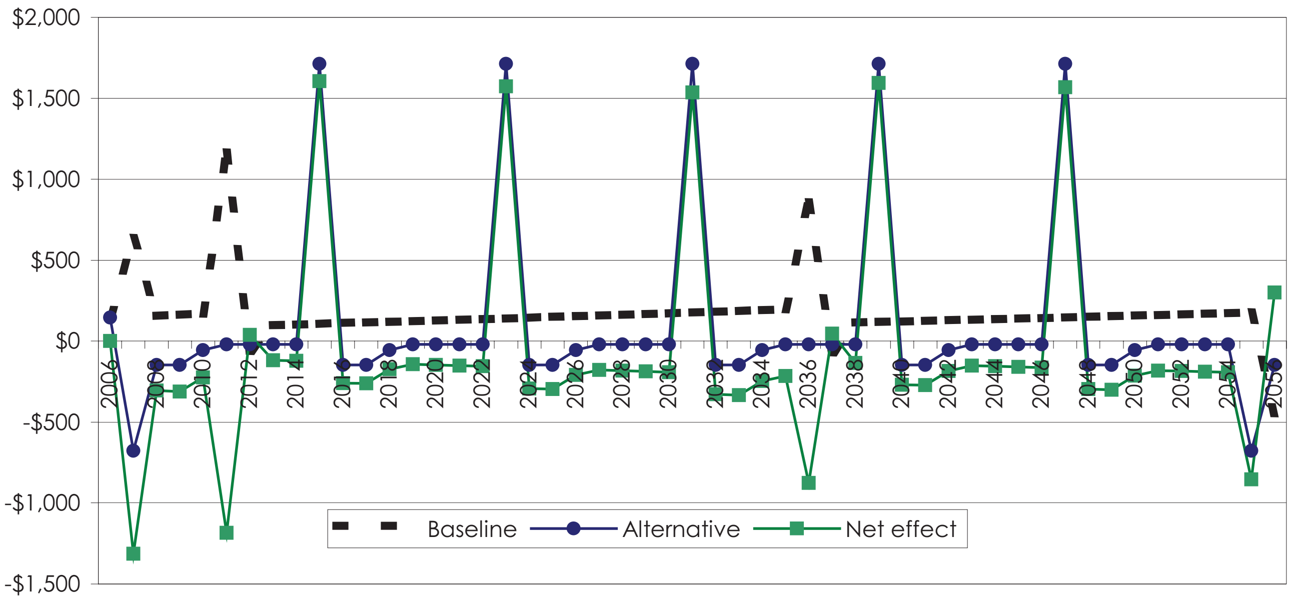
Figure 5.1: Illustrations of standing forest volumes (m3/ha) in selected natural forest types and eucalyptus plantations. It should be noted that plantations only include commercial trees, whereas natural forests include both commercial and non-commercial trees. Based on model estimates.





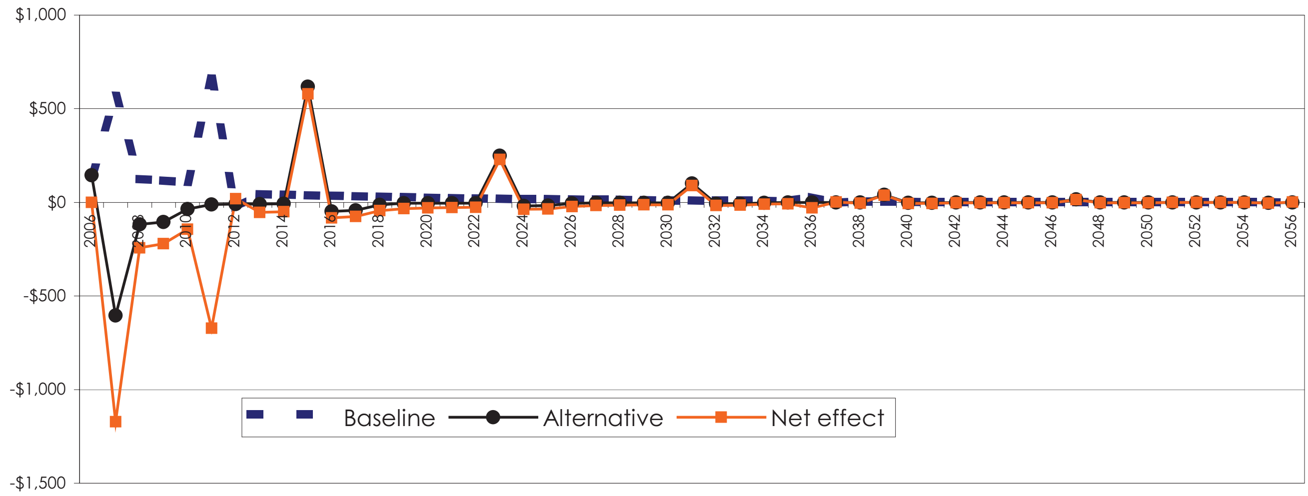
The value flow model can also illustrate how cash flows are allocated over the 50 years, as seen in Figure 5.2 for conversion of semi-evergreen forests to eucalyptus. Figure 5.2 visualises the predicted value flows for baseline and alternative uses, as well as the net effect of converting baseline natural forests to alternative uses.

Figure 5.2: Flow of costs and benefits over 50 years in scenario converting one hectare of semi-evergreen forest to eucalyptus plantation in 2007. Based on model estimates.



The figure shows that the initial establishment costs create a net loss in 2007 when seedlings are planted and nursing needed, whereas benefits are expected every eight years when the plantation is clear cut. On the other hand, the baseline natural forest creates net benefits in non-harvesting years through NTFP collection and environmental services. More significant benefits are projected in 2007 in terms of carbon benefits and in 2011 and 2036 from partial timber cuts. The initial investment costs in the establishment phase must be covered by the net present values of future benefits from wood harvesting. The amounts in Figure 5.2 are not discounted. The present value of future costs and benefits depends on the discount rate used. Figure 5.3 illustrates the effect of discounting using a 10 percent discount rate for the same scenario.

Figure 5.3: Discounted value flow over 50 years (10 percent discount rate) in scenario converting one hectare of semi-evergreen forest to eucalyptus plantation. Based on model estimates.



With a discount rate of 10 percent, the effect of future value flows will be lower, as illustrated in Figure 5.3. This means that, based on growth rates in this study, future benefits from pulp wood harvesting in eucalyptus plantations are not large enough to cover investment costs in the establishment phase and the lost indirect values and opportunity costs of sustainable harvesting when converting natural forests into plantations. Such investments seem unprofitable and should be evaluated very carefully on land occupied by natural forests.

5.3.2 Sensitivity Analysis for Indirect Values and Price Changes

The results of natural forest conversion scenarios are, as mentioned earlier, sensitive to fluctuations in product prices and production costs, as well as indirect values. A sensitivity analysis was conducted in order to evaluate how sensitive the results are to changes in indirect values. The analysis was conducted only for eucalyptus since eucalyptus had higher productivity and NPV than acacia in this study.

The results of the sensitivity analysis at different discount rates are shown in Appendix 8 (Table 1). The sensitivity analysis showed that the economic results are not very sensitive to changes in indirect values. If the indirect values are reduced to zero, the NPV is generally still negative from an economic point of view. A similar sensitivity analysis was conducted to evaluate the results' sensitivity to changes in pulp wood and timber prices. The results of this sensitivity analysis are shown in Appendix 8 (Table 2). The results do not seem to be very sensitive to changes in pulp wood or timber prices either. The main underlying cause for this is the opportunity cost of sustainable harvesting combined with questionable financial profits from pulp wood plantations in this study. The following section takes a closer look at the financial returns of eucalyptus and acacia plantations based on inventory data from plantations and production costs and wood prices in MacMillan (2004).

5.3.3 Productivity of Plantation Forests

Wood productivity is one of the most important factors for the financial viability of plantation forests. Growth of plantation forests is very much linked to biophysical conditions, the quality of seedlings and management practices (Barr and Cossalter 2004; Cossalter and Pye-Smith 2003). These factors are not well examined in Cambodia. This section therefore elaborates on what growth rates can be expected from plantations of fast-growing species. Information used in the value flow model from MacMillan (2004) suggests a Mean Annual Increment (MAI) of 16.5 tonne/ha/year, which equals approximately 26 m3/ha/year. This study's measurements on relatively poor soils found an average MAI of around 13.5 m^3/ha/year (8 tonne/ha/year) for eucalyptus and around 11.5 m^3/ha/year (7 tonne/ha/year) for acacia (Table 5.4).

Table 5.4: Results of Inventories in Acacia and Eucalyptus Plantations

Main species	Stand age (years)	Tree density (tree/ha)	Volume (m^3/ha)	MAI (m^3/ha per year)
Acacia mangium	5	621	52	10.5
Acacia auriculiformis	10	1,133	151	15.1
Acacia auriculiformis	12	1,050	108	9.0
Average for acacia plantations:				**11.5**
Eucalyptus camadulensis	6	650	62	10.3
Eucalyptus camadulensis	9	883	176	19.5
Eucalyptus camadulensis	12	817	126	10.5
Average for eucalyptus plantations:				**13.5**

Based on inventories in Kompong Chnnang and Takeo (n=21)

Assuming that production costs and prices are the same, the expected financial returns at different discount rates are listed in Table 5.5. In the model, it is assumed that 70 percent of the harvested volume (92 tonnes) is sold as pulp wood logs at a forest gate price of USD25 per tonne and the other 30 percent (40 tonnes) is sold as fuel wood at USD10 per tonne.

Table 5.5: Financial NPV at Different Discount Rates over 50 Years

Productivity of Acacia/Eucalyptus	Discount rate	Financial NPV
Pulp logs: 9.5 m^3/ha/year Fuel wood: 4 m^3/ha/year Rotation: 11 years	8 percent 10 percent 12 percent	-162 -331 -432
Pulp logs: 10.5 m^3/ha/year Fuel wood: 4.5 m^3/ha/year Rotation: 8 years	8 percent 10 percent 12 percent	-125 -271 -365
Pulp logs: 18 m^3/ha/year Fuel wood: 8 m^3/ha/year Rotation: 8 years	8 percent 10 percent 12 percent	380 100 -85
Pulp logs: 23 m^3/ha/year Fuel wood: 10 m^3/ha/year Rotation: 8 years	8 percent 10 percent 12 percent	936 509 225

Based on model estimates (plantation established after one year in 20[illegible])

This analysis indicated that from a financial point of view, plantation forests seem a risky investment strategy at a production level of less than 26 m^3/ha/year and discount rates over 10 percent. The plantations inventoried in this study were on relatively poor soils and growth could be better in more fertile areas if plantations were supported by good quality seedlings. On the other hand, another recent study by Lic and Shima (2005) in Mearnork Pulp Plantation, Kompong Chnnang

Province, found that the MAI in that area varied from 1.5 to 6.7 m^3/ha/year. These numbers indicate that high growth is by no means a certainty, and that numbers used in this study may not be at the lowest end of what currently can be expected from pulp wood plantations on poor soils. It also shows the importance of linking plantation development to research and technical capacity in managing plantation forests.

A review of experiences from eucalyptus and acacia plantations in Indonesia by Hartono (2002) documented that the average MAI in private and state-owned plantations ranged between 11.5 and 17.5 m^3/ha/year. The estimates in this study therefore seem reasonable and the findings illustrate that even without considering the indirect values of natural forests and opportunity costs, plantations of fast-growing species should be evaluated carefully if the government wants to use its land in a financially responsible way. In order to evaluate what can be expected from these kinds of plantations, more research should be conducted on plantation benefits under different biophysical and market conditions in Cambodia.

5.3.4 Management Aspects

Another important characteristic of plantations with fast-growing exotic pulp wood species in Cambodia is that they are mainly planned to be implemented in large-scale economic land concessions, where local people's benefits from wood production are argued to be very limited (Lang 2002; UNHCR 2004; NGO Forum 2005). Such large-scale plantations may produce financial benefits in some cases to private businesses, but there is a trade-off in terms of lost future benefits, especially local ones. If plantations replace natural forests that provide a range of products and services to local people, they will affect local livelihoods negatively. If the goal of forest management is to provide equitable access to forest resources as well as to reduce poverty and maintain the value of forest resources for future generations, there seems to be limited justification for converting high-value natural forest resources into pulp wood plantations. Such initiatives should in general be concentrated on suitable non-forested land, and based on consultation with local people and solid investment calculations, linked to technical knowledge and support.

It is important, however, to note that more locally based forest plantation systems do exist. Plantations may, for example, be integrated into community forestry systems or on small private plots. The questionable financial returns, however, indicate that such projects should be linked to technical assistance to avoid worsening the local livelihood situation. If plantations are promoted based on questionable assumptions about growth and without a supply of quality seedlings and sufficient extension services, there is a high risk that the projects will fail. Even with the technical part in place, small-scale projects must carefully analyse how plantations fit into diversified livelihood activities and link development initiatives to local capacity building in forest management.

Recent experiences from Laos documented by Lang and Shoemaker (2006) show that lending money to poor farmers to plant fast-growing exotic wood species on their plots can be a very risky development strategy if expected yields are not achieved. It is therefore extremely important that such projects be evaluated realistically and linked to sufficient technical assistance and seedlings suited for local conditions. The limited experience with plantations of fast-growing wood species in Cambodia indicates that there is still a lot to be learned about expected growth, and that plantation projects should in general be piloted on a small scale before allocating large areas to pulp wood plantations.

Finally, it is important to note that plantation forestry means more than eucalyptus and acacia plantations for pulp wood. Plantations with high value timber species will have longer rotations and provide a stable crown cover. Given the current negative trend in natural forests and increasing demands for timber, these kinds of plantations may play a role in future timber supply and at the same time provide important environmental services if established in areas with important watershed functions. Seed supplies are already established in natural forests all over the country, and options for plantations with indigenous species could be further explored in order to find alternative sources of future timber and fuel wood and to mitigate the environmental impacts of natural forest conversion.

5.4 Conversion to Perennial Crop Plantations

The perennial crops analysed in this study as alternatives to natural forest were oil palm, cashews and rubber. These perennial crops vary a great deal in terms of expected direct and indirect values. In general, the environmental benefits from these plantations are limited because production normally requires significant amounts of pesticides and fertilisers. Also, no stable crown cover is maintained to support watershed protection and counter soil erosion, especially in the establishment phase. Environmental services are therefore assumed to be negligible compared to natural forests in this study. Perennial crops in Cambodia are currently being developed mainly in large land concessions managed as monocultures for the sole purpose of producing agricultural products. There is no significant collection of NTFPs from these large plantations, and the economic value of perennial crops is close to the financial value.

