Chapter 7. Opportunity cost analysis

Objectives

Show how to:

1. Generate an opportunity cost curve of REDD
2. Review effect of changes in policy, prices and technical coefficients on an opportunity cost curve (sensitivity analysis)
3. Create maps of opportunity costs

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1. This chapter integrates the outputs from previous chapters. Here we combine different types of information about land use – land use change, carbon stocks, and profitability.

Estimate opportunity costs

2. An opportunity cost is a type of tradeoff. With REDD+, an opportunity cost is measure of a land use change expressed in terms of money and physical units - instead of only physical units, as tradeoffs are often compared. The opportunity costs of REDD+ are based on $ or € per ton CO_2e.

An opportunity cost curve

3. A REDD+ opportunity cost curve is a comparison of the opportunity costs of many different types of land use change. The height represents opportunity cost of each land use change. The curve also shows the quantity of potential emissions reduction per type of land use change. This is the width of the respective segments.

4. In a national "abatement curve" developed by *Dewan Nasional Perubahan Iklim* and McKinsey and Co. (Figure 7.1), which in fact is an opportunity cost curve (see Figure 1.6 and related text discussion), the highlighted options are related to land use. In this example, some opportunity costs are negative meaning that reducing such activity generates net earnings not costs. Such options are located to the left of the graph and below the horizontal axis. Nevertheless, as the width of these bars is narrow, the quantity of abatement potential is relatively small.

5. Other abatement options have positive costs. Examples related to land use include four abatement options of REDD+ from smallholders, reforestation, timber extraction and intensive plantation dryland forest. Although the costs range between €<1 and €15, the potential quantity for abatement is more substantial than less expensive abatement options.

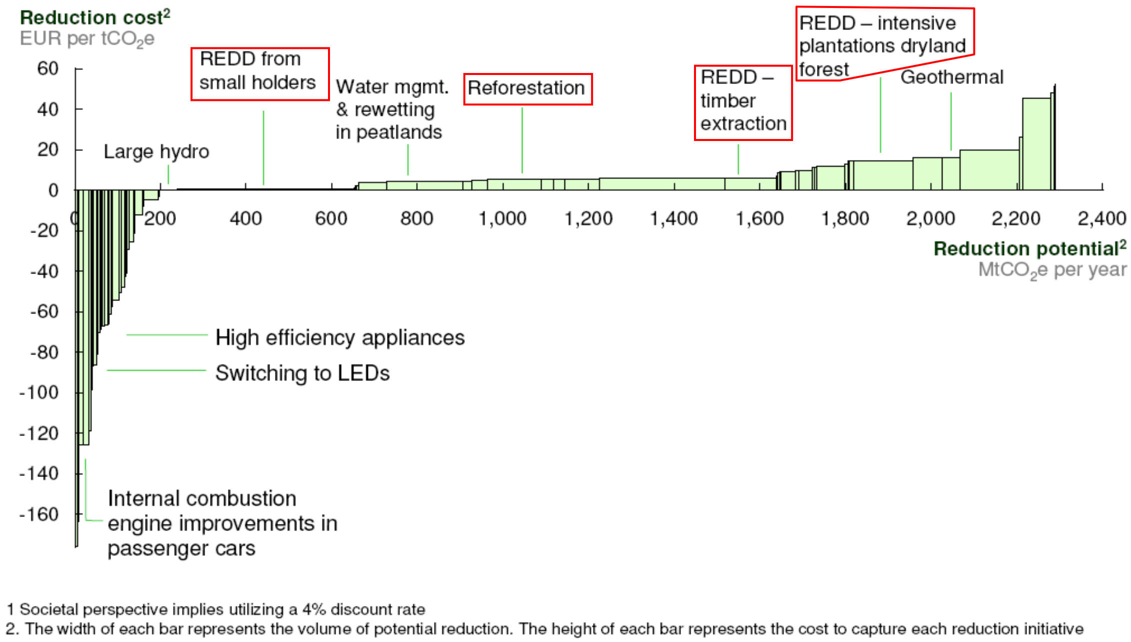

Figure 7.1. A national opportunity cost curve

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

6. Such a national analysis is a useful step in understanding the costs of carbon abatement. The results, however, are a simplification of a diverse reality. A broad range of national and sub-national contexts typically reveals considerable differences from generalized results.

