Abatement Cost Curves Relating Past Greenhouse Gas Emissions to the Economic Gains They Allowed

Four approaches are described to analyze land use change in tropical forest margins in the context of REDD+

Project Report

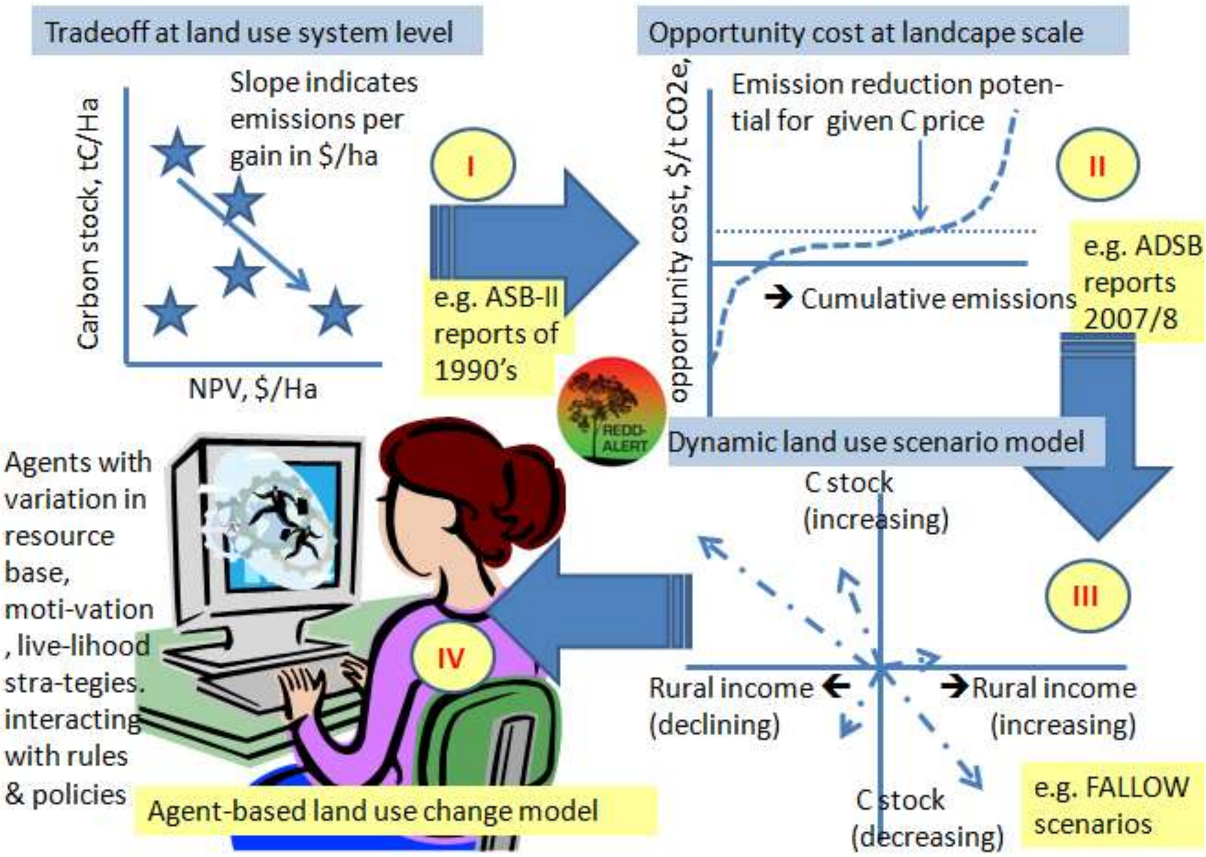
World Agroforestry Centre

BOX 1. Overview of the REDD ALERT project

The European Union financed the REDD ALERT project (contract number 226310) to contribute to the development and evaluation of market and non-market mechanisms and the institutions needed at multiple levels for changing stakeholder behaviour to slow deforestation rates of tropical landscapes and hence reduce greenhouse gas (GHG) emissions. Its specific objectives six-fold.

1. Document the diversity in social, cultural, economic and ecological ***drivers of forest transition*** and conservation and the consequences in the context of selected case studies in Indonesia, Vietnam, Cameroon and Peru as representative of different stages of forest transition in Southeast Asia, Africa and South America.
2. ***Quantify rates of forest conversion*** and change in forest carbon stocks using improved methods.
3. Improve accounting (methods, default values) of the consequences of land-use change for ***GHG emissions in tropical forest margins including peat lands***.
4. Identify and assess viable ***policy options addressing the drivers of deforestation*** and their consistency with policy approaches on avoided deforestation currently being discussed in UNFCCC and other relevant international processes.
5. Analyse scenarios in selected case study areas of the ***local impacts of potential international climate-change policies*** on GHG emission reductions, land use and livelihoods.
6. Develop ***new negotiation support*** tools and use these with stakeholders at international, national and local scales to explore a basket of options for incorporating REDD into post-2012 climate agreements.

Abatement cost curves relating past greenhouse gas emissions to the economic gains they allowed



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Synopsis

Abatement curves summarize the costs that are involved in reduction of pollution, in this case net greenhouse gas emissions[1], based on the volume of various types of emissions and the expected cost per unit emission reduction. Such representations support policy development, identifying an initial focus on the low-cost high-volume emission categories. Four approaches are described and compared to do such analysis for tropical forest margins in the context of Reducing Emissions from Deforestation and (forest) degradation. The four methods, of increasing complexity and costs of data collection are appropriate in different steps along the pathway to negotiated agreements that can meet 'Free and Prior Informed Consent' standards, while reducing overall transaction costs by early warnings for cases that are unlikely to lead to mutually beneficial agreements. In early screening of potential cases, a comparison of profitability and time-averaged carbon stock of the different landuse options within an area can be used to confirm that there are no high C stock + high profitability land uses (if there are the question shifts to why these are not universally adopted) and that there generally is a tradeoff. The presence of low C stock + low profitability land uses, can direct the focus on prevention of degradation and possibilities of win+win restoration. For a Project Information Note (PIN) this may give sufficient initial clues. In landscapes where tradeoffs are confirmed, a further quantification and spatial study of the emission pattern can use pixel-level ratios of change in C stock and profitability as basis for C price estimates ('OpCost curves'). Such curves give an indication of baseline emissions and the opportunity for economic incentives to shift away from emissions that yielded low benefits in terms of profitability increases in land use. Such information can inform Project Design Documents (PDD). For further negotiations of contracts, forward looking landscape scenarios can further support the negotiations, as they can help define the bottom-line levels of alternative livelihood provisions that will be needed to make low C emission scenarios equivalent in terms of local economy to high C stock emission business as usual scenarios. Finally, further detail on the scenarios by inclusion of agent-based variation in resources and preferences may add further detail, but for this class of methods further tests are needed to judge their predictive value and relevance in the negotiation processes.

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[1] This implies either ***sequestration*** of atmospheric CO_2 or ***reduction of emissions*** of carbondioxide (CO_2), methane (CH_4) or nitrous oxide (N_2O)

<table>
<tr><th>Publications/research tools</th><th>Policy briefs/ training material</th></tr>
<tr><td>Appendix 1. Minang, PA., van Noordwijk, M., and Gockowski, J.' 2011. Carbon trade-offs along tropical forest margins: Lessons from ASB work in Cameroon. In press</td><td>Appendix 3. White, D., Minang, P., Agus, F.,Borner, J., Hairiah, K., Gockowski, J., Hy-man, G., Robiglia, V., Swallow, B., Velarde, S. and van Noordwijk, M., 2010. Estimating the opportunity costs of REDD+, a training ma-nual. World Bank, Washington (D.C.), USA.</td></tr>
<tr><td>Appendix 2. REDD-ABACUS software</td><td rowspan="2">van Noordwijk M, Dewi S, Swallow BM, Purnomo H and Murdiyarso D. 2007. Avoided Deforestation with Sustainable Benefits (ADSB) in Indonesia-research briefs. Bogor, Indonesia. World Agroforestry Centre - ICRAF, SEA Regional Office.

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<tr><td>Appendix 4. van Noordwijk, M., Tata, H.L., Ruysschaert, D., Mulia, R., Rahayu, S., Mulyoutami, E., Widayati, A., Ekadinata, A., Zen, R., Dorsayo, A., Oktaviani, R., and Dewi, S. (2011??) Commodification, compensation or co-investment as basis for avoiding carbon emissions from peat swamp conversion to oil palm in orang-utan habitat: the case of Tripa (Sumatra, Indonesia). Land Use Policy (under review).</td></tr>
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Contents

1. Introduction

1.1 REDD+ as part of UNFCCC implementation arrangements

The ultimate objective of the Climate Change Convention (UNFCCC), agreed in 1992 in Rio is to achieve "... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Nearly twenty years past Rio, implementation agreements are still far from effective in reaching this goal.

As land-based emissions of greenhouse gasses are responsible for approximately half of the cumulative anthropogenic interference with the climate systems and between a quarter and a sixth of current greenhouse gas emissions, there is a strong rationale for including them in international agreements to achieve the UNFCCC objective.

Early efforts to contain the growth of greenhouse gas emissions (Kyoto protocol) have focussed on the fossil fuel emissions in 'developed' countries (Annex-I countries in the UNFCCC, or Annex-B countries in the Kyoto protocol). A small window was opened for 'afforestation/reforestation' activities in developing countries as part of the Clean Development Mechanism (hence: A/R-CDM), as starting point for engagement with land use and its emissions/sequestration potential in developing countries[2].

The agreement at the 2010 Conference of Parties of the UNFCCC in Cancun to include REDD+ (Reducing Emissions form Deforestation and (forest) Degradation, Plus forest restoration) came three years after the 2007 decision in Bali to start experimenting with such approaches. REDD and A/R-CDM refer to two phases (Fig. 1) of the 'Forest Transition' or more objectively, 'Tree Cover

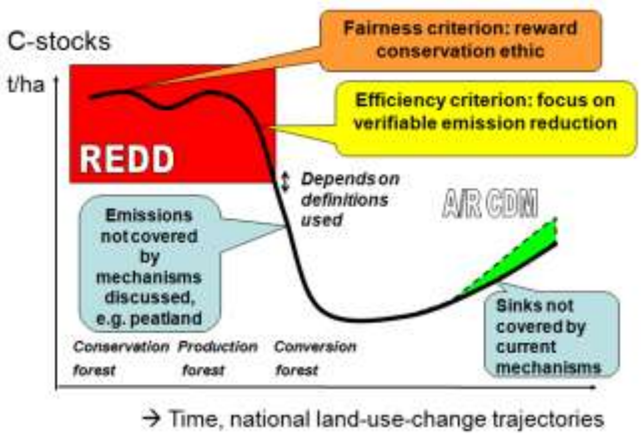


Figure 1. Schematic application domain of REDD and A/R-CDM mechanisms to reduce net land-based emissions in developing countries across the 'forest transition' portrayal of land use change, identifying the 'fairness' and 'efficiency' attention points within REDD (Source: van Noordwijk et al., 2008)

[2] Full accounting for land use change and its emission consequences in industrialized countries is still a contested issue in the context of the existing commitments to reduce net emissions

Transition' curve that provides a conceptualization of the non-linearity of anthropogenic land cover change (Lambin et al., 2003; Meyfroidt and Lambin, 2009; Rudel et al., 2005; Santos-Martin et al., 2011).

In its current definition the REDD+ mechanisms is restricted to the subset of all land cover types that falls within the 'forest' category (Fig. 2). In practice, however, the concept of 'forest' is far from operational and the interpretation remains contested (van Noordwijk *et al.*, 2008; van Noordwijk and Minang, 2009; van Noordwijk *et al*., 2010)[3]. In the light of multiple possible interpretations of forest categories, it is preferable to collect data on all land uses in relation to their C stocks and profitability, for subsequent use of a 'forest policy filter', rather than having to make a priori choices.

1.2 REDD+ and agricultural development

Land use is directly linked to agriculture and production of a wide array of goods, and there us fear that emission reduction will imply reduction of agricultural production. Several of the commodities, e.g. fibre and bioenergy, have fossil-fuel based alternatives and changes in fossil fuel use may impact on land use and vice versa. Reduction of land-based emissions needs to consider economic effects of changing the status quo (or the dynamic 'business as usual' scenarios). Attention is needed to characterize the way greenhouse gas emissions (or changes in terrestrial carbon stocks) are related to land use, with a quantification of the temporal and spatial patterns of both and a focus on causal interactions ('drivers') that can provide policy levers.