5.4.1 NPV of Conversion of Baseline Forests to Perennial Crops

The main results of financial and economic analysis of perennial crops are presented in Table 5.6 and Table 5.7. The analysis shows that the financial return from perennial crop plantations varies. In this study, rubber plantations have the highest financial NPV with an internal rate of return (IRR) of 20 percent. Oil palm and cashews are less financially viable, with IRR of 11 and 13 percent, respectively. The annualised NPV using a 10 percent discount rate was 31 USD/ha for oil palm, 45 USD/ha for cashews and 379 USD/ha for rubber.

Table 5.6: Financial NPV for Perennial Crops (USD/ha) over 50 Years

Alternative	Financial NPV (USD/ha) at different discount rates			Annualised NPV @ 10 percent
	8%	10%	12%	
Oil palm	1213	303	-260	31
Cashews	928	451	155	45
Rubber	6035	3756	2317	379

Based on model estimates (plantations established in 2007)

When analysing economic viability, however, there seem to be negative economic consequences of converting natural forests into perennial crop plantations, except for rubber.

Table 5.7: Economic NPV of Converting Natural Forests to Perennial Crops (USD/ha) over 50 Years

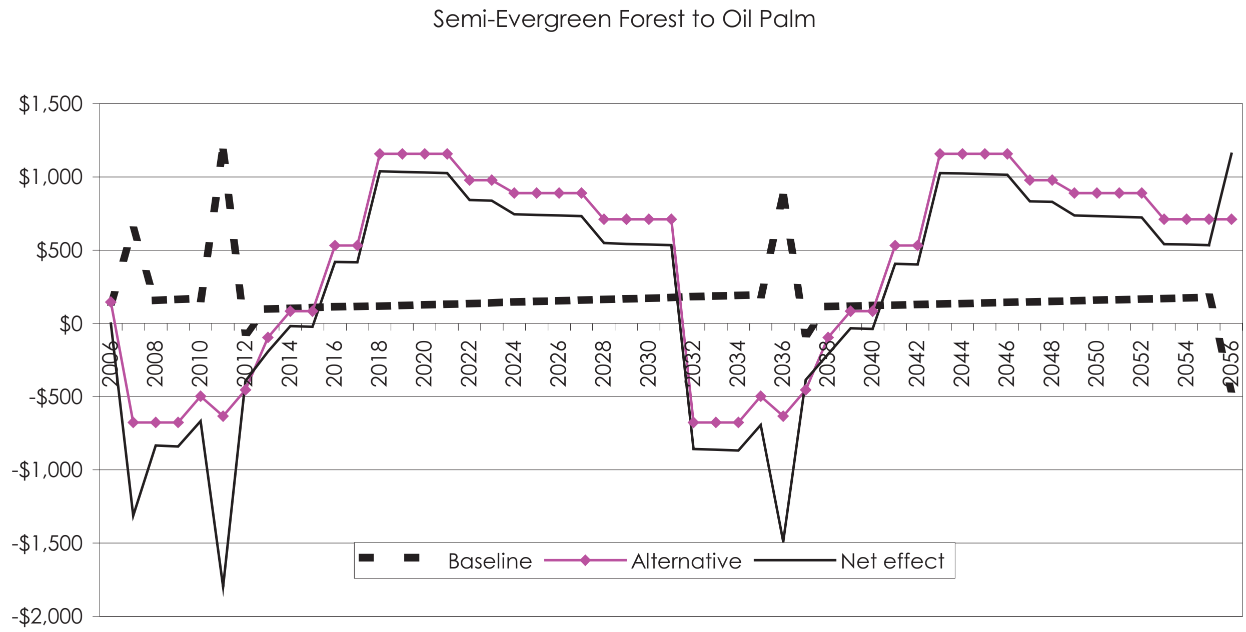
Alternative	Baseline	NPV at different discount rates (USD/ha)		
		8%	10%	12%
Oil Palm	Deciduous	-143	-808	-1203
	Semi-evergreen	-1363	-1863	-2131
	Evergreen	-2121	-2461	-2608
Cashews	Deciduous	-447	-660	-789
	Semi-evergreen	-1668	-1715	-1716
	Evergreen	-2426	-2313	-2193
Rubber	Deciduous	(4760)	(2724)	(1451)
	Semi-evergreen	3540	1670	524
	Evergreen	2782	1072	47

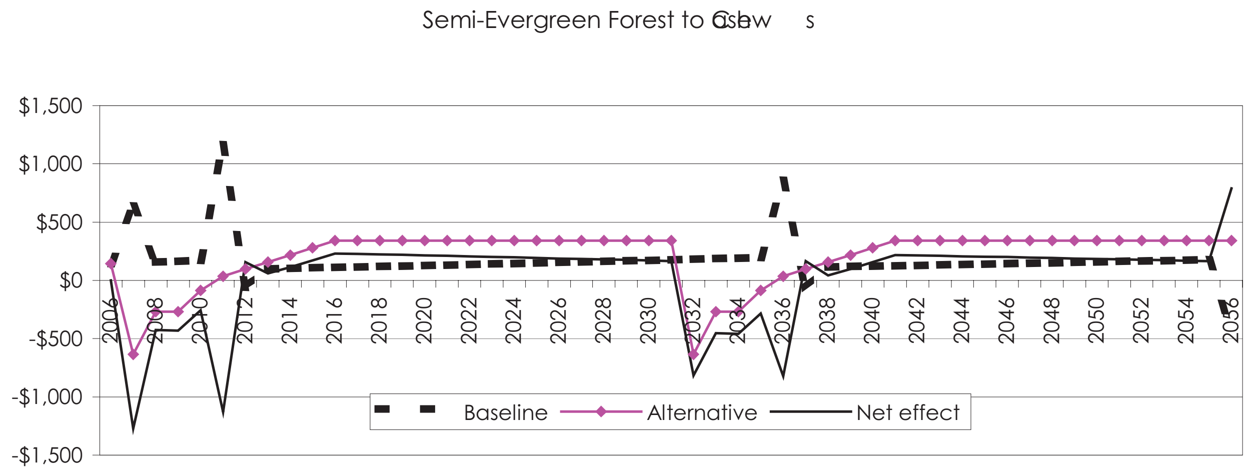
Based on model estimates (plantations established in 2007)

This study suggests that rubber is the most financially profitable perennial crop, and that conversion of natural forests to rubber may be both financially and economically viable. The positive NPVs for conversion of deciduous forests to rubber, however, should be interpreted with caution because the model does not consider if it is technically viable to grow rubber in areas with deciduous forest. It is therefore recommended that future research look more deeply into these issues to expand the application of the model to analyse the potential yields of rubber under different soil conditions.

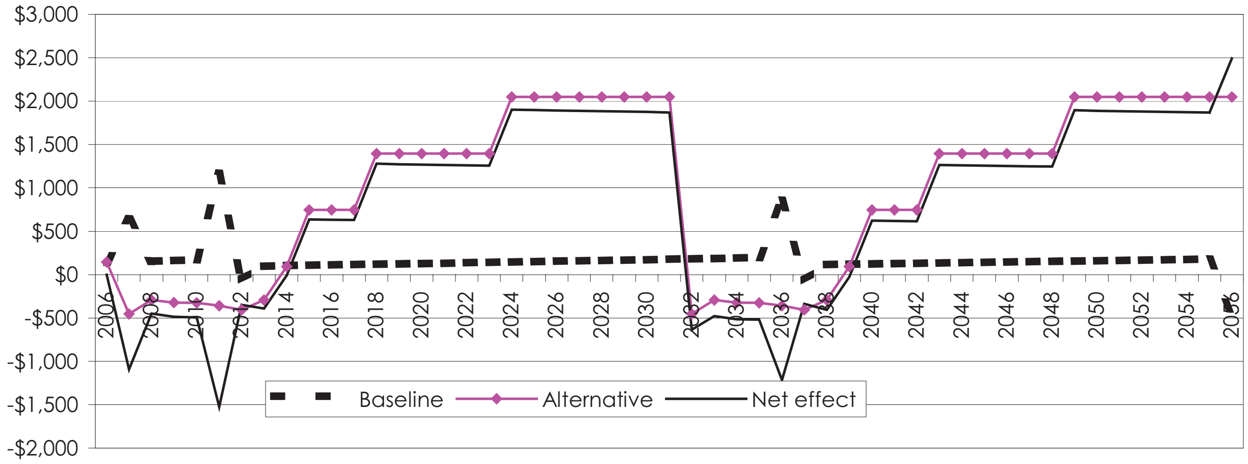
Figure 5.4 shows the value flows for scenarios converting semi-evergreen forests to oil palm, cashews and rubber.

Figure 5.4: Value flows over 50 years for scenarios converting natural forest to perennial crops.





Semi-Evergreen to Rubber



The analysis for perennial crops suggests that in some cases their financial returns may be high enough to generate a positive economic NPV and compensate for the environmental losses and opportunity costs included in the value flow model. This seems to be the case of rubber compared to all three forest types. In this sense, the model can serve as a transparent framework to ensure that decisions are based on assessments that consider environmental trade-offs.

5.4.2 Sensitivity of Results to Changes in Prices and Indirect Values

The sensitivity of the results of the scenarios converting natural forests to perennial crops was analysed according to changes in indirect values and prices of crops and timber (Appendix 8, Tables 1, 2 and 3). This analysis showed that the results were not especially sensitive to changes in indirect values. When indirect values were set to zero, cashews and oil palm generated a positive NPV only in deciduous forest types at discount rates of 10 percent and less. On the other hand, the sensitivity analysis showed that if rubber prices decrease by 20 percent, it was not economically viable to convert semi-evergreen and evergreen forests to rubber at a 10 percent discount rate.

Table 5.8: Sensitivity for Changes in Rubber Prices of Evergreen to Rubber Scenario

Change in rubber price	**Economic NPV at different discount rates (USD/ha)**		
	8%	**10%**	**12%**
+20 percent	5254	2807	1303
No change	2782	1072	47
- 20 percent	266	-69	-1231

Based on model estimates (plantations established in 2007)

At a 10 percent discount rate, the financial NPV of rubber changes from USD3756/ha to USD2003/ha if rubber prices decline by 20 percent. A similar increase in prices by 20 percent increases the financial NPV to USD5510/ha.

Table 5.9: Sensitivy of Financial NPV for Changes in Rubber Prices

Change in rubber price	Financial NPV at different discount rates (USD/ha)		
	8%	10%	12%
+50 percent	12269	8133	5485
+20 percent	8533	5510	3586
No change	6035	3756	2317
- 20 percent	3537	2003	1048
- 50 percent	-19	-629	-850

Based on model estimates (plantations established in 2007)

These examples illustrate how assumptions can affect the results. It is important that future in-depth research analyses likely trends for rubber prices and includes this in a risk analysis for rubber development under different conditions in Cambodia.

5.4.3 Management Aspects

The higher returns from rubber indicate that from an economic point of view, land occupied by natural forests in some cases may be better used for rubber production. But even when this is the case, it should be recognised that large-scale conversion of natural forests to rubber plantations will affect negatively on local people's access to natural resources. This will have negative effects on local livelihoods unless they are compensated sufficiently or involved in sharing the benefits. The results of the household survey in chapter 3 showed that the livelihood values derived from natural forests are quite significant, and if local people's use rights are not considered in conversion projects, it is highly questionable whether agricultural development will contribute to poverty reduction. The challenge would be to identify areas that are useful for rubber production as well as to develop transparent and accountable implementation systems to make sure that vulnerable local livelihoods are not harmed.

Current experiences with large economic land concessions have been closely associated with conflicts over property rights with local communities, thus raising much scepticism on the potential contribution of rubber plantations to poverty reduction strategies (UNHCR 2004; NGO Forum 2005). But similarly to wood plantations, there may be a better potential for pro-poor rubber production involving small farmers or cooperatives to overcome some of these problems. A future challenge for pro-poor development strategies through rubber plantations will be to find ways to increase the involvement of local people by integrating rubber into other livelihood activities, for example inter-cropping. The government could focus more on piloting new rubber management models in which rubber plantations are especially targeted towards poor households in, for example, social land concessions. Also, it will be important that risks of changes in market prices and yields are analysed and taken into consideration to make sure that agricultural development is based on realistic expectations of future benefits.

5.5 Conversion to Annual Crops

Comparing natural forests with annual crops in the value flow model as it is now is a bit arbitrary, because the value flow model cannot incorporate annual yield fluctuations. Value flows for annual crops in the model are therefore the same annually over the 50 years. Less emphasis has therefore been put on this part of the analysis of natural forest conversion scenarios. The following section provides a brief description of the main financial and economic findings and their local implications. Compared to plantation forests or perennial crops, there are fewer environmental benefits from annual crops because they are cleared every year. Compared to natural forests, annual crops are associated with significant soil erosion, little carbon storage capacity and limited biodiversity. On the other hand, these crops may provide significant direct financial benefits to local people involved in small-scale production.

5.5.1 NPV of Converting Baseline Forest to Annual Crops

The results of the analysis for annual crops are shown in Tables 5.8 and 5.9.

Table 5.10: Financial NPV for Annual Crops (USD/ha) over 50 Years

Alternative	NPV at different discount rates (USD/ha)			Annualised NPV
	8%	10%	12%	
Rice	357	289	242	29
Soy beans	1642	1330	1113	134
Cassava	1262	1022	855	103
Maize	853	691	578	70

Based on model estimates

An important feature of annual crop production compared to forests is that from a private farmer's point of view, there is more to gain per hectare from crop production than from NTFP collection from common property areas. As long as local people have no incentives or capacity to engage in sustainable forest management, they will therefore most likely continue encroaching on forest areas.

Table 5.11: Economic NPV for Annual Crops (USD/ha) over 50 Years

Alternative	Baseline	NPV at different discount rates (USD/ha)		
		8%	10%	12%
Rice	Deciduous	-1026	-848	-727
	Semi-evergreen	-2246	-1903	-1655
	Evergreen	-3861	-3327	-2929
Soy beans	Deciduous	162	97	50
	Semi-evergreen	-1058	-958	-878
	Evergreen	-2674	-2382	-2151
Cassava	Deciduous	-190	-183	-180
	Semi-evergreen	-1410	-1238	-1108
	Evergreen	-3025	-2662	-2381
Maize	Deciduous	-567	-483	-427
	Semi-evergreen	-1787	-1538	-1355
	Evergreen	-3403	-2962	-2629

Based on model estimates

5.6 Summary of Results

The results of the comparative analysis suggest that rubber currently is the most profitable alternative to natural forests, and that the conversion of natural forest into rubber may be an economically viable land use change. Other alternative land uses examined did not generate a positive economic NPV. The analysis, however, does not examine area variations in productivity and market access, and future research needs to look more deeply into such variations to scale up the results. An important lesson from the analysis is, therefore, that decisions on allocation of large economic land concessions should be evaluated very carefully in forested areas. For many crops, there seems to be a net economic loss if the baseline is natural forest, suggesting that investments in general should be focused on areas outside natural forests until more data on productivity and markets are collected.

