Estimating the opportunity costs of REDD+

A training manual

Version 1.3

Chapter 11. Appendices

Contents

Appendices

A. Glossary

Definitions to important words and terms:

Above ground biomass. Biomass above the soil surface: trees and other vegetation.

Accounting stance. The viewpoint from which costs and benefits are calculated. Typical accounting stances for analyzing REDD+ initiatives are that of: an entire country, individual groups within a country, the government, and global community.

Additionality. The reduction in emissions by sources or enhancement of removals by sinks attributable to a project/program activity.
(Modified from Climate Change 2001: Mitigation. http://www.grida.no/climate/ipcc_tar/wg3/454.htm).

Allometric equation. Scaling rule or equation that relates tree biomass (or similar properties) to stem diameter and/or tree height.

Attribute table. A database or tabular file with information linked to distinct features shown on maps; can refer to points, lines or polygons in a vector GIS or grid cells in a raster GIS.

Basal area. the cross section area of a tree stem in square cm commonly measured at breast height inclusive of bark (3.14 x radius^2)

Baseline. A reference scenario, the basis for comparison, against which a change in carbon stock/greenhouse gas emission or removal is measured (IPCC Special Report on Land Use, Land Use Change and Forestry. http://www.ipcc.ch/pdf/special-reports/spm/srl-en.pdf).

Below ground biomass. Biomass below the soil surface: plant roots and other soil biota.

Biomass. The total mass of living organisms including plants and animals for a given area usually expressed as dry weight in g m^{-2} or kg ha^{-1}. Organic matter consisting of or recently derived from living organisms (especially regarded as fuel) excluding peat. Includes products, by-products and waste derived from such material.

For most ecological research and for the purposes of this manual, "biomass" is a vegetation attribute that refers to the weight of plant material within a given area. Another commonly used term for biomass is "production" which refers to how much vegetation is produced in an area.

Capital. Also known as financial capital. Money and savings.

Carbon budget. The balance of the exchanges of carbon between carbon pools or within one specific loop (e.g., atmosphere –biosphere) of the carbon cycle.

Carbon dioxide equivalent. A measure used to compare different greenhouse gases based on their contribution to radiative forcing. The UNFCCC (2005) uses global warming potentials (GWPs) as factors to calculate carbon dioxide equivalent.

Carbon stocks. Total carbon stored (absolute quantity) in terrestrial ecosystems at a specific time, as living or dead plant biomass (above and below-ground) and in the soil, along with usually negligible quantities as animal biomass. The units are Mg ha^{-1}.

Carbon pool. A reservoir or subsystem which has the capacity to accumulate or release carbon. Examples of carbon pools are forest biomass, wood products, soils and the atmosphere. The units are mass (kg ha^{-1} or Mg ha^{-1}).

Carbon sequestration. The process of increasing the carbon content of a carbon pool other than the atmosphere.

Charcoal . Blackish residue, porous, consisting of impure carbon (about 85-90% C) obtained by removing water and other volatile constituents of animal and plants substances. It is usually produced by heating wood in the absence (or at low levels) of oxygen.

Classification system. A framework to arrange objects into groups, called classes, on the basis of characteristics. Classifications are based on criteria used to distinguish classes and the relationship between them. The definition of class boundaries should be clear, precise, possibly quantitative, and based upon objective criteria (FAO LCCS handbook, 2000).

Country-specific data. Data for either activities or emissions that are based on research carried out on sites either in that country or otherwise representative of that country.

Discount rate. A rate reflecting a time-preference at which the value future profits are reduced in a multi-period analysis.

Emissions. The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time (UNFCCC Article 1.4).

Enterprise budget. A detailed accounting of revenues and expenses related to a business (e.g. land use) activity.

Good Practice. A set of procedures intended to ensure that greenhouse gas (GHG) inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are quantified and reduced so far as possible. *Good Practice* covers choice of estimation methods appropriate to national circumstances, quality assurance and quality control at the national level, quantification of uncertainties and data archiving and reporting to promote transparency.

Ground truth. A remote sensing term referring to the actual condition of the Earth surface as determined by field visits.

Land cover. The classification of the biophysical surface of the Earth, comprising vegetation, soils, rocks, water bodies and areas built by humans.

Land use (LU). The classification of human activities, occupation and settlement of the land surface; e.g., annual crops, tree crops, plantations, urban, conservation area, etc.

Land use legend. The key to features in a classification system on a map, expressing each class as distinct colors, patterns or descriptions. In this manual, classes and sub-classes in a land cover legend to are matched with LUs.

Land use classification system. A framework for organizing land uses according to characteristics that differentiate them and make them unique (forests, agriculture, pastures, urban, etc)

Land use system (LUS). Dynamic characteristics and interactions in activities across space and time on the Earth surface. The word *system* refers to sequential cyclical changes that are part of a land use, such as the crop/fallow rotation in shifting cultivation systems. For the sake of brevity, the term *land use* is employed throughout the manual

Landscape. A non-exact area of land. A portion of land or territory which the eye can comprehend in a single view, including all the objects it contains.

Leakage. Changes in emissions and removals of greenhouse gases outside the accounting system that result from activities that cause changes within the boundary of the accounting system. There are four types of leakage: activity displacement, demand displacement, supply displacement, and investment crowding. If leakage occurs, then the accounting system will fail to give a complete assessment of the true aggregate changes induced by the activity. (IPCC Special Report on Land Use, Land Use Change and Forestry. http://www.ipcc.ch/pdf/special-reports/spm/srl-en.pdf)

Minimum mapping unit (MUU). The smallest homogeneous area, or unit, that can be distinguished from remote sensing data and associated map. The MMU is dependent on the resolution of the imagery. Higher image resolution enables smaller, precise MMUs.

Mixed mapping unit. A mapping unit that represents a combination of LUS units. Because of insufficient spatial resolution, units are combined into a class that represents two or more land covers or land uses.

Mortality/ Tree mortality. Dead trees per area.

Necromass or **Dead Organic Matter.** The weight of dead organisms, usually expressed as g m^{-2} or kg ha^{-1}. Necromass consists mainly of plant litter. It is usually on the soil surface or in the soil, but some may take the form of standing or attached dead material. Much of the transient or lag in response to rapid climate change by forest ecosystems can be estimated by the difference between tree regeneration (tree natality) and tree mortality. Annual necromass increments result from individual tree mortality within stands and from larger-scale disturbance and dieback events (fires, insect infestations, disease infestations, wind throw). In addition, a significant portion of the carbon stocks which comprise stored terrestrial carbon of forest and non-forest communities is in the form of necromass.

Net present value (NPV). The present value of an investment's future net cash flows minus the initial investment.

Net returns. See profit.

Organic matter (or **organic material**). Matter that has come from a once-living organism; is capable of decay, or the product of decay; or is composed of organic compounds.

Peatland. Peatland is the land rich in partly decomposed plant remains, with organic C of >18% and thickness of >50 cm. Peatland is intrinsic to many wetlands around the world. The tropical peat is about 1 to 7 m thick and at places it can be 20 m thick. Moss, grass, herbs, shrubs and trees may contribute to the buildup of organic remains, including stems, leaves, flowers, seeds, nuts, cones, roots, bark and wood. Peat forms in wetlands or peatlands, variously called bogs, moors, muskegs, pocosins, mires, and peat swamp. Through time, the accumulation of peat creates the substrate, influences ground-water conditions, and modifies surface morphology of the wetland.

Permanence. The longevity of a carbon pool and the stability of its stocks, given the management and disturbance environment in which it occurs. http://www.ipcc.ch/pdf/special-reports/spm/srl-en.pdf

Profit. Net returns, or revenues minus costs.

Raster GIS. represents the Earth surface as a grid of cells of uniform area, each holding information on characteristics of its respective geographic area; useful for continuous data such as satellite imagery or climate and elevation surfaces.

Removals. Removal of greenhouse gases and/or their precursors from the atmosphere by a sink.

Rent. Also known as economic rent or producer surplus. The value that producers obtain when actual price exceeds the minimum price sellers will accept. In a REDD+ context, rent is the different between the international price of carbon and REDD+ costs.

Resolution. See spectral and spatial.

Sink. Any process, activity or mechanism which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere. (UNFCCC Article 1.8). Notation in the final stages of reporting is the negative (-) sign.