In most cases there are trade-offs between food production and environmental integrity (Fig. 3), i.e., higher land use intensity brings food security and economic benefit but also causes GHG emissions that leads to climate change, apart from more local impacts on watershed functions and soil fertility. In the long run, without intervention, negative feedback mechanism will dominate and negative environmental impacts will reduce productivity. The challenge is to respond early enough to stay within safe operating space for humanity (Rockström et al., 2009). In this report we will consider various 2-D graphical displays that have an economic (productivity or profitability) as one axis and environmental integrity, C stocks or emissions, as another.

[3] The recent Indonesian REDD+ strategy (2011) explicitly refers to a vegetation-based forest concept in addition to an institutionally defined forest zone; in previous documents institutional concepts prevailed

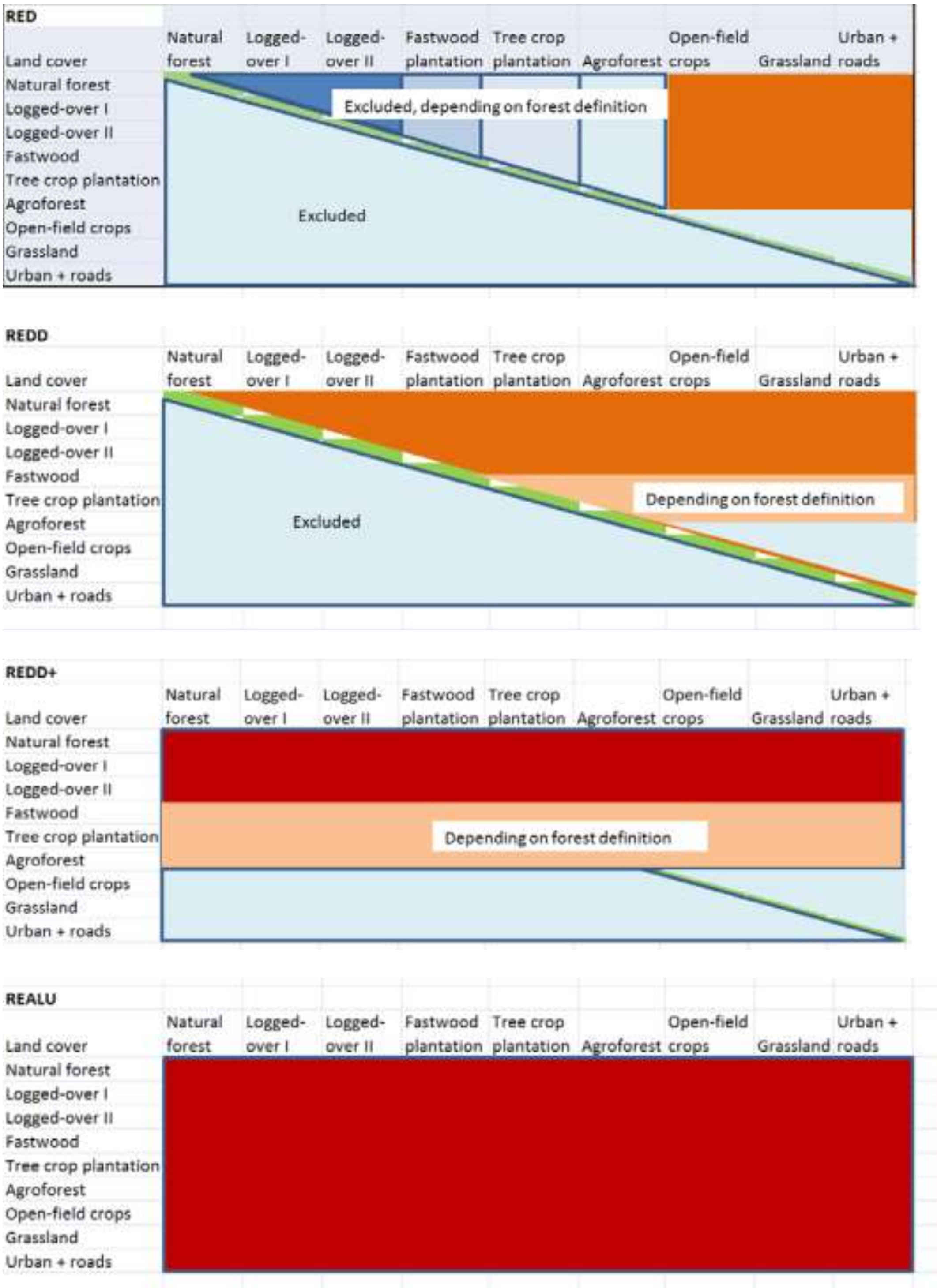


Figure 2. A simple land use change matrix with indication of eligibility of associated emissions for economic incentives under various proposed schemes, ranging from RED, via REDD and REDD+ to REDD++ (= REALU reducing emissions from all land uses); Land use change is from the initial state in the first column to a land use in one of the other columns, with the negative diagonal indicating 'no change'. Eligibility of changes is indicated with colours: red= permitted, orange = potentially permitted depending on national forest definition, blue = excluded; (source: van Noordwijk and Minang, 2009)

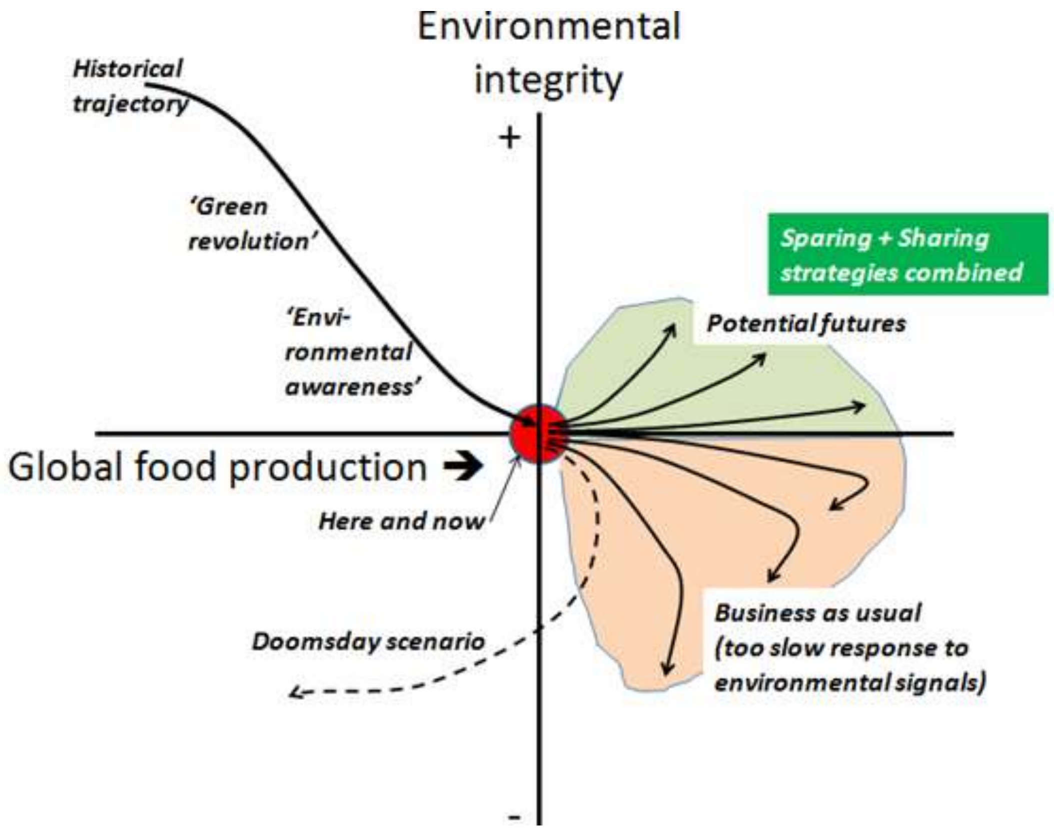


Figure 3. A simple view of the "development⇔/+ environment" debate as human trajectories in a space defined by 'global food production' and 'environmental integrity' axes

1.3 C stocks of land cover versus profitability of land use

Within UNFCCC, land-based emissions accounting has so far been the basis for global efforts to avoid dangerous anthropogenic climate change. This land-based emission accounting does not immediately capture the relationship between economic gains and environmental costs of land use and land use change. The alternative, commodity-based attribution of emissions, directly links emissions to the economic benefits derived from particular commodity productions. As contribution to the debate on REDD+ (and possible other policy instruments), we will in the following focus on the relationship between C stocks and profitability of the full set of land uses that can be found in tropical forest margins (Fig. 4).

In Figure 4 (and subsequent versions in Fig. 5 and other) the dynamic properties of a landscape are described as a matrix with it rows represent the area fraction of land cover types with distinct carbon stock and it columns represent the area fraction of land use types with distinct profitability/economic return. The rows are arranged such that land cover types are sorted in descending order in terms of carbon stock while the columns are arranged such that land use types are sorted in ascending order of profitability. The two dotted lines the lower panel of Fig. 4 separate forest and non-forest under different concepts of defining forest. The vertical line demarcates forest and others in terms of land use/institutional categories, which mainly associates stronger with profitability rather than carbon stock and vice versa for the horizontal line. It is necessary to have a clear understanding which 'forest' definition we use before embarking on any discussions.

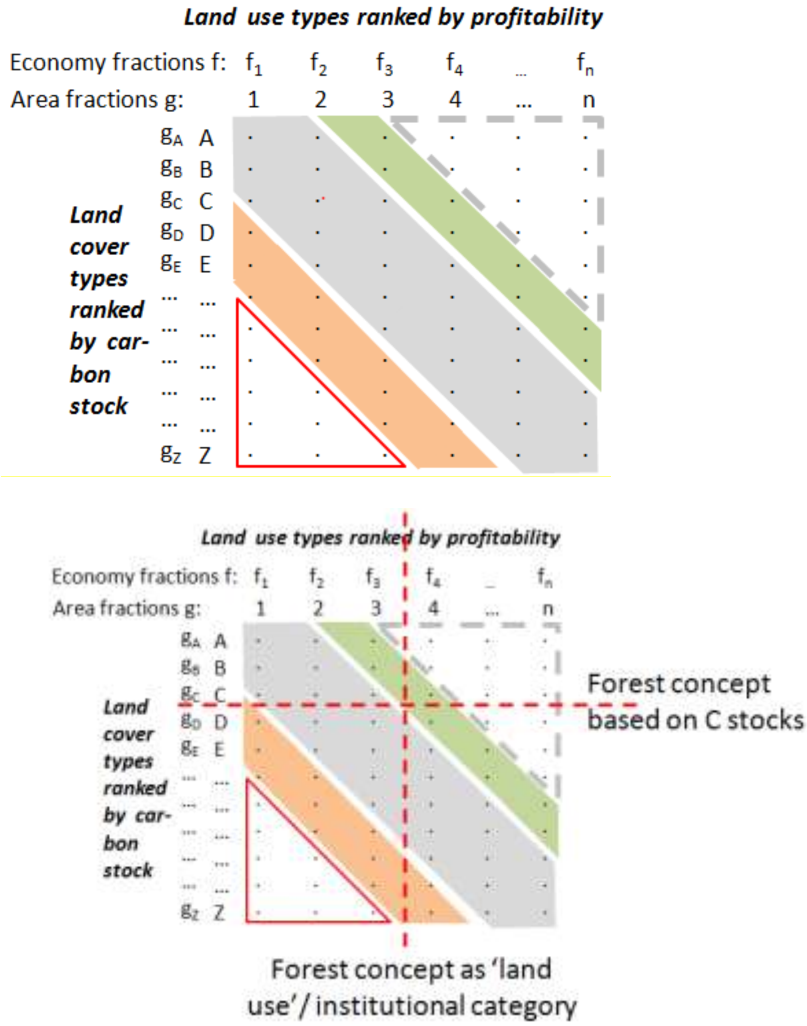


Figure 4. Basic land cover/land use comparison of the carbon stocks of land cover types and the profitability of land use practices (upper panel) and post-hoc identification of 'forest' concept based on current land cover and/or profitability and institutional dimensions of land use

Within the C-stock ⇔ Profitability space of Fig.4, the dominant trend during the early 'development' phase is either a shifting from the upper left towards the lower right corner, along the main diagonal (grey zone), when land use intensifications bring tangible economic benefits or a cycle within the lower left triangle of the diagram where land use intensification (e.g. reduction of fallow periods) does not associate with high profitability due to policy and/or market failures. Examples of desirable land use types that combine relatively high profitability and high C stocks (green zone) can be found among the 'agroforest' categories.