The analysis also shows that economic aspects of natural forest conversion can be evaluated in a more rational and consistent manner based on the framework developed for this study. The framework can be used to identify potentially viable conversion scenarios in a transparent and consistent way. The results also demonstrate how trade-offs in terms of lost environmental services and opportunity costs of sustainable harvesting can be incorporated into planning and decision making through a CBA. Still, there is a need for more reliable data on the productivity of different forest types and crops under different conditions to be collected and published, along with more in-depth studies on indirect values, if long-term effects of land use changes are to be better integrated into decision making.

When using CBA, it should also be acknowledged that NPV calculations should not be used on their own to evaluate land use changes, since they do not consider distribution of income. In other words, the scenario with the highest NPV may not benefit the most people or a specific target group. There will be changes in terms of who benefits and how much, and NPV calculations should therefore ideally always be supplemented with an income distribution analysis of how land use changes affect different people. Unfortunately, distributional effects have not been analysed in depth in this study, but household surveys showed that local use of forests is especially important for poor households and that forest conversion will affect these households negatively.

The current trend toward the development of large economic land concessions and their impacts on local people's access to natural resources call for a discussion of how land use changes can be best managed to supplement the important role of natural forests in poor people's livelihoods. Forests are well known for providing various benefits to local people in their every day life, whereas local benefits from the current agricultural development through large land concessions are uncertain. A challenge that land use planners face is how the production from natural resources can be enhanced without compromising the livelihoods of a growing rural population depending on natural forests to support them in times of hardship. A key element in this would be better integration of forest management systems supporting vulnerable groups into the overall planning process in order to maintain these functions.

The current need for agricultural development and poverty reduction, as stated in the National Strategic Development Plan, points to the importance of balancing forest conservation with agricultural development for improving rural income. A fundamental question is how forests can best contribute to this process. Management objectives may differ significantly depending on the environmental and socio-economic importance of forests in a given area. In some areas, they may provide fundamental watershed protection or significant biodiversity and/or recreational values that should be protected. In other areas, it may be more important that forests are managed to provide livelihood functions and support poor households, whereas in sparsely populated areas natural forests could be set aside for timber production to reduce the pressure on protected areas. At the moment, there is no clear national policy on how forests should be managed and for whom. This needs to be clarified in order better to integrate forest management into the overall planning of land use changes.

Chapter 6:

Implications of Results for the Forestry Sector

The results presented in the previous chapter suggest that it often may not be economically viable to convert natural forests to other land uses. This conclusion, however, is partly based on the assumption that sustainable forest management can be implemented in the near future. This section provides a brief analysis of the potential of different forest management systems to meet objectives of sustainable forest management in post-concession areas.

6.1 Sustainable Forest Management Options

Concession Forestry

As mentioned in the introduction, concession forestry has been the most dominant forest management approach applied in Cambodia. It was based on 25-year investment agreements between the government and private companies, mainly internationally owned. In the agreements, private concessionaires committed to the development of processing industries, royalty payments and sustainable management systems in return for harvesting rights in concession areas. The system was a public-private partnership in which the government, represented by the FA, was responsible for developing management guidelines and enforcement through approval and monitoring of strategic forest management plans (SFMPs) prepared by concessionaires. The idea was that the government would gain significant economic benefits from royalty payments with minimum efforts.

The implementation of concession forestry has been very problematic, and was highly criticised for high levels of uncontrolled logging, serious negative affects on forest resources, conflicts with local communities and limited contribution to rural poverty alleviation (McKenney *et al.* 2004). A series of critical reviews (e.g. ADB 2000), social protests and donor pressure resulted in a termination of all concessions and a moratorium on timber harvesting in December 2001 until companies had revised their SFMPs and these had been approved by the FA. The process of revising and evaluating SFMPs has continued until now, and different independent reviews have concluded that concessionaires have tended to focus entirely on short-term financial viability rather than on long-term sustainability, including environmental and social aspects of management (IFSR 2004; GFA 2005).

In 2004, an independent forest sector review (IFSR) by a team of international experts recommended that the concession system be abandoned because it was unlikely that companies would use long-term sustainable forest management approaches due to the economic losses they have faced during the moratorium (IFSR 2004). On the other hand, much effort has been put into improving the preparation and review of SFMPs, and a 2005 review recommended that two or three forest concessions could continue if problems with forest zoning, overestimation of annual allowable cuts, inadequate protection of resin trees and lack of community involvement were solved (GFA 2005). Based on the reviews, however, the World Bank has recommended that all concessions be terminated (World Bank 2005) and it is now up to the FA to decide what should happen with the remaining concessions.

Annual Bidding Coupes

Since the failure of the concession system, the FA has planned a new approach in which harvesting is managed through annual bidding coupes. This new approach is part of the recent reorganisation of central forest management, in which the 2002 Forestry Law gives the FA clear responsibility and control over forest resources (RGC 2002). This new approach is a more internally managed system in which annual harvesting rights are allocated through bidding coupes based on forest management plans prepared by the division chief of the FA. There are, however, some fundamental problems with this approach. First, the FA has put itself in a position where it acts as both planner and approver, with few or no checks and balances (IFSR 2004). This makes the system very vulnerable to rent-seeking behaviour since there is no accountability mechanism. It also seems that the focus is still on commercial timber harvesting with minimum involvement of local communities. It is therefore questionable whether the system will be able to solve conflicts with local people or problems of dealing with short-term interests of subcontractors. Donors have expressed concern about this new approach (World Bank 2005), and the latest review of SFMPs provides a strong warning that experience from other countries indicates that the annual bidding coupe system is not compatible with sustainable forest management (GFA 2005).

Community Forestry

CF has slowly evolved in Cambodia over the last decade. It involves local people in the conservation of forest resources by empowering communities to manage and utilise forest resources based on sustainable forest management plans. The assumption behind this approach is that if local people have secure harvesting and user rights over the forests, they will also have an incentive to implement sustainable harvesting. A fundamental issue in CF is therefore that forest user groups or communities should be able to exclude others from their area in order to maintain sustainable harvesting levels. For the government, it can be seen as a low-cost approach to forest protection in a situation where the state lacks the resources to protect forests. At the same time, it also provides good opportunities for rural development since local priorities are included in management plans and local people are directly involved in sharing economic benefits.

CF in Cambodia has evolved as a local response to declining forest access faced by communities located in areas under large forest concessions. The process has often been driven by donors and NGOs, and management models are therefore diverse, depending on the goals of the NGO involved. CF has been recognised in the 2002 Forestry Law, followed by a 2003 sub-decree and 2006 guidelines (RGC 2002; RGC 2003; RGC 2006). Even though the sub-decree was criticised for focusing too much on government control, it must still be seen as an important first step for legally recognised CF.

One problem experienced is that efforts so far have focused on degraded forest areas and that there is a five-year moratorium on logging in CF areas. In the current setting, communities have expressed limited confidence that they will be able to secure benefits from CF areas in the future, and they see benefits as future access to land rather than as a productive investment (IFSR 2004). If CF is expected to be self-sustaining, it will require a good quality resource base and secure future benefits to cover costs of organisation. Given the current situation of insecure land rights and the degraded forest resources allocated to CF, it is not clear if the incentives of future benefit flows are secure enough to form self-sustaining systems (IFSR 2004). The government should therefore try to pilot community forestry in higher value forests in post-concession areas if it wants to explore if the concept can meet conservation and development objectives of forest management.

Partnership Forestry

Another widely debated forest management approach outlined in the 2004 IFSR proposes that the FA should consider taking decentralised forest management a step further toward actual devolution in which authority is handed over by the central government to elected local governments. In Cambodia this has been conceptualised as partnership forestry intended to take the form of a commune forest plan that must be approved by the state. The system, however, is currently constrained by lack of clear legal provisions for commune councils to act as local forest managers. IFSR (2004) suggested that the FA should consider extending forest management rights to communes under specific conditions as an alternative to concessions and annual bidding coupes.

The idea behind partnership forestry is that if commune councils share benefits from forests, communes will have an incentive to protect forest resources against illegal harvesting and will put more demands on the state to prevent organised illegal harvesting. It should be noted that the partnership approach is not an alternative to CF. Within commune forest plans there would be a range of different implementations, including CF and private sector contracting. This system, however, is also not without problems, and experiences have to be monitored continuously to find solutions. One concern is that decentralisation is a new concept in Cambodia. Also, forest management seems to have low priority with commune councils, which currently also lack the technical capacity for it. Commune councils will be dependent on technical assistance from the FA, and it is unclear how this assistance will be delivered. For further discussion, see for example Nathan et al. (2006).

Plantation Forestry

Experiences with plantation forestry in Cambodia have, as mentioned in previous chapters, been centred on fast-growing exotic species for pulp wood production in large-scale economic land concessions. These experiences have caused much scepticism among observers about the contribution of plantations to rural development (Lang 2002; UNHCR 2004; NGO Forum 2005). An analysis of the list of land concessions, in Appendix 1, showed that the most recent land concessions signed by MAFF appear to involve different tree species. It therefore seems that the government is trying to reach its millennium development goal of maintaining forest cover of 60 percent through large-scale development of forest plantations. This is not a straightforward approach, given that plantations often are established in forested areas on land claimed and used by local communities. Large industrial plantations, however, are only one approach to plantation forestry, and it is important to note that more locally based plantation systems exist. Given the current trend in natural forest degradation, it seems important that alternatives to timber and fuel wood from natural forests are developed. Seed supplies for indigenous tree species are already established in natural forests around the country, waiting to be used. Well-managed long-term plantations of high-value indigenous species could have a role in future timber supply and at the same time provide significant indirect environmental benefits such as watershed protection and erosion control, if incorporated into overall landscape planning. Plantations could also be included in community forestry projects to increase the value of highly degraded forests or to meet local demand for fuel wood. Also, there may be scope for plantations on small farmers' plots to integrate plantation forestry into rural development and poverty reduction.

NTFP Enterprises

The significant value obtained from NTFPs for both consumption and cash income points to the importance of the trade and marketing of NTFPs. Very little is currently known about market linkages for NTFPs, but it seems there are very weak official channels and structures to accommodate this trade. Prom and McKenney (2003) recommended that the trade and marketing structure for forest products be improved through removal of restrictive licence and fee systems in order to encourage pro-poor trade and rural development. Increased commercialisation or marketing of NTFPs also needs to be accompanied by more effective and sustainable management systems. The FA should look into how commercial NTFP utilisation can be incorporated into community forestry or small private NTFP enterprises in order to increase the value of local forest resources.

6.2 Integrating Natural Forest Conversion into Land Use Planning

In the current forest management situation, it should be acknowledged that it is neither viable nor realistic to conserve all natural forests in post-concession areas. The direct and indirect values of these forests will vary significantly according to site-specific factors, such as market access, topography, proximity to water resources, level of degradation and biodiversity importance. It would therefore be important to better target sustainable forest management initiatives and to incorporate natural forest conversion into overall land use planning. Generally, sustainable forest management initiatives should be targeted at the most economically valuable forests and, similarly, forest conversion activities should be focused in suitable areas with less indirect forest values. An important challenge is to make proper assessments to ensure that the land allocated for alternative uses actually is suitable for crop production and that conversion is in the public interest and conducted in a transparent way though sound management practices. This study showed that in some cases it may be economically viable to convert natural forests, and the framework developed in this study may serve in identifying areas on a case by case basis. In this process, the value flow model should be expanded to include site variations. NPV calculations should also be supplemented by analysis of distributional effects and linked to, for example, participatory land zoning to assist in more transparent land use decisions.

Another fundamental factor in sustainable forest management and forest conversion concerns secure tenure and clear demarcation. Clear and secure land rights are fundamental for long-term investments in sustainable forest management by either private investors or local communities. Focus should therefore be on the completion of the collective titling process before new land is given to large economic land concessions. Once local people’s rights are secured through land titling, the permanent forest estate can be demarcated on maps and in the field. Forest functions could then be allocated. After this process has been completed, it can be considered whether some of the forests are better allocated for agricultural development.

Chapter 7:
Conclusions and Needs for Future Research

This paper has examined selected benefits and services provided by natural forests in Cambodia and assessed financial and economic aspects of forest conversion scenarios based on a value flow model. This section presents the main conclusions and recommendations of the study.

7.1 Local Livelihood Value Obtained from Natural Forests

The total livelihood values obtained from forests in the four study areas were: USD265/household in Kompong Thom, USD424/household in Kratie, USD167/household in Mondolkiri, and USD314/household in Pursat. The local livelihood value analysis showed that poor rural households are the most dependent on forest resources. On average they derive 42 percent, or USD280 per household per year, of their total livelihood value from forests. Better off households derive on average around 30 percent of their livelihood value from forests, but gain USD345 per household per year. This shows that forest resources are important to a large part of rural people living adjacent to forests, and that conversion of natural forest could have potentially significant negative impacts on rural livelihoods in terms of lost access to forest benefits and increased vulnerability, especially for poor households in times of hardship. This significant value demonstrated the importance of integrating forest management in rural development and poverty reduction strategies. Decisions promoting agricultural development in forested areas should acknowledge that there is a significant trade-off where poor people depend on forests to maintain their livelihoods.

7.2 Value of Natural Forests

The NPV of main direct and indirect values from sustainable management of selected natural forest types (evergreen, semi-evergreen and deciduous) was analysed over a 50-year time frame. The NPV of sustainable management at a 10 percent discount rate over this time frame was USD1194/ha (USD112/ha/year) for deciduous, USD2445/ha (USD247/ha/year) for semi-evergreen and USD3721/ha (USD375/ha/year) for evergreen forests.

A significant part of this potential value was from indirect values that normally are excluded from financial estimates and private "on the ground" forest management decisions. Local people rely heavily on forests on a day-to-day basis, and the most important value for them in the current management vacuum is collection of NTFPs. The average household value of NTFP collection was high, but when analysed on a per hectare basis, the average value ranged between USD12 and USD32/ha annually. This value seems low compared to average annual financial returns expected from alternative land uses (USD29 to USD134/ha/year), and locally driven forest conversion is likely to continue until new forest management systems that increase the local value of forests are implemented.

