Estimating the opportunity costs of REDD+
A training manual

Version 1.3

Chapter 1. Introduction

Objectives

1. Introduce the rationale behind REDD and REDD+
2. Describe the different costs of REDD+
3. Discuss risks and limitations of REDD+ and opportunity cost analysis
4. Introduce an example of opportunity cost estimation
5. Identify the training manual (a) goal, (b) learning objectives, and (c) targeted participants/end-users
6. Summarize the current state of the art of REDD+ opportunity cost analysis

Contents

What are REDD and REDD+?

1. Both REDD and REDD+ are intended to help reduce carbon emissions into the earth's atmosphere. REDD (Reducing Emission from Deforestation and Degradation) is a general term for an international policy and finance mechanism that will make possible the funding of forest conservation and establishment, and/or large-scale purchases and sales of forest carbon. REDD is intended to address both deforestation (the conversion of forested to non-forested land) and forest degradation (reductions in forest quality, particularly with respect to its capacity to store carbon).[1]

2. REDD+, an expanded version of REDD, was defined in the Bali Action Plan as: *policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation; and the role of conservation, sustainable management of forest and enhancement of forest carbon stocks in developing countries*.[2] For the purposes of this training manual, REDD+ is emphasized.

3. By making conservation and sustainable management of forests (along with their carbon) more economically feasible, REDD+ policy can influence land use decisions within countries. UNFCCC ratification of REDD+ would likely allow forested countries to sell carbon credits to interested buyers in markets or receive financial support from conservation funds. The particulars of REDD+ mechanisms are, however, still being clarified.

4. Financial flows from REDD+ programs could reach up to US$30 billion a year, in order to halve emissions between 2005 and 2030.[3] Besides reducing carbon emissions, the flow of funds, primarily North-South, could support new, pro-poor development, and help conserve biodiversity and other vital ecosystem services (UN-REDD, 2010).

National REDD+ strategies and benefit-sharing mechanisms

5. With ratification, REDD+ will affect, and potentially benefit, a wide range of land users.[4] Stakeholders include farmers, ranchers, loggers, rubber tappers, private businesses, etc. – anyone who has land-based activities in rural regions. Since REDD+ funds will pass through national governments, countries will need to decide how to prioritize programs and share the benefits. To facilitate the process of developing a national REDD+ strategy, this manual helps policymakers identify the costs of participating in REDD+ programs at a

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[1] Specifics for a single widely-accepted definition of forest degradation have not yet been generated, for more see Chapter 5 and http://www.fao.org/docrep/009/j9345e/j9345e08.htm.
[2] Paragraph 1 (b) (iii) of the Bali Action Plan (BAP).
[3] Kindermann, et al. (2008) estimate that halving emissions from deforestation between 2005 and 2030, which corresponds to 1.7 to 2.5 billion tons of carbon dioxide (CO_2) emissions, would require financial flows of US$17 to 28 billion per year. This would require a payment of US$10-21/t$CO_2$. A 10% emissions reduction over the same period would cost between US$0.4 and 1.7 billion annually and US$2-5/tCO2.
[4] This section has benefitted from the contributions of G. Frey (2010, personal communication).

national level, by focusing on the analysis of opportunity costs. Given the importance of benefit sharing, we briefly discuss some of the ways the benefits of REDD+ can be shared within a country.

6. In some cases, countries may choose to make direct financial payments to individuals, businesses and communities to compensate them for their activities that protect and conserve forests. In other cases, countries may fund programs to finance capacity-building and investments for alternative livelihood strategies and/or other community development activities. Such an approach is a form of indirect compensation. The selection of national policies for benefit sharing is an important component of a REDD+ readiness process.[5]

7. Identifying effective and equitable benefit-sharing mechanisms can be a challenging task. For instance, land ownership and associated rights may be contested or not formalized (titled) making fair and adequate compensation difficult. Similarly, if a REDD+ intervention is to reduce illegal logging, a policy to compensate to illegal operators could create perverse incentives to cut trees in order to receive payments. Here, indirect compensation and other mechanisms would likely work best to achieve a REDD+ goal. (*More on the risks and limitations of REDD+ and opportunity costs are discussed below in this chapter.*)

8. If a REDD+ strategy limits livelihood activities (being legal or not), then opportunity costs arise. If these costs are not compensated in some way (financially or otherwise) there are two implications: (1) pressure on forests will continue, or (2) the opportunity cost would cause harm to communities, which is a violation of international good practice standards (and World Bank Safeguards) of "doing no harm." (*See Chapter 3 for a discussion on safeguards.*)

9. This manual does not advocate any particular REDD+ strategy or benefit-sharing mechanism. Rather, it is the opinion of the authors that estimating opportunity costs can provide important information to the process of developing and implementing effective and equitable REDD+ strategies.

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[5] From FCPF (2010): *Use clear and transparent benefit-sharing mechanisms with broad community support, so that REDD+ incentives are used in an effective and equitable manner with the objective to further tackle deforestation and forest degradation. In some cases, the national government can be the best actor to enact and implement the necessary policy changes and regulations. But many changes will also require the involvement of indigenous peoples, local communities and the private sector, in which case these stakeholders or rights-holders would expect to partake in the REDD+ activities and the corresponding carbon revenues (or alternative financing or support) in recognition of their contributions. In other cases, indigenous peoples, local communities and the private sector would be the primary actors implementing the ER [Emission Reduction] Programs and thus expect to be the principal beneficiaries of ERPA [Emission Reductions Payment Agreement] payments. These arrangements will have to reflect the assessment of the drivers of deforestation and forest degradation.*

Costs of REDD+

10. In order to receive REDD+ funding, countries must reduce deforestation and forest degradation, and/or enhance carbon stocks. To do so, however, generates costs. These costs can be grouped into three general categories:

(1) *opportunity costs* resulting from the forgone benefits that deforestation would have generated for livelihoods and the national economy,

(2) *implementation costs* of efforts needed to reduce deforestation and forest degradation, and

(3) *transaction costs* of establishing and operating a REDD+ program.[6]

11. Although some of the individual components of implementation and transaction costs can be interchanged, implementation costs are typically associated with reducing deforestation directly, whereas transaction costs are indirectly associated. Brief descriptions of these costs are provided below and are summarized in Figure 1.1.

Opportunity costs

12. Deforestation, despite all its negative impacts, can also bring economic benefits. Timber can be used for construction, and cleared land can be used for crops or as pasture. Reducing deforestation and preventing land use change means forgoing these benefits. Similarly, forest degradation also generates benefits from selective logging, fuelwood collection, or grazing of animals, for example. Avoiding forest degradation implies forgoing these benefits. The costs of the forgone benefits (net of any benefits that conserved a forest generates) are known as "opportunity costs" and can be the single most important category of costs a country would incur while reducing its rate of forest loss within REDD+.

13. Opportunity costs include, most obviously, the forgone economic benefits of the alternative land use, what we term direct, on-site opportunity costs. They can also include social-cultural and indirect costs:

> *Social-cultural costs.* Preventing the conversion of forests to other land uses, can significantly affect the livelihoods of many rural dwellers. Such an alteration in the way of life may bring about social and cultural costs that are not easily measured in economic terms.[7] Examples of such costs could include psychological, spiritual or emotional impacts of livelihood change, loss of local knowledge, and erosion of social capital. These costs can be minimized if alternative livelihoods are viable and readily accessible with the implementation of a REDD+ program.

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[6] These categories are not definitive, but provide an overview of the different REDD+ costs. For a discussion of REDD+ costs, see Pagiola and Bosquet (2009). Costs can be arranged in fewer or more categories.

[7] See Chapter 3 for discussion of involuntary resettlement policy of the World Bank. For a comprehensive review of social impact assessment, see Richards and Panfil (2010).

Indirect, off-site costs. Changes in economic activities, from timber and agriculture to other productive sectors, can also affect downstream actors of associated product supply chains. In addition, less economic activity could have an effect on national tax revenues. Similar to opportunity costs, these indirect costs are not total, but need to be estimated on a difference basis (that is, with vs. without REDD+).[8] Such indirect costs associated to REDD+ can be estimated by using multipliers or multi-market economic models.

Other indirect costs include global feedback relationships arising from REDD+ policy. Land uses within a country under a REDD+ policy scenario would be different than a non-REDD+ scenario. Since more land would be in forest with REDD+, the prices of timber, agricultural and ranching products would likely increase. The combined effect of less conversion of forest to agriculture and more restoration of forests from agriculture would reduce land under cultivation, potentially increasing the costs of food, fiber and fuel. Such price changes could represent significant opportunity costs.[9]

14. This manual focuses on estimating direct, on-site opportunity costs. Along with other socio-economic information, the field-level economic data collected for this component of opportunity cost can be used to estimate indirect opportunity costs. The information and enhanced knowledge of farm, cattle and timber production and their performance within supply chains will help analysts understand potential REDD+ program impacts on the respective economic sectors. For the sake of brevity, the term *opportunity cost* will refer to direct, on-site opportunity costs throughout this manual.

