# The Cost of Avoiding Deforestation

## Report prepared for the Stern Review of the Economics of Climate Change

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**October 2006**

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**Acknowledgements**

This report was commissioned by the UK Department for International Development to support the work of the Stern Review on the Economics of Climate Change. The author would like to thank Gideon Hoffman, Helene Radcliffe, Catherine Cameron and Nicola Patmore of the Stern Review team and John Hudson of DFID for their helpful advice and comments.  Thanks are due also to a number of experts in forestry, economics and payments for environmental services who provided advice, literature and comments.  These include Arild Angelsen, Ken Chomitz, Bill Hyde, Gerdien Meijerink, Carlos Muñoz, Michael Richards, Roger Sedjo, Jesper Stage, Paul Steele, Tom Tomich, Maria-Teresa Vargas and Sandra Velarde.  Finally, the author gratefully acknowledges the invaluable research assistance provided by Nanete Neves and the help and advice given by IIED colleagues, in particular, James Mayers, Duncan Macqueen and Sonja Vermuelen.

## 1. Introduction

The objective of this report is to support the work of the Stern Review on avoided deforestation by producing a global estimate of the cost of cutting the rate of deforestation in half within a decade. This work would include confirming or otherwise the costs of avoided deforestation per hectare by country available so far and providing further country numbers where possible.

The Terms of Reference set out three elements that payment to avoid deforestation at country level would need to cover:

1. Value of the economic activity per hectare that leads to deforestation i.e. usually agriculture – this will of course vary between countries reflecting different alternative land uses. For example, coffee, cattle farming, soya etc.

2. Administration, monitoring and enforcement costs for the government.

3. An incentive element to undertake this effectively.

Key countries that should be part of this estimate are Brazil, Indonesia, Papua New Guinea, Cameroon, and Congo for the first element. Countries like Costa Rica and China, which have taken action to address forest loss, are important for the second element of administration, monitoring and enforcement of reduced deforestation.

This report sets out the approach to calculation and results for the first two elements.

## 2. The Target

Deforestation is taken to mean here complete removal of forest vegetation to provide land for agricultural purposes or other land uses. Statistics on deforestation are not widely available and it is necessary to use the proxy of net forest loss which as it includes also afforestation, reforestation and natural expansion is likely to be an underestimate. FAO's Forest Resources Assessment 2005 gives a global deforestation estimate of 13 million ha per year on average for 2000-2005 based on the countries with net forest loss but recognizes that this is an underestimate. It does not give deforestation figures at a national level. This is because reporting countries do not break down change in forest area into its various components: afforestation, reforestation, natural expansion and deforestation. To cut the global rate of deforestation by half would therefore require a reduction in the annual area deforested of at least 6.5million ha. It is assumed that deforestation continues at the same global rate over the next ten years. Given the uncertainty over deforestation data and the trend to revise downwards previous net forest loss figures[1], this is not unreasonable.

[1] FAO's Forest Resources Assessment (2005) presents estimates of annual global net forest loss for 1990-2000 that are 0.5 million ha less than the estimates for the same period in the 2000 Forest Resources Assessment.

## 3. The Approach

The terms of reference require the following countries to be included in the estimates of cost of foregone land use : Brazil, Indonesia, PNG, Cameroon and Congo. These countries all have large areas of tropical forest which are under threat from expanding agriculture and livestock sectors. Annual net forest loss in these countries equals 5.6 million ha, somewhat less than the target reduction required, even if deforestation were to be reduced 100% in all cases. Other countries where deforestation is considered serious and where data was readily available have been included. These are Ghana, Bolivia, and Malaysia. Annual net forest loss in these eight countries equals 6.2 million ha. Eliminating deforestation in all these countries would result in a 46% reduction in global deforestation[2].

This report makes a major simplifying assumption agreed with members of the Stern Review team. It is assumed that the governments of the countries concerned are able to implement a scheme at national level to avoid deforestation with 100% additionality and zero leakage. This means that it is only necessary to compensate for the area of annual deforestation as it is assumed that a national government is able to target this effectively.

It is also assumed that the alternative to deforestation is forest conservation without any exploitation of timber and corresponding revenues. This means that it is not necessary to factor in an offsetting stream of returns from sustainable forest management.

Two main elements are needed for estimating the value of the economic activity that leads to deforestation:

- The return per hectare under different land uses and different conditions
- The size of the area to which the different cost estimates should be applied.

**Estimation of returns to land**

Three main approaches can be distinguished in the literature.

***1) Estimates at the local/micro level***

Some estimates have been made at the local level, often in small communities using a random sample household survey. While the results may be sound for that location and its particular circumstances, they are not necessarily capable of being extrapolated over a wider area on a reliable basis. As Chomitz (2006) and others have pointed out, the returns vary considerably according to the location. Opportunity costs depend on

- Type of land use for which the forest lands are appropriate
- Soil and climate conditions which in turn affect yields
- Scale of operation – small, medium, large
- Inputs and technology

[2] Note that this does not translate easily into a reduction of land use related greenhouse gas emissions as the estimates available for these, such as those produced by Houghton for WRI, use a broad definition of land use change which includes harvest of wood in addition to the FAO's four components of net change in forest area.

- Distance from the market and quality of transport infrastructure.