An important characteristic of NTFP utilisation, however, is that NTFPs support the poorest and most vulnerable households in rural areas, and equitable access to these resources is important for future forest management initiatives aiming at poverty reduction and rural development. Involving local people in sustainable logging seems like a promising way to provide economic incentives for them to engage in sustainable management of forest resources. Potential benefits from harvesting timber and NTFPs are more significant in semi-evergreen and evergreen forests, and it seems important to expand joint forest management initiatives to these forest types in order to examine whether the current role of forests in rural development and poverty reduction can be increased.

7.3 Natural Forest Conversion

Financial and economic aspects of natural forest conversion were analysed based on a value flow model designed to compare the value of natural forests with the value of alternative land uses currently observed in Cambodia. The analysis demonstrated how indirect values of forest resources can be included in an economic valuation of land use changes as a tool to include environmental trade-offs and make land use change decisions in a more transparent way.

The current experiences with wood plantations in Cambodia suggest that financial returns from fast-growing acacia and eucalyptus plantations are questionable, with an NPV of USD100/ha for eucalyptus and -USD323/ha for acacia (10 percent discount rate and 50 years time frame). Large-scale development of pulp wood plantations should therefore be carefully evaluated in forested as well as non-forested areas until more knowledge on productivity and market opportunities is obtained. More research should be conducted on analysing potential yields and transportation costs under different conditions before large areas are allocated for pulp wood plantation development.

In this study, rubber was the financially most viable perennial crop, with a NPV of USD3756/ha. The study found that from an economic point of view, rubber plantations may be able to compensate for lost environmental services and direct benefits of natural forests. Conversion to oil palm and cashews, on the other hand, did not seem to generate a positive economic NPV when natural forests were the baseline. More research should analyse the viability of rubber production under different market access and soil conditions, and closely link this to a risk analysis for changes in rubber prices. The current development of large-scale rubber plantations seems questionable in terms of net local benefits, and more research should be conducted on locally based models to evaluate whether the contribution of rubber plantations to rural development and poverty reduction can be enhanced through such systems.

The framework and model introduced in this study could function as a transparent tool to analyse the economic viability of natural forest conversion scenarios, but the NPV results should be closely linked to risk analyses and distributional analysis to evaluate whether agricultural development decisions are pro-poor. An important point to clarify is whether the current development of large economic land concessions is the best way to achieve efficient agricultural development without compromising the livelihoods of poor people depending on natural forests. More research should be conducted on the economic viability of small vs. large plantation schemes to evaluate if the contribution of plantations to poverty reduction can be enhanced.

7.4 Future Application of the Value Flow Model and Lessons

Work with the value flow model during the final stages of this project has produced some important lessons useful for other Cambodian institutions. A main problem faced in the application of the value flow model was that it was developed by external modelling experts without proper involvement of local researchers in the design. Without this, limited local ownership of the model was generated. It has been difficult to apply and, more importantly, to modify the model to available data in Cambodia. The model as it is now has significant limitations in terms of reaching its intended user groups within the Cambodian research community and government institutions. Future initiatives on improving the model or involving similar kinds of modelling should focus on building the capacity of Cambodian researchers and planners to develop their own models, which can be improved continuously with updated data. Capacity building linked to collection of more reliable data nationwide should be a main objective for future natural resource planning projects, to ensure that natural resource planning is rooted in Cambodian capacities and based on reliable data that continuously can be updated.

7.5 Implications for the Forestry Sector

The value of natural forests and the results of the economic analysis depend to a high degree on whether an enabling legal and political environment for sustainable forest management is prioritised. Without improved forest governance, the value of natural forests is likely to continue declining, and opportunities for maintaining forests and their values will be reduced.

Clear and secure land titles and user rights are fundamental for long-term investments in sustainable forest management by foreign investors or local communities. Focus should therefore be on the completion of the ongoing collective titling process before new decisions on forest conversion through economic land concessions are made. Once local people's rights are secured through land titling, the permanent forest estate can be clearly demarcated on maps and in the field, and forest functions, including conversion forest, can be allocated. This should be a high priority centrally to avoid future conflicts in forest management and land conversion decisions.

Currently large areas of post-concession production forests are left unmanaged and thus under high risk of further degradation. The future of concession forestry is uncertain, and the prospects of the annual bidding coupe system overcoming previous problems with community involvement and conflicts seem limited. More focus should be on developing alternative joint forest management approaches to production forestry, in which benefits are more equally shared and in which more accountability is shared between loggers and local people.

Community forestry is supported by the 2003 sub-decree and the 2006 guidelines, but with too much emphasis on central government control. So far, community forestry activities have been focused on degraded forests with limited opportunities for local management to become self-financing and self-sustaining. It should be a high government priority to expand commercial CF activities to post-concession areas with higher value forests to enhance local incentives in the form of secure future benefits, if long-lasting sustainable CF systems are to evolve.

It should be acknowledged that plantation forestry is more than large-scale pulp wood production from fast-growing exotic species. Opportunities for reforestation through small private farming of more valuable (indigenous) timber or NTFP species could be further investigated in order to try to increase social and environmental benefits from forest plantations.

Chapter 8:

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Chapter 9:
Appendices

Appendix 1: List of Economic Land Concessions

Table 9.1: Economic Land Concessions with Signed Contracts as of August 2006

No.	Name of Company	Location	Size (ha)	Type of Crop	Date of Contract
1	Household Community Heng Sarat	Kg Cham	500	para rubber	23-01-92
2	Agro Star	Kg Cham	2,400	cashew-apple	01-09-95
3	Mong Rethy Investment Cambodia Oil Palm Cambodia	Sihanoukville	11,000	oil palm	09-01-96
4	Cambodia Eversky	Kg Thom	10,000	tree cotton	03-01-98
5	Talam Plantation Holding Snd. Bhd	Koh Kong	36,700	oil palm, para rubber	05-10-98
6	China Cambodia State Farm International	Koh Kong	7,500	agriculture crops and animal husbandry	06-10-98
7	Green Rich Group Co, Ltd	Koh Kong	60,200	oil palm and acacia	25-11-98
8	Cambodia Haining Group Co., Ltd	Kg Speu	23,000	castor oil and multiple agriculture	23-07-99
9	Henan (Cambodia) Economic & Trade Development Zone	Kg Speu	4,100	agricultural crops and animal husbandry	29-07-99
10	Ratana Visal Development Co., Ltd	Pursat	3,000	cashews, apples	15-10-99
11	Tapioca Starch Production Co., Ltd	Stung Treng	7,400	trincomali wood	13-11-99
12	C.J Cambodia Corporation Co., Ltd	Kg Speu	3,000	tapioca (cassava or manioc	15-11-99
13	Men Sarun Fellowship and RAK Khmer	Ratanakiri	20,000	oil palm	21-12-99
14	Phea Pimex	Pursat & Kg Chh	315,028	trees	08-01-00
15	Mong Rethy Investment Cambodia Tapioca Cambodia	SHV	1,800	tapioca	18-03-00
16	TTY Industrial Crops Development Import-Export	Kg Cham	1,070	rubber	02-05-00
17	Leang Hour Hong Import & Export	BTB	8,000	officianarum (sugar cane) and tapioca	07-06-00
18	China National Corporation for Oversea Economic Coope Laod Star Development Co., Ltd.	Kg Speu	8,000	agricultural and industrial crops	26-09-00
19	Kimsville Corporation	Kg Speu	3,200	tapioca	24-10-00
20	Khem Land Import Export	Kampot	16,400	oil palm	26-10-00
21	C.J Cambodia Corporation Co., Ltd	Kg Speu	5,000	tapioca (cassava or manioc)	20-04-01
22	LKhun Industrial Plants and Other Development	Kg Speu	12,506	cashews, apples	25-05-01
23	Cambo Victor Investing and Developing Co., Ltd	Kg Speu	26,550	agricultural crops	13-08-01
24	Green Sea Industry Co., Ltd	Stung Treng	100,852	trincomali wood	23-10-01

25	Golden Land Development Co.,Ltd	Kg Speu	4,900	agro-industry	05-03-04
26	Vinmna Import-Export Co.,Ltd.	Kg Cham	1,200	officianarum (sugar cane) and tapioca	28-04-04
27	Gialai Company Limited	Ratanakiri	9,380	rubber, cashews, apple, polonia	26-01-05
28	First Bio-Tech Agricultural (Cambodia) Co.,Ltd	Kampot	10,000	maize, beans, tapioca, acacia, eucalyptus	21-04-05
29	World Firstar Entertainment (Cambodia) Co.,Ltd	Kampot	9,800	maize, beans, tapioca, acacia	21-04-05
30	An Mady Group	Kg Thom	9,863	acacia	09-05-05
31	Green World Group (Cambodia) Development Ltd	Stung Treng	5,000	trincomali wood, crassna, fruit trees	18-05-05
32	Sopheak Nika Investment Agro-Industrial Plants	Stung Treng	10,000	acacia, trincomali wood, para rubber	08-08-05
33	Sal Sophea Peanich Co.,Ltd	Stung Treng	9,917	acacia, trincomali wood, para rubber	08-08-05
34	Mong Leng Heng Investment	Kg Cham	3,000	para rubber	08-11-05
35	Wuzhishan LS Group Co.,Ltd	Mondolkiri	10,000	para rubber	30-12-05
36	Grandland Agriculture Development (Cambodia) Co.,Ltd	Stung Treng	9,854	trincomali wood and other types of wood	23-01-06
37	Seav Ching Investment	Stung Treng	10,000	trincomali wood and other types of wood	24-01-06
38	Phou Mady Investment Group	Stung Treng	9,854	trincomali wood and other types of wood	24-01-06
39	Sok Heng Company Limited	Stung Treng	7,172	acacia, trincomali wood and other types of wood	27-01-06
40	Mon Sarun Import Export	Kg Cham	4,400	rubber, tapioca, acacia, and cashew-apple	10-02-06
41	Global Agricultural Development (Cambodia) Co.,Ltd	Kratie	9,800	trincomali wood	15-03-06
42	Asia world Agricultural Development Co.,Ltd.	Kratie	10,000	trincomali wood	15-03-06
43	Green Island Agricultural Development (Cambodia) Co., Ltd	Kratie	9,583	trincomali wood	15-03-06
44	Mean Rithy Co.,Ltd.	Kg Thom	9,784	rubber and acacia	16-03-06
45	HMH Co.,Ltd.	Kg Thom	5,914	acacia and other types of tree	17-03-06
46	Oryung Construction (CAM) Co.,Ltd	Ratanakiri	6,866	rubber	04-04-06
47	Sekong Development	Stung Treng	9,850	agro-industry and livestock	12-04-06
48	Samrang Rubber Industry PTE Ltd.	SR & ODM	9,658	rubber and tree	12-05-06
49	Heng Development	Ratanakiri	8,654	rubber and acacia	25-05-06
50	Real Green Co.,Ltd.	ODM	8,000	tapioca and agro-industrial crop	09-06-06
51	Crystal Agro Company Limited	ODM	8,000	tapioca and agro-industrial crop	17-07-06
Total area with signed contracts:			907,655		

Source: MAFF (2006a)

Appendix 2: Characteristics of Villages Studied and Sample Design

Table 9.2: Characteristics of the 16 Villages in the Survey

Province	Village	HHs	Population	No. of women	Distance to main forest (km)	Distance to nearest market (km)	Distance to post-concession area (km)	Type of forest accessible by village	Collection area (ha)
Mondolkiri	**Ou Am**	471	2,165	1,283	0.5-1	1	Bordering (Samling)	Evergreen	6400
	Ou Rona	117	545	218	2-3	4	On border (Samling)	Evergreen	1000
Kratie	**Mil**	160	779	359	1	23	On border (Samling)	Semi-Evergreen	4700
	Doung	82	413	212	<10	20	On border (Samling)	Semi-Evergreen	2600
	Srae Roneam	232	1,102	554	2-3	26	On border (Samling)	Deciduous	1500
	Samrang	155	667	378	10	25	On border (Samling)	Deciduous	1132
Kom-pong Thom	**Kang Kdar**	423	2,086	1,54	5	20	20 (GAT)	Semi-Evergreen	7544
	Tum Ar	172	766	423	1	2.5	6 (Colexim)	Evergreen	4863
	Ronteah	98	385	189	1	3.5	100m	Evergreen	3630
	Samret	118	579	313	5-6	2.5	N/A	Deciduous	1200
	Chramas	152	783	414	1	6	N/A	Deciduous	1200
Pursat	**Kol Totueng**	253	1,371	921	7	2	N/A	Deciduous	3099
	Srae Popeay	132	608	358	1.5	2.2	N/A	Deciduous	1200
	Ksetr Bourei	388	1,920	1,137	2	14	N/A	Evergreen	9700
	Veal Vong	253	1,113	580	25	10	20-30 (Super-wood)	Semi-Evergreen	4036
	Veal	126	557	265	7	14	N/A	Evergreen	3562

Table 9.3: Sample Size and Intensity in the 16 Villages Surveyed

Province	District	Commune	Village	No. of HHs	Sample Size (no.)	Income group: Poor (no.)	Income group: Medium (no.)	Sample intensity (%)
Mondolkiri	Kev Seima	Srae Ktum	Ou Am	471	20[A]	11	9	4.5
			Ou Rona	114	21	10	11	18.4
Kratie	Snuol	Ksuem	M	146	21	15	6	14.4
			Doung	82	21	8	13	25.6
			Srae Roneam	232	20	12	8	8.6
			Samrang	123	21	8	12	17.1
Kompong Tim	Santuk	Kaya	Dang Kar	482	66	35	31	13.7
	Sandan	Timring	Ronteah	98	29[a]	18	11	30.6
			Tim Ar	160	30	15	15	18.8
	Pasat Sambour	Sambour	Samret	119	30	26	4	25.2
			Chramas	157	32	24	8	20.3
Pursat	Pnom Kavanh	Santreae	Kstr Bourei	388	40	17	23	10.3
			Kl Ttueng	226	36	20	16	15.9
			Srae Bpeay	133	28	16	12	21.0
		Samraong	Val	119	32	17	15	26.9
		Rokat	Val Vng	285	56	32	24	19.6
Total number of households interviewed:					**[illegible]**	**[illegible]**	**[illegible]**	
Average sample intensity in the study:								**18.2**

a. Two households (one in Ou Am and one in Ronteah) were classified as rich and not included in the analysis

Appendix 3: Household Questionnaire with Seasonal Calendar

Household Interview

(សំភាសន៏ជាមួយប្រជាជន)