[8] In addition, the growth of other productive sectors needs to be estimated, as economic conditions are not static.

[9] Furthermore, global population increases and consumption patterns associated with higher living standards will also likely raise pressures to convert forests into pastures or agricultural fields, thereby increasing REDD+ opportunity costs. Nevertheless, these factors are independent of REDD+ programs and should therefore not be considered an indirect cost attributable to REDD+. Similarly, other factors such as technology change, which can improve the productivity of lands (e.g. higher yielding crops), could also be mistakenly included as an indirect benefit of REDD+.

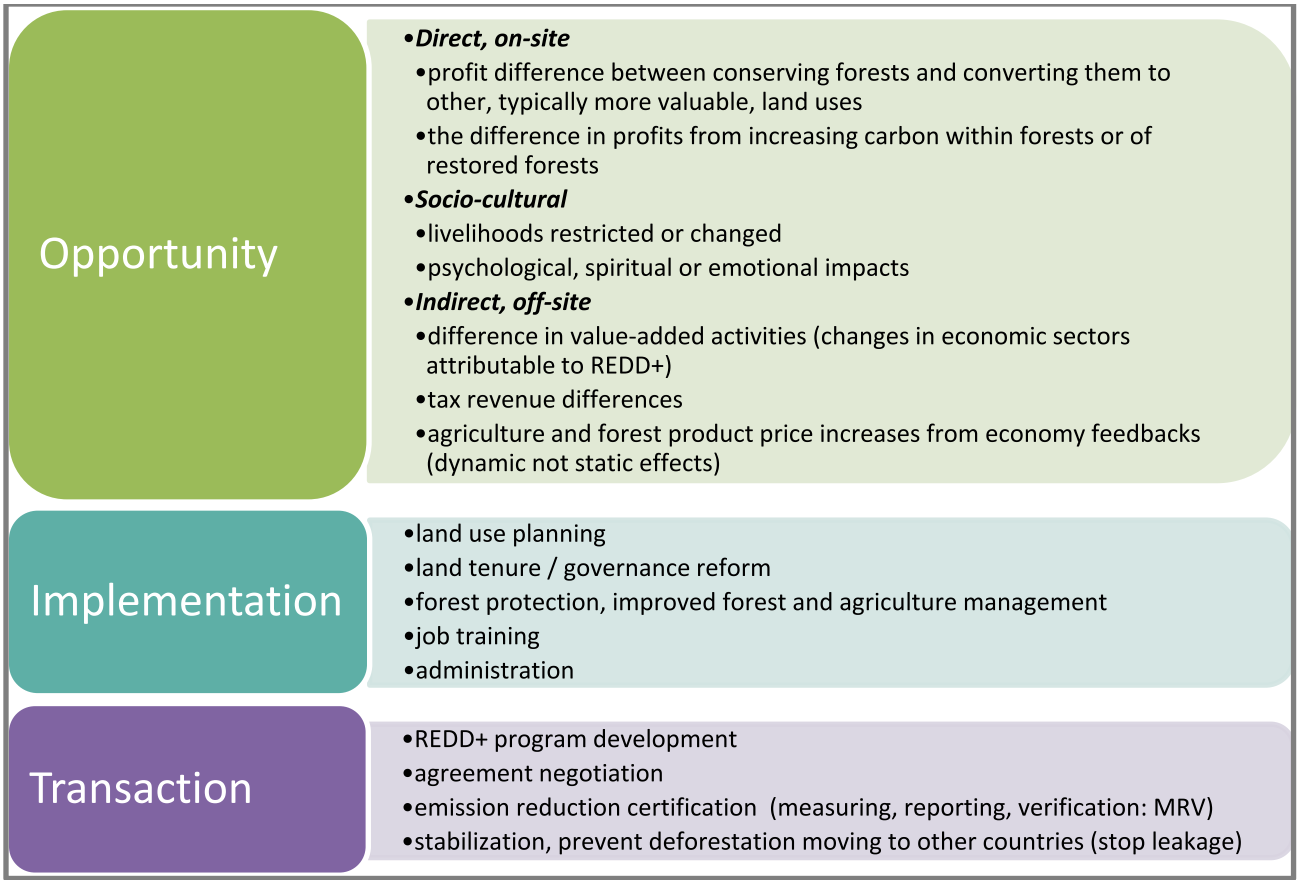


Figure 1.1. The costs of REDD+

Source: Authors.

Implementation costs

15. In addition to opportunity costs, there are also costs involved in implementing a REDD+ program. These are the costs directly associated with actions to reduce deforestation, and hence emissions. Examples include the costs of:

- guarding a forest to prevent illegal logging,
- replanting trees in degraded or logged forests,
- relocating timber harvesting activities away from natural forests to degraded forests scheduled for reforestation,
- intensifying agriculture or cattle ranching so less forest land is needed for food, fiber and fuel production,
- re-routing a road project so that less forest land is destroyed as a result of opening the road,
- relocating a hydroelectric production project away from a natural forest,
- delineating and/or titling land of indigenous and settler communities so that they have an incentive to continue protecting forests against conversion,

- providing capacity building, infrastructure or equipment to develop alternative livelihoods to communities.

16. All of these and similar measures incur up-front investment and perhaps recurring costs for public and/or the private sectors, which need to be adequately assessed and financed.

17. Implementation costs also comprise the institution- and capacity-building activities that are necessary to make the REDD+ programs happen. Examples of costs include the expenses associated with the goods, training, research, and the political, legal and regulatory processes, including consultations and government decision-making processes.

Transaction costs

18. Over and above opportunity costs and implementation costs, REDD+ also comes with transaction costs. Transactions costs are incurred throughout the process: REDD+ program identification, transaction negotiation, monitoring, reporting, and verifying the emission reductions. Transactions costs are incurred by the implementers of a REDD+ program and third parties such as verifiers, certifiers, and lawyers. To illustrate, transactions costs arise from (1) different parties involved in a REDD+ transaction, such as the buyer and seller or donor and recipient, and (2) external parties such as a market regulator or payment system administrator that oversee compliance of stated emission reductions. Such activities and associated costs are nevertheless necessary to the transparency and credibility of the REDD+ program.

19. Transactions costs are typically considered separate from implementation costs, since by themselves they do not reduce deforestation or forest degradation. Transactions costs may also include so-called 'stabilization costs' arising from the need to prevent deforestation activities from moving to other countries that are not participating in REDD+. Nevertheless, it is not yet clear whether REDD+ participants will have to allow for such costs.[10]

Examples of REDD+ cost estimates

20. Opportunity costs can be high (e.g. when forests are converted to establish lucrative oil palm plantations), low and even negative (e.g. when forest conversion is for low productivity pastures). A global review of 29 empirical studies by Boucher (2008a) found

[10] Stabilization costs for the eleven most important high forest-low deforestation (HFLD) countries would cost an estimated US$1.8 billion annually. To cover 7 to 10 countries would cost only US$365 million to US$630 million (da Fonseca et al., 2007). These estimates refer to maintaining emissions constant. Stabilization costs of REDD+ are likely to be higher. Participating REDD+ countries will likely not pay these costs on an individual basis, rather a common fund would be established. Contribution mechanisms to the fund have yet to be determined but could be based on the size of the national REDD+ program, a flat-rate membership or a mix of these options.

an *average* opportunity cost of US$2.51/t$CO_2$. Eighteen out of the 29 estimates of land use change were less than US$2/t$CO_2$, and 28 out of 29 were less than US$10/t$CO_2$.

21. For other REDD+ costs, US$1/t$CO_2$ was estimated to represent transaction, implementation and administrative costs (Boucher 2008b).[11] These costs somewhat overlap, possibly making this a conservative overestimation. Since these estimates were largely based on a project basis, cost efficiencies may be possible to achieve with larger REDD+ programs. Nevertheless, the estimate could be substantially higher in specific national contexts, thus impacting viability of some REDD+ program options.