Soil organic matter (SOM). Mass of soil organic matter in a unit dry mass of soil. It's often expressed in % by weight.

Soil organic carbon. Mass of carbon in a unit dry weight of soil, often expressed in % by weight. Unless measured directly, soil organic carbon is assumed 1/1.724 of soil organic carbon.

Soil bulk density. Oven-dry mass of soil in a unit volume of bulk soil (including the volumes of solid soil and soil pores).

Source. Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere (UNFCCC Article 1.9). Notation in the final stages of reporting is the positive (+) sign.

Spectral resolution. Refers to the capacity of airborne or satellite remote sensing systems to detect surface features across a range of the electromagnetic spectrum. High spectral resolution generally improves the capacity to characterize the surface.

Spectral signature. The unique way in which a given type of land cover reflects and absorbs light.

Spatial resolution. The size of pixels or grid cells that represent areas on the Earth surface. High spatial resolution permits the identification of more detailed objects on the surface.

Standing litter. The amount of litter weight at a given time. Usually refers to the amount of litter found at soil surface.

Understory. Any plants growing under the canopy formed by other plants, particularly herbaceous and shrub vegetation under a tree canopy.

Vector GIS. represents geographic features on digital maps as points, lines or polygons.

Wood density. Wood density is the oven-dry weight of a given volume of wood, usually expressed as kg dm^{-3}.

Wetland. Land where an excess of water is the dominant factor determining the nature of soil develop.

B. Required capacities for a national monitoring system of emissions

Table 11.1. Capacities required per phase

Phase	Requirement	Capacities
Planning and design	1. Forest monitoring system as part of a national REDD+ implementation strategy	• Knowledge of international UNFCCC process on REDD+ and of guidance for monitoring and implementation • Knowledge of national implementation strategy and objectives for REDD+
	2. Assessment of existing national forest carbon monitoring framework and capacities, and identification of gaps in existing data sources	• Understanding of estimation and reporting guidance provided in the IPCC *Good Practice Guide* and any other relevant guidance under the Convention • Synthesis of previous national and international reporting, if any (i.e. national communications and the Food and Agriculture Organization of the United Nations Forest Resources Assessment) • Expertise in estimating terrestrial carbon stocks and related human induced changes, and monitoring approaches • Expertise to assess usefulness and reliability of existing capacities, data sources and information
	3. Design of a forest carbon monitoring system driven by UNFCCC reporting requirements, with objectives for historical period and future monitoring	• Detailed knowledge of the application of methodologies in the IPCC *Good Practice Guide* and any other relevant guidance under the Convention • Agreement on definitions, reference units, and monitoring variables and framework • Institutional framework specifying roles and responsibilities • Capacity development and long-term improvement planning • Cost estimation for establishing and strengthening institutional framework, capacity development, and actual operations and budget planning
Data collection and monitoring	4. Forest area change assessment (activity data)	• Reviewing, consolidating and integrating the existing data and information • Understanding of deforestation drivers and factors, and management practices • If historical data records are insufficient, particularly with the use of remote sensing, the following capacities are required: - Expertise and human resources in accessing, processing and interpretation of multi-date remote sensing imagery for forest area changes - Technical resources (hardware/software, Internet, image database) - Approaches for dealing with technical challenges (i.e. cloud cover, missing data)
	5. Changes in carbon stocks (emission factors)	• Understanding of human-induced processes influencing terrestrial carbon stocks • Consolidation and integration of existing observations and information, that is, national forest inventories or permanent sample plots involving: - National coverage and stratification of forests by carbon density and threat of change - Conversion to carbon stocks & estimates of carbon stock change • Technical expertise and resources to monitor carbon stock changes, including:

		- In situ data collection of all the required parameters, and data processing - Human resources and equipment to carry out fieldwork (vehicles, maps of appropriate scale, global positioning system, measurement units) - National inventory & sampling (sample design, plot configuration) - Detailed inventory of areas of forest change or REDD+ action. - Use of remote sensing (stratification, biomass estimation) • Estimation at sufficient IPCC tier for: - The estimation of carbon stock changes due to land-use change - The estimation of changes in forest land remaining forest land - The consideration of the impact on five different carbon pools
	6. Emissions from biomass burning	• Understanding of national fire regime and related emissions of different greenhouse gases • Understanding of slash slash-and and-burn cultivation practices and knowledge of the areas where this is being practiced • Fire monitoring capabilities to estimate areas affected by fires caused by humans and associated emission factors • Use of satellite data and products for active fire and area burned • Continuous in situ measurements (particularly emission factors) • Separating fires leading to deforestation from degradation
	7. Accuracy assessment of activity data and uncertainty analysis of emission factors	• Understanding of sources of error and uncertainties uncertainty in the assessment process of both activity data and emission factors, and how errors propagate • Knowledge of the application of best efforts using appropriate design, accurate data collection processing techniques, and consistent and transparent data interpretation and analysis • Expertise on the application of statistical methods to quantify, report and analyze uncertainties for all relevant information (i.e. area change, change in carbon stocks, etc.) using, ideally, a higher-quality sample
Data analysis	8. National greenhouse gas information system	• Knowledge of techniques to gather, store, archive and analyze data on forests and other data, with the emphasis on carbon emissions and removals from changes in forest area • Data infrastructure, information technology (suitable hardware/ software) and human resources to maintain and exchange data, and quality control • Data access procedures for (spatially explicit) information presented in a transparent form
	9. Analysis of drivers and factors of forest change	• Understanding and availability of data for spatial-temporal processes affecting forest change, socio-economic drivers, spatial factors, forest management and land-use practices and spatial planning • Expertise in spatial and temporal analysis and use of modeling tools
Reference emission levels	10. The establishment of reference levels of emissions, which is regularly updated	• Data and knowledge of processes relating to REDD+ , associated greenhouse gas emissions, drivers and expected future developments • Expertise in spatial and temporal analysis and modeling tools • Specifications for a national implementation framework for REDD+
Reporting	11. National and international reporting and verification	Consideration of uncertainties and understanding procedures for independent international review and verification

Source: UNFCCC, 2009.

C. Allometric equations

Table 11.2. Tropical allometric equations

Note: BA= basal area

General classification	Species	Group Equation	Source	Data originating from	Max dbh
Dry (900–1500mm rainfall)	General	Biomass = 0.2035 x $dbh^{2.3196}$	Brown (unpublished)		63cm
Dry (< 900mm rainfall)	General	Biomass = $10^{(-0.535+log10basal\ area)}$	Brown (1997)	Mexico	30cm
Moist (1500–4000mm rainfall)	General	Biomass = exp(-2.289+2.649 x lndbh-0.021 x $lndbh^2$)	Brown (1997, updated)		148cm
Wet (> 4000mm rainfall)		Biomass = 21.297 – 6.953 x dbh+ 0.740 x dbh^2	Brown (1997)		112cm
Cecropia	*Cecropia* species	Biomass = 12.764 + 0.2588 x $dbh^{2.0515}$	Winrock	Bolivia	40cm
Palms	Palms (*motacu*)	Biomass = 23.487 + 41.851 x $(ln(height))^2$	Winrock	Bolivia	11m height
Lianas	Lianas	Biomass = exp(0.12+0.91 x log(BA at dbh))	Putz (1983)	Venezuela	12cm

Source: Pearson, et al., 2005.

Table 11.3. Agroforestry allometric equations

Note: BA = basal area.