Name of enumerator: ________________________________ Date:________________

(ឈ្មោះអ្នកសំភាសន៏) ថ្ងៃខែឆ្នាំ

Category of household interviewed (tick one): Poor:____ Medium:_____ Rich ___________

(ការចាត់ថ្នាក់នៃគ្រួសារសំភាសន៏) ក្រ មធ្យម មាន

Village name: ____

Name of respondent(s): ____

Number of people/HH: Adults:____________Chrildren (<12 year): ___________________

(ចំនួនសមាជិកក្នុង១គ្រួសារ)

Ethnicity: ____

Amount of rice consumed per person per year (kg):________________________________

Market price of rice (R/kg): ____

NTFP Ranking (ការរៀបតាមលំដាប់នៃអនុផលព្រៃឈើ) Use 200 beans total	
NTFP (អនុផលព្រៃឈើ)	Ranking (ការរៀបតាមលំដាប់) (Number of beans) (ចំនួនគ្រាប់សណ្តែក)
Rice sufficiency value	
Fuel wood (អុស)	
Resin (ជ័រ)	
Rattan (ផ្តៅ)	
Bamboo pole (ឬស្សី)	
Bamboo shoot (ទំពាំង)	
Vine (វល្លិ៍)	
Mushroom (ផ្សិត)	
Wooden pole (ដំបងឈើ)	
Leaves (ស្លឹកឈើ)	
Medicinal plants and bark (រុក្ខជាតិថ្នាំ)	
Wild vegetables (បន្លែព្រៃ)	
Honey (ទឹកឃ្មុំ)	
Wild pig (ជ្រូកព្រៃ)	
Monkey (ស្វា)	
Birds (សត្វស្លាប)	
Snakes (ពស់)	
Frogs (កង្កែប)	
Snails (ខ្យង)	
Insects (សត្វល្អិត)	
Lizards (តុកកែ)	
Fish (ត្រី)	
Red Muntjae	
Sambar	
Mouse deer	
Other:	

AGRICULTURE (កសិកម្ម)					
Livelihoods (ការចិញ្ចឹមជីវិត)	Total production (kg)	Area (ha) (ទំហំដី ហត)	Price/unit (តំលៃ/ឯកតា)	% Sale (លក់ប៉ុន្មាន%)	% Subsistence (ហូបប៉ុន្មាន%)
Wet season rice (ស្រូវដីខ្ពង់រាប)					
Dry season rice					
Upland rice (ស្រូវដីវាលទំនាប)					

HOME GARDEN (សួនដំណាំ) AREA (ha):				
Livelihoods (ការចិញ្ចឹមជីវិត)	Total Production (unit)	Price/unit (តំលៃ/ឯកតា)	% Sale (លក់ប៉ុន្មាន%)	% Subsistence (ហូបប៉ុន្មាន%)
Cassava (ដំឡូង)				
Maize (ពោត)				
Sweet potatoes (ដំឡូង)				
Mung beans (សណ្តែកបាយ)				
Soya beans (សណ្តែកសៀង)				
Ground nuts (សណ្តែកដី)				
Cashew nuts (គ្រាប់ស្វាយចន្ទី)				
Sesame (ល្ង)				
Water lily				
Pumpkins				
Cucumbers				
Gourds				
Sugar cane (ស្ករអំពៅ)				
Black pepper (ម្រេច)				
Tobacco (ថ្នាំជក់)				
Cotton (កប្បាស)				
Jute (ក្រចៅ)				
Rubber (កៅស៊ូ)				
Coffee (កាហ្វេ)				
Papaya (ល្ហុង)				
Mangoes (ស្វាយ)				
Coconuts (ដូង)				
Oranges (ក្រូចពោធិ៍សាត់)				
Lemons (ក្រូចឆ្មា)				
Bananas (ចេក)				
Rambutan (សាវម៉ាវ)				
Jackfruits (ខ្នុរ)				

Pineapples (ម្នាស់)				
Watermelons (ឪឡឹក)				
Chillies (ម្ទាស់)				
Eggplants (ត្រប់)				
Taro (ត្រាវ)				
Other:				

CHAMKAR (សួនដំណាំ) AREA (ha):				
Livelihoods (ការចិញ្ចឹមជីវិត)	Total production (units)	Price/unit (តំលៃ/ឯកតា)	% Sale (លក់ប៉ុន្មាន%)	% Subsistence (ហូបប៉ុន្មាន%)
Cassava (ដំឡូង)				
Maize (ពោត)				
Sweet potatoes (ដំឡូង)				
Mung beans (សណ្តែកបាយ)				
Soya beans (សណ្តែកសៀង)				
Ground nuts (សណ្តែកដី)				
Cashew nuts (គ្រាប់ស្វាយចន្ទី)				
Sesame (ល្ង)				
Water lily				
Pumpkins				
Cucumbers				
Gourds				
Sugar cane (ស្ករអំពៅ)				
Black pepper (ម្រេច)				
Tobacco (ថ្នាំជក់)				
Cotton (កប្បាស)				
Jute (ក្រចៅ)				
Rubber (កៅស៊ូ)				
Coffee (កាហ្វេ)				
Papayas (ល្ហុង)				
Mangoes (ស្វាយ)				
Coconuts (ដូង)				
Oranges (ក្រូចពោធិ៍សាត់)				
Lemons (ក្រូចឆ្មា)				
Bananas (ចេក)				
Rambutan (សាវម៉ាវ)				

Jackfruits (ខ្នុរ)				
Pineapples (ម្នាស់)				
Watermelons (ឳឡឹក)				
Chillies (ម្ទេស)				
Eggplants (ត្រប់)				
Taro (ត្រាវ)				
Other:				

EMPLOYMENT (ការប្រកបការងារ)	
Employment type	Payment ($/Year) (ការទូទាត់ប្រចាំឆ្នាំ)
Full time (ពេញម៉ោង)	
Seasonal (ប្រចាំរដូវ)	

OWN BUSINESS (រកស៊ីផ្ទាល់ខ្លួន)	
Total income ($/Year): (សរុបចំនូលប្រចាំឆ្នាំ)	
Net income ($/year):	

LIVESTOCK (ការចិញ្ចឹមសត្វ)					
	Price per head (តំលៃលក់ក្នុង១ក្បាល)	Number now (ចំនួនក្បាល)	Number sold (ចំនួនលក់)	Number consumed (ចំនួនសំរាប់ទុកហូប)	Other
Cows (adult)					
Cows (young)					
Buffalos (adult)					
Buffalos (young)					
Pigs (adult)					
Pigs (young)					
Goats (adult)					
Goats (young)					
Chickens (adult)					
Chickens (young)					
Geese (adult)					
Geese (young)					
Ducks (adult)					
Ducks (young)					
Other:					

EXPENSES ON HIRED LABOUR
Total expenses on hired labour per year ($/year)

Enumerator Name: **Date:** **Village Name:** **Income Category:**

ឈ្មោះអ្នកស្រង់ស្ថិតិ: ថ្ងៃខែ: ឈ្មោះភូមិ: ចំណាត់ថ្នាក់ចំណូល:

NTFP អនុផល ព្រៃឈើ	**January**		**February**		**March**		**April**		**May**		**June**		**July**	
	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា	Amount collected បរិមាណប្រមូល	Unit price ថ្លៃក្នុងមួយឯកតា
Fuel wood អុស														
Resin ជ័រឈើ														
Rattan ផ្ដៅ														
Bamboo poles ឫស្សី														
Bamboo shoots ទំពាំង														
Vines វល្លិ៍														
Mushrooms ផ្សិត														
Wooden poles ដំបងឈើ														
Leaves ស្លឹកឈើ														
Medicinal plants រុក្ខជាតិថ្នាំ														

Wild vegetables បន្លែព្រៃ														
Honey ទឹកឃ្មុំ														
Wild pigs ជ្រូកព្រៃ														
Monkeys ស្វា														
Birds សត្វស្លាប														
Snakes ពស់														
Fogs កង្កែប														
Snails ខ្យង														
Insects សត្វល្អិត														
Lizards តុកកែ														
Fish ត្រី														
Red Muntjae														
Sambar														
Mouse deer														
Others:														

Appendix 4: Socio-Economic Indicators for Different Wealth Groups

Table 9.4: Indicators for Different Socio-Economic Groups in Villages in the Survey

Village	Indicator	Household Classification		
		Poor	Medium	Rich
Ou Rona	Total families	68	45	4
	Land (ha)	<2	2.5	5-7
	Animals (head)	0	0	0
	House condition	Small leaf/thatch	Wood zinc	Wood zinc/brick
	Food security	Not enough	Enough	Enough
	Occupation	Upland rice, forest collection, chamkar	Business, chamkar, rice farm & forest collection	Business, chamkar
	Other	N/A	Bicycle and motorcycle	Motorcycle, TV and small car
Ou Am	Total families	354	80	37
	Land (ha)	<2	5	>5
	Animals (head)	0	0	0
	House condition	Small leaf/thatch	Wood zinc	Big wood zinc/brick
	Food security	Not enough	Enough	Enough
	Occupation	Rice & labour	Business & chamkar	Business & chamkar
	Other	N/A	Car, motorcycle & TV	TV, car, motorcycle
Mil	Total families	60	100	0
	Land (ha)	0	0-4	N/A
	Animals (head)	0	0-2	N/A
	House condition	Small & leaf	Medium & zinc	N/A
	Food security	Not enough	Enough	N/A
	Occupation	Labour/worker & forest dependent NTFP	Rice, chamkar, forest dependent & business	N/A
	Other	N/A	Bicycle, TV, motor	N/A
Dung	Total families	30	52	N/A
	Land (ha)	0	0-1.5	N/A
	Animals (head)	0	1-4	N/A
	House condition	Small & leaf	Medium & zinc	N/A
	Food security	Not enough	Not enough (2-3 months)	N/A
	Occupation	Forest dependent & labour/worker	Rice, chamkar, forest dependent, resin buyer & business	N/A
	Other	N/A	Radio, TV, motorcycle	N/A
Sae Roneam	Total families	130	92	10
	Land (ha)	0	0-1	1-4
	Animals (head)	0	1-3	5-7
	House condition	Small & leaf	Medium with zinc/brick	Medium & big with brick/zinc
	Food security	Not enough	Not enough (4-6 months)	Enough
	Occupation	Labour/worker & forest dependent	Rice, chamkar, forest independent or business	Business, traders
	Other	N/A	TV, bicycle, motor...	TV, bicycle, motor, small car
Smrang	Total families	92	48	15

	Land (ha)	0-0.5	0-1	2-3
	Animals (head)	0	2-4	3-5
	House condition	Small & leaf	Medium & zinc/brick	Medium & big
	Food security	Not enough	Enough	Enough
	Occupation	Labour/worker & forest independent	Rice, chamkar and business	Forest middlemen, resin buyer & business
	Other	N/A	TV and motorcycle	TV, motorcycle, car
Kang Kar	Total families	254	148	210
	Land (ha)	0.1-0.2	2	3
	Animals (head)	0	2-3	4-5
	House condition	Small leaf/thatch	Medium zinc/brick	Big wood brick/zinc
	Food security	Not enough	Enough	Enough
	Occupation	Small business, forest collection, & labour/worker	Trader, rice, chamkar, forest collection	Chamkar, rice, trader & business
	Other	N/A	Ox cart, motorcycle	TV, motorcycle, car, rice machinery
Tum Ar	Total families	120	52	0
	Land (ha)	3 (Gov. offered)	>3	N/A
	Animals (head)	0	2-4	N/A
	House condition	Small leaf	Medium wood zinc	N/A
	Food security	Lack (4-5 months)	Lack (2-3 months)	N/A
	Occupation	Worker/labour, forest collection & rice	Trader, rice, forest collected, chamkar,	N/A
	Other	N/A	Ox cart, motorcycle	N/A
Ronteah	Total families	63	30	5
	Land (ha)	0.15	1-2	5
	Animals (head)	0	2	2-4
	House condition	Small leaf	Medium wood zinc	Big wood brick
	Food security	Lack (7 months)	Lack (4-6 months)	Enough
	Occupation	Worker/labour, forest collection	Rice, worker/labour, forest collection	Grocery, rice, trader, chamkar
	Other	N/A	Motor	Motor, TV, Rice, machinery
Samret	Total families	77	30	11
	Land (ha)	<1	1-2	2
	Animals (head)	0	2	2-3
	House condition	Small leaf	Big wood leaf/zinc	Big wood zinc/brick
	Food security	Lack 3-5 months	Lack 1-2 months	Enough
	Occupation	Rice, worker/labour, forest collected	Rice, grocery, forest collected	Rice, chamkar, business
	Other	N/A	Ox cart, old motorcycle	TV, motorcycle, ox cart
Chramas	Total families	117	35	0
	Land (ha)	<1	2-3	N/A
	Animals (head)	1-3	1-4	N/A
	House condition	Small leaf	Medium & big wood leaf	N/A
	Food security	Lack (6 months)	Enough	N/A
	Occupation	rice, Worker/labour	Rice, chamkar, labour/worker, grocery	N/A
	Other	Ox cart, bicycle	TV, Radio, motorcycle, small car	N/A
Ksetr Bourei	Total families	291	87	10

	Land (ha)	0-0.5	1	>3
	Animals (head)	0	2-4	6-8
	House condition	Small leaf	Wood zinc	Wood zinc/brick
	Food security	Lack (5-7 months)	Enough	Enough
	Occupation	Rice, labour/worker, forest collected	Rice, cut forest, NTFP collected	Rice, cut forest, trader
	Other	Ox cart	Bicycle, motorcycle, ox cart	Bicycle, motorcycle, car, TV, radio
Val	Total families	102	23	1
	Land (ha)	2 (av. offered)	2-4	>
	Animals (head)	0	2-4	5-10
	House condition	Small leaf	Wood zinc	Wood brick
	Food security	Lack (4-5 months)	Lack (1-2 months)	Enough
	Occupation	Rice & labour	Rice, chamkar & forest cutting	Forest cutting and business
	Other	Bicycle	Radio, TV, motorccycle	Radio, TV, motorcycle, car
Val Vng	Total families	218	35	0
	Land (ha)	0.1-0.3	3-5	N/A
	Animals (head)	1-3	5-10	N/A
	House condition	Small leaf	Wood zinc	N/A
	Food security	Lack (4-5 months)	Enough	N/A
	Occupation	Rice, forest collection, labour	Rice, chamkar, forest cutting	N/A
	Other	Ox cart, bicycle	Motorcycle, car (mini-tractor) & TV	N/A
Srae Ppeay	Total families	97	35	0
	Land (ha)	0-0.25	>2	N/A
	Animals (head)	1-2	2-10	N/A
	House condition	Small thatch	Wood zinc/brick	N/A
	Food security	Lack (8 months)	Enough/year	N/A
	Occupation	Labour/worker	Rice, chamkar	N/A
	Other	Bicycle	TV, bicycle, motorcycle	N/A
Kl Ttueng	Total families	177	58	18
	Land (ha)	<1	3-5	>10
	Animals (head)	0	2	>4
	Food security	Lack (3-4 months)	Lack (1-2 months)	Enough
	House condition	Small leaf	Wood zinc	Wood zinc/brick
	Occupation	Rice & labour	Rice, chamkar, business	Rice, chamkar, business
	Other	Ox cart	TV and motorcycle	TV, motorcycle, tractor & rice machinery

Appendix 5: Productivity Data and Inventory Results for Natural Forests

Sustainable harvesting in natural forests in the model is based on inventory data, growth data from permanent sample plots and production costs data.