Why opportunity cost estimates are important

22. Estimating the opportunity cost of REDD+ is important for five basic reasons:

One, opportunity costs are thought to be the largest portion of REDD+ costs (Boucher, 2008a; Pagiola and Bosquet, 2009; Olsen and Bishop, 2009). Boucher's review of 29 regional empirical estimates found average opportunity costs to be between 80 and 95% of the costs of avoiding deforestation in the countries with the most forest cover. This estimate, however, will not necessarily be true for all countries. The relative magnitude of all REDD+ costs depends on national context and specific location. In some circumstances, the opportunity costs of some land uses, especially in remote areas, may be less than transaction and implementation costs.

Two, estimating opportunity costs provides insights into the drivers and causes of deforestation. Forests are not cut out of malice—they are cut because of the economic benefits generated. High opportunity costs tend to be linked with high deforestation pressures. Typically, such lands have been or are being converted to uses of higher economic value such as timber and agriculture (Pagiola and Bosquet, 2009). Here too, there is considerable variation; in some cases, forests are converted to very low-value uses (Chomitz, et al., 2006). By helping to better understand drivers of deforestation, opportunity cost estimates can thus help policymakers identify and develop appropriate responses.

Three, opportunity costs can help to identify the likely impacts of REDD+ programs across social groups within a country. Land uses are often associated with specific social groups. Knowing who would likely gain or would lose from a REDD+ program can help identify potential moral/ethical consequences – if losses were borne by marginalized groups. Possible hidden challenges of national REDD+ program strategies may also be apparent, such as losses being incurred by

[11] Transaction: $0.38/t$CO_2$ (Antinori and Sathaye, 2007), implementation: $0.58/t$CO_2$ (Nepstad, et al. 2007) and administration: $0.04/tCO2 (Grieg-Gran, 2006). In per hectare terms: a lower bound for annual administration costs is US$4 per ha and upper bound of US$15 per ha.

politically powerful groups able to prevent adoption of REDD+ policies or resist their implementation. With the insights gained from REDD+ opportunity cost estimates, national REDD+ strategies can develop effective policies and mechanisms to reduce deforestation and avoid adverse social consequences (Pagiola and Bosquet, 2009).

Four, opportunity costs help to identify fair compensation for those who change their land use practices as part of REDD+. Since livelihoods are affected by land use activities, REDD+ opportunity costs are an estimate of the amount of income that alternative livelihoods would need to provide. For instance, in cases where natural protected areas are strengthened, opportunity costs are an estimate the loss of income to nearby communities arising from use restrictions. Even if these communities are not directly compensated, the cost information is important for policymakers to understand the impacts of a REDD+ conservation policy in order to develop other types of compensation.

Five, the information gathered to estimate opportunity costs is a basis for improving estimates of other REDD+ costs. Opportunity and other REDD+ costs are likely to significantly differ within a country – even for similar land use changes. The process of gathering sub-national information, increases knowledge of local biophysical and socioeconomic contexts, which can also improve understandings needed to refine estimates based on generic values. For example, models of indirect opportunity costs, which typically employ average opportunity cost estimates, can become more accurate by taking into account sub-national information. Similarly, implementation and transactions costs can also be estimated on a spatially differentiated basis.

Risks and limitations of REDD+ opportunity cost estimates

Risks

23. Opportunity cost analysis can help inform the development of national REDD+ policies. Nevertheless, some serious risks can arise. Below are two risks associated with opportunity cost estimates, along with remedies to reduce possible harm.

One, inaccurate application of opportunity cost estimates. Seemingly similar land use changes may have very different opportunity costs. Many factors determine opportunity costs, both biophysical and socio-economic. Therefore, opportunity costs should never be applied uncritically. For example, opportunity costs may differ due to distinct soil fertility or market access contexts. ***Remedy:*** *Estimate and identify valid sub-national areas to which site-specific results can be extrapolated. This process is a crucial discussion topic within this training manual. In* *addition, to foster a process of timely improvement (i.e. precision and accuracy)*[12] *of opportunity cost estimates, three levels of data and analysis requirements (analogous to the UNFCCC Tiers 1,2,3) are suggested. (More on this in Chapter 2.)*

Risks of opportunity cost estimates:
- inaccurate application
- considering opportunity costs to be equal to all REDD+ costs

Two, opportunity cost is considered to be the only component of REDD+ costs. Opportunity costs are only one piece of the REDD+ cost puzzle. If transaction and implementation costs are also taken into account, different conclusions regarding viable national REDD+ strategies could be reached. ***Remedy:*** *Analysis and policies should not only focus on opportunity costs, but also address other REDD+ costs (implementation and transaction) that are important in developing nationally-appropriate REDD+ strategies.*

Limitations

24. Opportunity cost analysis in general, and the approach specifically presented here, both have limitations that should be considered while estimating REDD+ costs:

One, opportunity cost analysis does not account for the cost of lost employment that could arise from wide-scale change in land use. To obtain alternative employment, time and training is often required. Moreover, in many rural contexts where REDD+ is likely to be implemented, high levels of under- and un-employment prevail. Therefore, jobs forgone, from agricultural to forest land uses for example, could lead to substantial costs. In addition, many classes of people may not be eligible for compensation, yet their livelihoods would be affected, including people without land title, rural laborers, illegal loggers and potentially other groups of affected people. ***Remedy:*** *Estimate employment impacts per type of land use change associated with a REDD+ program. Examine tradeoffs and scenarios (Chapter 9). Magnitude of costs will depend on the size of the REDD+ programs and their effect on the landscape. Results from analysis will enable policymakers to identify priority areas and efforts to generate jobs (a type of implementation cost). The success of REDD+ programs (i.e., sustainably diverting forest adverse activities) depends on creating lucrative alternative activities in intensified agriculture, forestry or other sectors of the national economy.*

Two, direct, on-site opportunity costs underestimate total opportunity costs. REDD+ could substantially alter forestry and agriculture economic sectors, input and output prices, and patterns of land use. Thus, other components of opportunity

[12] Accuracy is how close the estimates are to the "true" value, whereas *precision* is how close the estimates are to each other.

costs, socio-cultural and indirect off-site costs, also need to be considered within REDD+ policy analyses. ***Remedy:*** *Direct on-site opportunity costs can approximate the effect of such cost components within sensitivity and scenario analyses (Chapter 9). For example, a multiplier or additional socio-cultural costs can be estimated for specific land use changes. Similarly, additional costs arising from economic changes (e.g. prices) can be included with multipliers. These initial analyses can be used as a basis for discussion and justification for subsequent multi sector economic modeling.*

25. Despite these risks and limitations, the authors consider the analytical approach as a useful and essential step to understanding opportunity costs. The manual strives to illustrate a process of data collection and analysis to transparently estimate REDD+ opportunity costs and avoid calculation and interpretation pitfalls.

Important issues not addressed by opportunity cost analysis

One, off-site environmental impacts (externalities) of land uses. Although opportunity cost analysis of land uses is based multi-year time horizons, associated environmental impacts (e.g. negative downstream effects, biodiversity loss) are not explicitly taken into account. ***Remedy:*** *Such negative impacts can be discussed when reviewing opportunity costs at sub-national and national levels. Adequate costing of negative effects can be accomplished within a country accounting stance (defined in Chapter 3). On-site impacts, such as land degradation, can be examined with sensitivity and scenario analysis of the opportunity cost estimates (Chapters 7 and 9). For example, yield estimates from agricultural activities can decrease over the time horizon of the analysis.*

Other important REDD+ issues:
- environmental impacts
- governance
- illegal forest activities

Two, land and resource governance. Since legal and customary rights may not coincide, especially where land and resource rights are not well defined or enforced, determining the opportunity costs and who bears them may not be possible. An opportunity cost analysis that only takes into account legal rights without recognizing customary rights and uses will fail to estimate the true cost impact of REDD+ on individuals and communities. Moreover, if REDD+ strategy or intervention is based on a misrepresented estimate, particular vulnerable groups could be disenfranchised. ***Remedy:*** *As part of a national REDD+ strategy development process, discussion of governance is essential. Participation in discussions (and analysis) should go beyond government and include affected stakeholders in civil society.*

Three, appropriate strategies and interventions to reduce illegal forest activities. When laws are enforced as part of a national REDD+ strategy, actors in illegal practices will bear an opportunity cost. How and if the opportunity costs are recognized, may be different according to type of actor. In cases such as illegal logging by foreigners, a country may decide it is not appropriate to compensate opportunity costs. In this case, the more substantial cost of REDD+ would not be the opportunity cost, but the implementation cost of adequately enforcing the law. In other cases, such as customary but illegal activities undertaken by low-income groups, a country may decide to compensate for opportunity costs (either directly or indirectly). ***Remedy:*** *Like the above limitation, a national REDD+ strategy development process should include discussion of legal and illegal forest activities. Participation in discussions should also include affected stakeholders in civil society. In this case, compensation should be given in form of creating legal jobs as an alternative to illicit forest depleting activities.*

REDD+ safeguards

26. Advances in social and environmental safeguards include defining and building support for a higher level of social and environmental performance from REDD+ programs. As REDD+ policy moves forward, the participation of local and indigenous communities in the identification and analysis of potential positive and negative impacts of REDD+ can inform safeguard policies that ensure forest users can maintain their traditional rights and uses of land resources.