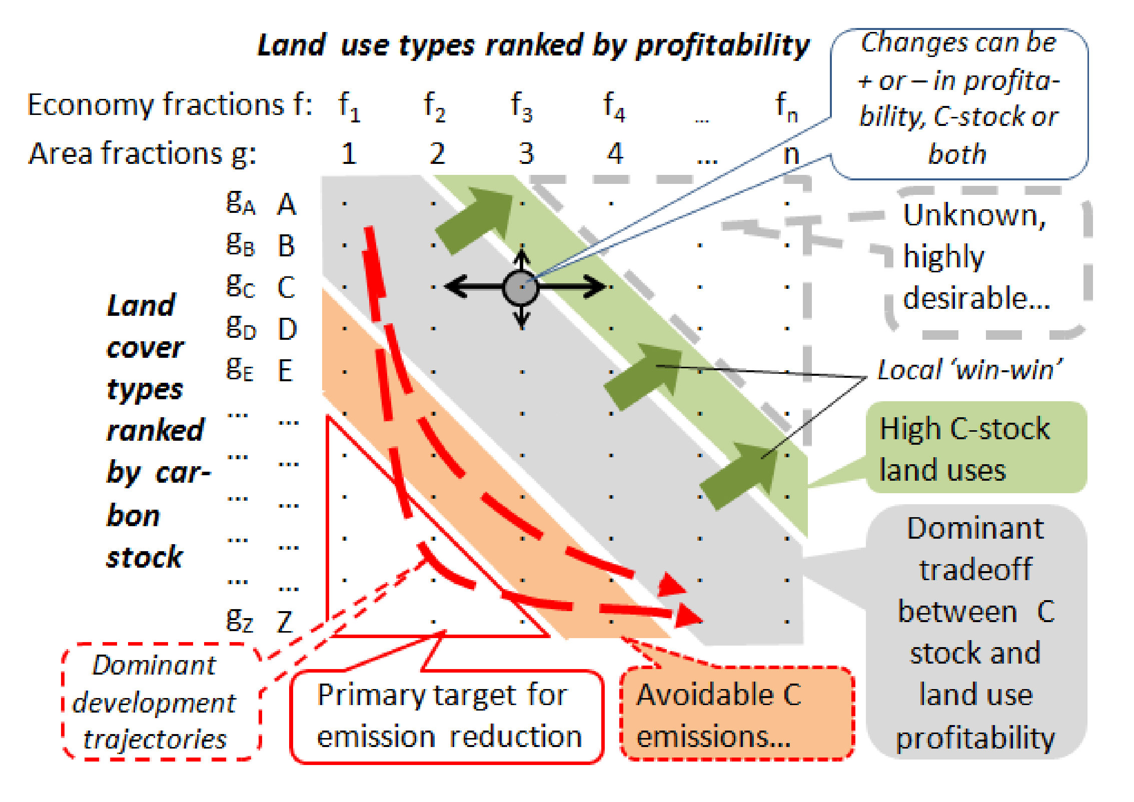


Figure 5. Interpreting the zones along the main diagonal of Fig 4 and indicating common land use change trajectories (for further discussion see text)

Land use change may consist of a gradual process that, if observed with sufficiently short time steps, consists of several steps between natural forest, via cyclical systems such as swiddens and associated fallow recovery or logging and regrowth cycles, to more permanent land use types, such as open-field agriculture, tree crop plantations, forest plantations or agroforests. In other cases, land use change may be more radical, as in the conversion of primary forest to open-field agriculture or tree-crop plantations, within a single time-step of the observation system. In the gradual case, a number of steps can be separately evaluated for their profitability change plus carbon stock loss, while the rapid transition may be represented by a single vector (and slope in the emission + profitability change space).

While the most desirable 'win+win' solution in the upper right corner of the graphs of Figure 4 (grey triangle) may be elusive, there usually is an abundance of low C-stock + low profitability land (red triangle). These areas should be the primary focus of efforts to reduce emissions without negative effects on economic opportunities, by provision of compensation of the generally low 'opportunity costs' of such change. The analysis of 'abatement costs' is targeting the quantification and identification of these low gain/high C emission transformations in the landscape.

1.4 Fairness versus efficiency? Nested REDD designs for 2-way exchanges

The “fairness versus efficiency” debate in targeting REDD+ investments differentiates among parts of the forest transition curve, as hinted at in Fig 2. Efficiency is generally associated with the highest emission reduction (that can be claimed by reference to a business as usual scenario) per dollar invested in a landscape. Efficiency considerations therefore need to know the details of the land use change trajectory, as they may focus on the ‘lowest hanging fruit’ of low ‘opportunity costs’. . Fairness considerations generally take a longer time frame into consideration and the interconnectedness of the various changes that may occur in a landscape. It also considers spatial variability in the wider landscapes. Both perspectives need quantification of the likely changes on C stock and profitability, although various stakeholders may interpret the data in different ways subsequently (Fig. 6).

Figure 6. Cartoons of the relationship between efficiency (left side of both diagrams) and fairness considerations (right side), in which full respect for free and prior informed consent of local stakeholders is needed while carbon finance that displaces instead of reduces net global emissions is frowned upon

One further complication in all REDD+ discussions is scale (Fig. 7). REDD+ agreements will primarily be accounted for at national scale through the global discussion in the UNFCCC of which efficiency aspects dictate the focus on a few high-emission countries, while the fairness aspects imperative to reaching consensus in the decision making impose the inclusion of a larger number of countries.

At subnational scale, there is a similar fairness versus efficiency issue at the implementation level; prioritizing subnational entities (defined by area, e.g. provinces, or sector) with high emissions linked to low profitability for efficiency has to be balanced by the inclusions of subnational entities with high carbon stock and relatively low emissions.

At local level, for REDD+ implementation to be successful, the drivers of deforestation and land cover changes need to be addressed efficiently. Beyond REDD+, to achieve fairness as well as longer-term efficiency, long term sustainable livelihood solutions are necessary.

Across the scales the efficiency considerations are linked in a 'REDD+ value chain' that can be characterized by the way C-emission reduction claims relate to C-finance (performance-based payments or investments to be settled against future performance). In parallel to that, a 'fairness' value chain relates respect, recognition and free and prior informed consent at each step.

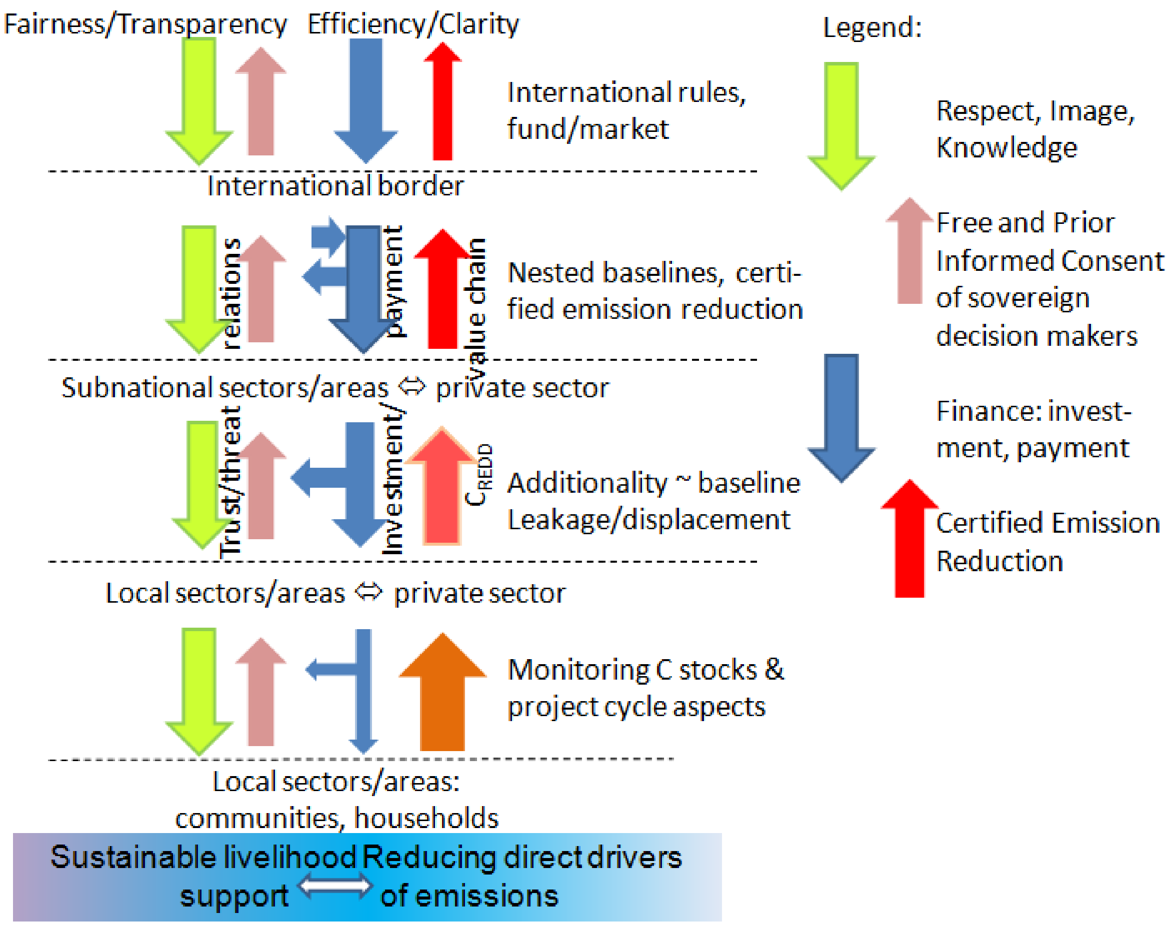


Figure 7. Two-way exchanges in both the fairness and efficiency domains of a nested REDD process that links performance from local to national scales with support for sustainable livelihood options that reduce emissions compared to the 'normal' development pathway

BOX 2. Five actions eligible for support under REDD+, as agreed by UNFCCC in Cancun in December 2010:

- Reducing emissions from deforestation (actions to diverge from the reference level by **reducing the conversion of forest to non-forest**)
- Reducing emissions from forest degradation (diverging from the reference level by **reducing the gradual loss of biomass due to activities under the canopy**)
- Conservation (**continued good stewardship of forests**, even without threat of deforestation or forest degradation)
- Sustainable management of forests (reducing emissions through **harvesting activities** with lower impact)
- Enhancement of forest carbon stocks (**enhanced sequestration** of carbon through afforestation, reforestation and restoration of forest land)

Relative to such a 'nested REDD' perspective, the REDD-ALERT project in its 6 work packages

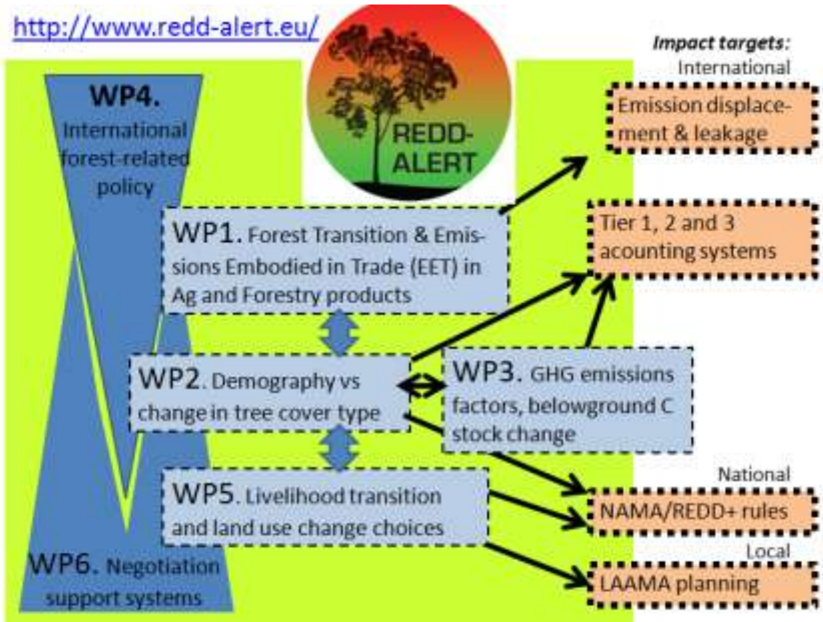


Figure 8. Aspects of the development of REDD+ mechanisms that can support outcomes and impact targets at local level (locally appropriate adaptation and mitigation actions = LAAMA), national level (nationally appropriate mitigation actions = NAMA) and associated REDD^{+} rules, as well as internationally trustable C accounting systems and analysis of cross-border C emission displacement ('leakage')

1.5 Questions for this analysis

Key questions to be addressed in this analysis are centred around the way the design of nested REDD can be supported by the abatement cost curves that relate past greenhouse gas emissions to the economic gains they allowed:

1) How are '***abatement***' costs related to ***opportunity***, ***transaction*** and ***implementation*** costs?