Timber was divided into different qualities and royalty classes. Prices applied for each class in the model are shown in Table 9.5.

Table 9.5: Products and Prices Applied for Natural Forests

Royalty class	Timber	Class B	Small wood	Fuel wood
Luxury	(200)	(120)	(20)	(10)
Class I	150	80	20	10
Class II (resin)	(120)	(80)	(20)	(10)
Class II	120	80	20	10
Class III	90	80	20	10
Non-commercial	80	70	20	10

Sources: Field survey (2005), McKenney et al. (2004), Boscolo (2004)

Average percent saleable timber was calculated based on inventory data (see tables under each forest type) and entered into the model. An example for evergreen forest is presented in Table 9.6.

Table 9.6: Distribution of Products Applied for Evergreen Forest in the Model (percent)

Royalty class	Timber	Class B	Small wood	Fuel wood
Luxury	48	0	52	0
Class I	59	0	41	0
Class II (resin)	64	0	36	0
Class II	69	0	31	0
Class III	53	0	47	0
Non-commercial	54	0	46	0

Field survey (2005)

Production costs of sustainable harvesting in natural forests were divided into partial cut costs, transportation costs, production and protection costs (including opportunity costs of, for example, timber for construction at local level), and royalty payments. Royalties were applied only for the timber part of harvesting according to the average percent saleable log volume in each forest type.

Table 9.7: Production Costs Applied for Evergreen Forest in the Model

Costs	Average
Partial cut costs (USD/m3)	33
Transportation costs (USD/m3)	20
Protection costs (USD/ha)	25
Royalties (USD/m3)	31

Sources: Field survey (2005), Boscolo (2004), MacMillan (2004))

Table 9.8: Average Density in Evergreen Forest (n=12)

Royalty class	I	II	II (resin)	III	Luxury	NC	Total
Diameter (cm)	**Density (trees / ha)**						
<10 cm	158.7	137.3	19.3	304.7	186.7	1575.3	2382.0
10-<20	38.7	15.3	4.0	73.3	12.7	143.7	287.7
20-<30	26.7	6.0	1.7	21.3	3.7	24.7	84.0
30-<40	15.5	4.3	2.0	6.8	2.2	10.0	40.8
40-<50	9.3	1.7	2.2	1.5	0.5	5.3	20.5
50-<60	6.2	1.8	1.5	0.8	0.5	1.8	12.7
60+ cm	7.2	1.5	1.7	1.3	0.0	1.7	13.3
Total	**262.2**	**168.0**	**32.3**	**409.8**	**206.2**	**1762.5**	**2841.0**
Total >40	22.7	5.0	5.3	3.7	1.0	8.8	46.5
Total >60	7.2	1.5	1.7	1.3	0.0	1.7	13.3
Confidence interval:							
Total	138.3	188.2	21.2	169.6	94.4	677.8	800.7
Total >40	6.6	3.1	4.9	2.4	1.6	3.5	9.4
Total >60	2.9	1.1	1.7	1.0	0.0	1.1	4.4

Table 9.9: Average Volume in Evergreen Forest (n=12)

Royalty Class	I	II	II (resin)	III	Luxury	Other	Total
Diameter (cm)	**Volume (m3/ha)**						
<10 cm	1.14	1.03	0.11	2.57	1.19	9.68	15.71
10-<20	5.34	2.20	0.82	10.15	1.61	16.24	36.38
20-<30	12.03	3.11	0.84	10.52	1.86	10.05	38.40
30-<40	16.18	4.84	2.44	6.78	2.14	9.84	42.22
40-<50	16.86	3.01	3.97	2.59	0.80	8.65	35.88
50-<60	17.49	5.09	4.98	2.15	1.08	5.23	36.02
60+ cm	46.03	11.62	13.22	7.86	0.00	13.70	92.43
Total	115.07	30.90	26.37	42.61	8.68	73.39	297.03
Total >40	80.37	19.73	22.17	12.60	1.88	27.58	164.32
Total >60	46.03	11.62	13.22	7.86	0.00	13.70	92.43
Confidence intervals (+/-)							
Total	36.44	16.79	19.73	19.95	6.61	18.21	46.37
Total >40	33.58	12.63	18.63	10.17	3.33	10.01	47.12
Total >60	27.63	8.44	11.80	7.97	0.00	8.29	37.25

Table 9.10: Average Percent Saleable Log Volume in Evergreen Forest (n=12)

Royalty class	I	II	II (resin)	III	Luxury	Other	Total
Diameter	**% saleable log volume**						
40-<50	53	67	70	48	43	61	57
50-<60	61	71	71	53	54	56	62
60-<70	57	72	64	51	0	52	59
>40	57	68	66	51	48	57	58
>50	59	69	64	53	54	50	59
>60	58	67	57	53	44	54	57

Table 9.11: Average Density in Semi-Evergreen Forest (n=12)

Royalty class	I	II	II (resin)	III	Luxury	NC	Total
Diameter (cm)	Density (no. of trees / ha)						
<10 cm	259.3	52.7	6.0	154.0	268.0	1368.0	2108.0
10-<20	35.7	15.0	0.7	23.7	14.0	173.7	262.7
20-<30	14.0	6.3	0.7	12.0	3.0	44.3	80.3
30-<40	6.5	1.3	0.3	6.8	1.3	15.8	32.2
40-<50	2.2	0.3	0.5	2.0	0.7	6.0	11.7
50-<60	1.3	0.7	0.0	1.7	0.5	2.7	6.8
60+ cm	2.8	0.2	0.0	2.2	0.5	5.3	11.0
Total	**321.8**	**76.5**	**8.2**	**202.3**	**288.0**	**1615.8**	**2532.7**
Total >40	6.3	1.2	0.5	5.8	1.7	14.0	29.5
Total >60	2.8	0.2	0.0	2.2	0.5	5.3	11.0

Confidence interval:

Total	153.9	63.7	33.4	90.8	305.0	481.4	776.7
Total >40	2.9	1.0	0.7	2.4	3.1	3.8	9.1
Total >60	1.6	0.3	0.0	1.5	1.2	1.7	4.1

Table 9.12: Average Volume in Semi-Evergreen Forest (n=12)

Royalty class	I	II	II (resin)	III	Luxury	NC	Total
Diameter (cm)	Volume (m^3/ha)						
<10 cm	2.21	0.47	0.11	1.46	1.59	10.04	15.88
10-<20	3.45	1.91	0.12	3.10	1.53	19.51	29.61
20-<30	5.39	3.24	0.29	5.49	1.26	18.63	34.30
30-<40	5.95	1.44	0.33	6.20	1.37	13.65	28.94
40-<50	3.55	0.63	1.07	3.53	0.89	9.59	19.26
50-<60	3.28	2.23	0.00	4.47	1.34	6.22	17.54
60+ cm	18.91	0.63	0.00	11.46	1.80	34.63	67.43
Total	42.75	10.55	1.92	35.70	9.78	112.26	212.96
Total >40	25.75	3.49	1.07	19.46	4.03	50.43	104.23
Total >60	18.91	0.63	0.00	11.46	1.80	34.63	67.43

Confidence intervals (+/-)

Total	13.21	8.47	2.28	11.98	6.29	29.71	36.64
Total >40	11.44	3.68	1.52	10.29	4.90	21.27	27.12
Total >60	11.19	1.27	0.00	8.72	2.44	19.31	26.02

Table 9.13: Average Percent Saleable Volume in Semi-Evergreen Forests (n=12)

Royalty class	I	II	II (resin)	III	Luxury	Other	Total
Diameter	**% saleable log volume**						
40-<50	60	56	57	62	N/A	54	56
50-<60	58	68	N/A	49	N/A	52	54
60-<70	N/A	N/A	N/A	61	43	58	58
>40	62	65	57	60	43	54	57
>50	62	68	N/A	59	43	53	57
>60	63	N/A	N/A	64	43	54	58

Table 9.14: Average Density in Deciduous Forest (n=15)

Royalty class	I	II	II (resin)	III	Luxury	NC	Total
Diameter (cm)	Density (no. of trees / ha)						
<10 cm	1088	1109	288	448	64	1333	4331
10-20	379	40	171	304	64	480	189
20-30	19	117	59	117	48	171	704
30-40	131	56	24	21	13	45	29
40-50	75	27	13	11	16	03	144
50-60	32	19	03	05	05	05	69
60+cm	05	05	00	00	03	03	16
Total	**190.1**	**182.9**	**55.7**	**90.7**	**21.3**	**204.0**	**744.8**
Total>40	112	51	16	16	24	11	229
Total>60	05	05	00	00	03	03	16
Confidence interval:							
Total	856	1105	80	463	8	808	1789
Total >40	67	34	17	13	24	09	9
Total >60	07	07	00	00	05	00	10

Table 9.15: Average Volume in Deciduous Forest (n=15)

Royalty class	I	II	II (resin)	III	Luxury	NC	Total
Diameter (cm)	Volume (m3/ha)						
<10 cm	081	09	023	031	011	121	357
10-20	379	49	182	283	056	459	1853
20-30	60	455	275	363	173	674	2636
30-40	1242	549	29	172	124	315	269
40-50	1166	420	240	09	18	018	2134
50-60	23	577	068	150	082	136	196
60+cm	180	314	000	000	066	055	615
Total	4669	289	1084	109 1	709	1777	12230
Total>40	2269	1312	308	242	345	208	4685
Total>60	264	29	000	000	061	051	672
Confidence intervals (+/-)							
Total	2543	1509	753	514	451	739	3653
Total>40	1404	9	406	241	374	224	2211
Total>60	20	424	000	000	127	106	461

Table 9.16 Average Percent Saleable Volume in Deciduous Forest (n=15)

Royalty class	I	II	II (resin)	III	Luxury	Other	Total
Diameter	% saleable log volume						
40-50	69	61	53	24	55	38	61
50-60	46	59	64	60	50	68	53
60-70	40	64	NA	NA	NA	33	50
>40	60	61	55	42	54	46	57
>50	46	60	64	60	50	50	53
>60	40	64	NA	NA	NA	33	50

Appendix 6: Data for Alternative Land Uses

9.6.1 Pulp Wood Plantations

Pulp wood production in the model is based on an eight-year rotation cycle. Productivity of wood plantations depends on several factors such as soil quality, silvicultural practices and planting material. A total yield of 132 tonnes/ha after 8 years was assumed. Depending on the quality of wood, wood from pulp wood plantations is priced differently. In this study, 70 percent of the yield was pulp wood logs and 30 percent was fuel wood. Products and prices are shown in the table below.

Table 9.17: Products and Prices for Pulp Wood Plantations

Product	Fuel wood	Pulp wood logs
Price(USD)/tonne	10	25

Source: MacMillan (2004)

The production costs vary over the production cycle. Costs applied in the model are listed in the table below.

Table 9.18: Production Costs (USD/ha) for Pulp Wood Plantations

Activities	Year 1	Year 2	Year 3	Year 4	Year 5 - 8
Land clearance, burning	0	0	0	0	0
Raking and reburning	19	0	0	0	0
Land grading	217	0	0	0	0
Fencing	0	0	0	0	0
Posts (2 m long)	56	0	0	0	0
Barbed wire (100 m long)	91	0	0	0	0
Nails	2	0	0	0	0
Labour	28	0	0	0	0
Labour for planting	17	0	0	0	0
Weeding	38	38	38	19	0
Fertiliser	57	57	57	0	0
Labour for applying fertiliser	17	17	17	0	0
Seedlings	83	0	0	0	0
Seedling transportation	17	0	0	0	0
Fire line establishment	36	36	36	36	0
Protection	0	0	0	0	20
Total	**678**	**148**	**148**	**55**	**20**

Source: MacMillan (2004)

9.6.2 Plantation Inventories

Three plantations of different stand ages were selected for study. One is located in Meanok village (five- and six-year-old stands) of Samaki Meanchey district, Kompong Chnnang province, and one each in Srae Chrak (nine- and 10-year-old stands) and Trapeang Ampeak (12-year-old stand) of Treang district, Takeo province.

Calculation of Form Factor

We used Huber's formula to calculate the form factor (form coefficient) of the trunk of each species, without felling the trees. In total, 36 tree trunks (18 each of acacia and eucalyptus) of different ages and plantations were randomly selected for measurement. First, individual tree trunks were divided into separate sections of 2 m, measuring from the ground to the end of commercial height using a ladder. Then the diameter at the middle point of each piece was measured. This meant that we measured the diameter at 1, 3, 5 and 7 m and higher, if applicable, from the ground. The form factor (F) of each trunk was then calculated using the following formula:

$$F = \frac{1}{5} \times \frac{D_{1m}^2 + D_{3m}^2 + D_{5m}^2 + D_{7m}^2 + D_{9m}^2}{D_{1.3m}^2}$$

where $D_{1.3}$ is the diameter at breast height (DBH) and D_{1m}, D_{3m}, D_{5m},… are the diameter measured at 1, 3, 5 m … from the ground, respectively.

Inventory of Plantation Forest

In total, 21 sample plots of 20 x 20 m were randomly located for inventory (Table 1). As far as possible, the inventory team tried to place the plot in the average growth stand of each plantation (between rich and poor stands), following general observation and recommendations from the chief of the plantation. Around three plots were measured in each stand age. Data on DBH and commercial height of all trees located within each plot were collected. The data were then used to calculate average tree density, stand volume and mean annual increment (MAI) of each stand age. The MAI was simply calculated as the product of commercial volume divided by the total stand age; while the commercial volume of each trunk (V) was calculated using the following formula:

$$V = \frac{\pi \times D_{1.3m}^2}{4} \times H \times F$$ where H is the commercial height of the tree trunk.