27. Besides the World Bank safeguards presented in Chapter 3, an international review is in process to ensure consistency across the country-specific interpretations (CCBA and CARE International, 2010). Proposed standards include principles, criteria and indicators that define the issues of concern and performance levels. The following principle addresses cost analysis:

Principle 2: The benefits of the REDD+ program are shared equitably among all relevant rights holders and stakeholders.	
Criteria	***Framework for indicators***
2.1 The projected costs, potential benefits and associated risks* of the REDD+ program are identified for relevant rights holder and stakeholder groups at all levels using a participatory process.	2.1.1 Projected costs, potential revenues and other benefits and associated risks of the REDD+ program are analyzed for each relevant rights holder and stakeholder groups at all levels using a participatory process.

**All analysis of costs, benefits and risks should include those that are direct and indirect and include social, cultural, human rights, environmental and economic aspects. Costs should include those related to responsibilities and also opportunity costs. All costs, benefits and risks should be compared against the reference scenario which is the most likely land-use scenario in the absence of the REDD+ program.*

28. International efforts have been made to classify and prioritize REDD+ activities and assess critical constraints to sub-national project development. For example, well-defined land-use rights along with equitable and effective governance plays a key role in implementing REDD+ (e.g., illegal logging/conversion on public or private lands). Principles of good governance include transparency, participation, accountability, coordination and capacity (World Resources Institute, 2010). To address these and other challenges, reviews and reforms of legal, political, and institutional framework for carbon finance are typically required (see Richards, et al., 2010, The Forests Dialogue, 2010).

An important question

29. With REDD+ programs, lost are the potentially larger profits from future agriculture and logging activities.[13] So we need to ask:

Can REDD+ programs provide enough incentive to conserve or restore forests?

30. The quick reply: it depends on the international carbon price, the type of land use change and the different types of REDD+ costs that a country will face in order to reduce emissions. Thus the answer to the question will be 'yes' for some forms of deforestation, and 'no' for others, and unclear in yet others. Because agro-ecological, economic, and social conditions can greatly differ from place to place within a country, the costs of REDD+ can likewise differ substantially. Furthermore, the cost and effectiveness of measures to reduce deforestation will vary per location.

31. It is quite likely that every country will find many locations in which REDD+ would not be justified by any realistic payment per ton of carbon emission reduction. Conversely, it is also very likely that every country will find that it has many areas in which even modest payments for avoided emissions would render efforts to reforest or avoid deforestation attractive. The real issue is not whether REDD+ payments would be attractive at all, but how many emission reductions a country would find it attractive to provide at any given price per ton of carbon reduced. Understanding the opportunity costs of land use changes is a critical step (but not the only step) in answering this question.

32. Let's first examine three typical land use changes, from forest to:

High-value agriculture

Examples: soybean, oil palm or cattle on productive lands

probably no

33. Compensation from a REDD+ program is likely to be less than the profits from high-value activities on productive lands. In other words, the opportunity cost of the high-value agriculture is greater than the potential income from a REDD+ program. Carbon prices would need to be very high in order

[13] The term agriculture also includes ranching and tree-based or perennial cropping activities.

for REDD+ to be attractive, unless there were also significant co-benefits to conserving forests, such as protecting the water supplies of downstream users.

Mid-value agriculture

Examples: soybeans, oil palm or cattle on normal quality lands

maybe

34. Income from a REDD+ program may be more than the profits of mid-value agriculture. Compensation from REDD+ is slightly more than the opportunity costs of such land use activities. Yet, transaction and implementation costs of a REDD+ program may erase net benefits.

Low-value agriculture

Examples: shifting cultivation or cattle on marginal lands

probably yes

35. Most likely, income from a REDD+ program is more than the profits from low productivity agricultural activities. In this situation, it is worthwhile for a landowner to accept compensation associated with REDD+ and maintain land as a forest (instead of converting it to agricultural use).

36. So far, we have only mentioned land use changes that involve deforestation. What about increasing carbon stocks on lands already where the forest cover has been partly or totally removed? Low-productivity lands exist throughout much of the world, such as some degraded forests, pastures, grasslands, shifting cultivation lands, old and exhausted perennial croplands, etc. Depending on the specific REDD+ policy negotiated and implemented, restored low carbon / low productivity lands may have a significant role to play in carbon funds and markets.

Reforestation or afforestation

Examples: Native timber tree plantations on low-productivity agricultural or pasture lands

maybe

37. The investment costs to re-establish forests may be compensated by REDD+ programs. Earnings from the reforested areas may be greater than from low productivity agricultural, ranching uses, especially if timber is selectively harvested in the future.

What about the value of wood and timber?

38. The above deforestation examples only recognized the value of agricultural production after the land use change from forest. As we will show in this manual, the value from other sources can greatly affect opportunity cost estimates of land use change. These sources can include profits from timber, charcoal and firewood that are produced when

clearing the forest or, alternatively, with enhanced forest management. When these profits exist, accurate REDD+ opportunity costs estimates should include the contribution of these forest products as well.

An opportunity cost example

39. Since learning about opportunity costs is best illustrated with numbers, we present an example. Let's compare a hectare of forest to a hectare of agricultural land. Figure 1.2 summarizes the carbon stock and profits of each land use. The forest has approximately 250 tons of carbon per ha (tC/ha), whereas agricultural use has about 5 tC/ha.[14] (*Procedures on how to estimate the tC/ha stock value per land use is in Chapter 5.*) The estimated profits from agriculture are $400/ha, while forest profits are $50/ha, expressed in Net Present Value (NPV) terms.[15] *(An explanation of how to estimate NPV profits is in Chapter 6.)*

40. While the forest stores more carbon, agriculture produces more profit, revealing a land use tradeoff between carbon and profits. Converting a forest into an agricultural land use increases profits by $350/ha but reduces carbon stock by 245 tC/ha.

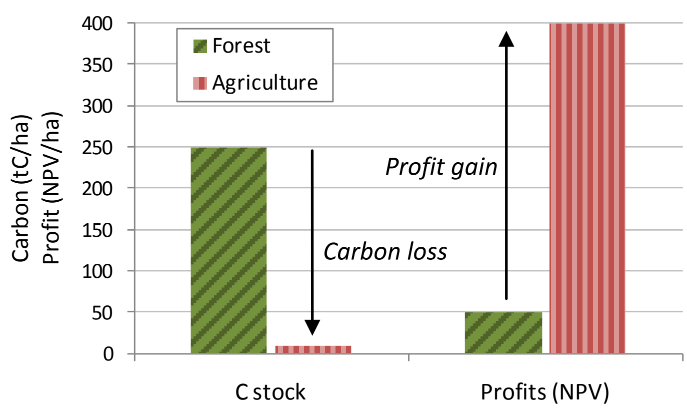


Figure 1.2. Carbon loss and profit gain from converting forest to agriculture

41. The opportunity cost of not changing forest to agriculture is equal to the $350/ha of profit difference ($400–$50=$350/ha) divided by the 245 tC/ha not emitted (250–5=245tC/ha). Thus, the opportunity cost, per ton of carbon, is $1.43/tC (=$350/245tC).

42. REDD+ compensation, however, is not based on carbon (tC), but rather on emissions of carbon dioxide equivalents (CO_2e). A conversion factor of 3.67 is needed to translate tC

[14] These figure are illustrative. Significant variation can arise within landscapes and across countries.
[15] Net present value is the summing of a stream of annual profits, whereby future profits are reduced by a factor (i.e., discount rate) that reflects the inherent preference for money now, rather than profits generated in the future.

to tCO_2e. (*See Box 1.1 for further explanation.*) So, the potential emissions of the land use change is 899tCO_2e/ha (245tC/ha * 3.67 tCO_2e/tC = 899tCO_2e/ha).

43. With an estimate of the difference in profits ($350/ha) and the emissions avoided (899 tCO_2e/ha), an opportunity cost of avoided emissions can be estimated. The opportunity cost is $0.39/$tCO_2e$ of not converting a forest into agricultural land.

44. This per ton carbon equivalent estimate is one way of expressing opportunity costs. Yet for landholders, the more relevant way to express opportunity costs is per hectare. In this example, the per unit land area estimated opportunity cost is $350/ha. In other words, by not converting a forest to agriculture, the farmer forgoes $350/ha in NPV profits.