Other factors complicating these estimates include:

- Differences in assumptions about the cost of labour, particularly family labour

- Variation in prices of agricultural commodities over time – coffee prices for example between 1997 and 2001 fell by 70% in nominal terms and to below the costs of production in many producing countries (FAO 2005)

- Differences in assumptions on discount rate and time horizon.

A key factor affecting the magnitude of the estimates is the treatment of the net costs of the conversion process to agriculture and pasture. There are revenues from one-off harvesting of commercially valuable timber but there are also costs of clearcutting the remaining trees and in the case of cattle ranching, of establishing the pasture. Merry et al (2001) in a study of Bolivia present data showing that the costs of clearing and pasture establishment exceed the revenues from the sale of timber or timber rights. They do not however, separate pasture establishment costs from clearing costs. Arima et al (2006) cite research for Brazil from the end of the 1980s that the sale of timber rights from 3 ha of forest was sufficient to finance the rehabilitation of one ha of pasture.

It is not always clear in the literature how this aspect has been dealt with and whether costs of clearing have been included in estimates of returns to agriculture or cattle ranching. Margulis (2003) includes in estimates of the returns to cattle ranching in Brazil the cost of clearing land and establishing pasture but excludes the returns from timber harvesting as it is assumed that the land has already been stripped of commercial timber. Other studies such as Arima and Uhl (1997) which gives estimates of returns to dairy farming in Brazil appear to exclude both clearing costs and pasture establishment. Vera Dias's (2005) estimate of annual returns per ha from soya production probably excludes clearing costs because it is assumed that production of this crop is preceded by several years of cattle ranching.

The returns to timber harvesting also vary considerably depending on location and proximity to market as well as density of commercial species. Barreto et al (1998) present data (taken from Stone 1996) showing how stumpage fees in Para, Brazil, vary by location, increasing with greater proximity to an urban centre. Within 20 km of the nearest town the stumpage fees were US$310 per ha, dropping to US$125 per ha at 130 km distance. The forest conversion process does not always involve timber harvesting or results in minimal returns to this activity because of legal, practical and market restrictions. For example, the country report for Cameroon of the Alternatives to Slash and Burn programme (Kotto-Same et al 2000) did not attempt to incorporate timber revenues in its estimates of returns to land use. This was because in Cameroon deforestation is primarily driven by smallholder agriculture. The State holds all timber rights and smallholders are prohibited from harvesting timber except for their own use. As a result timber is often burnt rather than sold. The ASB report for Indonesia (Tomich et al 1998) makes a similar argument for smallholder agriculture there.

*2) Estimates based on generic/average data*

There are also some generic estimates based on "average" production costs and revenues per hectare or per tonne of agricultural product or typical production costs. for the country. In some cases average costs or returns have been extrapolated from another country (eg Silva Chavez (2005) estimate of returns to soya production in Bolivia uses Brazil data). These estimates run the risk of not capturing local variation eg in yields or the differences between scales of operation. Some estimates eg Osafo (2005) on Ghana, do not include costs of production, equating opportunity cost to value of production. These overstate the opportunity costs of avoiding deforestation. To use such estimates it is necessary to make an assumption about the costs of production.

*3) Land prices*

In theory the price of land should reflect the discounted stream of returns from its most productive/valuable use. Land price estimates in the literature do not lend themselves well to indicating the cost of avoiding deforestation for two main reasons. Firstly, in large areas of forest in Brazil, for example, the problem of deforestation partly stems from the lack of clear ownership and lack of land markets. Settlers can obtain land for free and establish a claim to it by clearing the forest. In areas where land markets do exist, markets may not be well-developed with relatively few transactions so prices are not very representative. In addition, as Chomitz (2006) notes, it is necessary to deduct from the land price the net costs of clear-cutting timber after timber sales and the costs of planting the pasture. Studies reporting land prices in the literature rarely give this information (with the exception of Merry et al 2002) nor do they always make clear the essential characteristics of the land such tenure security, soil fertility, location which affect its price. Land prices may often reflect the returns from a potential land use rather than the actual land use (Arima et al 2006). For these reasons, the land price approach has not been used for this report even though some of the studies in the literature do report land prices.

*Approach taken for this estimate*

A combination of local-level estimates of returns and more generic estimates has been used for this report. The local level estimates tend to be for small-scale farmers and so are useful for this purpose. Adjustments made are as follows:

- All cost estimates are expressed in US$ and converted to 2005 prices using the GDP deflator.

- Annual returns per hectare are converted to net present value per hectare, with a 10% discount rate and a time horizon of 30 years. This is in line with some of the estimates in the literature. In some cases estimates already expressed in NPV terms in the literature were used. Most of these had been calculated with a 10% discount rate, the exception being the estimates for Indonesia made by the Alternatives to Slash and Burn programme (Tomich et al 1998) for which a rate of 20% was used.

The land use returns per ha used to make the global and national level estimates are set out in Table 1 together with details of their source and rationale.