2) How do opportunity costs interact with the other abatement cost components during the negotiation of nested REDD+ implementation arrangements?

3) What methods exist to estimate opportunity costs in tropical forest margins?

4) How can methods of analyzing opportunity costs with increasing sophistication, complexity and cost be linked to different stages of negotiation of locally applicable actions that can be both fair and efficient?

In the final discussion section we will focus on

- Connections between the various levels of opportunity cost analysis presented
- Approached to harmonize the land cover ⇔ land use legends
- Potential scope for flow-based carbon accounting approached to anthropogenic emissions that relate to land use and commodity value chains as a complement to current approaches.

2. Abatement, opportunity, transaction and implementation costs

The total costs of reducing emissions from deforestation and degradation consist of components accruing to the local stakeholders involved in land use change, as well as the external investors and regulators. A simple scheme identifies three main categories: transaction, opportunity and implementation costs (Fig. 9; Table 1).

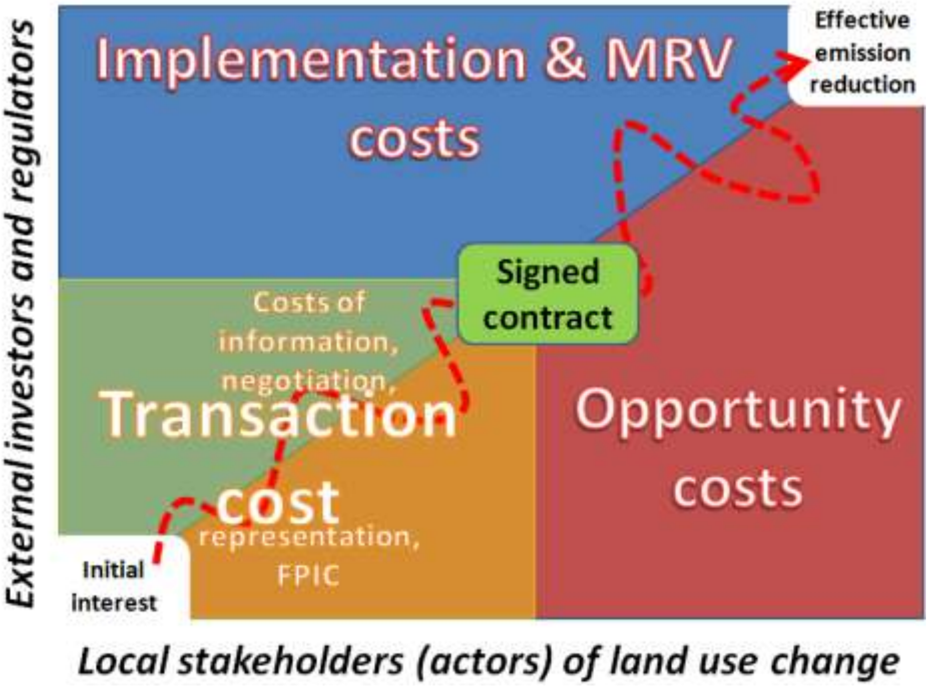


Figure 9. Cost categories involved in efforts to reduce emissions from deforestation and forest degradation; A. linked to project development trajectory, B. examples of cost elements

A simple formulation of the expected net benefits in financial terms for either side of a REDD+ implementation contract is:

$B_l = Rec_l – Imp_l – Opp_l - T_l + Cobenefits_l$ [1a]

$B_e = C_{REDD} - Pay_e – Imp_e – Opp_e - T_e + Cobenefits_e$ [1b]

$B_i = n_i (T_l + T_e) + (Pay_e - Rec_l)$ [1c]

where

B_l , B_e , B_i = Net benefits for local and external stakeholders and intermediaries, respectively,

C_{REDD} = verified reduction of greenhouse gas emissions

Rec_l and Pay_e = the payments received locally and paid externally, respectively

$Cobenefits_l$, $Cobenefits_e$= expected ‘co-benefits’ for local and external stakeholders, respectively,,

Table 1. Elements of transaction, implementation and opportunity cost categories (N = natural, H = human, S – social, I = infrastructural and F = financial capital; ~ = breakeven, ↑ increase, ↓ decrease)

	Transaction costs	**Implementation, MRV costs**	**Opportunity costs**
Cost compo-nents	Meetings Studies, surveys Data management Information products Social mobilization Establishing baseline C stocks and negotiating 'business as usual' scenario Building up monitoring and reporting capacity Development of regu-latory framework, incl. recognition of rights Documented 'free and prior and informed consent' (FPIC)	Depending on design: • Labour and technical costs to guard and/or restore • Change in tax and incentive systems • Change in LU plans and regulations • Investment in alternative livelihood strategies with less dependence on forest exploitation or conversion • Measures to reduce leakage ***MRV***: measurement and monitoring, data handling and independent verification Learning and adjustment in multi-stakeholder context	Missed opportunities for legal and more remunerative land use options (labour and land rent) compared to REDD+ scenario land use Socio-cultural and psycho-logical effects of constrain-ed development Missed tax and retribution revenue for local govern-ment With large-scale REDD+ implementation: increased commodity prices due to reduced supply (potentially inducing 'leakage')
Potential co-bene-fits	Social mobilization, human capacity and negotiation expe-rience Improved governance	Enhanced transparency of land use change and decisions on development pathways Enhanced 'green' profile of area and country, translating to new business options & investment	Enhanced natural capital providing local environ-mental services Biodiversity resources conserved
Local capitals	N~ ,S↑, H↑, I~ ,F~	N↑,S↑, H↑, I↑ ,F~	N↑, S~ , H~ ,I~ ,F ~
External capitals	N~ ,S↑, H~ ,I~ ,F↓	N↑,S↑, H~ ,I~ ,F↓	N↑,S~ , H~ , I~ ,F↓
Primary transfer	External finance for increase in H and S capitals	External finance for increase in N capitals + transfers to local H, S and/or I investment	External finance for increase in N capitals

Imp_l , Imp_e = Implementation costs, for local and external stakeholders, respectively,

Opp_l , Opp_e = Opportunity costs of foregone profitable legal land use for local and external stakeholders, respectively,

T_l , T_e = transaction costs for local and external stakeholders, respectively

n_i =net benefit rate for intermediaries on the transaction costs paid by local and external stakeholders[4].

In practice, however, the transaction costs involve several steps which may lead to a breakdown of negotiations towards a contract, with the likelihood that there are no returns on the investments made up to that point. When the negotiation process is described as a Markov chain, the tem E (expected benefits) has to be differentiated by the stage in the stepwise process (Fig. 10).

Early culling of project ideas that will not lead to net benefits in project implementation has to be an important part of any strategy to increase net benefits to local as well as external partners, as the transaction costs incurred in negotiation processes that do not lead to signed contracts and successful project implementation have no positive terms to counter them. Such approach is primarily driven by efficiency arguments, but it also reduces unfair allocation costs to and false expectations for local stakeholders who are unlikely to involve in the final contract.

It is necessary to conduct an early assessment of the likelihood that benefits obtained are likely to exceed implementation + opportunity costs, after allowance for transaction costs. Implementation costs are generally borne by the external partner and will need to be clarified during the negotiation process; opportunity costs are borne largely by the local stakeholders and may have have complex 'multiplier effects' in the local economy (esp. where local stakeholders were not fully paid for their contributions to the local value chains). It is therefore important that an early assessment of the 'opportunity costs' is made before negotiations go too far and the tab on transaction costs runs too high. Unless opportunity costs are substantially below the price level that external partners are willing to commit, further negotiations are likely to lead to a net loss for the local partners. An early, low-cost assessment of opportunity costs can increase cost-effectiveness of the overall process and is thus an important step within the project initiation and development process (Fig. 11).

Opportunity costs of foregone land use conversion are based on any difference in earnings from conserving or enhancing the original land uses (largely forests), versus converting them to other legal and typically more valuable, land uses; it quantifies forgone net benefits from voluntarily agreeing to not change land uses within what is legally allowed, such as potentially to more lucrative agricultural crops or intensified agroforestry use. Of the five types of activities that can be supported in REDD+ according to the Cancun agreements (Box 1), the 'non-conversion' of forest to agricultural land uses is likely to involve the highest opportunity costs and the most complex stakeholder arrangements. It therefore deserves special attention in opportunity cost analysis.

[4] Intermediaries live of transaction costs and usually their net benefit does not depend on the ultimate success of the transactions they mediate.

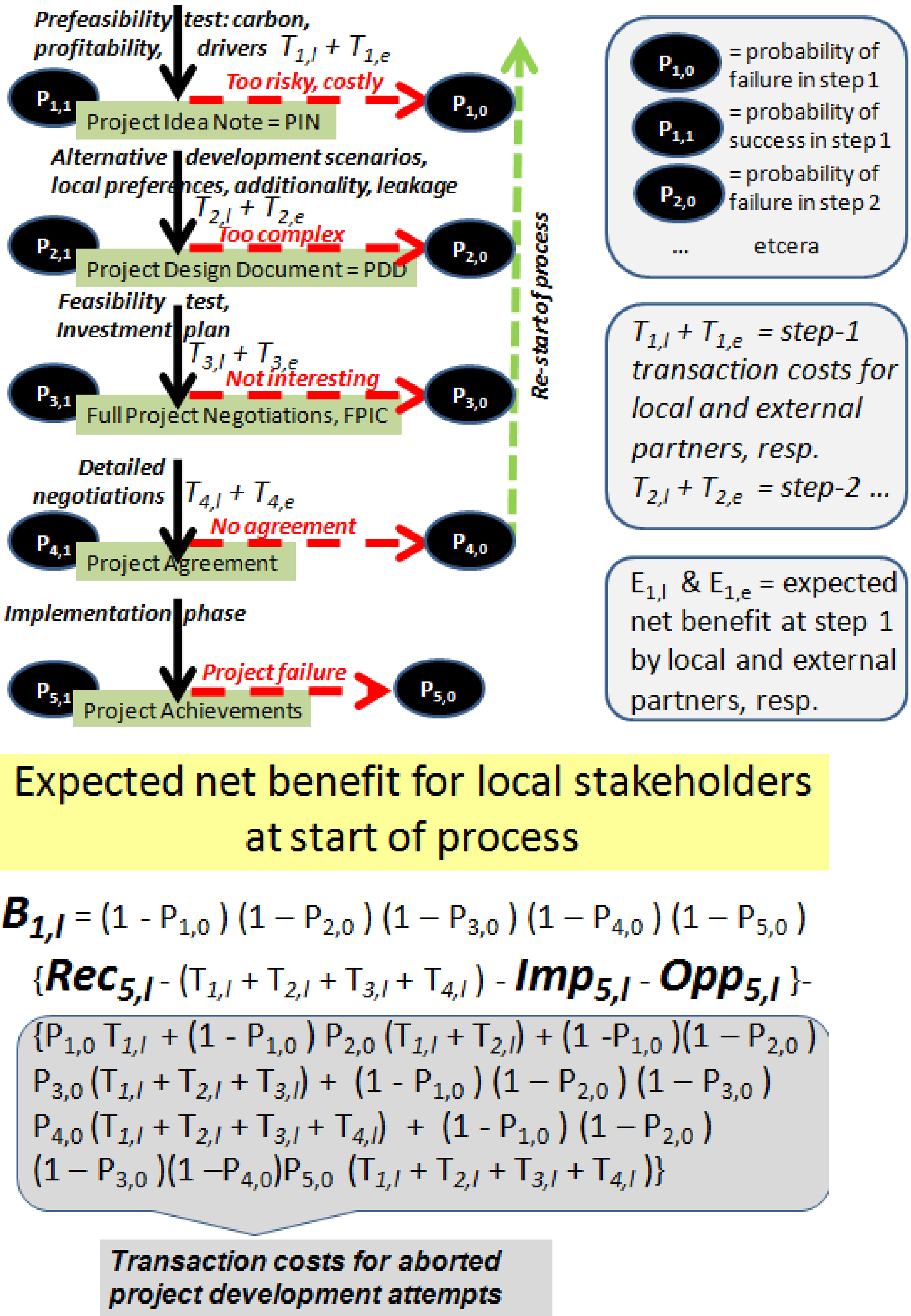


Figure 11. Markov chain representation of a 5-step process towards project implementation with transaction costs and risks of failure at any step

A stepwise approach to any situation that might benefit from local REDD+ action, will therefore require estimates of the opportunity costs (Fig. 12).