Two versions of opportunity cost:

- per unit carbon (tCO_2e)
- per unit land area (ha)

45. Although estimating opportunity costs is relatively simple in theory, in practice, generating reliable estimates can be difficult. Multiple series of calculations are required, each with possibilities of making errors. In addition, numerous assumptions about measures and methods need to be made, often requiring discussion and agreement, in order to generate precise and accurate estimates of both carbon and profits of land uses.

46. It is important to note that opportunity costs are not based on land use, but rather the change in land use. Land use change is the difference between an initial state and an end state. The time period of analysis can be of any length, but should follow the Intergovernmental Panel on Climate Change (IPCC) reporting requirements (i.e., 5 years) and/or the time frame of a national strategic plan (perhaps more than 5 years).

Box 1.1. What is a carbon dioxide equivalent?

The major greenhouse gas associated with land use change is carbon dioxide (CO_2). Carbon is approximately 46% of the biomass (per kilogram of dryweight) stored in trees and 57% of soil organic matter. When one unit of tree carbon is burned or otherwise decomposes, the carbon combines with two units of oxygen to produce one unit of CO_2. Given the atomic weights of carbon (12) and oxygen (16), one unit of C is equal to 3.67 units of CO_2 ((12+(2*16))/12)=3.67).

Deforestation and degradation also produce other greenhouse gases (GHGs) including nitrous oxide (N_2O) and methane (CH_4). N_20 has 231 times higher global warming potential than CO_2. Whereas, CH_4 has 23 time the warming potential. To standardize the effect of different gas emissions, international convention measures greenhouse gas loading in terms of CO_2 equivalents, represented by CO_2e.

Source: IPCC, 2006.

Carbon – profit tradeoffs

47. Let us extend the previous example to compare forests against three distinct land uses: agriculture, agroforests, and low-productivity pastures (Figure 1.3).

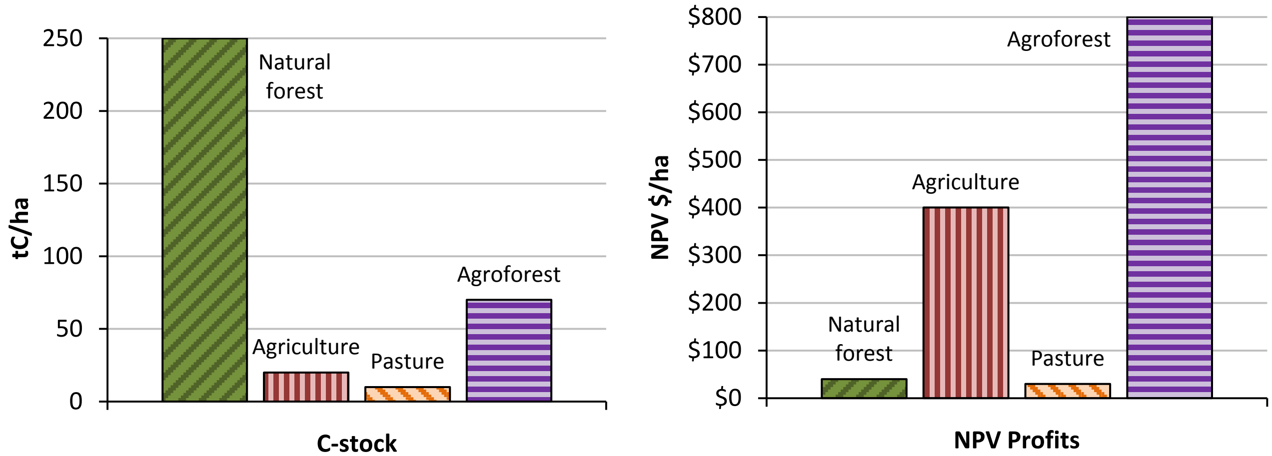


Figure 1.3. Carbon and profits of four land use categories

48. Comparing the land uses in this example, we can see that:

- Carbon stocks of agriculture, pasture and agroforestry are all lower than natural forest.
- Profit from agroforestry is highest, with agriculture about half as much. Profits from forest and pastures are both low.
- Low-productivity pastures have low carbon content (5tC/ha) and low profits ($40/ha). Therefore, unlike conversion to agriculture, conversion to pastures would not be a carbon-profit tradeoff.
- Although agroforestry has lower carbon stocks than forests, the carbon content of agroforestry is substantially (80tC/ha) more than agriculture (5tC/ha). Of particular interest is the high NPV profit ($800/ha).

Comparing opportunity costs

49. Figure 1.4 presents the opportunity costs of three types of land use change (forest to pasture, agriculture, and agroforestry). Each has a different opportunity cost. Both changes to agriculture and agroforestry land uses have higher opportunity costs. Since agriculture has lower NPV profits and lower carbon content than agroforestry, the opportunity costs of avoiding the emissions from changes to agriculture are less than those of agroforestry.

50. In the case of forest to low-productivity pastures, the opportunity costs of the land use change is not actually a cost. *The opportunity cost is negative – which can be considered a potential benefit.* Landholders could realize an economic gain by not deforesting for producing cattle on low-productivity pastures. Profits would increase from $40 to $50/ha reflecting the lack of a carbon-profit tradeoff. In terms of the associated CO_2e, the opportunity cost is negative, that is -$0.01/t$CO_2$e. This is example of so-called low-hanging fruit – where REDD+ compensation may not be necessary in financial terms, but may be available and needed, to avoid such a land use change or restore a forest.

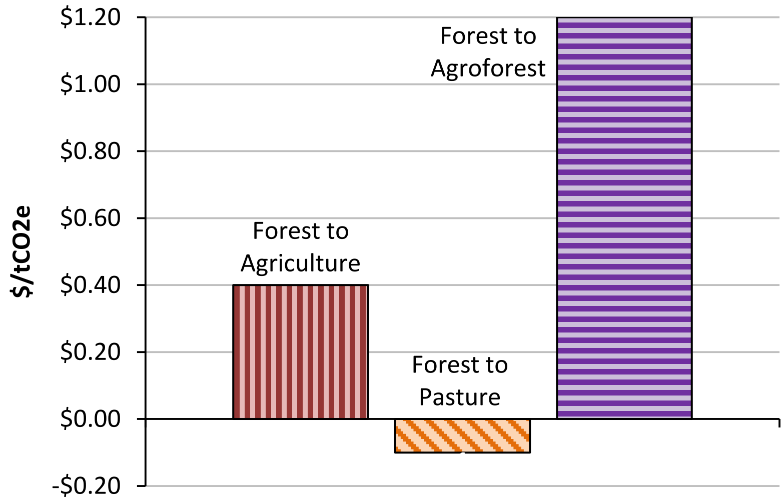


Figure 1.4. Example opportunity costs of three land use changes

Tradeoffs within a national landscape

51. People use land in many ways. Table 1.1 presents eleven categories of land use with their respective estimates of carbon stock, profits and rural employment. These land uses are representative of many tropical countries and can be adjusted to match predominant land uses.

52. Land uses with trees tend to have higher carbon, but with lower profits and employment. Throughout this training manual, these eleven land use categories and associated estimates will be used to illustrate how to estimate opportunity costs of REDD+ policies and their associated effects on countries, economic sectors and citizens.

Table 1.1. Example carbon, profits and employment of land uses, Peruvian Amazon

Land use	C stock time-averaged (tC/ha)	CO_2e stock time-averaged (tCO2e/ha)	Profitability (NPV*, $/ha)	Rural employment (workdays/ha/yr)
Natural forest	250	918	31	5
Logged forest	200	734	300	15
Heavily logged forest	120	440	500	25
Agroforest 1	80	294	300	120
Agroforest 2	60	185	120	100
Cocoa	50	147	604	135
Oil palm	40	183	245	84
Improved pastures	3	11	618	7
Low-productivity pastures	2	7	336	5
Agriculture 8yr fallow	5	18	302	27
Agriculture 3yr fallow	3	11	409	43

* Estimated using a 5% discount rate.

Sources: Palm, et al. 2004; White, et al. 2005.

53. To illustrate a wide range of carbon-profit relationships, Figure 1.5 plots eleven land uses of Indonesia according to their C stocks and NPV profits. Most of the land uses fall along a tradeoff arc (green line) ranging from high profitability with low carbon stocks to low profitability with high carbon stocks. The graph also identifies the landscape average (average C stock and average NPV).

54. A few points in the lower left corner (red circle) represent low level conditions of C stock ***and*** profit, such as low-productivity pastures. Converting these low carbon – low profit lands into more profitable land uses could be a feasible and attractive REDD+ policy priority.