Three sets of cost estimates have been prepared, one assuming that no returns to one-off timber harvesting have to be compensated for as part of land conversion, another assuming that timber is harvested in 100% of the deforestation area and an intermediate scenario which takes account of practical limitations on timber harvesting in some of the countries concerned. The assumptions made for the intermediate scenario are as follows:

- Cameroon and DRC: no timber harvesting as deforestation is smallholder-driven
- Ghana: harvesting in 100% of the deforestation area
- Brazil: 70% - no timber harvesting in small-scale cattle ranching and food crops and in perennials areas.
- Bolivia: 30% - No timber harvesting in the cattle ranching area
- PNG: harvesting in 100% of the deforestation area (all forests community-owned)
- Indonesia: 66% - no timber harvesting in smallholder rice and manioc areas)
- Malaysia: 80% - no timber harvesting in rice fallow area

**Determining the area to which cost estimates apply**

Most of the cost estimates in the literature do not go beyond estimating a return per hectare to different land uses. To estimate the cost of avoiding deforestation at a national level it is necessary to apply these estimates to a geographical area. This means predicting how much of the area deforested each year will end up as different land uses, whether pasture, soybeans, food crops etc. In other words, how many hectares would be cleared for low return use and how many for high return crops such as soya? As land use patterns depend on a number of local factors such as soils, climate, access to markets, it is challenging to make robust predictions. Where estimates of returns differ according to scale it is also necessary to determine how much of the area deforested is likely to involve farms of different scales.

To make such predictions for Brazil, this report uses data from Chomitz and Thomas (2001) on proportions of cleared land in forest margin area that are dedicated to different types of land use. These authors show that 77% of cleared land in forest margins in Brazil is under pasture, 8% under annual crops. It might be reasonable therefore to assume that 77% of further land deforested in Brazil in the next few years will end up as pasture. Chomitz and Thomas (2001) also show that almost half of the agricultural land in these areas corresponds to large scale farms and only 1.5% to farms of less than 20 ha. Unfortunately, similar studies with such quantification of land use patterns do not appear to be available for the other significant deforestation countries.

The percentage breakdown of land uses in most cases is therefore based on more subjective assessment, drawing from qualitative statements in the literature about the importance of different land uses in deforested areas and land use patterns at national level. These assumptions are cross-checked where possible by recent trends in the number of hectares dedicated to different land uses. For example, for Indonesia, oil palm is considered to be a significant driver of deforestation. Between 1990 and 2003, the area dedicated to oil palm increased by roughly 12% per year (Zen *et al* 2005). Expansion in 2004 and 2005 has been at a similar rate. If it is assumed that all of this increase is associated with deforestation, then the current annual increase of oil palm area corresponds to 32% of the annual rate of deforestation. This provides some justification for assuming that 32% of the area deforested each year will be used for oilpalm. This of course assumes that past trends are a good guide to future trends. This may not be the case particularly when prices change.

In some cases though, there is very little information to draw from to justify the assumptions made. It is this aspect of the whole exercise that is the least robust.

The percentage breakdowns of land uses for each country that form the basis of the global and country level estimates are set out in Table 2. The rationale for making these assumptions is also given.

## 4. Results - Opportunity costs of foregone land uses

The estimates for opportunity costs of foregone land uses are set out by country in Table 3. Total costs for the eight countries are approximately US$3 billion. These costs more than double if returns from one-off timber harvesting are included, as shown in Table 4. Costs in a more realistic scenario, which takes account of legal, practical and market constraints on timber harvesting, are roughly US$ 5 billion.

Other factors that could affect the costs are the discount rate used to calculate NPV, the time horizon over which returns are calculated and the assumptions on commodity prices, whether a single year estimate at a low or a high point of the cycle or an average of several years. A major influence on the results however, is the assumption about the proportion of deforested area that will be in high or low value agricultural alternative use. For example if it is assumed for each country that the highest return land use[3] in that country applies over the whole deforestation area, the total costs exceed US$11 billion (excluding returns from one-off timber harvesting).

These estimates are also highly dependent on the assumptions of 100% additionality and zero leakage. There are significant challenges in identifying and targeting areas most at risk from deforestation and preventing displacement of deforestation to other areas, as evidenced by experience with payments for environmental services schemes. For this reason, it is likely that activities to control deforestation such as

[3] In the case of Brazil, the returns to soya were used for this estimate rather than the highest return land use (tree plantations) as this was considered to be a more likely threat at large scale.

compensation payments would have to be directed to an area larger than the desired reduction in deforestation at least in the initial years. This is illustrated by the experience of Mexico's Payments for Watershed services schemes. A model of deforestation risk was developed and a comparison was made with areas at risk and areas in the payment scheme (Muñoz et al 2005). The results showed that there was a lack of additionality. In 2003, only 11% of the participating hectares were classified as having high or very high deforestation risk. This increased however, to 28% in 2004.

## 5. Administration Costs

Without full details of how a compensation scheme will operate at the country level and therefore which activities will be involved, estimates of administration costs can only be speculative. Chomitz (2006) argues that measurement, monitoring and transaction costs are prohibitively high at the property level, especially for small properties, raising doubts about the practicality of relying solely on payments to conserve forest at the individual forest owner level. He identifies a portfolio of interventions that governments can use to tackle deforestation such as fire prevention programmes, improvement of tenure security, enforcement of regulations against illegal deforestation, taxation of large scale land clearance, promotion of off-farm employment and intensification.