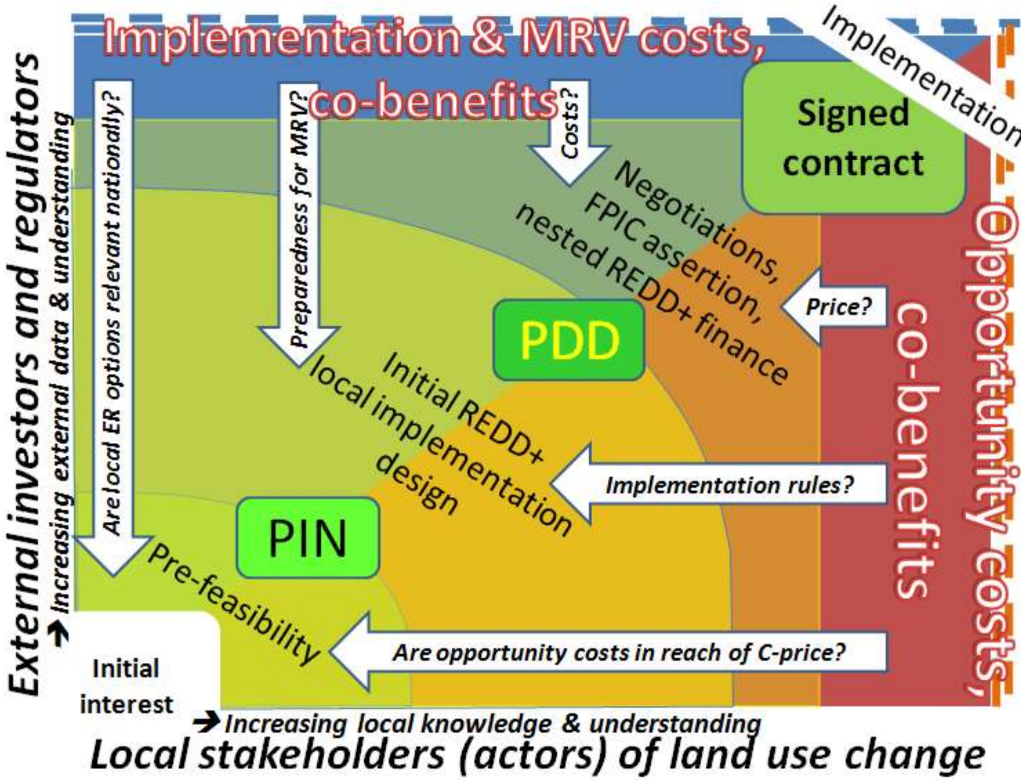


Figure 12. Stepwise increase in local and external knowledge and understanding of the likely benefits of a contract for local REDD+ implementation (via Project Idea Note (= PIN) and Project Design Document (= PDD) to signed contracts based on Free and Prior Informed Consent (= FPIC)) and recognition of transaction, implementation and opportunity costs as well as opportunities for co-benefits; externally monitored 'safeguards' need to be added

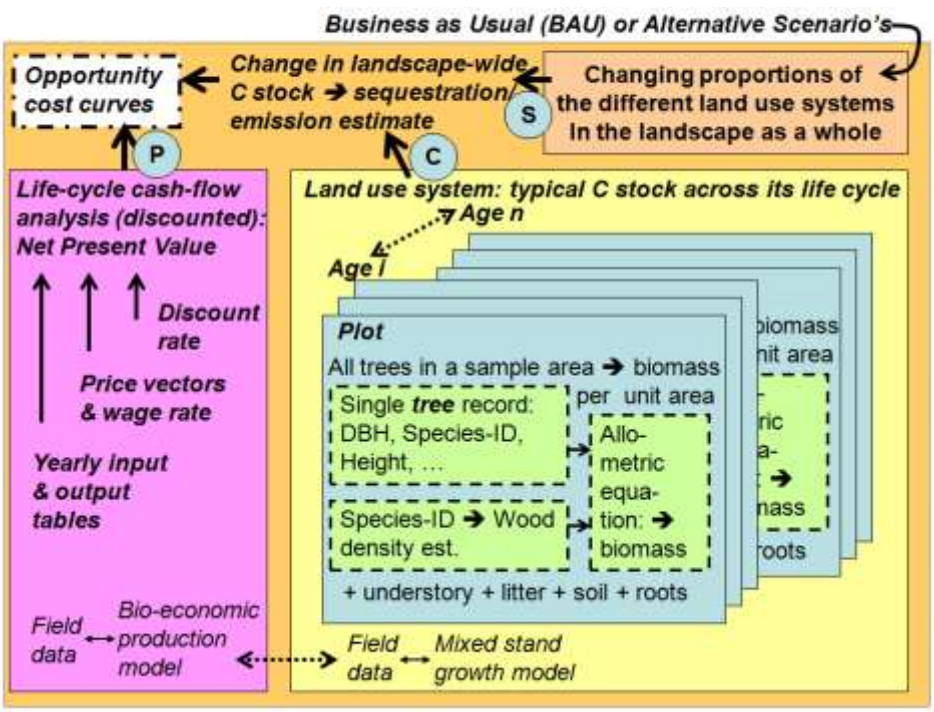


Figure 13. Components of opportunity cost curve quantification, emphasizing the need to get the biophysical and economic description of various stages of a life-cycle approach aligned

3. Four levels of opportunity costs analysis

Tradeoffs between carbon storage and profitability of land use systems can be analyzed in a stepwise manner at least to four different levels of engagement (Fig. 14):

I. Comparison of system properties, e.g. using scatter plot of the time-averaged C-stock of a land use system and the Net Present Value as intensity measures of carbon storage and profitability that can both be expressed per unit area (e.g. as t C/ha and $/ ha). Straight lines are to be expressed in an equivalent carbon price ($/ t C) as in the ASB analysis of land use in tropical forest margins in the 1990's (Palm et al., 2005; Tomich et al., 1998, 2002, 2005; Murdiyarso et al., 2002).

II. Abatement cost curves that relate the cumulative amount of historical emissions (area of land use change multiplied with difference in time-averaged C stock) to the net benefits (difference in profitability per unit emissions) (van Noordwijk et al., 2007; Swallow et al., 2007)

III. A comparison of landscape-level C stock and farm income as derived from dynamic land use models under alternative scenarios (Suyamto et al., 2005, 2006, 2009; van Noordwijk et al., 2008)

IV. As III but derived from agent-based models (Villamor et al., 2010) that represent heterogeneity in agent properties and preferences.

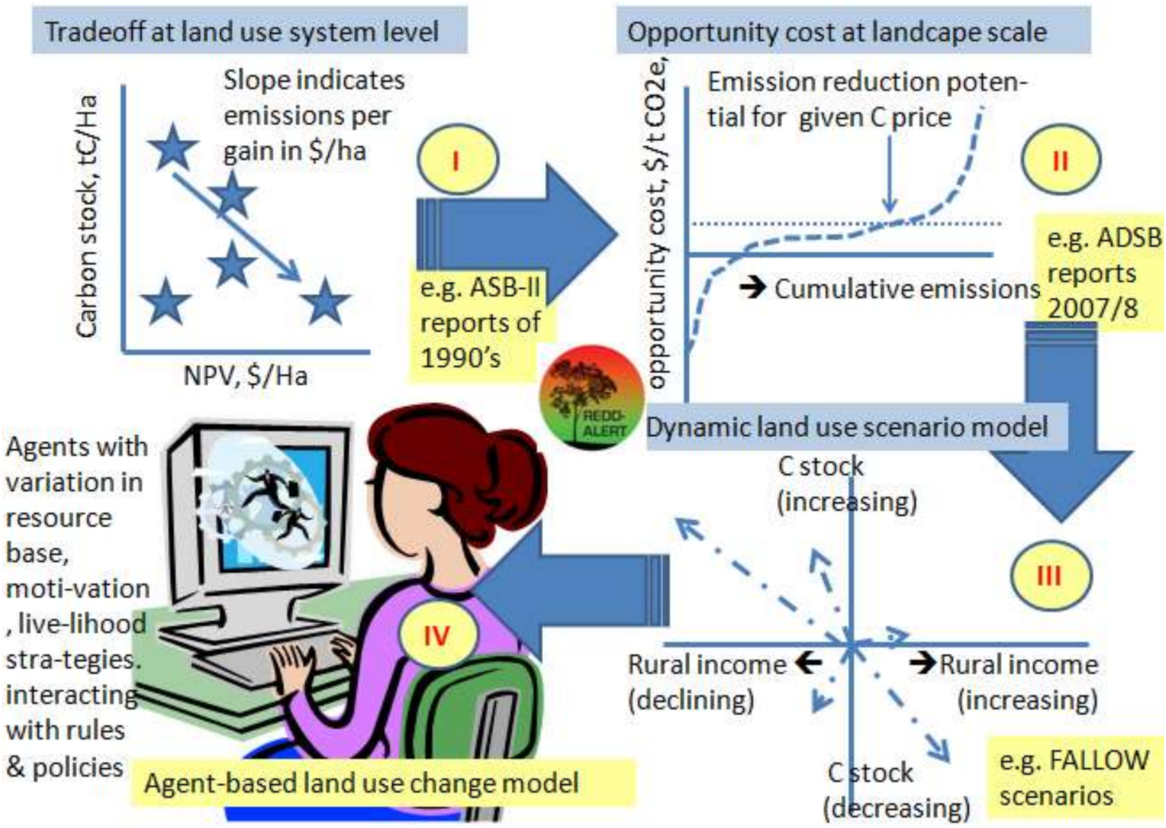


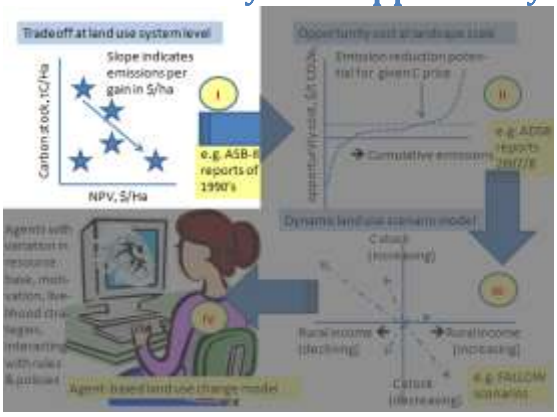
Figure 14. Four levels of analysis of the tradeoffs between terrestrial carbon storage and the profitability of land use options

In the later phase of project development, increasing level of detail and engagement in analyzing opportunity cost is necessary. As REDD+ project implementation planning is closer to securing agreement, the most sophisticated opportunity cost analyses should be conducted (Table 2).