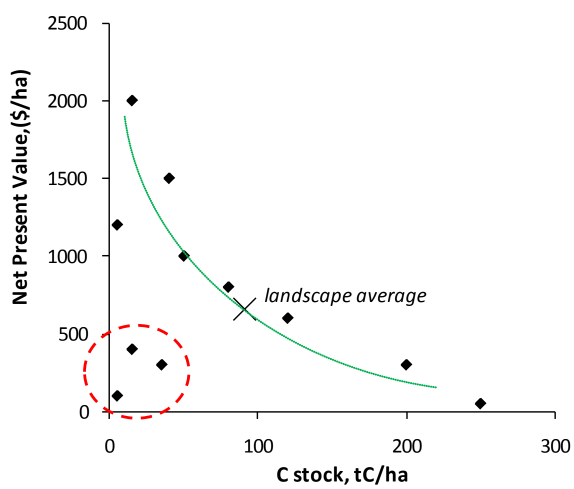


Figure 1.5. Tradeoffs and low-level conditions of NPV profit and carbon stocks

Source: Swallow, et al. 2008.

What is an abatement cost curve?

55. An abatement cost curve compares the quantity of potential emission reductions with their costs (i.e., opportunity, implementation and transaction). The vertical axis represents the abatement cost of the emissions reduction option (in monetary units per tCO_2e), while the horizontal axis depicts the corresponding quantity of reduction (often measured in million tCO_2e per year).

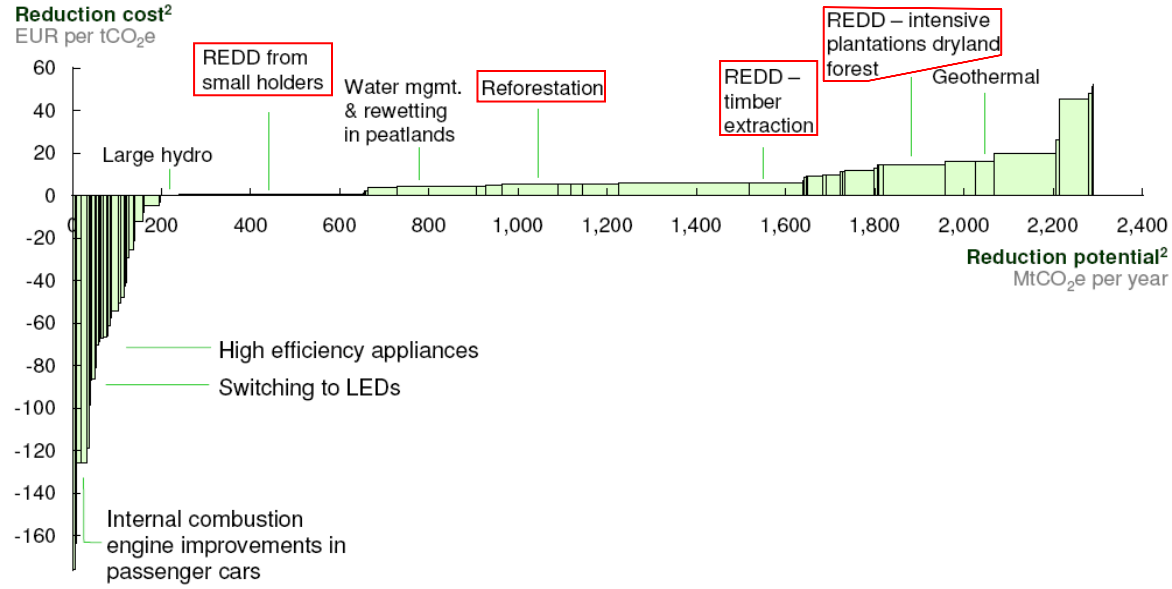
56. Besides representing potential REDD+ transactions, an abatement cost curve also helps to:

- summarize the attractiveness and feasibility of REDD+ options in a given region or country,
- clarify potential gains from REDD+ carbon trading.

57. Abatement, and opportunity, costs can be estimated at different levels: sub-national, national, and global, depending upon the scale of a REDD+ program. Figure 1.6 is a supposed example of a national abatement cost curve, for Indonesia, which includes abatement costs from both agricultural and industrial activities. Nevertheless, this "abatement cost curve" only considers direct, on-site opportunity costs (Dyer and Counsell, 2010). The fact that such a widely shared and well-publicized analysis is not actually of REDD+ abatement costs highlights the importance of reviewing methodological assumptions. Despite actual abatement costs being higher, arising from implementation and transactions costs, the graph is useful for illustrative purposes.

58. Reduction options associated with REDD+ are highlighted by red boxes. Their relative contribution is measured by the width of the respective bars. For example, abatement of forest conversion to smallholder agriculture would reduce emissions by approximately 250 $MtCO_2e$ per year, whereas avoiding timber extraction would reduce about 90 Mt CO_2e per year. Reforestation could reduce emissions by approximately 100 $MtCO_2e$ per year (Dewan Nasional Perubahan Iklim and McKinsey & Co., 2009).

59. The differences in opportunity costs can be substantial. The vertical height of each bar represents the cost of each option. While reducing forest conversions to low productivity slash-and-burn agriculture is estimated to cost less than €2 per tCO_2e, the opportunity cost of reforestation is approximately €10 per tCO_2e and reduced forest conversion to intensive agricultural production can cost over €20 per tCO_2e. Such cost differences affect feasibility of abatement options within national REDD+ programs.



1 Societal perspective implies utilizing a 4% discount rate

2. The width of each bar represents the volume of potential reduction. The height of each bar represents the cost to capture each reduction initiative

Figure 1.6. A national opportunity cost curve (Indonesia)

Source: Dewan Nasional Perubahan Iklim (National Council on Climate Change) and McKinsey & Co. 2009.

60. By representing both the amount of emission reduction and cost per type of land use change, an abatement cost curve (representing opportunity, implamentaion and transactions costs) can help answer the question: *what quantity of CO_2 emissions reduction may be possible at a carbon price of $X/$tCO_2e$?* It can also help to answer the question: *which emissions reduction options are attractive to the country at a carbon price of $X/$tCO_2e$.*

61. Opportunity costs can greatly differ per country and within countries. For example, the value of timber and agricultural activities depend upon numerous factors including market access, soil fertility and rainfall patterns. Production factors such as labor and machinery inputs also need to be taken into account when estimating costs.

62. To address these challenges, the manual provides a systematic approach to identifying and analyzing data required to estimate the opportunity costs of REDD+ programs. To illustrate the process, the training manual contains detailed presentations of methods and assumptions. Below is a summary of the goal, objectives and likely users of the manual.

Goal

Countries estimate opportunity costs of REDD+ to help guide national policy.

Objectives

1. To provide methods and tools to estimate the opportunity cost of forgoing land use changes and fostering enhancements of forest carbon at a national level,[16]
2. To document case study examples that enable professionals (governmental, university, non-governmental) to learn, adapt and use the analytical methods, interpret results, analyze different land use scenarios and identify optimal national REDD-related policies,

Likely users

National-level decision makers and planners involved in REDD+ policy and planning who want to be able to interpret and apply the results of opportunity cost studies in REDD+ national plans and international negotiations,

National practitioners and experts involved in studies of opportunity costs of REDD+ who want to understand how their own expertise (e.g., agricultural and forestry economics, forest ecology, geography, remote sensing, spatial analysis) contributes to estimating opportunity costs and associated REDD+ policy decisions.

63. Within this manual, we provide guidance on how to gather and analyze the necessary information to address questions of the economic viability and other decision criteria related to REDD+ programs at a national level. Such non-economic decision criteria include effects on biodiversity, water and livelihoods. Central to the analysis is the comparison of

[16] And also acknowledging and including the wide range of forests and other land use types found in those landscapes.

opportunity costs arising from preventing land use changes (e.g., forest to agriculture, forest to pastures), or fostering land use changes (e.g., degraded land to forest).

64. In order to inform national level decisions, the current land uses are identified throughout the country along with drivers of land use change. Since carbon and profit levels of all land uses can differ according to bio-physical (e.g., soil quality) and socio-economic (e.g., distance to markets) conditions, sub-categories of land uses are also identified. This also ensures accuracy of the information required to estimate REDD+ opportunity costs. With knowledge of the types of land uses, likely future changes in land use and the related opportunity costs, REDD+ programs planners can review the implications of reducing carbon emission per type and sub-national location of land use. The results from these analyses enables countries to become informed of the potential costs linked to REDD+ program commitments and thereby identify optimal national development strategies.[17]

Who else may be interested in opportunity costs?