Spreadsheet analysis exercise

7. The spreadsheet file entitled **OppCost** is a simplified example of an opportunity cost analysis. (See **Appendix F** for sections of the described spreasheets and manual website to download the file **SpreadsheetExercisesREDDplusOppCosts.xlsm** (with macro).

8. It is important to note that opportunity cost analysis is based on land use changes. Therefore, in addition to the land use legend, information on current land uses and land use changes at the national level are required.

9. In this example, land use information is based on the percentages. The initial land use distribution is within a single column of cells. Whereas, the row of future land use is a result of numerous land use changes corresponding to a matrix of cells. Land uses changes produce carbon emissions in three instances (Figure 7.2). The opportunity cost of avoiding a change of logged forest to agriculture is the lowest at \$0.44/tCO_2e. A land use change from logged forest to agroforestry has an opportunity cost of \$1.14/tCO_2e; and a change from natural to logged forest has the highest opportunity cost of \$1.36/tCO_2e. A land use change from agriculture to agroforestry would imply a negative opportunity cost (in other

words – a potential benefit) of $0.84/$tCO_2$e. This type of land use change reflects how the higher profits can also store more carbon.

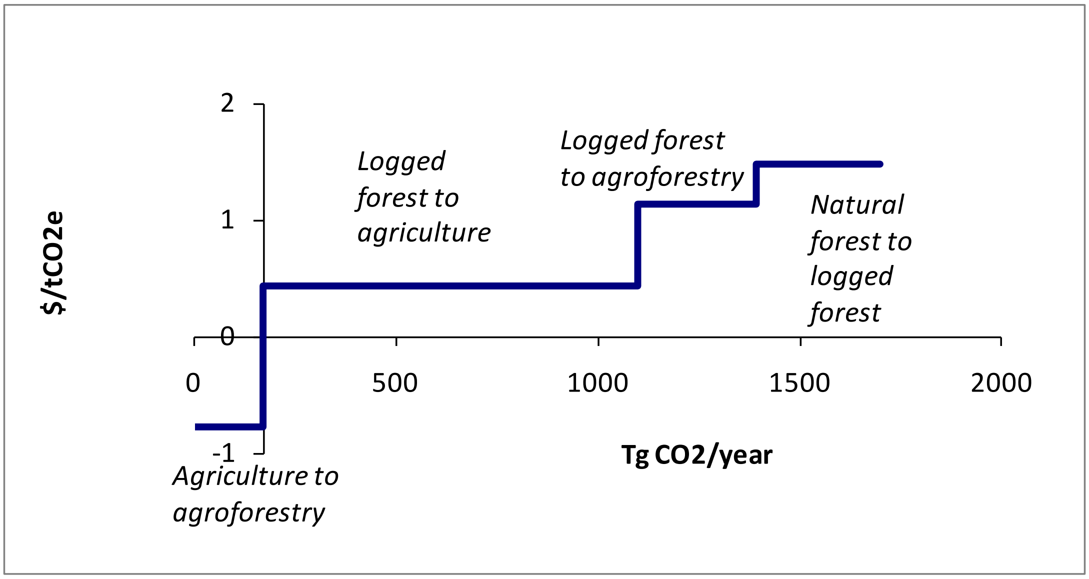

Figure 7.2. Example opportunity cost results from spreadsheet

10. As the number of land uses within an analysis increases, difficulties arise in discerning which factors matter most. A convenient way to identify major determinants is through sensitivity analyses. One (or more) parameters (e.g. input costs, wages, product prices) within an analysis can be changed sequentially or simultaneously in order to assess how much it influences the results. In addition, a structured sensitivity analysis, conducted by raising and lower the value of a parameter by a certain percentage, is useful means to assess the potential implications of uncertain parameters.