General classification	Species	Group Equation	Source	Data originating from	Max dbh
Agroforestry Shade Trees	All	Log10Biomass = -0.834 + 2.223 (log10dbh)	Segura et al.	Nicaragua	44cm
Agroforestry Shade Trees	*Inga spp.*	Log10Biomass = -0.889 + 2.317 (log10dbh)	Segura et al.	Nicaragua	44cm
Agroforestry Shade Trees	*Inga punctata*	Log10Biomass = -0.559 + 2.067 (log10dbh)	Segura et al.	Nicaragua	44cm
Agroforestry Shade Trees	*Inga tonduzzi*	Log10Biomass = -0.936 + 2.348 (log10dbh)	Segura et al.	Nicaragua	44cm
Agroforestry	*Juglans olanchama*	Log10Biomass = -1.417 + 2.755 (log10dbh)	Segura et al.	Nicaragua	44cm
Agroforestry Shade Trees	*Cordia alliadora*	Log10Biomass = -0.755 + 2.072 (log10dbh)	Segura et al.	Nicaragua	44cm
Shade grown	*Coffea arabica*	Biomass = exp(-2.719 + 1.991 (ln(dbh))) (log10dbh)	Segura et al.	Nicaragua	8cm
Pruned coffee	*Coffea arabica*	Biomass = 0.281 x $dbh^{2.06}$	van Noordwijk et al. (2002)	Java, Indonesia	10cm
Banana	*Musa X paradisiaca*	Biomass = 0.030 x $dbh^{2.13}$	van Noordwijk et al. (2002)	Java, Indonesia	28cm
Peach palm	*Bactris gasipaes*	Biomass = 0.97 + 0.078 x BA – 0.00094 x BA^2 + 0.0000065 x BA^3	Schroth et al. (2002)	Amazonia	2–12cm
Rubber trees	*Hevea brasiliensis*	Biomass = -3.84 + 0.528 x BA + 0.001 x BA^2	Schroth et al. (2002)	Amazonia	6–20cm
Orange trees	*Citrus sinensis*	Biomass = -6.64 + 0.279 x BA + 0.000514 x BA^2	Schroth et al. (2002)	Amazonia	8–17cm
Brazil nut trees	*Bertholletia excelsa*	Biomass = -18.1 + 0.663 x BA – 0.000384 x BA^2	Schroth et al. (2002)	Amazonia	8–26cm

Source: Pearson, et al., 2005.

D. Steps to calculate time-averaged carbon stock: from plot to land use

Main output: Time-averaged C stock per land use (Mg ha^{-1}).

For monoculture systems

- Select plots of different ages of trees.
- **Tree level**: Measure trees by following the sample protocol/methods in Hairah et al, 2010. Calculate tree biomass by using the right allometric equation by species if possible, using the criteria described in this module.
  Output 1: Biomass per tree (Kg), extrapolate to Mg C ha^{-1}
  Output 2: Root biomass estimated using default value 4:1 (shoot/root ratio)
  Output 3: C biomass (Output 1 + Output 2) x 0,46 = C (Mg C ha^{-1})
- **Plot level**: Measure necromass and soil organic matter as explained in Hairah et al, 2010.
  Output 4: C Necromass (Mg ha^{-1}) x 0,46 = C (Mg C ha^{-1})
  Output 5: C Soil organic matter (Mg ha^{-1}) x 0,47 = C (Mg C ha^{-1})
- Sum up outputs 3, 4 and 5 to calculate total C stock per hectare. (Mg ha^{-1})
- **Land use:** Develop the total C stock equation for the monoculture per life cycle (see Figure 2-1). Find the value of the median C stock. This is the time-averaged C stock for the species (in the monoculture).

For a Mahogany plantation

Example: 20 trees of mahogany of different ages (5, 15, 25 and 30 years old) are found in one plot of 200m^2 of land use type A. The farmer informed us that Mahogany is harvested when it is about 50 years old. What is the time-average C stock for Mahogany in this case?

Step 1. Use the most suitable allometric equation for Mahogany and calculate the biomass (Mg ha^{-1}) for each tree.
Step 2. Transform biomass to total C by multiplying it by 0,46. Calculate the value per hectare.
Step 3. Add the necromass and soil organic matter estimations to the biomass per hectare. Transform them to total C by multiplying them by 0,46.
Step 4. Calculate total C by age (biomass, necromass and soil organic matter).
Step 5. Calculate the total C regression curve for Mahogany-monoculture system as in Figure 11.1. Note that it includes biomass, necromass and soil organic matter for each age group.
Step 6. If the trees would be harvested when 50 years old as expressed by the farmer, then we take the median of total C calculated with the equation at year 25 as the time-average carbon stock for this monoculture. This value is about 150 Mg C ha^{-1}.

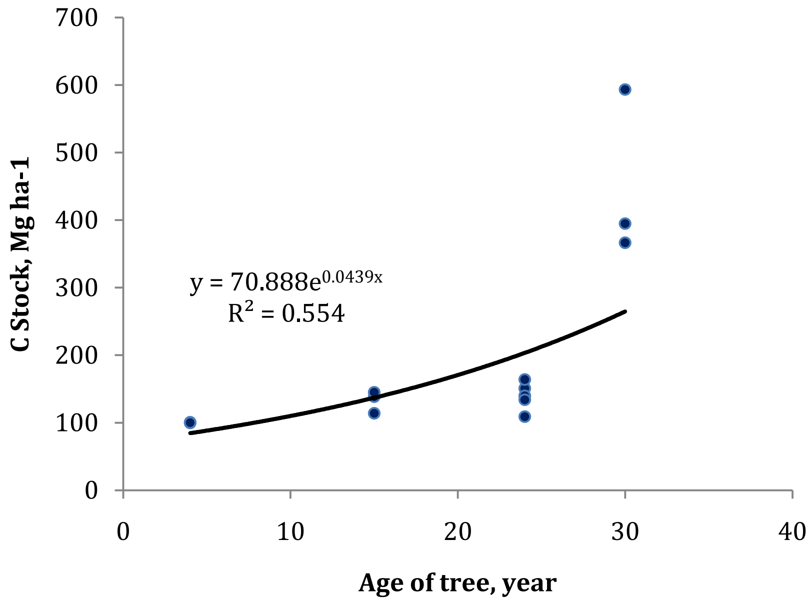


Figure 11.1. Carbon stock changes in Mahogany-monoculture system, East Java

For mixed systems such as agroforestry

- Select plots of different stages within the same land use after forest conversion.
- **Tree level:** Measure all trees within the sampling plot by following the sample protocol/methods in Hairah et al, 2010. Calculate tree biomass by using the right allometric equation by species if possible.
  Output 1: Biomass per tree (Kg per tree), extrapolate to (Kg ha^{-1})
  Output 2: Root biomass estimated using default value 4:1 (shoot/root ratio), (Kg ha^{-1})
  Output 3: C biomass (Output 1 + Output 2) x 0,46 = C (Mg C ha^{-1})
- **Plot level:** Measure necromass and soil organic matter as explained in Hairah et al, 2010.
  Output 4: C Necromass (Mg ha^{-1}) x 0,46 = C (Mg C ha^{-1})
  Output 5: C Soil organic matter (Mg ha^{-1}) x 0,46 = C (Mg C ha^{-1})
- **Land use level:** Sum up outputs 3, 4 and 5 to calculate total C stock per hectare in the mixed land uses per age of plot after forest conversion:
  - 3 years
  - 15 years
  - 40 years
- Calculate the average of total C stock of the three ages. This would be the time-averaged C stock of a mixed land use. The reason we do not use total C curves as per the monoculture case is the diversity of species and ages found in mixed systems.

For example: The total C in an agroforestry system of 3 year old is 15 Mg C ha^{-1}, for 15 year old is 40 Mg C ha^{-1} and 40 years old is 80 Mg C ha^{-1}. Time-averaged C stock would be (15+40+80)/3 = 45 Mg C ha^{-1}.

E. Methods to estimate the economic value of biodiversity

1. The Convention on Biological Diversity (CBD) recognizes the importance of economic valuation, and states that *economic valuation of biodiversity and biological resources is an important tool for well-targeted and calibrated economic incentive measures* (CBD, 1998). Economic valuation, based on sound theoretical foundations, can help clarify tradeoffs facing public policy decisions. Nevertheless, exceptions exist for prioritizing economic values over other cultural, traditional and spiritual values. Since numerous methodological limitations and moral questions regarding the rigor of economic valuation persist, non-economic values need to be recognized and addressed.

2. At the core of the debate are conflicting views regarding the concept of value. Philosophies clash. For some, the wants of the people are morally justified – costs may seem little or not even be considered. Priorities are to be identified through political process. For others, costs are relevant since they represent alternative use of funds. (Prioritization of alternative uses also has moral implications.) For people of such a perspective, priorities are best clarified through procedures such and benefit-cost analysis and multi-criteria analysis in order to inform decisions. Whichever viewpoint, a consensus prevails on the importance of conserving biodiversity while considering the associated costs (OECD, 2002).