65. The analytical methods and preparation plans within this manual can help to address a variety of questions arising from the concerns of people potentially affected by REDD:

A government policymaker

66. Trees make money when cut for timber; under REDD+, they can also make money when they remain standing. With carbon payment schemes such as REDD, tree carbon becomes an internationally-traded commodity like lumber. Much of our national economy, however, depends on cutting trees. Timber companies create jobs and benefit nearby towns. If trees are not cut, such economic activities and growth would not happen.

- What would be the cost to our country and to our citizens of avoiding deforestation?
- How big would the cost be, and who would bear it?

An environmental conservation investor

67. We want to conserve lands and defend forests from being cleared. The value of carbon in these landscapes may be a good incentive to protect forests and watersheds and to restore degraded lands.

- What are the conservation costs, including opportunity costs, of different lands?
- How can environmental benefits from forests, such as biodiversity and water, affect decisions about REDD?

[17] Optimal is defined as having the most positive qualities, with respect to national objectives. Objectives can be numerous, including economic, social, cultural and environmental considerations.

A logger, agri-business person, smallholder farmer, rancher

68. REDD+ programs will impact how I earn my living from the land. My livelihood depends on cutting trees clearing forest.

- How much should I be ask to be compensated?

69. The concept of REDD+ is based on the belief that forests can help mitigate climate change *only if* their protection is viable and attractive within national development strategies. Therefore, as countries advance REDD+ preparations, an analysis of future costs and benefits of these programs is needed to inform both national and international policy decisions. The next section outlines the different approaches used in opportunity cost analysis.

Box 1.2. Managing big numbers used with C accounting

Since REDD+ at national or global scale addresses large quantities of carbon, the scientific notation frequently used can be unfamiliar and confusing. Even more confusing is that sometimes (particularly in the scientific literature) mass is expressed in terms of grams not tons (e.g., 1t = 1Mg). The below table summarizes the common notation.

Useful scientific notation for weight measures

Prefix	Abbreviation	Scientific notation	Equivalent Value
-	t	10^0	1000 kg
kilo	kt	10^3	1,000t
mega	Mt	10^6	1,000,000t
giga	Gt	10^9	1,000,000,000t
tera	Tt	10^{12}	1,000,000,000,000t
peta	Pt	10^{15}	1,000,000,000,000,000t

Current state-of-the-art in REDD+ opportunity cost analysis

70. Despite intense efforts of including REDD+ within climate change negotiations, relatively little is known about the opportunity costs of REDD. Existing studies can be divided into three distinct groups (Boucher, 2008b):

- **Global models**: a top-down approach, based on dynamic economic models.
- **Regional-empirical models:** a bottom-up approach, which relies on detailed empirical analysis of the tradeoffs between economic profits and carbon associated with land use change.
- **Area-based models**: a per area approach, using a synthesis of sub-national and global analyses to generate global estimates.

71. The studies differ in the type of questions addressed. The top-down and per area approaches emphasize estimating amounts of global emission reductions at specific opportunity costs. In contrast, the bottom-up approach (presented in this training manual) is typically used for estimating the opportunity costs of specific land use changes. Within a REDD+ preparedness context, the bottom up approach answers the question from the country perspective. All approaches employ a series of distinct methodological and data assumptions.

Top-down approach (global models)

72. Top-down approaches evaluate REDD+ economic potential from aggregate economic variables. Three research groups have produced the most frequently cited studies: Ohio State University, the International Institute for Applied Systems Analysis in Austria (IIASA), and the Lawrence-Berkeley National Laboratory.

73. Kindermann, et al. (2008) and Boucher (2008b) summarize the methods and assumptions of the top-down studies. The analytical models share a common approach, based on the opportunity costs of different land uses. The models differ, however, in many of their details, for example: the economic sectors included, how dynamics of the world economy (e.g., forest, agriculture and energy sectors) are simulated, spatial divisions of the globe and the interest rates applied. In addition, the models are based on different data sets, such as the distribution of carbon densities in world forests and rates of deforestation.

74. The Ohio State studies apply the Global Timber Model (GTM) – a dynamic model that calculates optimal area, tree age class, and management regime for 250 classes of forestlands worldwide (Sohngen, et al., 1999; Sohngen and Mendesohn, 2003). The GTM model assumes that forest lands are managed for timber production; it does not explicitly consider alternative land uses. GTM generally assumes lower opportunity costs than the other two models, partly because GTM assumes profits from agriculture and higher C stocks on forest land.

75. The IIASA studies apply the Dynamic Integrated Model of Forestry and Alternative Land Use (DIMA). The DIMA model focuses on the allocation of land between forestry, grazing and agriculture. The model predicts that deforestation will occur where land value in other uses is higher than in forest, and that afforestation will occur where land value in forestry is higher than in other land uses. The resolution of results from the DIMA model are based on 0.5° grid cells (~56x56 km at near the equator).

76. The Lawrence Berkeley laboratory studies use the Generalized Comprehensive Mitigation Assessment Model (GCOMAP). GCOMAP is a dynamic partial equilibrium model that analyzes afforestation in short- and long-term tree species and reductions in deforestation in ten regions of the world.

77. Limitations and uncertainties of global modeling efforts include:

- Use of average carbon stock estimates,
- Estimates of forest extent in each region based on imprecise data,
- Simplistic modeling of land use change (e.g., one type of forest to one type of agriculture),
- Only timber production considered to determine forest value,
- Lack of country-specific economic data.

Strengths of the global modeling efforts, include:

- explicit assumptions about future conditions shaping timber models (e.g., population pressure)
- explicit consideration of REDD+ policy effects on timber prices.

78. The three global models produce an array of results (Figure 1.7). Results generally reflect the higher productivity and value of agricultural activities in Asia and Latin America. With a scenario of reducing emissions from deforestation by 50% between 2005 and 2030, opportunity cost estimates range from a low of \$1.7/tCO_2e in Latin America (GTM) to \$38/tCO_2e in Asia (GCOMAP). The mean opportunity costs for Africa, the Americas and Asia were respectively US\$2.22, US\$2.37 and US\$2.90/tCO_2e. Differences across the continents, however, were not statistically significant (Kindermann, 2008).

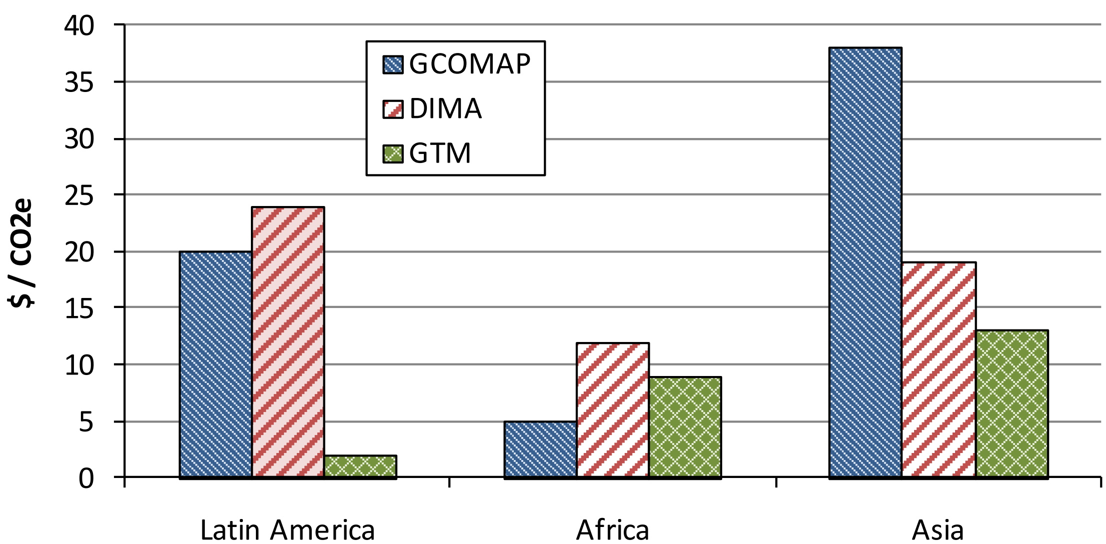


Figure 1.7. Carbon price needed to reduce deforestation by 50% in 2030

Source: Kindermann, 2008.

Bottom-up approach (regional-empirical models)

79. Bottom-up studies are based on sub-national, on-the-ground, empirical data. Both estimates of carbon density (ton/ha) and per-area opportunity cost (\$/ha) are specific to particular regions or time periods. Thus, opportunity cost estimates depend on the availability and quality of local information.