Sensitivity analyses

11. Sensitivity analyses are conducted to check the robustness of a quantitative analytical model, such as the opportunity cost model presented in this manual. By using such an approach, it is possible to identify the parameters that account for more effect in the model results. In short, the process of sensitivity analysis involves changing the value of input parameters of the model to capture and understand the impact that such changes would have on the results. Key steps thus include:

- Identifying the key input parameters and assumptions that are likely to affect the results,
- Prioritizing parameters for sensitivity analysis (e.g. inputs, yields, prices),
- Determining the realistic range of variation of the parameter or assumption,
- Examining the results of low and high estimates of each parameter,
- Documenting, comparing and discussing the results,
- Identifying priority scenarios to consider in policy discussions,

- Considering additional land use classifications in order to improve precision,
- Identifying priority areas of research to clarify the range of specific parameters (e.g. inputs, yields, prices).

12. In the case of opportunity cost analysis, key parameters for consideration are profits and carbon content of the land uses. Profits can change as a result of price or yield changes. Estimates of carbon content for different land use may be different with a country or as new research results become available.

13. Here we examine two parameter changes to see their effect on opportunity costs.

Sensitivity analysis A. Logged forest generates $400NPV instead of $300NPV.

In the spreadsheet page **OppCost**, a change in profitability of the logged land use affects three of the four opportunity costs (Figure 7.3).

1. *From logged forest to agriculture.* The opportunity cost estimate decreases from $0.44 to $0.29. In other words, a $100 increase in NPV reduces the opportunity cost of the land use change by 34%.
2. *From logged forest to agroforestry.* The opportunity cost estimate decreases from $1.14 to $0.91. Here, a $100 NPV increase reduces the opportunity cost of the land use change by 23%.
3. *From natural forest to logged forest .* The opportunity cost estimate increases from $1.47 to $2.02. In this case, a $100 NPV increase increases the opportunity cost of the land use change by 37%.
4. *From agriculture to agroforestry.* No effect.

Note that the quantity of emission does not change for any of the above.

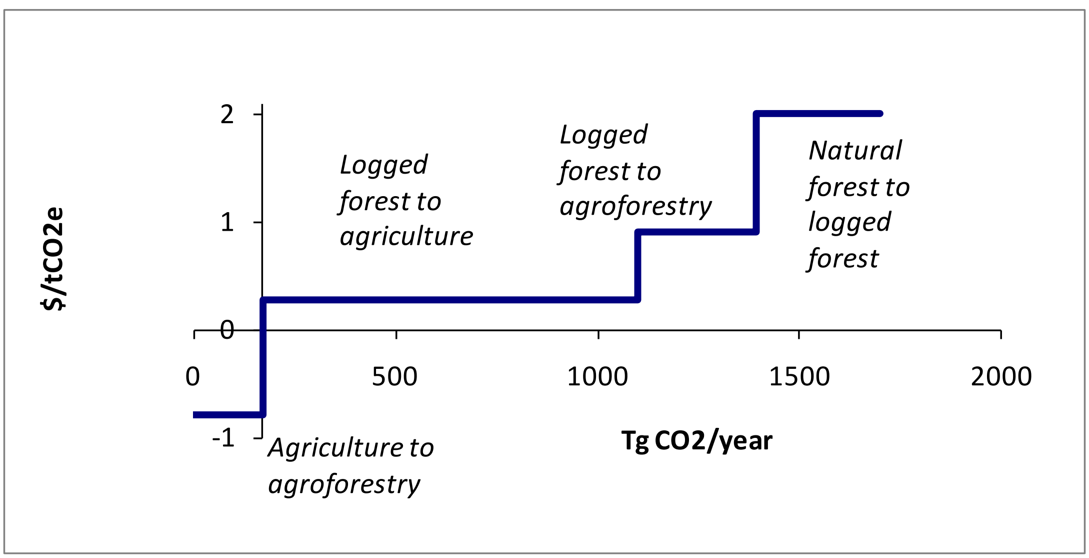

Figure 7.3. Sensitivity analysis A (with logged forest of $400NPV)

Sensitivity analysis B. Logged forest contains 150 tC/ha instead of 200tC/ha.

In the spreadsheet example **OppCost**, a change in carbon content of the logged land use also affects three of the four opportunity costs and corresponding emissions (Figure 7.4).