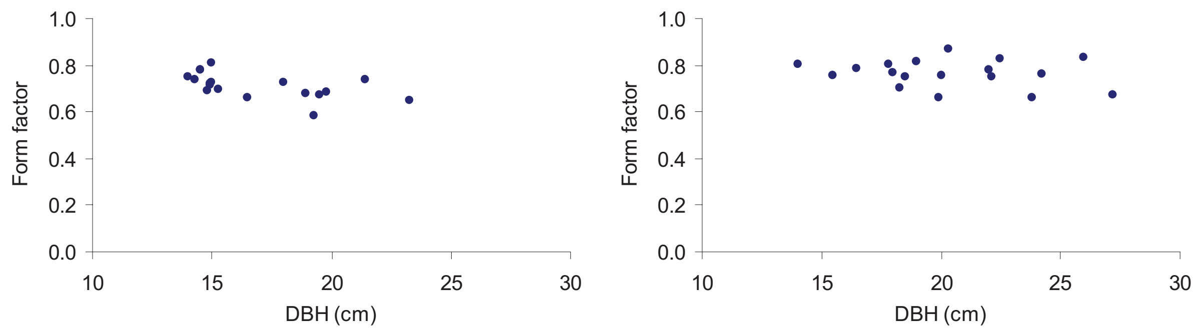
Table 1: Number of Sample Plots of Acacia and Eucalyptus Plantations Selected for Inventory

Main species	Number of plots	Stand age (years)	Location (village)
Acacia mangium	6	5	Meanok
Acacia auriculiformis	3	10	Srae Chrak
Acacia auriculiformis	3	12	Trapeang Ampeak
Eucalyptus camadulensis	3	6	Meanok
Eucalyptus camadulensis	3	9	Srae Chrak
Eucalyptus camadulensis	3	12	Trapeang Ampeak

Results

Fig. 1 shows the variation of form factors of acacia and eucalyptus species at different diameters. The form factor of acacia ranges between 0.58 and 0.81, with an average of 0.71 (n=18); and eucalyptus ranged higher, between 0.66 and 0.87, with an average of 0.76 (n=18). The variation of the form factor among different trunks was relatively small. Therefore, the average results found in this study can be used for stands in other locations of the region or country.

Figure 9.1: Form Factors of Acacia and Eucalyptus Species at Different Diameters



a) acacia b) eucalyptus

Tree densities of each stand varied depending on stand ages and locations. The density of young stand of acacia (five years) and eucalyptus (six years) located in Kompong Chhnang is less than that of older stands in Takeo (Table 2). This is similar for the case of stand volume per ha. The difference may be associated with age of the stand volume and silvicultural technique applied for each plantation for tree density.

It was clear cut last year to improve tree growth. The Mean Annual Increment (MAI) of each stand varied between 9.0 and 15.1 m^3/ha for acacia and 10.3 and 19.5 m^3/ha for eucalyptus (Table 2). The lowest growth rate (9.0 m^3/ha) was that of the oldest stand (12 years) of acacia, while the highest (19.5 m^3/ha) was that of the nine-year-old stand of eucalyptus. This may be explained by the difference in micro-climate (rainfall) and soil type of each plantation. It should be noted that there is a large variation in growth rate of different stands. Therefore, the results reported in this study should be used only for plantations of similar climate condition and soil type.

Table 9.19: Tree Density, Commercial Volume, and MAI of Different Stand Ages of Plantations

Main species	Location (village)	Stand age (years)	Tree density (tree/ha)	Volume (m3/ha)	MAI (m3/ha/year)
Acacia mangium	Meanok	5	621	52	105
Acacia auriculiformis	Srae Chrak	10	1,133	151	151
Acacia auriculiformis	Trapeang Ampeak	12	1,050	108	90
Eucalyptus camadulensis	Meanok	6	650	62	103
Eucalyptus camadulensis	Srae Chrak	9	883	176	195
Eucalyptus camadulensis	Trapeang Ampeak	12	817	126	105

9.6.3 Cashew Plantations

In the model, harvesting of cashews starts in year three. Three kilograms of dried cashew nuts can be expected in the first year of harvesting. The harvested amounts keep increasing until the mature age, at which each cashew tree provides around 10 kg of dried cashews. There are approximately 100 cashews planted on one hectare, which gives a production of 1000 kg/ha.

Table 9.20: Cashew Yields (kg/ha) Applied in the Model

Year	1	2	3	4	5	6	7	8	9	10-25
Yield (kg/ha)	0	0	0	400	500	600	700	800	900	1000

Source: Field survey (2005)

The gross revenues from cashew plantations vary from year to year according to the yield and price of dried cashew nuts over the period. The selling price of cashew nuts ranged from USD550 to USD700 per tonne from 1999 to 2004. In the model, a constant price of USD625/tonne was applied. Assuming this price, the average gross revenue of a mature cashew plantation is USD625/year.

The production costs of cashew are divided into material costs, labour costs and management and infrastructure costs. At year one, site preparation and planting material costs occur. Seedling costs are about USD54/ha and costs for site preparation such as land clearing, digging holes and planting USD60/ha. The total costs at year 1 are USD634/ha: material costs USD479, labour costs USD98 and management and infrastructure costs USD58. The total costs do not change much in the following years. At mature age, the total costs are USD283/ha: material costs USD213, labour costs USD45 and management and infrastructure USD26.

Table 9.21: Costs of Cashew Production (USD/ha) Applied in the Model

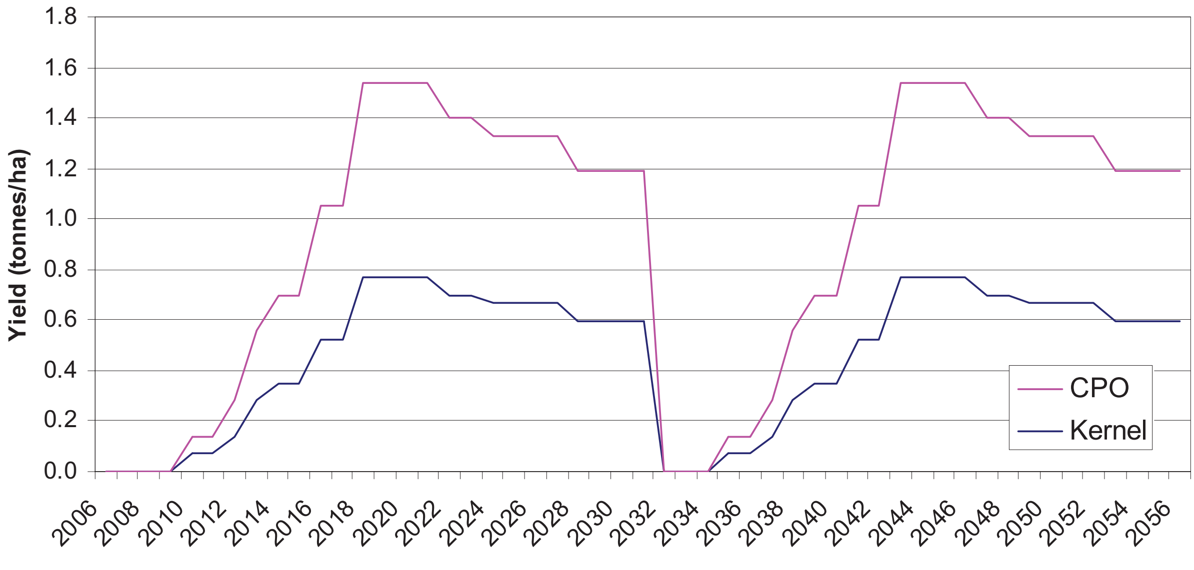
Activities	Year 1	Year 2-9	Year 10-25
Planting materials (seedlings)	54	0	0
Fertiliser, NPK	165	83	83
Fertiliser, manure	260	130	130
Land clearing	31	0	0
Dig planting holes	10	0	0
Planting	19	0	0
Maintenance & fertiliser	37	30	30
Harvesting	0	10	15
Management & infrastructure	58	25	26
Total costs	**634**	**278**	**283**

Source: Field Survey (2005)

9.6.4 Oil Palm Plantations

Production of fresh fruit bunches from oil palm plantations varies with age. Harvesting of fruit begins after four years, and yield increases continuously until mature age. The average extraction rates applied are 22 percent for crude palm oil (CPO) and 3.5 percent for kernels. Expected yields in the model are presented in Figure 9.2.

Figure 9.2: Expected Yields from Oil Palm Plantation in the Model.



Source: Field Survey (2005)

The viability of the oil palm industry depends partly on changes in the world demand for oils and fats and consequently on price fluctuations for CPO and kernels. Average prices applied in the model were USD375/tonne for CPO and USD200/tonne for kernels.

Table 9.22: Products and Prices for Oil Palm Production

Product	CPO	Kernel
Price (USD/tonne)	375	200

Source: Field survey (2005)

The total costs of oil palm production can be broken down into immature upkeep costs, mature upkeep costs, harvesting and transportation costs, indirect charges, manufacturing costs and capital costs. The immature upkeep costs are around USD543 during the first four years. From year five onwards, the total costs of oil palm plantations are about USD811.

Table 9.23: Costs of Oil Palm Production (USD/ha) Applied in the Model

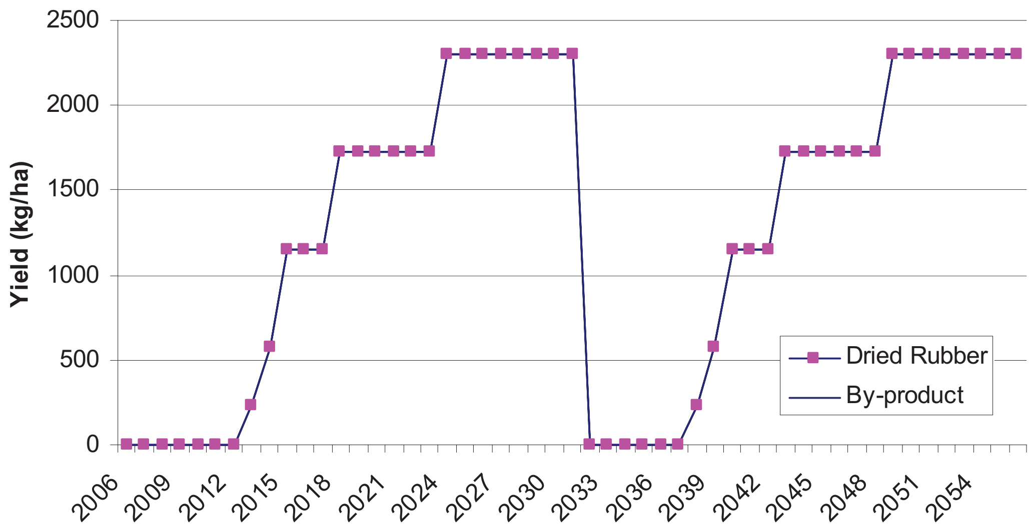
Costs		**Year 1-4**	**Year 5-25**
Immature upkeep		543	0
Mature upkeep	Weeding & spraying	0	45
	Drainage & water management	0	5
	Fertiliser	0	200
	Pruning	0	10
	Pests & diseases	0	5
	Roads & bridges	0	15
Harvesting & transport		0	129
Indirect charges		50	70
Manufacturing costs		0	249
Capital costs		83	83
Total costs		**676**	**811**

Source: Field Survey (2005)

9.6.5 Rubber Plantations

The main product from rubber plantations is dried rubber. Rubber harvesting begins in year seven in a 25-year production cycle. Estimated yields are shown in Figure 9.3.

Figure 9.3: Expected Yields of Dried Rubber and By-Products in the Model.



Source: Field Survey (2005)

The price of dried rubber applied in the model is USD1.3/kg. By-products are traded for USD1/ha.

Table 9.24: Products and Prices for Rubber Production

Product	Dried rubber	By-product
Price (USD/kg)	1.3	1.0

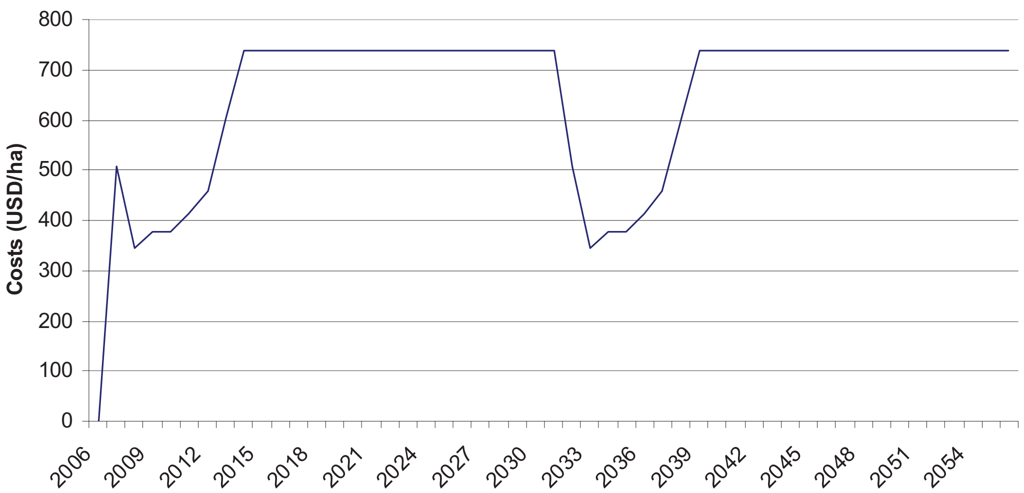
Source: Field survey (2005)

The costs of rubber production vary significantly over a production cycle. Main costs included in the model are maintenance of rubber trees, tapping and harvesting, material and equipment, manufacturing, taxes and overheard expenses. Main production costs in the model are presented in Table 9.25, and total production costs over the time frame are illustrated in Figure 9.4.

Cost	Activities	Year	Average (USD/ha)
Maintenance of rubber trees	Land clearing, roads, bridging, stream	1, (2-25)	74, (5)
	Setting up poles, digging holes, planting	1, (2)	103, (11)
	Maintenance	1-25	46
	Fertilising	(1-2), 3-6	(63), 154
	Maladies treatment	4-25	14
Tapping and harvesting	Tapping wages	7-25	108
	Tapping bonus	7-25	73
	Chemicals	7-25	47
	Transport of latex	7-25	23
Material/ equipment	Material for tappers	7-25	5
	Material for rubber trees	7-25	15
	Tanks and harvesting equipment	7-25	1
Manufacturing/ coagulating	Wages	7-25	7
	Oil	(1-6), 7-25	(5), 17
	Maintenance of machinery	1-25	7
	Electricity/water	(1-7), 8-25	(11), 52
	Chemicals	7-25	11
	Wrapping and transport	7-25	40
Taxes	Export taxes and fees	7-25	115
Overhead	Overhead expenses	(1-7), 8-25	(25), 153

Source: Field Survey (2005)

Figure 9.4: Total Costs of Rubber Production in the Model. Source: Field Survey (2005)



Appendix 7: Brief Discussion of Methodology

The validity and reliability of the results presented from household surveys and in the economic model are linked to the methodology used. This appendix provides a brief discussion of the main parameters of uncertainty in order to evaluate the limitations of the survey and main potential risks of biases.