80. Over twenty of these studies estimate a few land use changes, not complete supply curves (Boucher, 2008b). Much of the empirical base for the opportunity cost analysis in this manual was generated in the context of the Alternatives to Slash and Burn program (ASB). Swallow, et al. (2007) present sub-national opportunity cost curves for ASB sites in Indonesia, Peru and Cameroon. Such studies generate detailed cost curves based on detail field research thus requiring fewer assumptions than global models.[18] Nevertheless, bottom-up approaches do not necessarily take into account global feedback relationships that would change prices (e.g., food and timber), and thus costs as a REDD+ system develops (Boucher, 2008b).[19]

81. Börner and Wunder (2008) used a municipal-level methodology based on official Brazilian land-use statistics in a pilot analysis for two federal states. Including additional data sources (e.g., profit rates for land use categories, simulated future deforestation scenarios, etc.), the approach was extended to the entire Brazilian Amazon (Börner, et al., 2010).

Per area approach (area-based models)

82. The Grieg-Gran (2006) study within the Stern Review is an area-based synthesis of data and analysis from eight countries representing the majority of tropical forest (Brazil, Bolivia, Cameroon, Democratic Republic of the Congo, Ghana, Indonesia, Malaysia, and Papua New Guinea). The approach has a disadvantage of low resolution, thereby limiting its use at sub-national level. Furthermore, the opportunity cost estimates lack corresponding carbon density estimates, despite sub-national estimates opportunity cost information ($/ha) being used to estimate a global per-area cost of reducing deforestation.[20] The midpoint (US$3.48/tCO2e) of the estimates was 36% higher than the mean of the local estimates of the bottom-up approach, due in part to no spatial variation of carbon density. The approach, however, permits data on per-area opportunity costs to be used for regions where no per-ton carbon costs exist (Boucher, 2008b). [21]

83. Strassburg et al. (2008) conducted a similar study with data from 20 countries. The "field approach" used FAO data on forest area and past deforestation rates. Combined with global and regional biomass models and data, the analysis estimated carbon content per hectare for each country. Two different approaches were used to estimate profits from land uses. Recent field data from the top 8 developing countries by annual deforested area were

[18] Borner and Wunder (2008) base their analyses largely on official government statistics, possible in Brazil because of their availability.

[19] The effect of changing prices and costs can be addressed with sensitivity analysis (Module T).

[20] Termed *global-empirical models* by Wertz-Kanounnikoff, 2008.

[21] To convert estimates based on area ($/ha) to emissions ($/Co2e), Boucher (2008b) used a conversion factor for mean carbon density: 3.94 billion tCO_2 of emissions from 10.1 million hectares deforested, from Strassburg, et al. (2008).

used to estimate a general relationship between deforestation and opportunity costs that was then applied to the forest data of each of the 20 countries.

84. In the other approach, a recent GIS-referenced global map of potential economic returns from agriculture and pasture (Figure 1.8; Naidoo and Iwamura, 2007) was overlaid with GIS referenced global databases of spatial distribution of deforestation. Results show that at very low opportunity cost[22] (~US$5.5/t), a mechanism could reduce 90% of global deforestation (Strassburg et al. 2008).

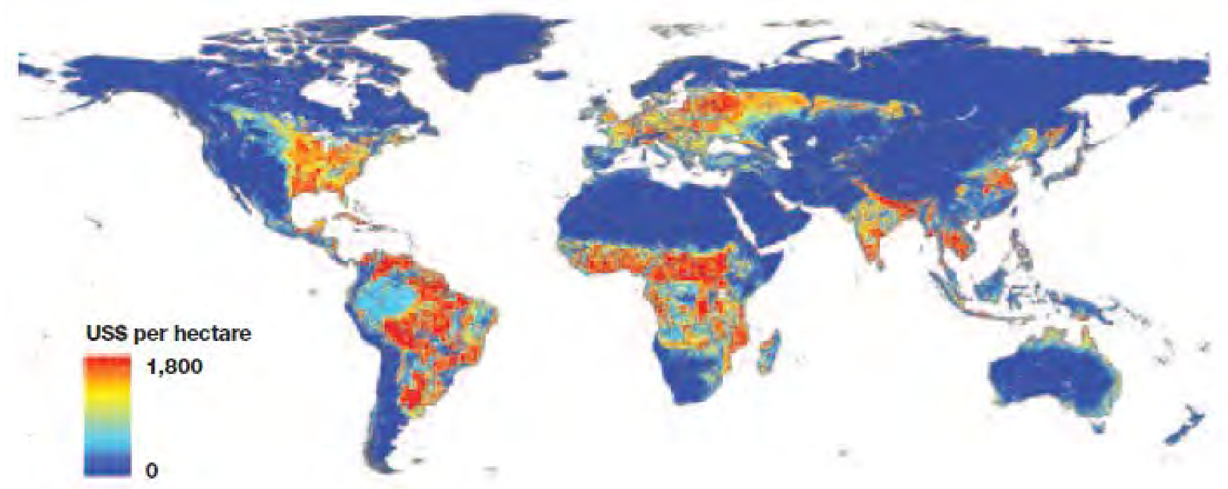


Figure 1.8. Agricultural returns per ha

Source: Sukhdev (2008) from Strassburg, et al. (2008) based on data from Naidoo & Iwamura (2007).

Three approaches compared

85. Figure 1.9 summarizes the results of the three approaches. A review of sub-national opportunity cost analyses reveals a mean opportunity cost of US$2.51/t$CO_2$e, with 18 of the 29 estimates at less than US$2. Per area estimates conclude that in order to reduce global deforestation by 46 percent, opportunity costs range from US$2.76 to US$8.28/tCO_2e. Associated investments required to achieve such decreases range from US$5 to 15 billion per year. The global models produce much higher estimates of the costs of reduction than either the sub-national, empirical estimates or the area-based estimates of the Stern Review. Estimates from global models include the effects of local and global price changes arising from altered forest and agricultural activities (Boucher, 2008b).

[22] Since other costs of REDD+ were not considered, the original phrasing of *$C0_2e$ prices* is more like an opportunity cost.

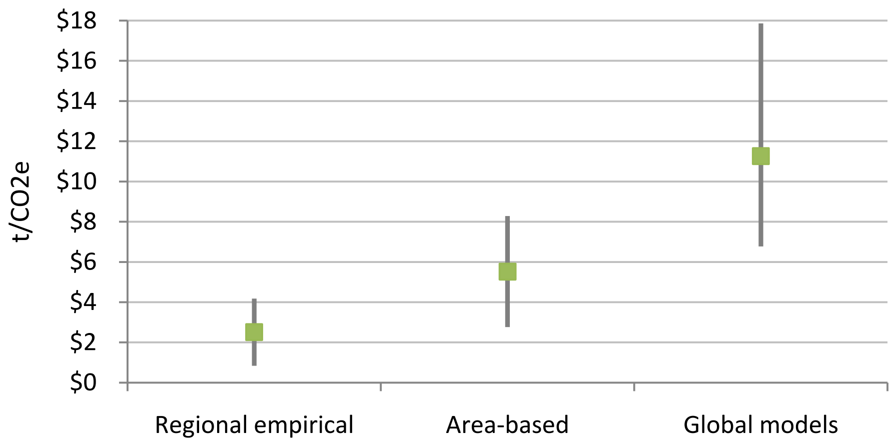


Figure 1.9. Mean estimates of opportunity cost approaches (and high-low range)

Source: Boucher, 2008b.

86. In addition to the differences in opportunity cost per type of emission reduction, costs can increase significantly if all deforestation in a region is to be stopped. With the global models, smaller reductions in emissions are less costly. A 10% reduction over the same period would cost only US$ 1 to 8/tCO_2e. In Brazil, Nepstad et al. (2007) estimated that eliminating 94% of emissions from deforestation and forest degradation would cost $0.76 per t$CO_2$e. Costs to eliminate 100% would be nearly double ($1.49 per t$CO_2$e).

87. For the purposes of generating national-level analysis of REDD+ opportunity costs, the bottom-up approach is recommended. Opportunity cost estimates are not only based on local information but will also easily fit within analytic frameworks developed by the IPCC for land use change (IPCC, 2003) and national inventories of greenhouse gases (IPCC, 2006). Furthermore, individual countries considering participating in a REDD+ require information on what it would cost them to reduce emissions from deforestation, forest degradation, and reforestation. Estimates of global costs provide little assistance. Similarly, the average approximations of large-scale analyses do not reflect the potentially wide range in conditions found within a country (Pagiola and Bosquet, 2009).

88. The next chapter provides an overview of the training manual contents and the process of estimating REDD+ opportunity costs.

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