Whether a national government proceeds with a payments for environmental services approach or channels the money into improving enforcement of land use restrictions, there are some activities that will definitely be required such as monitoring of deforestation and measurement of forest carbon. Chomitz (2006) makes the point that there are economies of scale in sampling as the accuracy of the estimate depends on the size and representativeness of the sample, and not on the size of the population. Costs of monitoring deforestation at a rather coarse scale to pick up 25 ha patches would not differ so much by country and could be as little as US$2 million per year. This would not serve for an accurate assessment of changes in carbon stock but would be an important part of an implementation strategy (Chomitz pers comm.)

Experience from national level payment for environmental services schemes in Latin America gives some indication of the costs involved if a compensation scheme takes the form of payments. These have to be considered as lower bounds of the estimates as these schemes have been introduced in contexts where there were already institutions in place and a history of subsidies to forestry. FONAFIFO, the organisation that administers the Payments for Environment Services Scheme of Costa Rica is required by law to spend no more than 7% of its budget on administering the scheme and the rest on the payments. According to Rodriguez (2005), FONAFIFO's total budget over ten years has been 40 billion colones (US$110 million) giving an average annual administration budget of US$770,000. By October 2005, the programme had approximately 250,000 ha under contract (GEF 2005), implying an average administration cost of US$3 per hectare over the whole contracted area.

PES recipients also incur costs in the application process. As the division of transaction costs between the administering agency and the applicants reflects the design of the scheme, as well as the strength of local institutions and the capacity of applicants it may be valid to consider these costs also. In other contexts where there is less institutional capacity, it may be necessary for the administering agency to take on more of these costs. An indication of the magnitude of transaction costs assumed by applicants is given by the charges made by local intermediaries to assist applicants with the process including technical assistance and monitoring. These range from 12% to 18% of the total amount of the contract over five years (Miranda *et al* 2003). If 50% of PES recipients pay 15% of their contracted amount to an intermediary, this implies an expenditure of roughly US$800,000 per year (50% of annual budget for payments net of administration costs = US$5.1 million times 15% = US$0.77 million). Including these costs in the calculation would almost double the administration costs.

The payment scheme initiated in Mexico in 2003 also has a ceiling for costs of operation, evaluation and monitoring stipulated in the legislation, in this case 4% (Carlos Muñoz per comm). The annual budget for the scheme is US$18 million implying expenditure on administration of up to US$700,000 per year. This does not include fixed costs of computers, satellite access, land registry update etc which were paid for by the Forestry agency (Carlos Muñoz per comm.). Over the three years of the programme some 480,000 ha have been incorporated into the scheme, implying an operational cost (excluding fixed costs) of US$1.5 per ha per year if the cumulative total is considered or US$4-6 per ha per year if new applications only are considered .

At the other extreme, small local PES schemes have relatively high transaction costs reflecting the large fixed cost element. For the scheme in Pimampiro, Ecuador, which targets a group of 24 landholders owning 390ha of forest and 163 ha of native Andean grassland, the costs of monitoring and management are US$1,800 and US$4,800 per year respectively (Alban and Wunder 2005). This works out at US$12 per hectare targeted and up to US$19 per hectare included in the payment scheme as not all of the landholders participate. (Payments made equal US$4,200 per year, US$6-12 per ha per year depending on the degree of intervention/whether primary or secondary forest or grassland ).

From these schemes, a lower bound figure for annual administration costs of US$4 per ha and an upper bound of US$15 per ha (midway between 12 and 19) can be derived. These represent the likely range of operational costs of a compensation scheme employing a system of payments.

Annual administration costs associated with payment schemes compensating for 6.2 million hectares of avoided deforestation would therefore range from US$25 million to US$93 million. To maintain this reduced rate of global deforestation over time will require substantial increases in administration cost as each year. In the second year, compensation payments would need to be initiated for another 6.2 million ha and payments made for the 6.2 million ha from the first year. By year 10, annual administration costs would range from US$250 million to just under US$1 billion. Fixed costs of monitoring deforestation (but not at a level of accuracy to monitor carbon) , taking Chomitz's estimate of US$2 million per country would be at least US$16 million.

## 6. Conclusions

This report has estimated the avoided costs of deforestation for eight countries with large areas of tropical forest: Bolivia, Brazil, Cameroon, DRC, Indonesia, Malaysia and PNG. Annual net forest loss in these countries averaged 6.2 million ha over the period 2000-2005, equal to just under half of FAO's estimate of annual global deforestation in this period.

The total costs of avoided deforestation in the form of the net present value of returns from land uses that are prevented as a result of controlling deforestation for the eight countries concerned are approximately US$ 3 billion per year if no account is taken of the foregone returns to selective logging before forest clearing takes place. This would be representative of a situation where selective logging is allowed to proceed before conservation. Total costs more than double to US$6.5 billion per year if foregone returns from selective logging are included for all countries. Costs in a more realistic scenario which takes account of legal, practical and market restrictions on logging are somewhat less at US$5 billion per year.

These estimates are heavily dependent on the assumptions made about returns to different types of agricultural activity and the patterns of land use in deforested areas. An upper bound to the estimates can be given by examining a scenario where the highest return land use in each country is assumed to occupy the whole of the annual deforested area. In this case, the costs increase to US$11 billion per year (not including foregone returns from one-off timber harvesting.