1. *From logged forest to agriculture.* The opportunity cost estimate increases from \$0.44/tCO_2e to \$0.58. In other words, a 50tC/ha decrease increases the opportunity cost of the land use change by 32%. The associated emissions change from 928 to 855 TgCO2e.
2. *From logged forest to agroforestry.* The opportunity cost estimate decreases from \$1.14/tCO_2e to \$0.74. Here, a 50tC/ha decrease reduces the opportunity cost of the land use change by 35%. The associated emissions decrease from 293 to 171 TgCO2e.
3. *From natural forest to logged forest .* The opportunity cost estimate increases from \$1.47/tCO_2e to \$1.95. In this case, a 50tC/ha decrease increases the opportunity cost of the land use change by 33%. The associated emissions increase from 305 to 611 TgCO2e.
4. *From agriculture to agroforestry.* No effect.

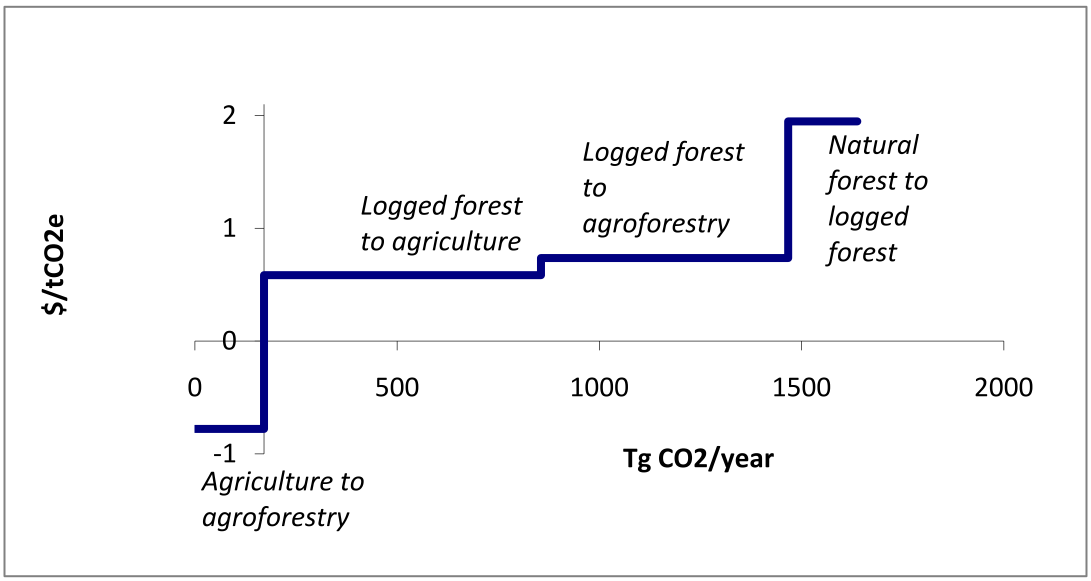

Figure 7.4. Sensitivity analysis B (with logged forest of 150tC/ha)

14. In addition, an appraisal of trends, locations, and behavioral dynamics relating to change in a given country can also help identify priority parameters to examine. In this manner, sensitivity analyses thereby become related to analysis of different scenarios of future conditions and pathways (Chapter 9).

15. Sensitivity analyses require interpretation and critique of results. Changes in results should reflect a "normal" difference, whereby "normal" is determined with discussion to

ensure that the result make sense. In other words, sensitivity analysis requires skills of science and knowledge of the context. Since models are simplifications of a larger and more complex reality, the objective of sensitivity analysis is to ensure that the model behaves as expected.

REDD-Abacus

16. Opportunity cost curves of only a few land uses can be easily estimated with Microsoft XL spreadsheets. Two limitations hinder larger analyses:

1) Emission reduction options must be ordered according to costs, with lower costs to the left of the figure and increasing along the horizontal axis. A macro sub-program is needed to create opportunity cost curves.
2) Identifying and labeling each segment of the curve with a figure requires separate manual tasks, which cannot yet be automated.

17. REDD-Abacus is a computer program that facilitates the creation of cost curves (World Agroforesty Center, et al., 2010). Carbon and profit data of numerous land uses and sub-national regions can be examined entered within the program for analysis (Figure 7.5). By dividing a country into distinct sub-national zones, different characteristics that affect carbon content (e.g., rainfall or elevation) and profit levels (e.g., yields, farmgate prices) of land uses can be recognized in order generate a more accurate analysis of opportunity costs. Consequently, the resulting opportunity cost curves represent not only each possible land use change but also correspond to each sub-national region (Figure 7.6). The ease of data management and calculations helps to speed the process of sensitivity and scenario analyses. **Appendix G** contains an example analysis with results interpretation.