3. Achieving cost-effectiveness is not straightforward. Conservation policies are often weighted down by attempts to deliver multiple outcomes. Two approaches are commonly used to identify priorities: (a) the use of money or price weights, which define benefit-cost relations, or (b) the calculation of scores, typically derived from experts or public opinion.

4. Both types of analysis produce measures to reveal the importance of biodiversity. Nevertheless, the determination of monetary values enables biodiversity conservation to compete on the same standardized basis against other demands for public funding. Below are outlined numerous approaches to estimate the economic value of biodiversity.

5. Despite the role of important economic measures, the participation of numerous stakeholders is often central to public decision-making processes. Deliberative and inclusive approaches that identify social preferences are an increasingly popular approach as governments respond to calls citizen involvement, consultations and recognition in policy decisions. Scientific information is typically provided in order to inform the participants in deliberation and decision processes. Resulting negotiation and/or consensus can be perceived as a better or fairer reflection of social preferences than benefit-cost analysis. Although results from public participation can reflect biases, insights gained from wider discussion and involvement can permit a more comprehensive socio-economic analysis for policy decisions when combined with benefit-cost approaches (OECD, 2002).

6. Efforts to estimate the economic values of biodiversity at spatial scale are being advanced (Wünsher, et al. 2008; Wendland, et al. 2009), including those by Conservation International (CI) and other NGOs. Future maps on biodiversity benefits can incorporate the total economic value, with an assessment of direct and indirect use values (concept presented below). Benefits transfer methods, which involve taking economic values from one context and applying them to another, could potentially be used to help establish these values, where site-specific analyses do not exist. Nevertheless, analyses are still likely to be a data and time-intensive (Karousakis, 2009). Furthermore, the validity of benefit transfer methods can be suspect.

7. Economic values of biodiversity are derived from the preferences that people have for the functions of biodiversity. Since market prices rarely exist for biodiversity function, preferences are estimated via willingness to pay (WTP) in order to secure or retain functions. One advantage of this approach is that the benefits of biodiversity are expressed in monetary units, thereby enabling direct comparison with alternative actions.

8. The sum of the WTPs, of all relevant people affected by a due to a policy or project, is the total economic value representing the change in well-being. Total economic value consists of use values and non-use values (Figure 11.2). Use value refers to the value arising from an actual use of a given resource. Examples include use of forest for timber, or of a lake for recreation or fishing, and so on. Use values are further categorized into three types. One, direct use value, which refers to actual uses such as fishing, timber extraction, etc. Two, indirect use value, which concerns the benefits deriving from ecosystem functions. For example, the function of forests in protecting watersheds. Three, future option values represent an individual's willingness to pay to safeguard an asset for the option of using it at a future date.

9. Non-use values are more problematic in definition and estimation. Non-use values are comprised of bequest value and existence value (see Arrow et al, 1993). Bequest value is the benefit accruing to any individual from the knowledge that others might benefit from a resource in future. Existence value derives simply from the existence of any particular asset, and is unrelated to current use or option values. An example is individual's concern to protect the snow leopard although he or she has never seen one and is never likely to. Just knowing that leopards exist is the source of value. Altruistic value reflects the concern that the biodiversity is available for others.

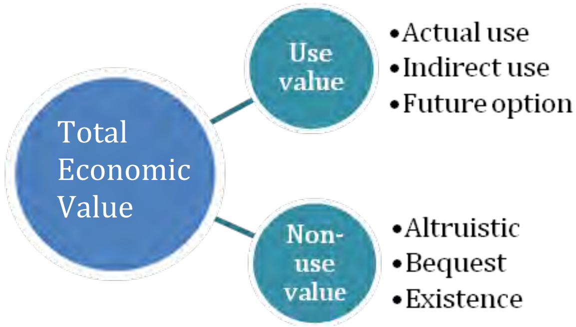


Figure 11.2. Economic values attributed to environmental assets

10. Differentiating between use and non-use values is helpful for estimating the value of biodiversity. Non-use values are can be much larger than use values, especially when the species or ecosystem is rare and widely valued (e.g., charismatic species and ecosystems). Nevertheless, estimates of non-use values can be controversial; therefore it is beneficial to separate these values for presentational and strategic purposes.

11. An array of methodologies is available for eliciting and estimating economic values.[79] They can be divided into three broad approaches. One, the stated preferences or direct approach comprises techniques that attempt to elicit preferences directly by the use of surveys and experiments, such as the contingent valuation and choice modeling methods. People are asked directly to state their strength of preference for a proposed change.

12. Two, the revealed preferences or indirect approaches are techniques which seek to elicit preferences from actual, observed market-based information. Preferences for the environmental good are revealed indirectly when an individual purchases a marketed good to which the environmental good is related. In other words, revealed preference methods use observed behavior to infer the value. Since these techniques do not rely on people's direct answers to questions about how much they would be willing to pay for an environmental quality change, value biological resources instead of biodiversity.

[79] Although much of the world's threatened biological diversity is in the developing world, the theory and practice of economic valuation has been developed and applied mainly in the industrialized world. Consequently, it is important to assess if rich country methodologies can be applied in poor country contexts (Pearce and Moran, 1994).

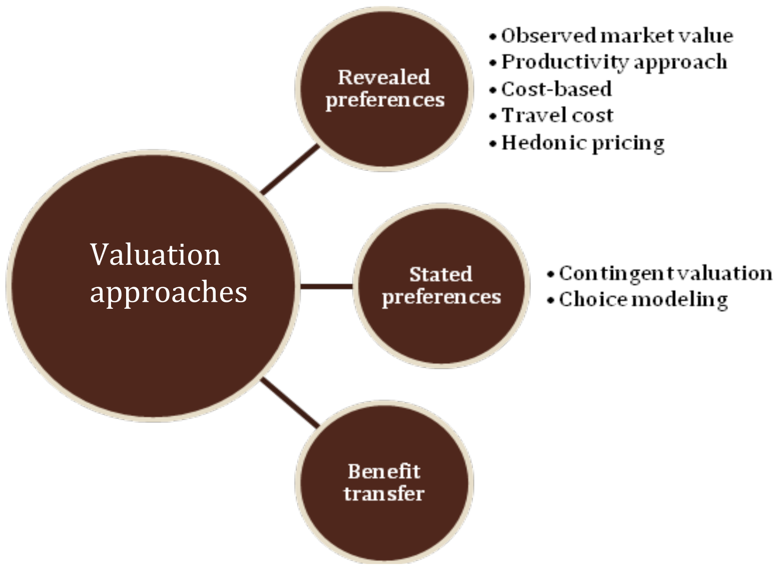


Figure 11.3. Valuation methods for biological diversity and resources

13. Three, benefit transfer borrows an estimate of WTP from one site or species for use in a different context. Although fraught with methodological difficulties (e.g., reliability and validity), transferring benefit estimates is appealing. Avoidance of a detailed benefit study can save considerable resources for funders and agencies implementing environmental projects. developed countries, such savings are motivating interest in an analysis of appropriate conditions for transferring estimates (Boyle and Bergstrom, 1992).

14. Details on the above are available in numerous publications. For more information see OECD (2002), Arrow, 1993, Pearce and Moran (1994). Issues of applicability and validity continued to be refined in the scientific literature.