Table 2. Tentative linkage of level of detail in opportunity cost analysis to the stage of progress of negotiations of locally appropriate REDD+ implementation

Stage in local REDD+ negotia-tion (compare Fig. 3)	Approach to opportunity cost analysis (compare Fig. 14)	Data requirements	**Outputs obtained**
Initial interest	I. Comparison of land use options	Effective land use classification, time-averaged C-stock estimates + Net Present Value calculations	Pont-by-point comparison of slope (➔ potential C cost of abatement)
PIN = project idea note	II. Analysis of part land use change in combination with C emissions and changes in profitability	***Idem,*** plus a land use change matrix reflecting recent history (or 'business as usual' scenario) using a consistent legend with the level-I data	Volumes of emission s differentiated by apparent C price and policy regime
PDD = project design document	III. Dynamic scenario modelling	***Idem,*** plus parameters of household decision making and other land use performance indicators; scenarios for incentives and land use restrictions	Emissions for forward-looking scenarios & external investment evaluated
Negotiated contract	IV. Agent-based models that include agent-diversity in circumstances and preferences	***Idem,*** plus descriptors of agent diversity in resource endowment and preferences in land use decisions	Equity aspects of scenarios

3.1 Level-I analysis of opportunity costs



Level-I analysis directly compares the Net Present Values and time-averaged C stocks of land use systems

The first step in the level-I analysis of opportunity costs is the identification of a functional taxonomy of land use systems that provides the legend for maps and the entries to tabulations. The taxonomy has to combine the types of land cover that can be effectively distinguished from remote sensing data and a systems approach to land use that attribute distinct trajectories of land cover types with a a land use system. Such a land use system represents an entity upon which an economic assessment of annual input/output budgets and, in combination with a discount rate, a Net Present Value can be done (van Noordwijk et al., 2001). Tradeoff analysis is doable on the harmonized land cover & use legends between remote sensing land cover that associates with 'time-averaged C stock' and financial analysis on land use system that associated with 'Net Present Value'. (Fig. 15).

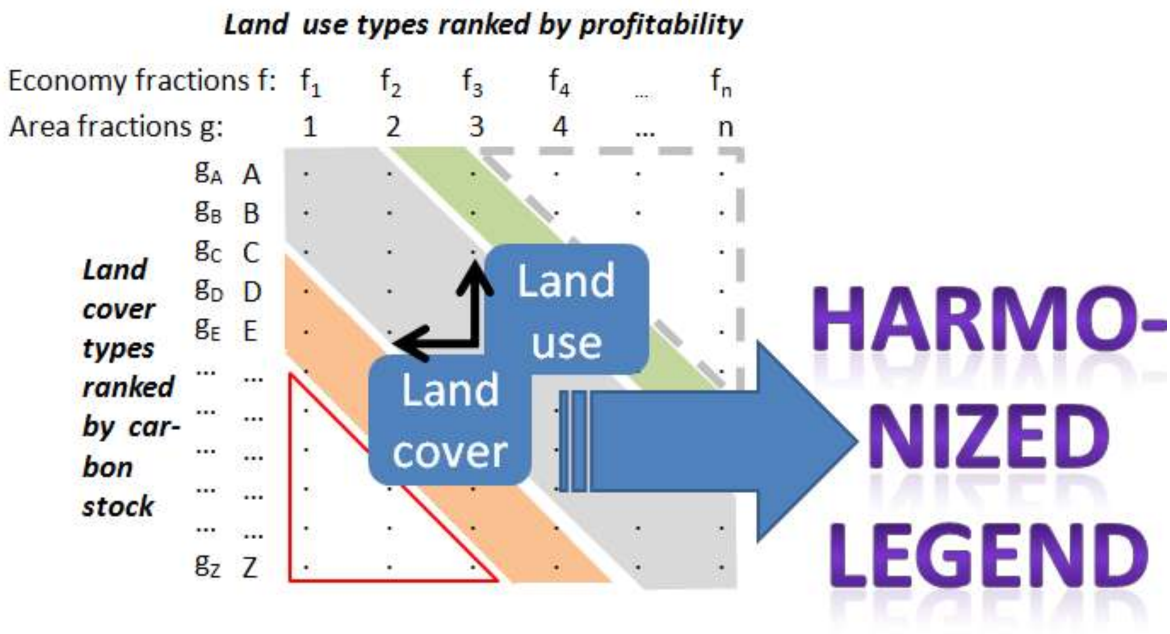


Figure 15. Carbon stocks are primarily related to 'land cover', while profitability depends on the use of inputs and type and quantity of products harvested, as described in a 'land use' concept

Most land use systems that involves the management of trees and other perennial crops have multiple phases. If a land use system is in an equilibrium phase, the spatial fractions of different stage (land cover types) are equal to the relative duration of these stages. If a particular land use system is increasing in the landscape, early stages dominate and if it declines the late stages do. A combination of farmer interviews that establishes a 'typical' life cycle and remote sensing analysis of the resulting mosaic of land cover stages in the landscape may be needed to capture the local land use dynamics.

Agricultural intensification in tropical forest margins can follow different pathways, as described by van Noordwijk et al. (2009; Fig. 16), that leads to various tradeoffs between C stocks and profitability or the human population density that can be supported sustainably.

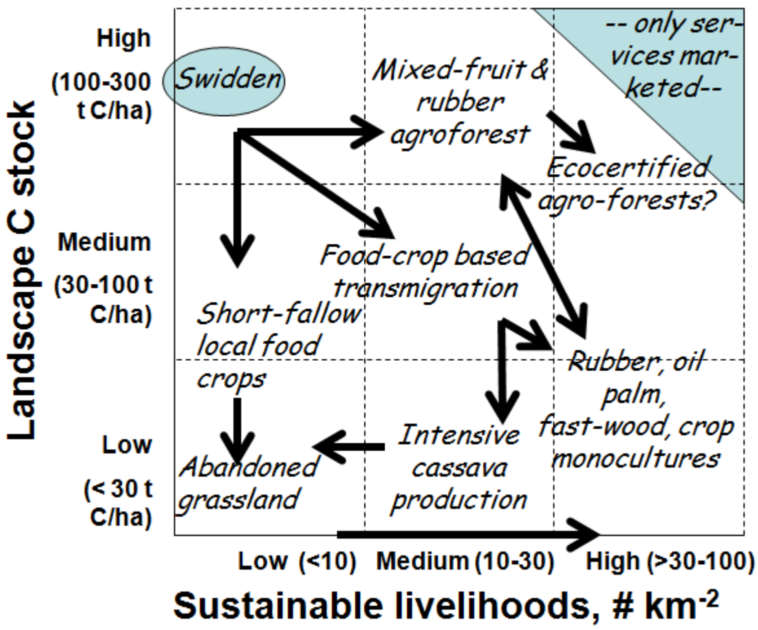
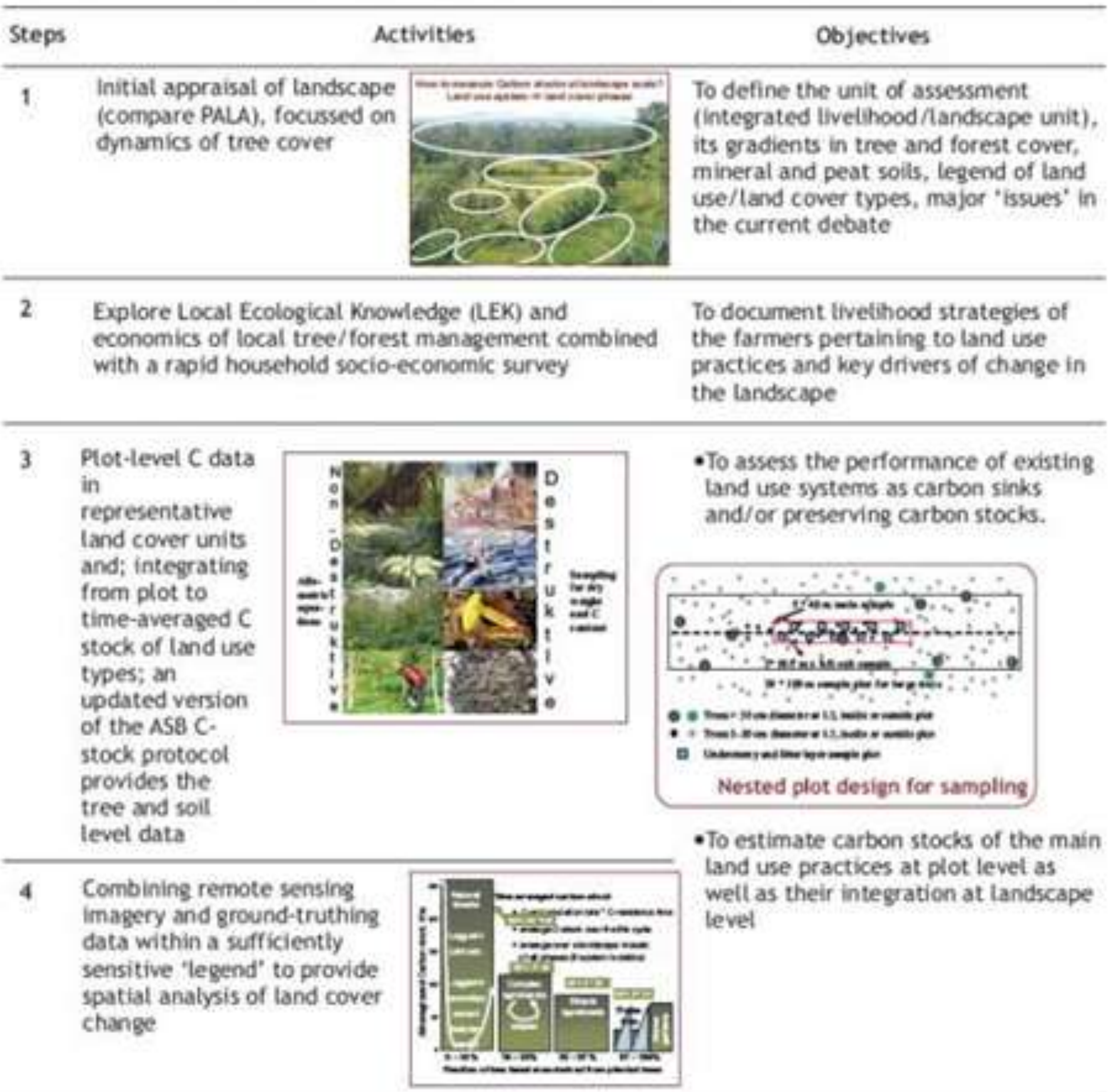


Figure 16. Tradeoff between landscape-level C stock and the human population density that can secure sustainable livelihoods in tropical forest margins in depenence of the pathway for agricultural intensification emerges from 'swidden' types of land use that alternate cropping with fallow regrowth (Source: van Noordwijk et al., 2009)

Establishing a locally appropriate 'legend' for the analysis of tradeoffs will usually require an iterative process that involves economists, geographers, ecologists and social scientists, to reconcile the divergences in the various components of the analysis.

Following the process of establishing such a legend, data on the C stocks of different land cover types are needed, along with an area-based sampling approach, as well as farm/household based analysis of activities, costs and benefits. The C stock analysis can follow the steps established for the RaCSA (Rapid Carbon Stocks Appraisal) protocol (Fig. 17).