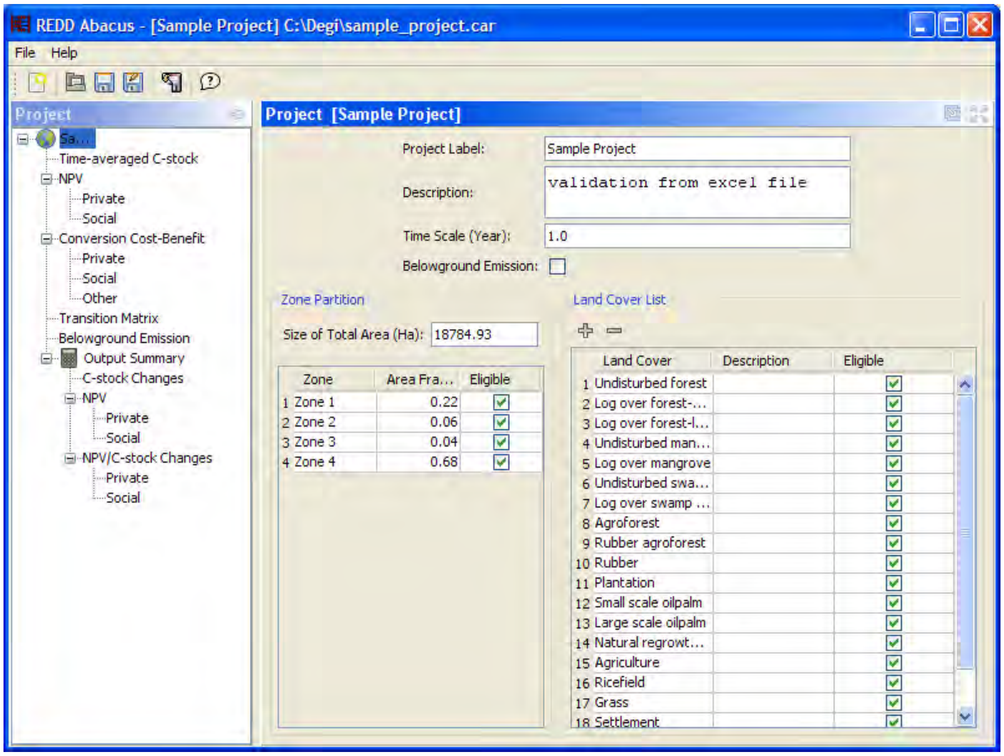

Figure 7.5. Land uses and regions of a sample analysis within REDD-Abacus

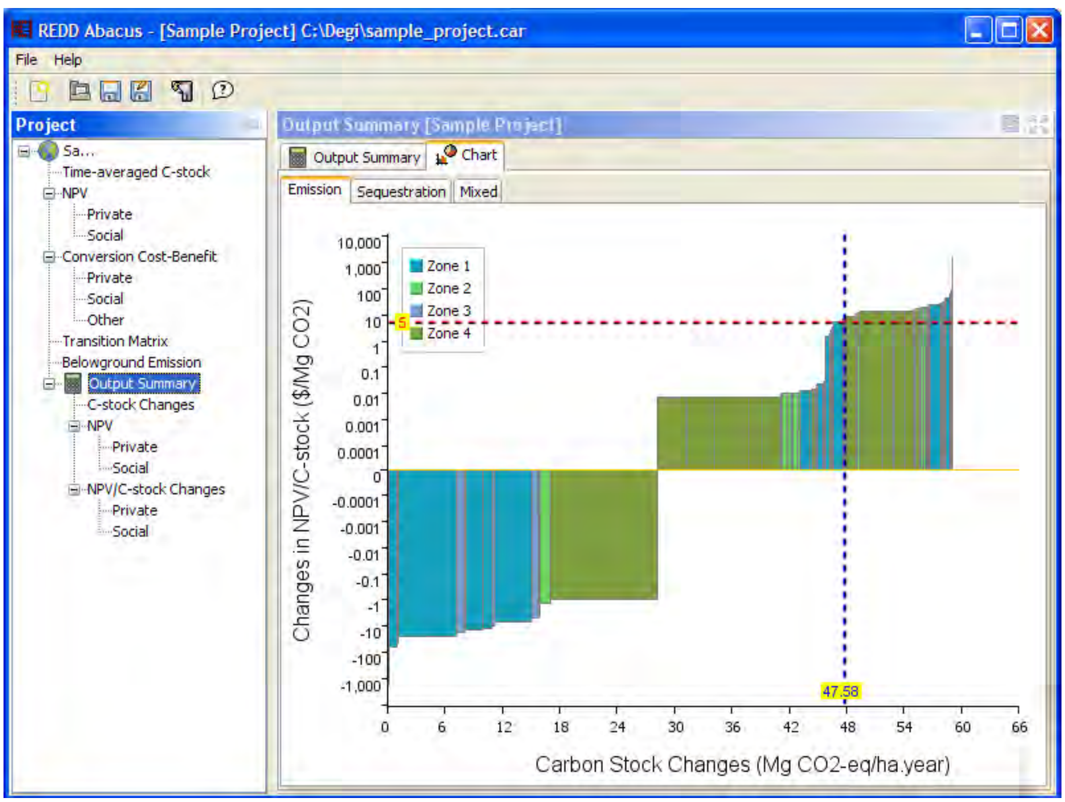

Figure 7.6. An opportunity cost curve per land use change and sub-national region

Opportunity costs maps

18. Maps of opportunity cost estimates are useful for visualizing the economic cost of avoiding deforestation and benefits of increasing carbon stocks. The analysis team can use the results of opportunity cost estimates to analyze their spatial distribution.

19. Figure 7.7 shows results of the type of map that may be useful for determining a starting point in the development of a REDD+ compensation program. It shows the four largest areas of forest transition in a central Peruvian Amazon study site between 1990 and 2007. The values of net emissions and abatement costs, shown in the cost abatement bar graph, are derived from the opportunity cost spreadsheet calculations. These calculations can be converted to database or tabular files that can then be imported into a GIS, where they are linked to the land use transition maps described above.