F. Spreadsheet examples

15. This appendix contains pertinent sections of computer spreadsheets described in Chapters 7 and 9.

Figure 11.4, OppCost Spreadsheet (a): example inputs and outputs (Chapter 7)

Opportunity cost estimate worksheet (national level)

Data inputs:	**Outputs:**
1. Land uses (LU) initial & changes	1. Final land use estimates
2. C stock per LU	2.Opportunity cost curve
3. Profit per LU	3. National level summary
4. Workdays per LU	

All numbers in yellow cells are parameters that you can change

Land use legend	Time-averaged C stock (Mg C/ha)	Profit-ability (NPV, $/ha)	Employment (workdays/year)
Natural forest	250	30	5
Logged forest	200	300	15
Agro-forestry	80	800	120
Extensive agriculture	10	600	100

Period of analysis	**30**	years
Size of country	**2,000,000**	km2
Total population	**1,000,000**	
Pop working age	**60%**	
Workdays / year	**230**	days

Performance at national scale:	
Total LU-based emission, Pg CO2e/yr	0.00
Total C stock in land use, Pg C	34.00
Total NPV of land uses (M$)	60,400
Total rural employment	0.56
Emissions as percentage of C stock	0.0

(vertical axis)

Opportunity costs of land uses changes: $ per tCO2

Initial \ Final	Natural forest	Logged forest	Agro-forestry	Extensive agriculture
Natural forest	0.00	1.47	1.24	0.65
Logged forest	-1.47	0.00	1.14	0.43
Agro-forestry	-1.24	-1.14	0.00	0.78
Extensive agriculture	-0.65	-0.43	-0.78	0.00
Carbon	*250*	*200*	*80*	*10*
NPV Profits	*30*	*300*	*800*	*600*

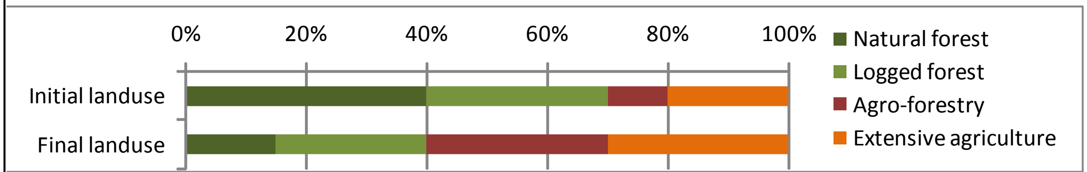
(horizontal axis)

Emissions, Tg CO2e/yr

Natural forest	0.0	305.6	0.0	0.0
Logged forest	0.0	0.0	293.3	928.9
Agro-forestry	0.0	0.0	0.0	0.0
Extensive agriculture	0.0	0.0	-171.1	0.0

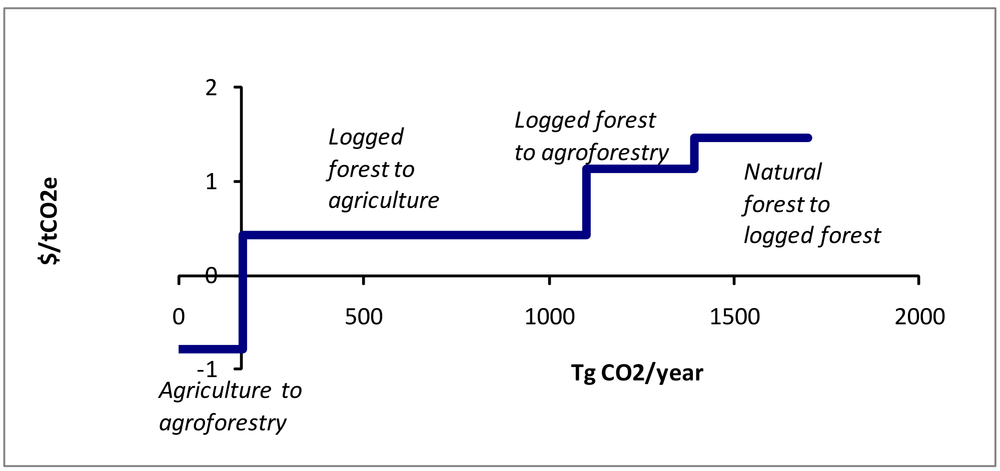
Figure 11.5, OppCost Spreadsheet (b): example inputs and outputs (Chapter 7)

Land use distribution



Land use change matrix	**Final landuse**	Natural forest	Logged forest	Agro-forestry	Extensive agriculture	*Inconsis-tency check*
Initial landuse		**15%**	**25%**	**30%**	**30%**	
Natural forest	**40%**	15%	25%	0%	0%	*0.0%*
Logged forest	**30%**	0%	0%	10%	20%	*0.0%*
Agro-forestry	**10%**	0%	0%	10%	0%	*0.0%*
Extensive agriculture	**20%**	0%	0%	10%	10%	*0.0%*
LU change (%/year)	**100%**	2.1	1.3	0.8	0.8	

Original



Scenario 2 Logged forest $300 -> $400 NPV/ha

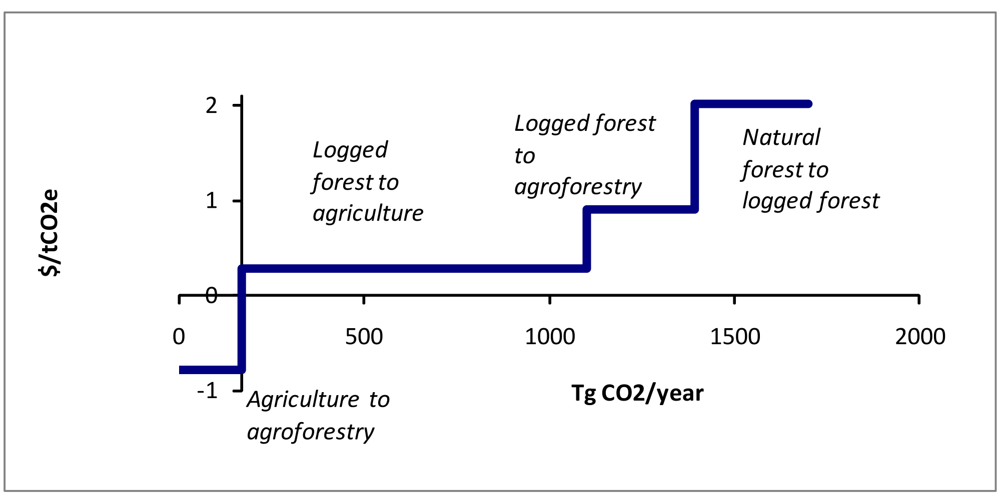


Figure 11.6. Tradeoffs (Chapter 9)

Tradeoff comparisons

Data inputs:

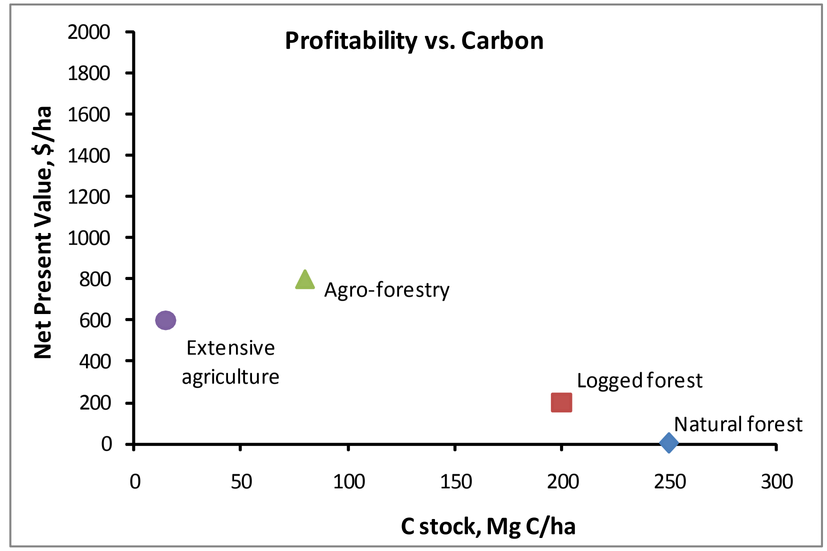
1. C stock per LU
2. Profit per LU
3. Workdays per LU

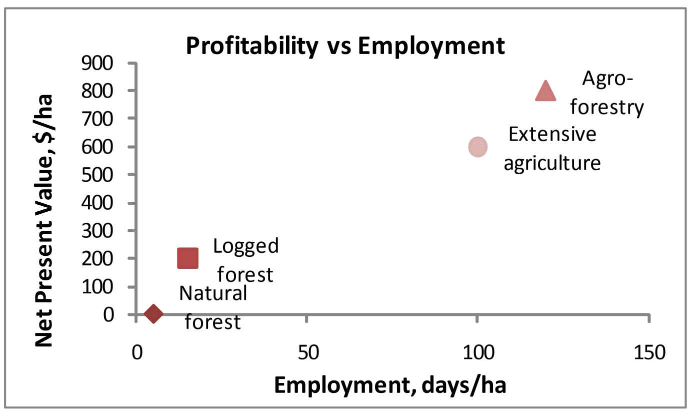
Output:

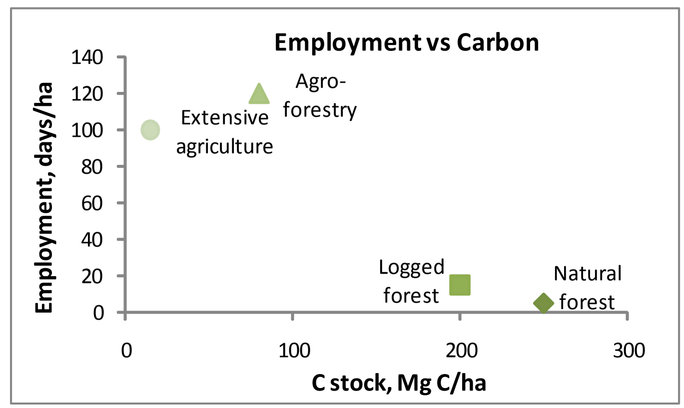
Tradeoff graphs:

1. Profitability v Carbon
2. Profitability v Employment
3. Employment v Carbon

Land use legend	**Time-averaged C stock** (Mg C/ha)	**Profitability** (NPV, $/ha)	**Rural employment** (workdays/year)
Natural forest	250	2	5
Logged forest	200	200	15
Agro-forestry	80	800	120
Extensive agriculture	15	600	100







G. Example analysis using REDD Abacus

16. On the REDD Abacus website (www.worldagroforestry.org/sea/projects/allreddi/softwares), a sample file representing a context in Indonesia (Project Examples–Project.car file) can be examined within the REDD Abacus program (downloadable on the same website). To open, click **File** on the Toolbar, then click **Open Project**. A dialogue box opens for files stored on the computer. The file is called: **sample_project.car**. When opened, a reviewing pane is on the left of the screen, which shows one's location within the program. On the right section of the screen is a box for data entry and of results.

Data entry

17. The first screen (**test1**) is a context description of the analysis – which can either be a sub-national project or national program. The right box contains subsections with the *Project label*, *Description*, *Time Scale (Year)* and an option of including *belowground emissions*. Two other subsections are for the *Zone Partition* and *Land Cover List*. The *Zone Partition* contains a box to enter the *Size of the Total Area* (ha). Each identified Zone is a fraction of the Total Area, in decimal terms, and can be classified (via a checkmark) as being eligible or not within a REDD policy scenario. The *Land Cover List* is where the names of the land covers are entered, along with a brief description (if needed). Each of land covers can be identified as either eligible or ineligible within a REDD policy scenario. The (**+**) adds an addition land cover to the list, while the (**–**) erases the highlighted cover. The **sample_project** example has 4 zones and 20 land covers (Figure 11.7).

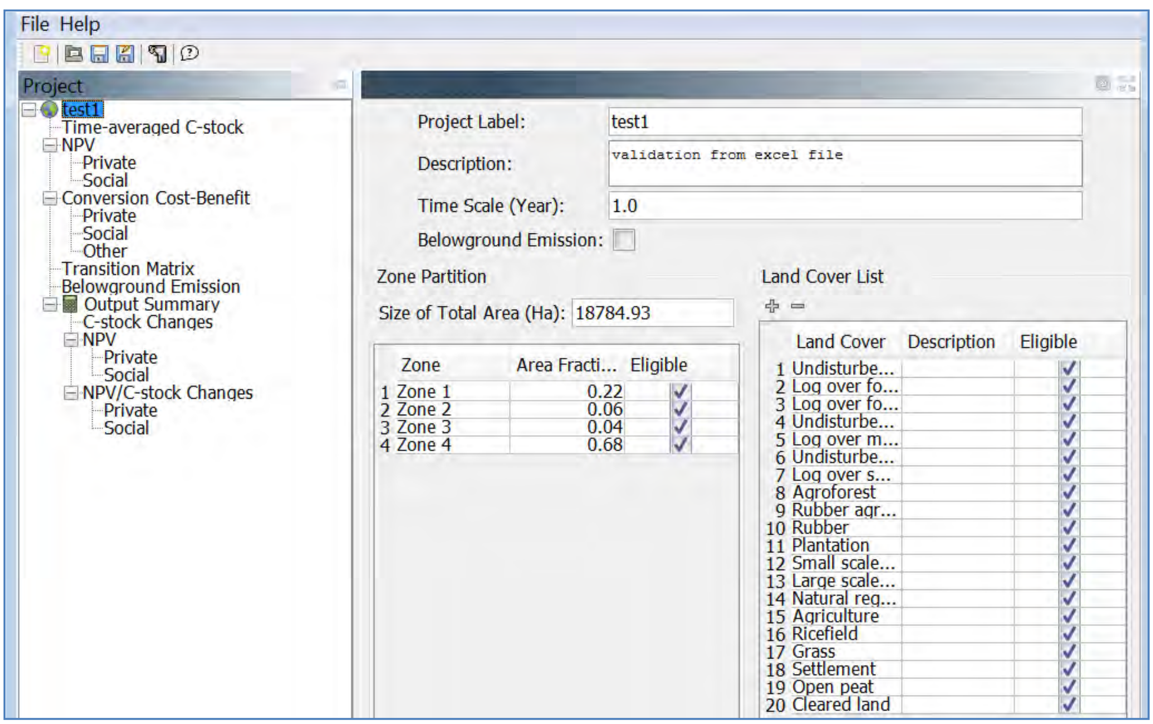
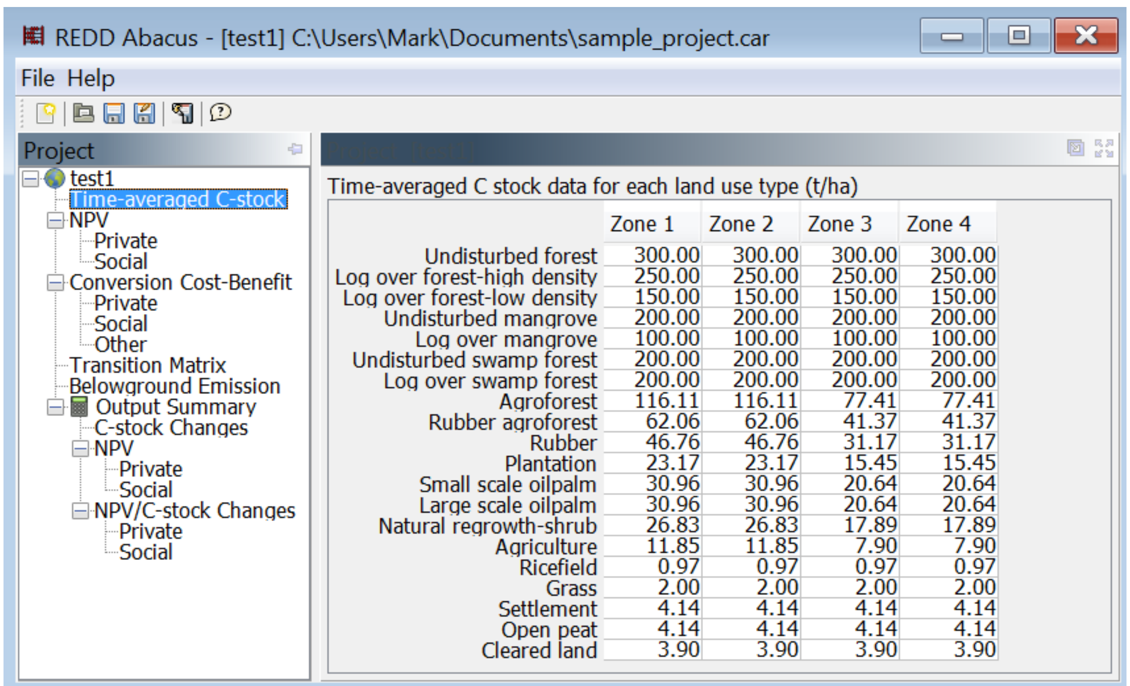


Figure 11.7. Context description screen of REDD Abacus example

18. If starting a new file, a series of dialogue boxes will prompt the user for information on:

- title
- description
- number of zones
- total area

19. The second screen, *Time-averaged C-stock*, accepts data for each of the land uses per zone (Figure 11.8). For the example, 20 land uses in the 4 zones requires carbon data (t/ha) for 80 different land use contexts.