9.7.1 Sampling and Stratification

Household Survey

The sample frame and intensity in the survey influence the reliability of the findings and the limitation for scaling up the findings. The overall sample frame was communities living adjacent to forests, and the results will be valid mainly in rural areas with forest land. In the sample frame, however, the study attempted to survey different forest zones equally to get an overall NTFP value for an average household living adjacent to forest resources. All households in the survey were randomly selected, and the proportion of households sampled in the two socio-economic groups reflects the local distribution of poor and medium households.

Forest Inventories

The number of forest inventories used in the timber value estimations is statistically limited, and the confidence levels of estimates are quite large. Natural forests are very diverse, and it is very difficlt to get a precise average of standing volumes in a typical natural forest. In order to minimise the variation, forests were stratified into three main types, although even these categories are very diverse. The number presented in this study should be interpreted as a representative example of the different forest types and not as a national average. It should be noted that the purpose of this study is merely an economic valuation of selected forest types, rather than forest planning for a specific area, which would require a much higher level of precision.

Plantation Inventories

The plantation data were also based on a limited number of plots to triangulate growth rates used in other studies and to provide a sense of what can be expected from these kinds of plantations. The inventoried sites differed significantly according to local variations in rainfall and soil quality. The numbers presented in this study should therefore be interpreted only as an average stand in the areas surveyed. In other locations, growth can be expected to be better or worse, and similarly the financial returns.

9.7.2 Use of Recall Periods in Household Survey

The valuation of livelihood factors was, as mentioned in chapter 2, based on individual households' recalling consumption and sale in seasonal calendars. Cavendish (2002) points out several problems with using recall periods, and the livelihood value results are likely to be biased by a recall period of one year. Annual recall introduces the risk of significantly understating environmental resource use, because casual, short-term use and seasonal characteristics make the use easily forgettable (Cavendish 2002). The findings of extensive and daily recurring NTFP utilisation in the study area could therefore be understated. In such a short time it was also impossible to catch the complete diversity of household income within a village. Important income sources may therefore not have been detected for some households, thus adding uncertainty to the estimates.

Estimates for household cash income could have been improved by triangulation with expenditures, but this approach was excluded due to time constraints and because the measuring of total household cash income was not the main focus of the study. To minimise bias from seasonality, quarterly or even shorter recall periods, as suggested by Cavendish (2002), could have been applied to increase the reliability of the findings on the NTFP value.

9.7.3 Enumerators and Pre-Testing of Questionnaire

The household survey was conducted by several enumerators using a standardised questionnaire. In order to minimise biases in the data collection, all enumerators were trained to a common understanding of how to phrase questions in the interviews as well as how to facilitate the different exercises included in the interview. Main income activities and NTFP categories were identified during focus group interviews and included in the questionnaire before it was pre-tested. The questionnaire was pre-tested in 20 households in Kratie to make sure that all questions were understandable and to check that NTFP categories and income activities included in the questionnaire were relevant. The questionnaire, however, was tested only in Kratie province, and there is a risk that some locally important NTFPs or income activities in the other provinces were left out. The respondents were encouraged to list additional NTFP and income activities during the interview, but some could have been left out nevertheless.

9.7.4 Use of Secondary Data

Production data: The reliability of the data on production costs and sales prices depends on a number of assumptions. This study collected data from nine alternative land uses to natural forest. It attempted to triangulate these findings from different studies in order to make the best possible estimate. The reliability of data is often constrained by a lack of studies on different land uses, and the results should be viewed with caution. One thing that requires special attention is that data on alternative land uses often illustrates ideal management under good soil conditions. There are a number of examples of the expected yield and quality not being achieved due to bad management, poor growth conditions or poor seed quality.

Indirect values: A large part of this analysis should have been based on Cambodia-specific data on indirect values. These studies, however, are lacking, and the use of secondary data from other studies in the assessment of indirect values adds a great deal of uncertainty. To provide more accurate measures of these values, more studies should be conducted on indirect values at different locations.

9.7.5 The Value Flow Model

The results derived from the model are directly linked to the data entered into the model. All the above mentioned sources of biases can therefore affect the reliability of the model's predictions. One of the main constraints in the analysis was that data had to be gathered from studies in different locations. The data are site-specific and should be interpreted as indicative only for that area, not for Cambodia as a whole. The model, however, is designed to be a framework for more site-specific analyses and can be used as more data becomes available.

Appendix 8: Sensitivity Analysis for Wood Plantation Scenarios

Table 1: Sensitivity of Results to Changes in Indirect Values at Different Discount Rates

Alternative	Baseline	Indirect value relative to baseline value %	NPV at different discount rates (USD/ha)		
			8%	10%	12%
Eucalyptus plantation	Deciduous	90	-733	-799	-837
		80	-623	-709	-761
		50	-293	-439	-532
		10	147	-79	-226
		0	256	11	-150
	Semi-evergreen	90	-1.886	-1.797	-1.717
		80	-1.709	-1.651	-1.592
		50	-1.177	-1.212	-1.217
		10	-469	-627	-718
		0	-291	-481	-593
	Evergreen	90	-2.623	-2.375	-2.174
		80	-2.424	-2.209	-2.030
		50	-1.829	-1.710	-1.598
		10	-1.035	-1.045	-1.023
		0	-836	-879	-879

Table 2: Sensitivity of Results to Changes in Pulp Wood Prices at Different Discount Rates

Alternative	Baseline	Change in crop prices %	NPV at different discount rates (USD/ha)		
			8%	10%	12%
Eucalyptus plantation	Deciduous	+20	-323	-506	-624
		+10	-583	-698	-769
		- 10	-1.103	-1.080	-1.058
		- 20	-1.363	-1.271	-1.203
	Semi-evergreen	+20	-1.543	-1.561	-1.552
		+10	-1.803	-1.752	-1.697
		- 10	-2.323	-2.135	-1.986
		- 20	-2.583	-2.326	-2.130
	Evergreen	+20	-2.301	-2.159	-2.029
		+10	-2.561	-2.350	-2.173
		- 10	-3.081	-2.733	-2.462
		- 20	-3.341	-2.924	-2.607

Table 3: Sensitivity of Results to Changes in Timber Prices at Different Discount Rates

Alternative	Baseline	Change in timber prices %	NPV at different discount rates (USD/ha)		
			8%	10%	12%
Eucalyptus plantation	Deciduous	+20	-927	-958	-973
		+10	-885	-923	-943
		- 10	-801	-854	-884
		- 20	-760	-820	-855
	Semi-evergreen	+20	-2.305	-2.154	-2.026
		+10	-2.184	-2.049	-1.934
		- 10	-1.942	-1.838	-1.749
		- 20	-1.821	-1.733	-1.656
	Evergreen	+20	-3.471	-3.104	-2.813
		+10	-3.146	-2.823	-2.565
		- 10	-2.496	-2.260	-2.070
		- 20	-2.172	-1.979	-1.823

Appendix 9: Sensitivity Analysis for Perennial Crop Scenarios

Table 1: Sensitivity of Results to Changes in Perennial Crop Prices at Different Discount Rates

Alternative	Baseline	Change in crop price %	8%	10%	12%
Oil palm plantation	Deciduous	+20	1.842	629	-130
		+10	849	-89	-667
		- 10	-1.135	-1.527	-1.740
		- 20	-2.128	-2.246	-2.276
	Semi-evergreen	+20	622	-425	-1.058
		+10	-371	-1.144	-1.595
		- 10	-2.355	-2.581	-2.668
		- 20	-3.348	-3.300	-3.204
	Evergreen	+20	-136	-1.023	-1.535
		+10	-1.129	-1.742	-2.071
		- 10	-3.113	-3.179	-3.144
		- 20	-4.106	-3.898	-3.681
Cashew nut plantation	Deciduous	+20	436	-4	-285
		+10	-6	-332	-537
		- 10	-889	-988	-1.040
		- 20	-1.331	-1.316	-1.292
	Semi-evergreen	+20	-785	-1.058	-1.213
		+10	-1.226	-1.387	-1.465
		- 10	-2.109	-2.043	-1.968
		- 20	-2.551	-2.371	-2.219
	Evergreen	+20	-1.543	-1.656	-1.690
		+10	-1.984	-1.985	-1.941
		- 10	-2.867	-2.641	-2.444
		- 20	-3.309	-2.969	-2.696
Rubber plantation	Deciduous	+20	6.303	3.848	2.296
		+10	5.219	3.086	1.745
		- 10	3.051	1.564	643
		- 20	1.966	803	92
	Semi-evergreen	+20	5.083	2.793	1.368
		+10	3.999	2.032	817
		- 10	1.830	509	-285
		- 20	746	-252	-835
	Evergreen	+20	4.325	2.195	892
		+10	3.241	1.434	341
		- 10	1.072	-89	-761
		- 20	-12	-850	-1.312

Table 2: Sensitivity of Results to Changes in Timber Prices at Different Discount Rates

Alternative	Baseline	Change in timber price %	8%	10%	12%
Oil palm plantation	Deciduous	+20	-226	-877	-1.262
		+10	-185	-843	-1.233
		- 10	-101	-774	-1.174
		- 20	-59	-739	-1.144
	Semi-evergreen	+20	-1.605	-2.073	-2.316
		+10	-1.484	-1.968	-2.224
		- 10	-1.242	-1.758	-2.038
		- 20	-1.121	-1.652	-1.946
	Evergreen	+20	-2.771	-3.024	-3.102
		+10	-2.446	-2.742	-2.855
		- 10	-1.796	-2.179	-2.360
		- 20	-1.472	-1.898	-2.113
Cashew nut plantation	Deciduous	+20	-531	-729	-848
		+10	-489	-695	-818
		- 10	-406	-625	-759
		- 20	-364	-591	-730
	Semi-evergreen	+20	-1.910	-1.925	-1.901
		+10	-1.789	-1.820	-1.809
		- 10	-1.547	-1.609	-1.624
		- 20	-1.426	-1.504	-1.531
	Evergreen	+20	-3.075	-2.875	-2.688
		+10	-2.750	-2.594	-2.440
		- 10	-2.101	-2.031	-1.946
		- 20	-1.776	-1.750	-1.698
Rubber plantation	Deciduous	+20	1.883	734	33
		+10	1.925	768	63
		- 10	2.008	837	122
		- 20	2.050	872	151
	Semi-evergreen	+20	2.694	1.075	92
		+10	2.815	1.181	185
		- 10	3.057	1.391	370
		- 20	3.178	1.496	462
	Evergreen	+20	1.529	125	-694
		+10	1.854	406	-447
		- 10	2.503	969	48
		- 20	2.828	1.251	296

Table 3: Sensitivity of Results to Changes in Indirect Values at Different Discount Rates

Alternative	Baseline	Indirect value relative to baseline value %	NPV at different discount rates		
			8%	10%	12%
Oil palm plantation	Deciduous	90	-21	-708	-1.117
		80	100	-607	-1.031
		50	464	-306	-773
		10	950	96	-429
		0	1.071	196	-343
	Semi-evergreen	90	-1.174	-1.706	-1.997
		80	-986	-1.549	-1.862
		50	-420	-1.079	-1.459
		10	335	-452	-921
		0	523	-296	-787
	Evergreen	90	-1.911	-2.284	-2.454
		80	-1.701	-2.107	-2.300
		50	-1.071	-1.577	-1.840
		10	-231	-870	-1.225
		0	-21	-694	-1.072
Cashew nut plantation	Deciduous	90	-326	-560	-703
		80	-205	-459	-617
		50	160	-158	-359
		10	645	244	-15
		0	767	345	71
	Semi-evergreen	90	-1.479	-1.558	-1.582
		80	-1.290	-1.401	-1.447
		50	-724	-931	-1.044
		10	30	-304	-506
		0	219	-147	-372
	Evergreen	90	-2.216	-2.136	-2.039
		80	-2.006	-1.959	-1.886
		50	-1.376	-1.429	-1.425
		10	-536	-722	-811
		0	-326	-545	-657
Rubber plantation	Deciduous	90	4.278	2.441	1.291
		80	4.399	2.541	1.377
		50	4.764	2.843	1.635
		10	5.249	3.245	1.979
		0	5.371	3.345	2.065
	Semi-evergreen	90	3.125	1.443	412
		80	3.314	1.599	546
		50	3.880	2.069	950
		10	4.634	2.696	1.487
		0	4.823	2.853	1.622
	Evergreen	90	2.388	864	-46
		80	2.598	1.041	108
		50	3.228	1.571	569
		10	4.068	2.278	1.183
		0	4.278	2.455	1.337

Table 4: Sensitivity of Results to Changes in Plantation Crop Prices at Different Discount Rates

Alternative	Baseline	Change in crop price %	8%	10%	12%
Eucalyptus plantation	Deciduous	+20	-323	-506	-624
		+10	-583	-698	-769
		- 10	-1.103	-1.080	-1.058
		- 20	-1.363	-1.271	-1.203
	Semi-evergreen	+20	-1.543	-1.561	-1.552
		+10	-1.803	-1.752	-1.697
		- 10	-2.323	-2.135	-1.986
		- 20	-2.583	-2.326	-2.130
	Evergreen	+20	-2.301	-2.159	-2.029
		+10	-2.561	-2.350	-2.173
		- 10	-3.081	-2.733	-2.462
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		+10	-371	-1.144	-1.595
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		- 20	-760	-820	-855
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		+10	-2.184	-2.049	-1.934
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		+10	-2.446	-2.742	-2.855
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		- 20	-1.426	-1.504	-1.531
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		+10	-2.750	-2.594	-2.440
		- 10	-2.101	-2.031	-1.946
		- 20	-1.776	-1.750	-1.698
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		- 10	2.008	837	122
		- 20	2.050	872	151
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		+10	2.815	1.181	185
		- 10	3.057	1.391	370
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	Evergreen	+20	1.529	125	-694
		+10	1.854	406	-447
		- 10	2.503	969	48
		- 20	2.828	1.251	296

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