The estimates are also highly dependent on the assumptions of 100% additionality and zero leakage. Costs would be higher if governments are not able to identify and target the areas most at risk from deforestation or are unable to prevent displacement of deforestation to other areas. This would mean that a larger area would need to be compensated to achieve the desired reduction in deforestation. There are also significant administration costs involved in achieving high additionality and low levels of leakage. This is a challenge that has faced payment for environmental services schemes.

Administrative costs for a scheme to control deforestation would be highly dependent on the nature of the measures taken. The existing payment for environmental services schemes in Central and South America provide some indication of annual operational costs if a system of compensating individual forest owners were adopted. From these schemes, a lower bound figure for annual administration costs of US$4 per ha and an upper bound of US$15 per ha can be derived. These represent the likely range of operational costs of a compensation scheme employing a system of payments.

Annual administration costs associated with payment schemes compensating for 6.2 million hectares of avoided deforestation would therefore range from US$25 million to US$93 million. To maintain this reduced rate of global deforestation over time will require substantial increases in administration cost as each year. In the second year, compensation payments would need to be initiated for another 6.2 million ha and payments made for the 6.2 million ha from the first year. By year 10, annual administration costs would range from US$250 million to just under US$1 billion.

**Table 1 Derivation of Land Use returns**

| Country | Land Uses | Returns<br>*2005* US$/ha | Source/rationale | |
|---|---|---|---|---|
| **Cameroon** | Annual food crops short fallow | 774 | Kotto-Same et al (2000) Table 16 page 35 | Social returns to take account of trade restrictions |
| | Annual food crops long fallow | 346 | Kotto-Same et al (2000) Table 16 page 35 | Social returns to take account of trade restrictions |
| | Cocoa with marketed fruit | 1,365 | Kotto-Same et al (2000) Table 16 page 35 | Social returns to take account of trade restrictions |
| | Cocoa without marketed fruit | 740 | Kotto-Same et al (2000) Table 16 page 35 | Social returns to take account of trade restrictions |
| | Oil palm and rubber | 1,180 | Kotto-Same et al (2000) Table 16 page 35 | Social returns - Assume same return for rubber |
| | One-off timber harvesting | n.a. | Assume same as for Ghana | |
| **DRC** | Annual food crops short fallow | 774 | Assume same as for Cameroon | |
| | Annual food crops long fallow | 346 | Assume same as for Cameroon | |
| | Cocoa with marketed fruit | 1,365 | Assume same as for Cameroon | |
| | Cocoa without marketed fruit | 740 | Assume same as for Cameroon | |
| | Oil palm and rubber | 1,180 | Assume same as for Cameroon | |
| | One-off timber harvesting | n.a. | Assume same as for Cameroon | |
| **Ghana** | Small-scale maize and cassava | 197 | Revenue per ha from Osafo 2005. Assume 15% return | |
| | One-off timber harvesting | 830 | Osafo 2005 - Community's share of stumpage fees = US$498/ha. Total stumpage fees used. | |
| **Bolivia** | Beef cattle | 390 | Assume Brazil figures apply | |
| | Soya | 1,999 | Assume Brazil figures apply - assume US$100/ha for clearing costs | |
| | One-off timber harvesting | 236 | Assume same as for Brazil | |
| *Notes* | *Returns are NPV in 2005 US$ at discount rate of 10% over 30 years except where otherwise stated* | | | |

| Country | Land Uses | Returns<br>*2005* US$/ha | Source/rationale |
|---|---|---|---|
| **Brazil** | Beef cattle medium/large scale | 390 | Margulis 2003 - Average of 5 representative farms in Para, Rondonia and Mato Grosso |
| | Beef cattle small scale | 2 | Lewis et al 2002 (ASB Brazil) |
| | Dairy | 154 | Arima and Uhl 1997. Costs of clearing assumed at US$100/ha |
| | Soybeans | 1,899 | Vera Diaz 2005 - Return to farmers in Mato Grosso. Assume US$100/ha clearing cost |
| | Manioc/rice | 2 | Assume same as for pasture Negative in ASB report |
| | Perennials bananas | 2 | Assume that perennials, fallow and degraded land have same return as manioc/rice |
| | Tree plantations | 2,378 | Assume same as for Coffee-bandarra system in Lewis et al 2002 (ASB Brazil) |
| | One-off timber harvesting | 236 | Average stumpage fee in Paragominas in 1995 Stone 1996 in Barreto et al 1998 |
| **PNG** | Oilpalm estates | 1,670 | Assume same as for Indonesia |
| | Smallholder oil palm | 480 | Assume same as for Indonesia |
| | Smallholder subsistence crops | 702 | Gross returns from Anderson (2006) assume 15% return |
| | One-off timber harvesting | 1,035 | Tomich et al 2002 Assume that Indonesia estimates apply to PNG |
| **Indonesia** | Large scale oil palm | 1,670 | Vermeulen and Goad 2006 drawing from Zen et al 2005 |
| | Supported growers - oil palm | 1,050 | Vermeulen and Goad 2006 drawing from Zen et al 2005 |
| | High yield independent - oil palm | 1,170 | Vermeulen and Goad 2006 drawing from Zen et al 2005 |
| | Low yield independent - oil palm | 480 | Vermeulen and Goad 2006 drawing from Zen et al 2005 |
| | Smallholder rubber | 36 | Tomich et al 1998 (ASB Indonesia) Social prices 20% discount rate |
| | Rice fallow | 26 | Tomich et al 1998 (ASB Indonesia) Social prices (upper bound) 20% discount rate |
| | Cassava monoculture | 18 | Tomich et al 1998 (ASB Indonesia) Social prices 20% discount rate |
| | One-off timber harvesting | 1,035 | Tomich et al 2002 |
| **Malaysia** | Oil palm Large scale/government | 1,670 | Assume same as for Indonesia |
| | Oil palm supported growers | 1,295 | Based on data from Ismail et al 2003 |
| | Oil palm Independent grower | 1,328 | Based on data from Ismail et al 2003 |
| | Smallholder rubber | 36 | Assume same as for Indonesia |
| | Rice fallow | 26 | Assume same as for Indonesia |
| | Cassava monoculture | 18 | Assume same as for Indonesia |
| | One-off timber harvesting | 1035 | Assume same as for Indonesia |
| *Notes* | *Returns are NPV in 2005 US$ at discount rate of 10% over 30 years except where otherwise stated* | | |