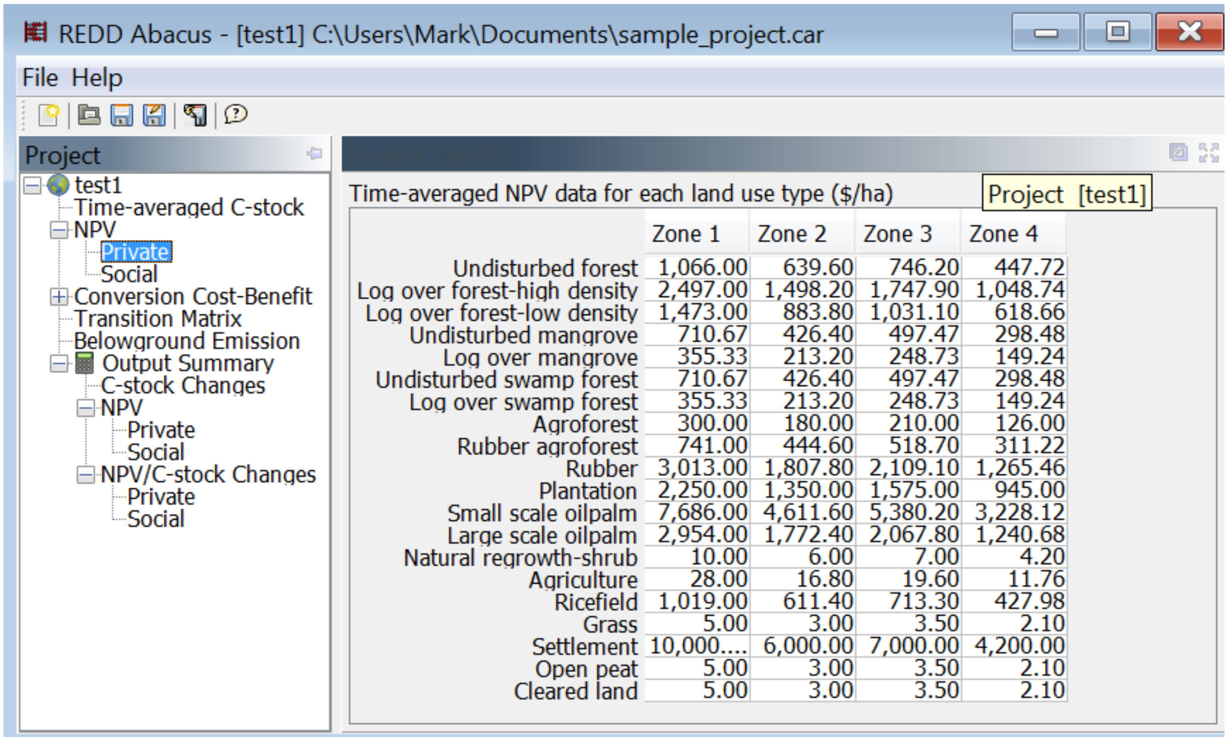


	Zone 1	Zone 2	Zone 3	Zone 4
Undisturbed forest	300.00	300.00	300.00	300.00
Log over forest-high density	250.00	250.00	250.00	250.00
Log over forest-low density	150.00	150.00	150.00	150.00
Undisturbed mangrove	200.00	200.00	200.00	200.00
Log over mangrove	100.00	100.00	100.00	100.00
Undisturbed swamp forest	200.00	200.00	200.00	200.00
Log over swamp forest	200.00	200.00	200.00	200.00
Agroforest	116.11	116.11	77.41	77.41
Rubber agroforest	62.06	62.06	41.37	41.37
Rubber	46.76	46.76	31.17	31.17
Plantation	23.17	23.17	15.45	15.45
Small scale oilpalm	30.96	30.96	20.64	20.64
Large scale oilpalm	30.96	30.96	20.64	20.64
Natural regrowth-shrub	26.83	26.83	17.89	17.89
Agriculture	11.85	11.85	7.90	7.90
Ricefield	0.97	0.97	0.97	0.97
Grass	2.00	2.00	2.00	2.00
Settlement	4.14	4.14	4.14	4.14
Open peat	4.14	4.14	4.14	4.14
Cleared land	3.90	3.90	3.90	3.90

Figure 11.8. Time-averaged carbon stock of REDD Abacus example

20. Profit data from land uses are entered in the third screen (in NPV - net present value per hectare). Profit levels can differ according to accounting stance (sectors being: private or social) in addition to the distinct zones. Although the discount rate is typically a major difference between the two stances, the example employs the same rate for both. (Private sector typically has a higher discount rate given the time value of money corresponding to a prevailing interest rate.) In the example, all social NPVs are higher than private NPVs - except for the rice field land cover. The lower social NPV of rice fields is the result of a 30% government tariff policy on rice imports, which artificially inflates the farm gate price of

rice. In contrast, export taxes on oil palm and rubber depress the prices that farmer receive, thus the social NPVs are higher than the private NPVs (Figure 11.9).



	Zone 1	Zone 2	Zone 3	Zone 4
Undisturbed forest	1,066.00	639.60	746.20	447.72
Log over forest-high density	2,497.00	1,498.20	1,747.90	1,048.74
Log over forest-low density	1,473.00	883.80	1,031.10	618.66
Undisturbed mangrove	710.67	426.40	497.47	298.48
Log over mangrove	355.33	213.20	248.73	149.24
Undisturbed swamp forest	710.67	426.40	497.47	298.48
Log over swamp forest	355.33	213.20	248.73	149.24
Agroforest	300.00	180.00	210.00	126.00
Rubber agroforest	741.00	444.60	518.70	311.22
Rubber	3,013.00	1,807.80	2,109.10	1,265.46
Plantation	2,250.00	1,350.00	1,575.00	945.00
Small scale oilpalm	7,686.00	4,611.60	5,380.20	3,228.12
Large scale oilpalm	2,954.00	1,772.40	2,067.80	1,240.68
Natural regrowth-shrub	10.00	6.00	7.00	4.20
Agriculture	28.00	16.80	19.60	11.76
Ricefield	1,019.00	611.40	713.30	427.98
Grass	5.00	3.00	3.50	2.10
Settlement	10,000....	6,000.00	7,000.00	4,200.00
Open peat	5.00	3.00	3.50	2.10
Cleared land	5.00	3.00	3.50	2.10

Figure 11.9. NPV estimates for REDD Abacus example

21. The fourth screen, *Conversion Cost-Benefit*, allows the user to include the per hectare cost-benefit associated with each land use change. In other words, the NPVs given up when converting one specific land use into another, e.g., converting (clearing) of undisturbed forest implies US$ 1,066 US$/ha of forgone profits.

22. The fifth screen, *Transition Matrix*, is a summary of each type of land use change within the area of analysis (Figure 11.10). This is the same as the **Land use change matrix**, mentioned within this manual (in Chapter 4). Each cell represents the fraction of change per sub-national Zone. (The sum of all cells is equal to 1.) As can be seen in the example, although 400 different land use changes are possible, changes did not occur for all land use covers.