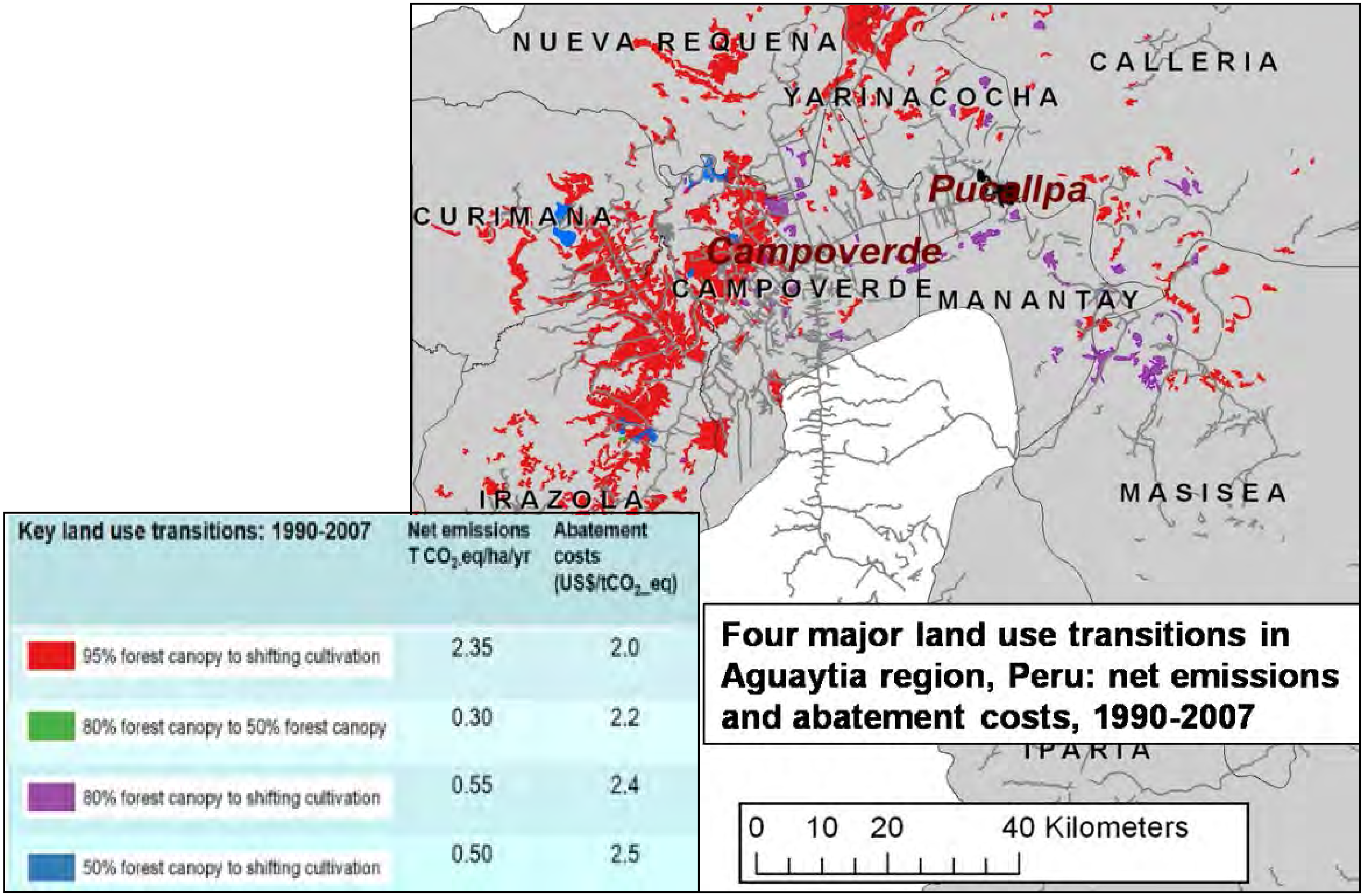

Figure 7.7 An opportunity cost map, central Peruvian Amazon 1990 – 2007.

Source: White and Hyman, 2009.

20. Analyzing results of the opportunity cost calculations in the GIS has several advantages:

- Future land use transitions are likely to be found adjacent to past transitions. The analysis team can overlay these areas on maps of protected areas, biodiversity hotspots, population distribution, the road network, indigenous reserves and other maps.
- Analysts can then visualize where different interventions may be necessary in a REDD+ program.
- Future analysis could use predictions of deforestation and land use change to better target REDD+ initiatives.

References and further reading

Dewan Nasional Perubahan Iklim (National Council on Climate Change) and McKinsey and Co. 2009. *Indonesia's Greenhouse Gas Abatement Cost Curve,* Interim Report, Jakarta: September.

van Noordwijk, M., P. Akong Minang. 2009. If we cannot define it, we cannot save it. In: A.J. Van Bodegom H. Savenije, M. Wit. (eds.) *Forests and Climate Change: Adaptation and Mitigation*. Tropenbos International, Wageningen, The Netherlands. xvi + 160 pp.

van Noordwijk, M., T.P. Tomich, J. Gockowski, S. Vosti. 2001. Analysis of trade-offs between local, regional and global benefits of land use. Lecture note 10. 14p. In: van Noordwijk, M., S. Williams and B. Verbist (Eds.) *Towards integrated natural resource management in the humid tropics: local action and global concerns to stabilize forest margins.* ICRAF: Nairobi.

White, D., G. Hyman. 2009. *What are the Opportunity Costs of Reducing Carbon Emissions from Deforestation? An Amazon Case study in Ucayali, Peru.* CIAT and ASB: Cali, Colombia.

World Agroforestry Center (ICRAF), Directorate General of Forest Planning, Ministry of Forestry (Ditjen Planologi), Brawijaya University (UB) and Indonesian Centre for Agricultural Land Resources Research and Development (ICALLRD). 2010. *REDD-Abacus: ABAtement Cost cUrveS for Reducing Emission from Deforestation, Degradation.* Accountability and Local Level Initiative to Reduce Emission from Deforestation and Degradation in Indonesia (ALLREDDI) program. Version 1.0.2. ICRAF: Bogor Indonesia. http://www.worldagroforestrycentre.org/sea/projects/allreddi/softwares