## Table 2 Derivation of Land Uses

| Country | Land Uses | % of Deforested Area | Rationale |
|---|---|---|---|
| **Cameroon** | Annual food crops short fallow | 39% | Kotto-Same et al 2000 ASB Cameroon p6-7 and 52-53 |
| | Annual food crops long fallow | 20% | Kotto-Same et al 2000 ASB Cameroon p6-7 and 52-53 |
| | Cocoa with marketed fruit | 30% | Dominant land use but production not increasing because of low price |
| | Cocoa without marketed fruit | 10% | Assume 25% of cocoa driven deforestation is in area too remote for sale of fruit |
| | Coffee | 0.00% | Dominant land use but production area decreasing because of low price |
| | Oil palm and rubber | 1% | Not considered a threat to deforestation by Kotto-Same et al 2000 ASB but increasing prices may change this. Oil palm area has increased by roughly 1000ha/yr since 2000 |
| **DRC** | Annual food crops short fallow | 39% | Same as for Cameroon |
| | Annual food crops long fallow | 20% | Same as for Cameroon |
| | Cocoa with marketed fruit | 30% | Same as for Cameroon |
| | Cocoa without marketed fruit | 10% | Same as for Cameroon |
| | Coffee | 0% | Same as for Cameroon |
| | Oil palm and rubber | 1% | Same as for Cameroon |
| **Ghana** | Small-scale maize and cassava | 100% | Osafo 2005 |
| **Bolivia** | Beef cattle | 70% | According to Merry 2002 important beyond peri-urban areas. Increase in cattle since 2001 |
| | Soya | 30% | Over 40% increase in area planted 1999 - 2004. Implies 70,000 ha/yr 26% of deforestation |

**Table 2 Continued**

| Country | Land Uses | % of Deforested Area | Rationale |
|---|---|---|---|
| **Brazil** | Beef cattle medium/large scale >200ha | 63.0% | Chomitz and Thomas 2001: 77% of forest margin land was pasture. Table 2 p20 18.3% of agricultural land in farms of 20-200 ha = 14% of pasture. Assume that divided equally between beef cattle and dairy |
| | Beef cattle small scale (<200ha) | 7.0% | |
| | Dairy | 7.0% | |
| | Soybeans | 5.0% | Chomitz and Thomas 2001: 8% of forest margin land was used for annual crops Assume that most but not all is for soybeans and rest for manioc/rice |
| | Manioc/rice | 3.0% | |
| | Perennials bananas | 1.0% | Chomitz and Thomas 2001: Less than 2% of agricultural land in perennials or planted forest |
| | Tree plantations | 1.0% | |
| | Fallow | 3% | Chomitz and Thomas 2001 - Assume return to manioc/rice applies |
| | Abandoned/degraded land | 10% | |
| **PNG** | Oilpalm estates | 33.30% | Oil palm fastest growing agricultural export so assume 50% of deforestation area |
| | Smallholder oil palm | 16.65% | Split between estates and smallholders based on their share of production |
| | Smallholder subsistence crops | 50.00% | Assumption based on importance of subsistence agriculture |
| **Indonesia** | Large scale oil palm | 20% | 12% annual average rate of expansion in area planted 1990-2003 and 2003-2005. 12% of area in 2005 =590 which equals 32% of annual deforestation area Vermeulen and Goad 2006 Assume percentages at national level apply in deforestation area |
| | Supported growers - oil palm | 6% | |
| | High yield independent - oil palm | 2% | |
| | Low yield independent - oil palm | 4% | |
| | Smallholder rubber | 30% | Assumption based on land use systems in Tomich et al 1998 (ASB Indonesia) |
| | Rice fallow | 19% | Assumption based on land use systems in Tomich et al 1998 (ASB Indonesia) |
| | Cassava monoculture | 19% | Assumption based on land use systems in Tomich et al 1998 (ASB Indonesia) |
| **Malaysia** | Oil palm Large scale/government | 18% | Assume percentages at national level from Ismail et al 2003 apply in deforested areas |
| | Oil palm supported growers | 9% | Assume percentages at national level from Ismail et al 2003 apply in deforested areas |
| | Oil palm Independent grower | 3% | Assume percentages at national level from Ismail et al 2003 apply in deforested areas |
| | Smallholder rubber | 30% | Based on Malaysian Rubber Board Statistics -Area increasing in Sabah and Sarawak since 1998 |
| | Rice fallow | 20% | Assumption based on land use systems in Tomich et al 1998 (ASB Indonesia) |
| | Cassava monoculture | 20% | Assumption based on land use systems in Tomich et al 1998 (ASB Indonesia) |