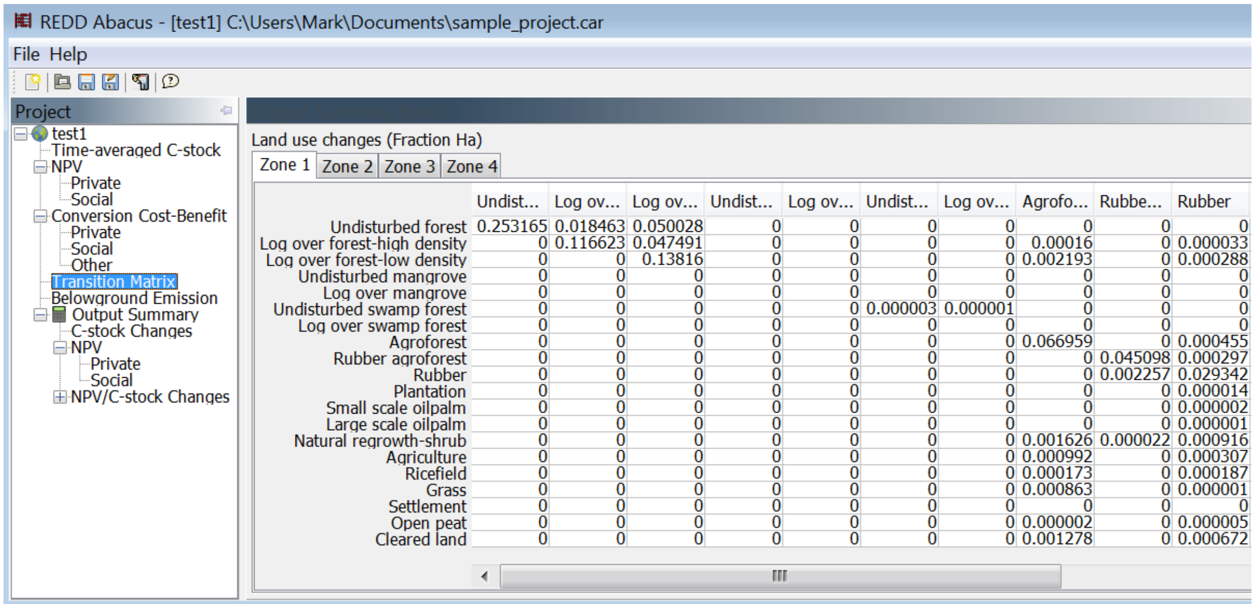


Figure 11.10. Transition matrix for REDD Abacus example

23. The sixth screen, *Belowground Emissions,* provides a way to examine the effects of including belowground carbon pool of different land uses within an opportunity cost analysis. Belowground emissions or sinks, which typically occur at a slower rate, can be substantial, especially in peatlands.

Analysis results

24. The *Output summary* screen presents results from the opportunity cost analysis. The program calculates carbon emissions, sequestration and eligible emission (according to the REDD policy selected). The six summary results include: *Average Emission* per hectare per year (Mg CO_2e/ha/year), *Total emission* per year (Mg CO_2e/ha/year), *Average sequestration* per hectare per year (Mg CO_2e/ha/year), *Total sequestration* per year (Mg CO_2e/year), *Average Eligible Emission* per hectare per year (Mg CO_2e/ha/year) and *Total Eligible Emission* per year (Mg CO_2/year).

25. In addition, it is possible to examine the effect of a cost threshold, which can represent a carbon price, to identify which emission abatement options have a lower opportunity cost. The threshold can be changed by altering the value in the box or dragging the corresponding line in the graph. The analysis also generates a summary measure of *Net Emission by Threshold*, which is the cumulative level of abatements and sequestrations that have opportunity costs less than the cost thresholds. By clicking the **Detail**, the associated NPV and Emission for each of the contributing land use change options are displayed. (represented by the vertical axis labeled: Changes in NPV/C-stock (\$/Mg CO_2)). Bars to the

left and below the dotted lines have opportunity costs of emissions abatement that are lower than the stated threshold.

26. The **Chart** tab in the *Output Summary* screen displays an opportunity cost curve. All the land uses changes in each of the sub-national zones are represented. The different colors of the bars identify the zones, while the specific land use changes can be highlighted with the cursor. Three different charts can be generated: *Emission*, *Sequestration*, *Mixed* [Both]. For any of the charts, labels that correspond to each bar can be temporarily highlighted by moving the cursor over the bar, or be added to the chart by right clicking on the desired bar and clicking *Add Label* in the dialogue box.

27. In Figure 11.11, a cost threshold value of $5 corresponds to an emission level of 47.59 Mg CO_2e/ha/year. Most of the land use changes have opportunity costs lower than the threshold level. For example, the land use change of Undisturbed mangrove to Log over mangrove has an opportunity cost of -$0.9 and contributes approximately 11 Mg CO_2e/ha to the (total) emission level. (Note: some of the land use options may not be readily apparent in the graph. This could be a result from either:

a) the opportunity cost is close to or equal to zero. In such a case, the height of the bar is the same as the horizontal axis.
b) the amount of emission reduction is relatively small. Therefore, the width of the bar is very narrow with only the gray color of the borders showing.

Enlarging the graph can help reveal the less visible land use change emissions.

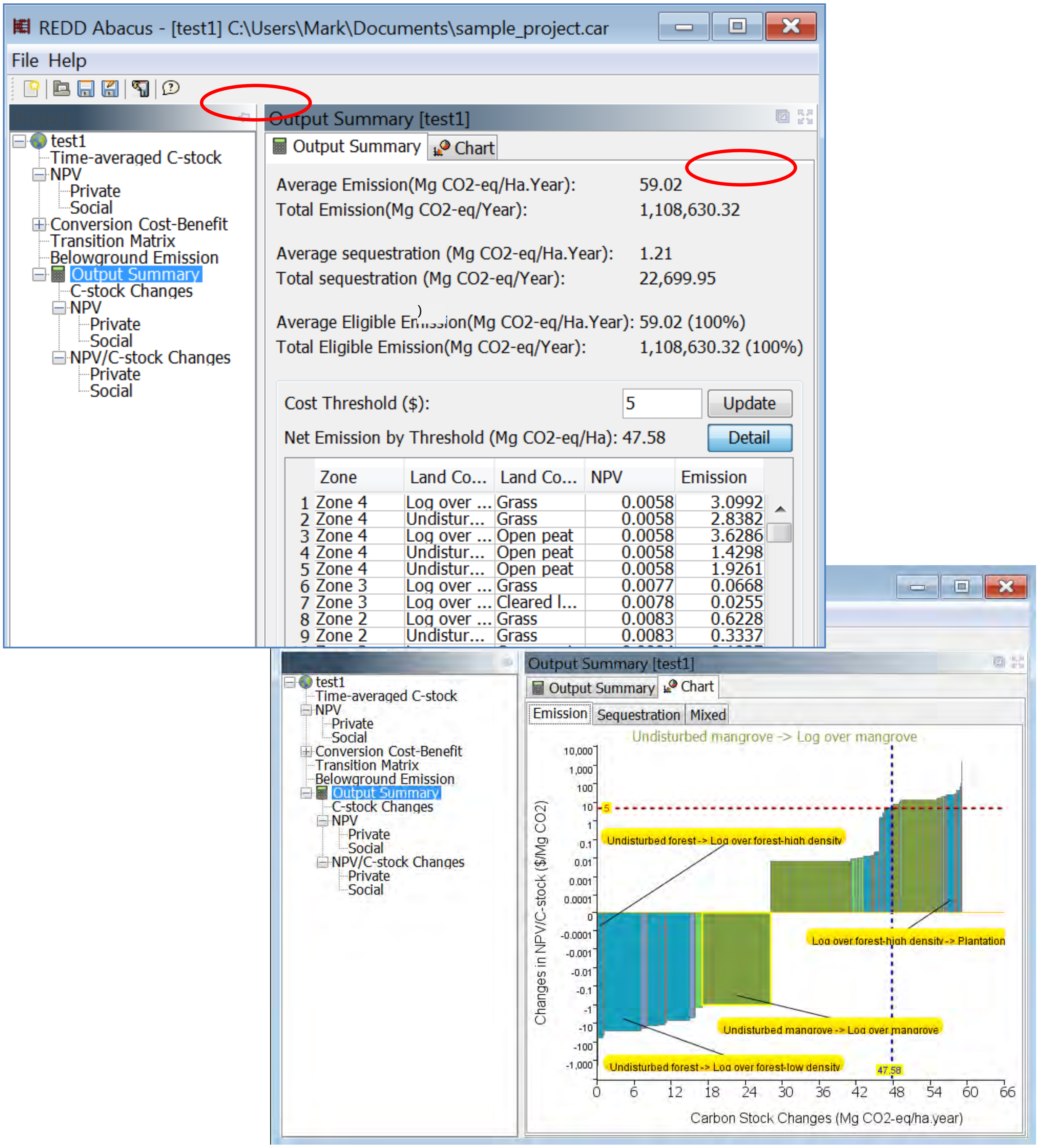


Figure 11.11. Output Summary and associated Chart from REDD Abacus example

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For specific information on the training manual and workshops, please contact fcpfsecretariat@worldbank.org.

www.worldbank.org/wbi