Methods for profitability analysis of the land use systems with their qualitative strengths and weaknesses (RAFT, http://www.worldagroforestrycentre.org/sea/Publications/files/leaflet/LE0152-09.PDF) can be followed by quantification of input/output tables per year of multi-year cyclical systems. The Policy Analysis Matrix approach of Monke and Pearson allows the profitability to be assessed at private (farmgate) and social (national economy) accounting stance. The results for



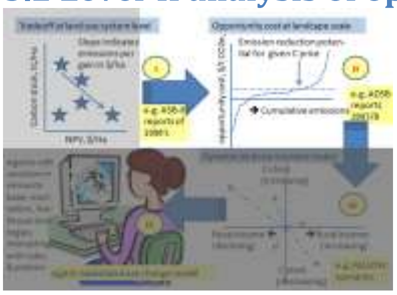
Steps	Activities	Objectives
1	Initial appraisal of landscape (compare PALA), focussed on dynamics of tree cover	To define the unit of assessment (integrated livelihood/landscape unit), its gradients in tree and forest cover, mineral and peat soils, legend of land use/land cover types, major 'issues' in the current debate
2	Explore Local Ecological Knowledge (LEK) and economics of local tree/forest management combined with a rapid household socio-economic survey	To document livelihood strategies of the farmers pertaining to land use practices and key drivers of change in the landscape
3	Plot-level C data in representative land cover units and; integrating from plot to time-averaged C stock of land use types; an updated version of the ASB C-stock protocol provides the tree and soil level data	•To assess the performance of existing land use systems as carbon sinks and/or preserving carbon stocks.
4	Combining remote sensing imagery and ground-truthing data within a sufficiently sensitive 'legend' to provide spatial analysis of land cover change	•To estimate carbon stocks of the main land use practices at plot level as well as their integration at landscape level

Figure 17. Steps in the Rapid Carbon Stock Appraisal (RaCSA) protocol ([http://www. World agrof orestrycentre.org/sea/projects/tulsea/sites/default/files/inrm_tools/13_TULSEA_RaCSA.pdf](http://www.worldagroforestrycentre.org/sea/projects/tulsea/sites/default/files/inrm_tools/13_TULSEA_RaCSA.pdf))

systems involving tree production are sensitive to the discount rates used, and a difference between social and private discount rate can suggest that private decisions of using trees on farm are suboptimal from a societal perspective (Santos-Martin and van Noordwijk, 2011). A further specification of the profitability perspectives of local and national government would provide a relevant addition but has not yet been mainstreamed in the approach. If our landscape of interest is large enough to bear spatial patterns that affect the output input components then zoning and stratification are necessary to reduce uncertainties. The examples are spatial patterns in infrastructure, accesses and other factors that influence input costs, product prices and wages, patterns in biophysical characteristics that affects production per unit areas.

Level-I analysis of tradeoffs uses a 2-D scatterplot of time-averaged C stocks (tC/ha) and the Net Present Value ($/ha) of alternative land use options within a landscape or agro-ecological zone. As in figures 3 and 4, the upper right corner of the graph is typically empty (if high C stock land uses would have superior profitability there shouldn't be an emission problem…), while many points fall on the main negatively sloped diagonal. The slope of line (tC/ha)/($/ha) can be used to derive an equivalent carbon price (converting a difference in C stock to the resulting CO_2 emissions by multiplication with 44/12 for the respective molecular weights). In most cases there are low-C-stock & low-profitability land use systems in the lower left corner of the graph, and avoiding conversion to such systems and/or returning them to higher C stock and/or higher profitability uses will be an important part of landscape level REDD+ scenarios. To evaluate the total emission reduction that can be expected in such strategies, however, we need to know the amount of land in each land use type and the dynamics of land use change under a business as usual scenario. That requires a Level-II analysis.

3.2 Level-II analysis of opportunity costs (REDD-ABACUS)



Level-II analysis includes the time dimension of land use change among the various land use systems that were characterized for C stocks and Net Present Value at level I

Building on the legend of land use types, the C stock and profitability data of a Level-I analysis, combination with land use change data can lead to a further quantification of opportunity costs, at level II (Fig. 18).

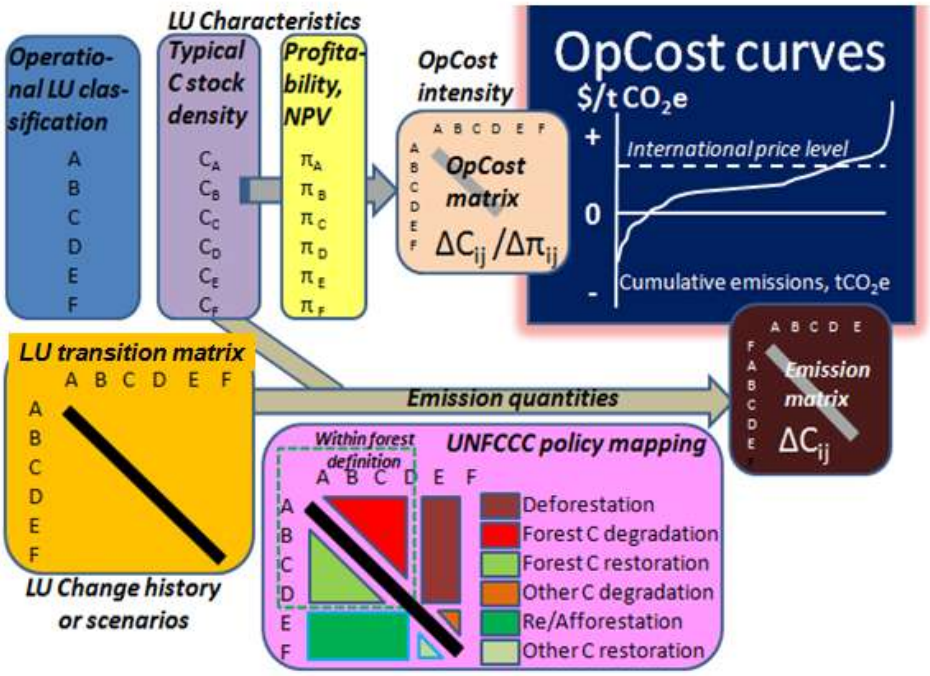


Figure 17. Flow chart of a level-II opportunity cost analysis as developed by van Noordwijk et al. (2007) and Swallow et al. (2007); a detailed training manual (attachment 3) is available

The REDD-ABACUS software (attachment 2) was developed along these lines and provides opportunity cost curves differentiated by zone, provided that data inputs are differentiated (Fig. 19). Users can easily check interactively different issues such as what particular land use changes have the major emission shares and at what level of opportunity costs, at a particular level of compensation price, how many percent of emissions can be abated. This software also allows some simple future scenario simulation by modifying the land use transition matrix, e.g., in Protected Areas, future deforestation is targeted to be zero, while degradation rate stays the same as in the past, in Areas of Other Uses, the rate of conversion of logged over forest to oil palm will be doubled while shrubs conversion to croplands are tripled. Also the changes in NPV with increasing demand for particular commodity can be simulated. The output of ABACUS can be an emission curve, sequestration curve, C-profit tradeoffs matrix or summary table of emissions per unit areas or total emissions and sequestration for each zone.

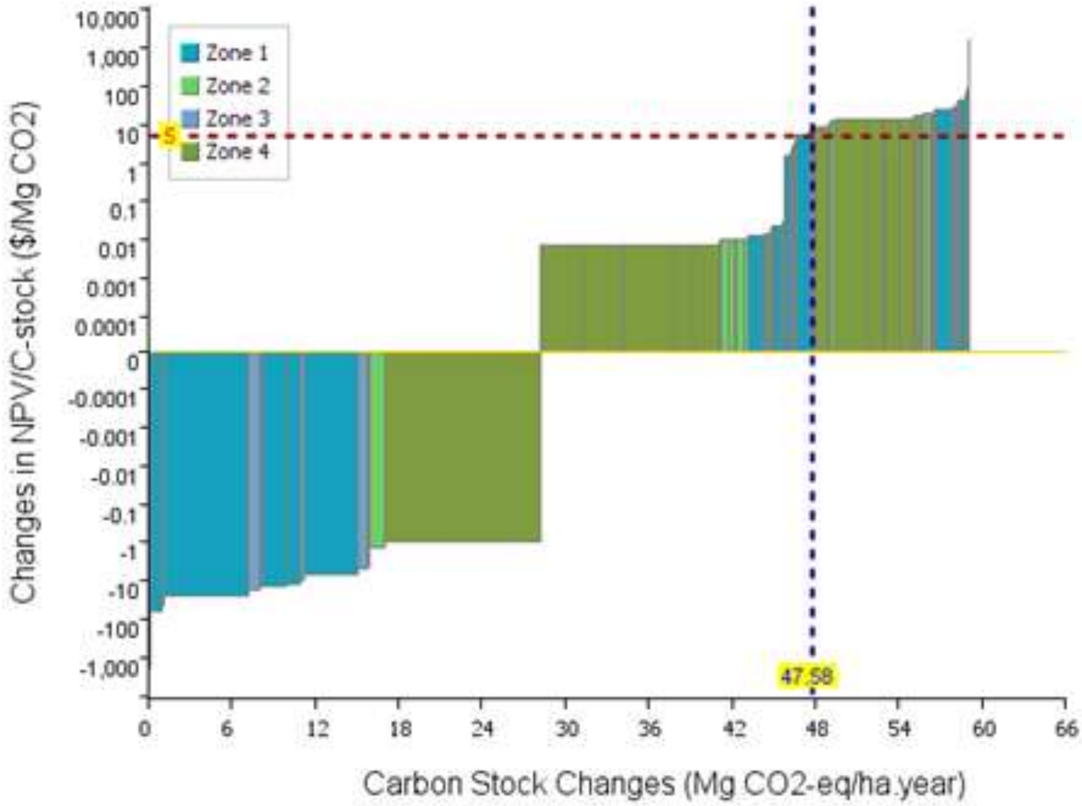


Figure 19. Example of the output of REDD+-Abacus software (attachment 2) for processing data on land use change, C stocks and profitability into 'opportunity cost' curves

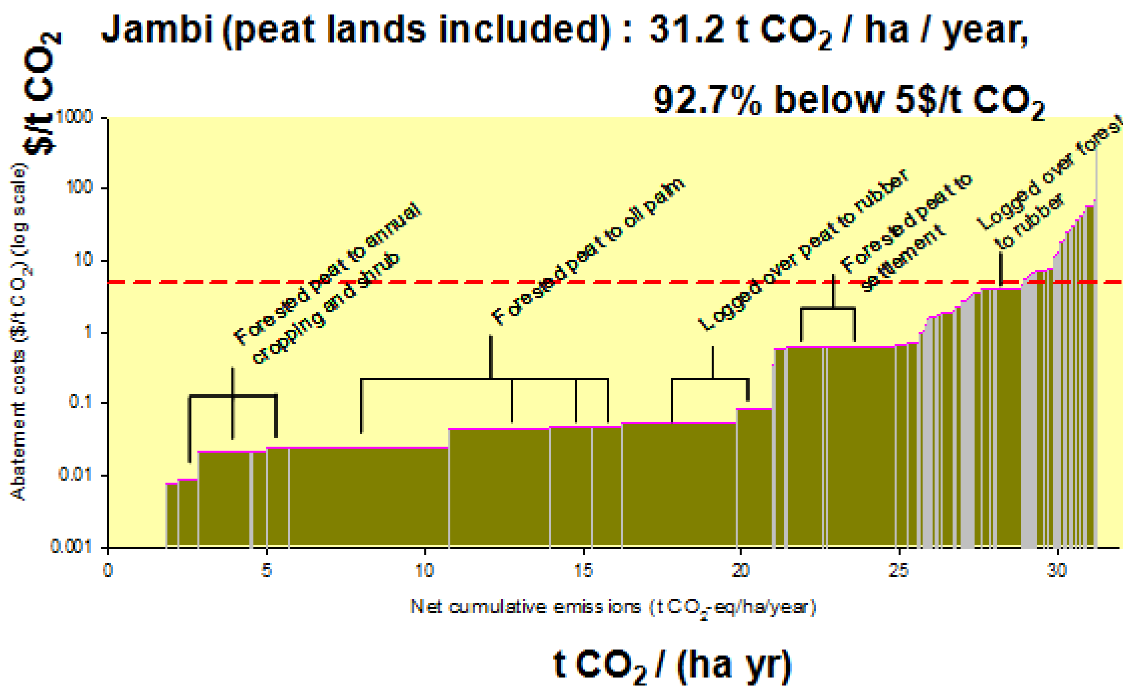
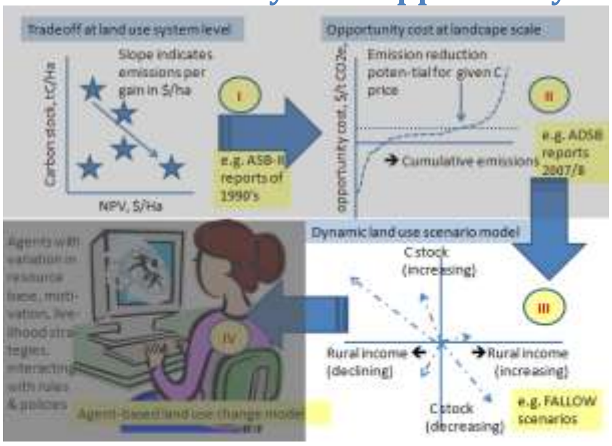


Figure 20. Example of opportunity costs based on 2000-2005 land use change in Jambi province (Indonesia) (source: van Noordwijk et al., 2007)

3.3 Level-III analysis of opportunity costs (FALLOW)



At level III the relationship between landscape C stock change and profitability is analyzed for forward scenarios that can incorporate a range of REDD+ implementation mechanisms, either spatially explicit (change in land use planning) or programmatically (change in determinants of profitability and/or improvements of agricultural/agroforestry extension)

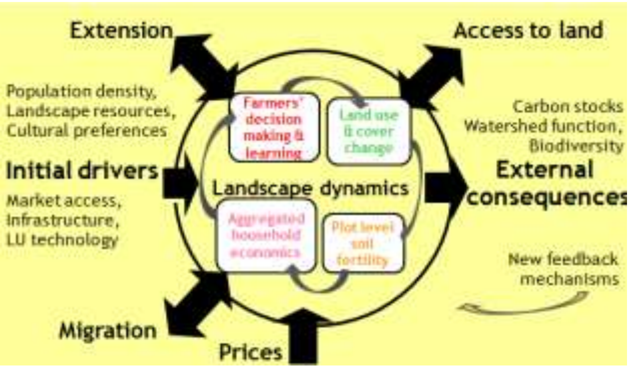


Figure 21 Flow-chart of the FALLOW model, which can be used for Level-III OpCost analysis of land use change scenarios that follow a 'Business as Usual' extrapolation of current trends, or include area-based restrictions to certain types of land use ('land use planning') or generic changes to profitability determinants of all or selective land use types

The FALLOW model (Fig. 21 - 24)), which is a process-based, spatially explicit model of land use changes, can be used for Level-III analyses that use the historical approach of a level-II analysis of past trends as basis for exploring 'plausible' futures. Other dynamic land use models that are open to policy levers that are either generic or spatially explicit can be similarly used.