## Table 3 Global and National Costs of Foregone Land Uses (excluding one-off timber harvesting)

| Country | Land Uses | US/ha | No of ha (000) | Cost US$ 000 |
|---|---|---|---|---|
| **Cameroon** | Annual food crops short fallow | 774 | 85.8 | 66,373 |
| | Annual food crops long fallow | 346 | 44 | 15,222 |
| | Cocoa with marketed fruit | 1,365 | 66 | 90,062 |
| | Cocoa without marketed fruit | 740 | 22 | 16,279 |
| | Oil palm and rubber | 1,180 | 2.2 | 2,595 |
| | ***Total*** | | 220 | **190,530** |
| **DRC** | Annual food crops short fallow | 774 | 124.41 | 96,241 |
| | Annual food crops long fallow | 346 | 63.8 | 22,071 |
| | Cocoa with marketed fruit | 1,365 | 95.7 | 130,589 |
| | Cocoa without marketed fruit | 740 | 31.9 | 23,604 |
| | Oil palm and rubber | 1,180 | 3.19 | 3,763 |
| | ***Total*** | | 319 | **276,269** |
| **Ghana** | Small-scale maize and cassava | 197 | 115 | 22,667 |
| | ***Total*** | | 115 | **22,667** |
| **Bolivia** | Beef cattle | 390 | 189 | 73,645 |
| | Soya | 1,899 | 81 | 153,779 |
| | ***Total*** | | 270 | **227,424** |
| **Brazil** | Beef cattle medium/large scale | 390 | 1,955 | 761,735 |
| | Beef cattle small scale | 2 | 217 | 528 |
| | Dairy | 154 | 217 | 33,353 |
| | Soybeans | 1,899 | 155 | 294,553 |
| | Manioc/rice | 2 | 496 | 1,208 |
| | Perennials (Bananas, sugarcane pineapplesNPV | 2 | 31 | 75 |
| | Tree plantations | 2,378 | 31 | 73,779 |
| | ***Total*** | | 3,103 | **1,165,232** |
| **PNG** | Oilpalm estates | 1,670 | 46 | 77,299 |
| | Smallholder oil palm | 480 | 23 | 11,109 |
| | Smallholder subsistence crops | 702 | 70 | 48,777 |
| | ***Total*** | | 139 | **137,185** |
| **Indonesia** | Large scale oil palm | 1,670 | 380 | 634,148 |
| | Supported growers - oil palm | 1,050 | 109 | 114,778 |
| | High yield independent - oil palm | 1,170 | 30 | 35,645 |
| | Low yield independent - oil palm | 480 | 79 | 38,022 |
| | Smallholder rubber | 36 | 561 | 20,174 |
| | Rice fallow | 26 | 355 | 9,276 |
| | Cassava monoculture | 18 | 355 | 6,476 |
| | ***Total*** | | 1,871 | **858,519** |
| **Malaysia** | Oil palm Large scale/government | 1,670 | 25 | 42,323 |
| | Oil palm supported growers | 1,295 | 13 | 16,448 |
| | Oil palm Independent grower | 1,328 | 4 | 5,248 |
| | Smallholder rubber | 36 | 42 | 1,510 |
| | Rice fallow | 26 | 28 | 731 |
| | Cassava monoculture | 18 | 28 | 510 |
| | ***Total*** | | 140 | **66,770** |
| | **GRAND TOTAL** | | **6,177** | **2,944,595** |

**Table 4 Global and National Costs of Foregone Land Uses (including one-off timber harvesting)**

| Country | Land Uses | US/ha | No of ha (000) | Cost US$ 000 |
|---|---|---|---|---|
| **Cameroon** | Annual food crops short fallow | 1,629 | 86 | 139,732 |
| | Annual food crops long fallow | 1,201 | 44 | 52,842 |
| | Cocoa with marketed fruit | 2,220 | 66 | 146,492 |
| | Cocoa without marketed fruit | 1,595 | 22 | 35,089 |
| | Oil palm and rubber | 2,035 | 2 | 4,476 |
| | ***Total*** | | 220 | 378,630 |
| **DRC** | Annual food crops short fallow | 1,629 | 124 | 202,611 |
| | Annual food crops long fallow | 1,201 | 64 | 76,620 |
| | Cocoa with marketed fruit | 2,220 | 96 | 212,413 |
| | Cocoa without marketed fruit | 1,595 | 32 | 50,879 |
| | Oil palm and rubber | 2,035 | 3 | 6,490 |
| | ***Total*** | | 319 | 549,014 |
| **Ghana** | Small-scale maize and cassava | 1,052 | 115 | 121,008 |
| | ***Total*** | | 115 | **121,008** |
| **Bolivia** | Beef cattle | 626 | 189 | 118,249 |
| | Soya | 2,135 | 81 | 172,895 |
| | ***Total*** | | 270 | **291,144** |
| **Brazil** | Beef cattle medium/large scale | 626 | 1,955 | 1,223,523 |
| | Beef cattle small scale | 239 | 217 | 51,838 |
| | Dairy | 390 | 217 | 84,663 |
| | Soybeans | 2,135 | 155 | 331,203 |
| | Manioc/rice | 239 | 496 | 118,487 |
| | Perennials (Bananas, sugarcane pineapplesNPV | 239 | 31 | 7,405 |
| | Tree plantations | 2,614 | 31 | 81,109 |
| | ***Total*** | 0 | 3,103 | **1,898,229** |
| **PNG** | Oilpalm estates | 2,705 | 46 | 125,211 |
| | Smallholder oil palm | 1,515 | 23 | 35,065 |
| | Smallholder subsistence crops | 1,737 | 70 | 120,716 |
| | ***Total*** | | 139 | **280,991** |
| **Indonesia** | Large scale oil palm | 2,705 | 380 | 1,027,205 |
| | Supported growers | 2,085 | 109 | 227,927 |
| | High yield independent | 2,205 | 30 | 67,181 |
| | Low yield independent | 1,515 | 79 | 120,014 |
| | Smallholder rubber | 1,071 | 561 | 601,173 |
| | Rice fallow | 1,061 | 355 | 377,243 |
| | Cassava monoculture | 1,053 | 355 | 374,442 |
| | ***Total*** | | 1,871 | **2,795,185** |
| **Malaysia** | Oil palm Large scale/government | 2,705 | 25 | 68,556 |
| | Oil palm supported growers | 2,330 | 13 | 29,600 |
| | Oil palm Independent grower | 2,363 | 4 | 9,338 |
| | Smallholder rubber | 1,071 | 42 | 44,984 |
| | Rice fallow | 1,061 | 28 | 29,713 |
| | Cassava monoculture | 1,053 | 28 | 29,493 |
| | ***Total*** | | 140 | **211,683** |
| | **GRAND TOTAL** | | **6,177** | **6,525,885** |

**Table 5 Global and National Costs of Foregone Land Uses (medium scenario of one-off timber harvesting)**

| Country | Land Uses | US/ha | No of ha (000) | Cost US$ 000 |
|---|---|---|---|---|
| **Cameroon** | Annual food crops short fallow | 774 | 86 | 66,373 |
| | Annual food crops long fallow | 346 | 44 | 15,222 |
| | Cocoa with marketed fruit | 1,365 | 66 | 90,062 |
| | Cocoa without marketed fruit | 740 | 22 | 16,279 |
| | Oil palm and rubber | 1,180 | 2 | 2,595 |
| | ***Total*** | | 220 | 190,530 |
| **DRC** | Annual food crops short fallow | 774 | 124 | 96,241 |
| | Annual food crops long fallow | 346 | 64 | 22,071 |
| | Cocoa with marketed fruit | 1,365 | 96 | 130,589 |
| | Cocoa without marketed fruit | 740 | 32 | 23,604 |
| | Oil palm and rubber | 1,180 | 3 | 3,763 |
| | ***Total*** | | 319 | 276,269 |
| **Ghana** | Small-scale maize and cassava | 1,052 | 115 | 121,008 |
| | ***Total*** | | 115 | **121,008** |
| **Bolivia** | Beef cattle | 390 | 189 | 73,645 |
| | Soya | 2,135 | 81 | 172,895 |
| | ***Total*** | | 270 | **246,540** |
| **Brazil** | Beef cattle medium/large scale | 626 | 1,955 | 1,223,523 |
| | Beef cattle small scale | 2 | 217 | 528 |
| | Dairy | 154 | 217 | 33,353 |
| | Soybeans | 2,135 | 155 | 331,203 |
| | Manioc/rice | 2 | 496 | 1,208 |
| | Perennials (Bananas, sugarcane pineapplesNPV | 239 | 31 | 7,405 |
| | Tree plantations | 2,614 | 31 | 81,109 |
| | ***Total*** | 0 | 3,103 | **1,678,330** |
| **PNG** | Oilpalm estates | 2,705 | 46 | 125,211 |
| | Smallholder oil palm | 1,515 | 23 | 35,065 |
| | Smallholder subsistence crops | 1,737 | 70 | 120,716 |
| | ***Total*** | | 139 | **280,991** |
| **Indonesia** | Large scale oil palm | 2,705 | 380 | 1,027,205 |
| | Supported growers | 2,085 | 109 | 227,927 |
| | High yield independent | 2,205 | 30 | 67,181 |
| | Low yield independent | 1,515 | 79 | 120,014 |
| | Smallholder rubber | 1,071 | 561 | 601,173 |
| | Rice fallow | 26 | 355 | 9,276 |
| | Cassava monoculture | 18 | 355 | 6,476 |
| | ***Total*** | | 1,871 | **2,059,252** |
| **Malaysia** | Oil palm Large scale/government | 2,705 | 25 | 68,556 |
| | Oil palm supported growers | 2,330 | 13 | 29,600 |
| | Oil palm Independent grower | 2,363 | 4 | 9,338 |
| | Smallholder rubber | 1,071 | 42 | 44,984 |
| | Rice fallow | 26 | 28 | 731 |
| | Cassava monoculture | 1,053 | 28 | 29,493 |
| | ***Total*** | | 140 | **182,701** |
| | **GRAND TOTAL** | | **6,177** | **5,035,621** |

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