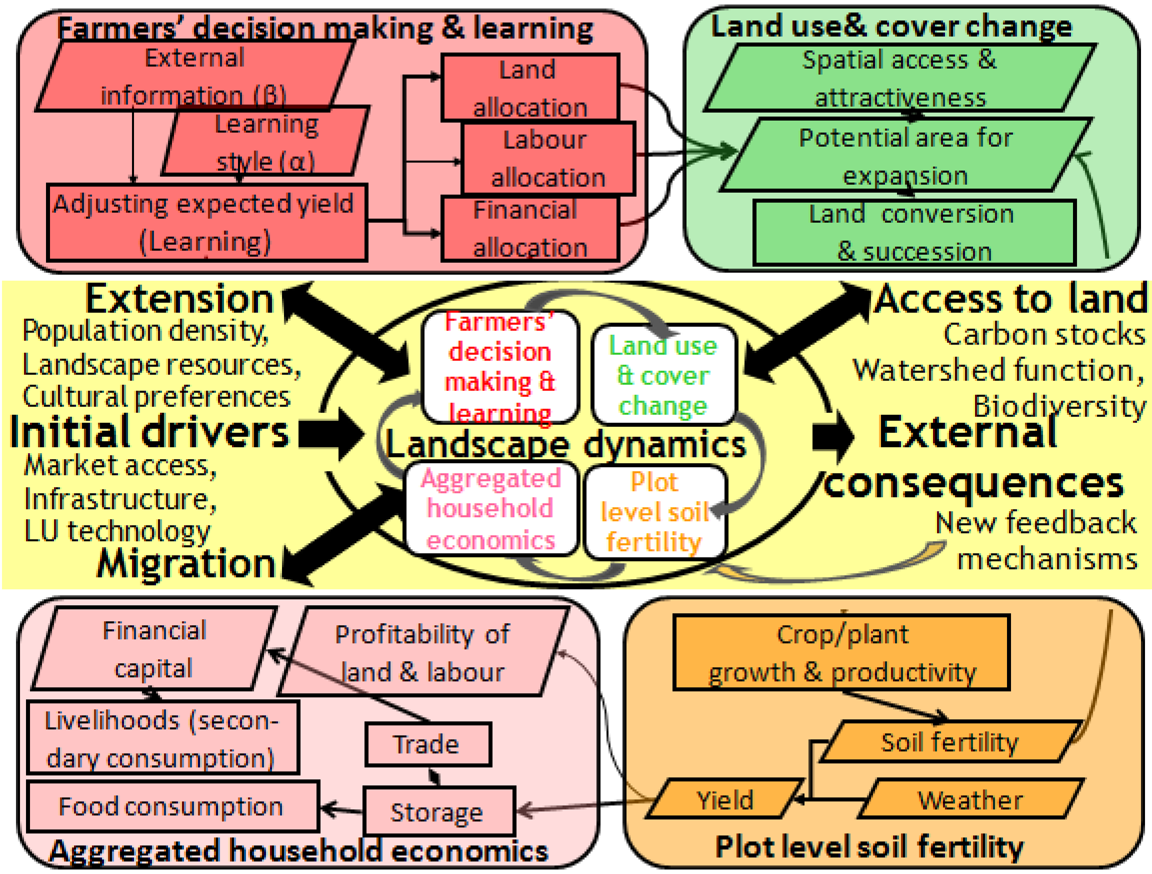


Figure 22. Four core modules of the FALLOW model specify the interacting dynamics at a) farm household decision making, b) land use and cover change, c) plot-level soil fertility, C stocks and productivity and d) aggregated household economics; households can be stratified by assets and multiple 'learning styles' can interact with locally generated and externally supplied (extension) information on the likely performance of land use alternatives

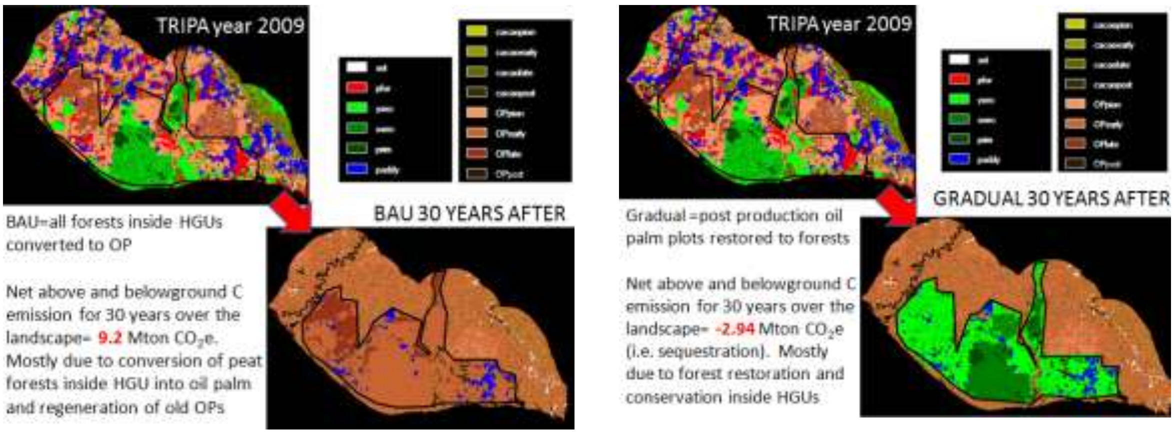


Figure 23. Example of FALLOW application to a landscape in Aceh (Sumatra, Indonesia) where peat swamps, oil palm concessions and orangutans interact with local livelihood options (Tata et al., 2010; attachment 4)

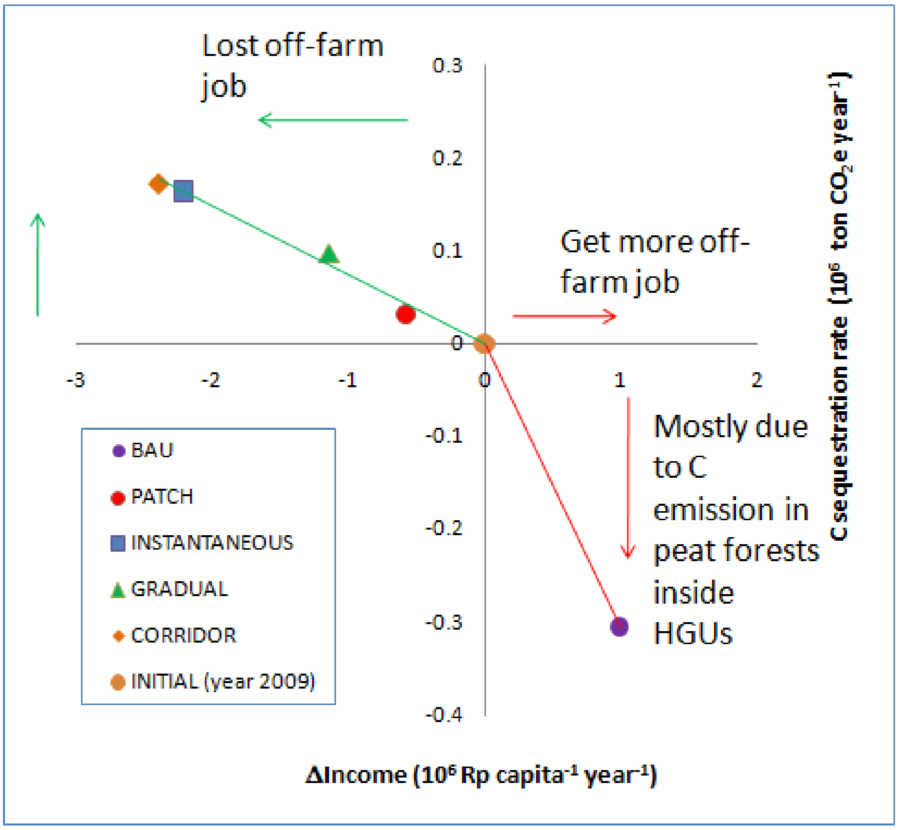
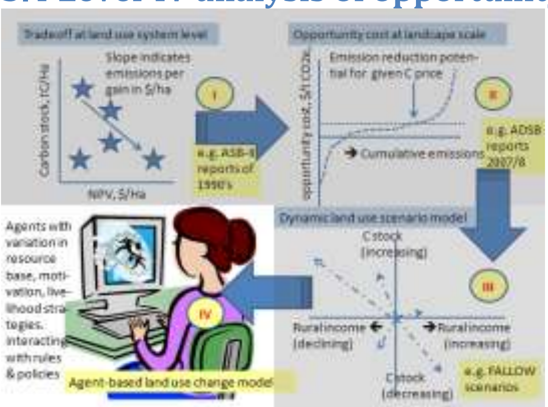


Figure 24. Example of a scenario-based tradeoff analysis of the relationship between landscape-level carbon stocks and local economic activity (human population size times net benefits derived from land use patterns (based on Tata et al., 2010; see also van Noordwijk et al., under review (attachment 4)); HGU is a 'land use concession'

3.4 Level-IV analysis of opportunity costs (Agent-based models)



Level-IV analysis enriches the results of level-III scenarios by replacing the 'stratified' description of farm households by one that reflects the full diversity of household resources during a human life-cycle, plus social interactions that extend beyond economic rationality considerations

Full level-IV analyses do not yet exist, to our knowledge, but there is work in progress. Within REDD-ALERT work package 6 is exploring the merits of such models and developing them for some of the research sites.

Diversity in land cover can result from differences of the following concepts (Villamor et al., 2010):

- Differences in ***time*** - if we consider that at household/farm level there are relatively small windows of opportunity for change, decision points linked to the individual life and investment cycle;
- Differences in s***pace*** - different land suitability for the various land use options under variable or changing climate; heterogeneous nature of topography of an area creates complex spatial pattern;
- Differences in ***resource endowment*** - with the land/labour ratio of the household interacting with its financial capital, effective discount rates for financial investment and the cost of hired labour;
- Differences in ***knowledge*** - array of options to be considered, specific expectations of potential performance;
- Differences in ***cultural preference*** - e.g. a preference for subsistence food production as form of security and negative preferences for certain types of work or food;
- Differences in ***policy constraints –*** e.g. restrictions of access of parts of the landscape for specific types of resource use;
- Differences in appreciation of ***environmental services*** (either based on intrinsic appreciation alone, or with additional external incentives through moral persuasion, rules or incentives); and/or
- Differences in ***portfolio diversity*** at the individual level, linked to risk management. It is not easy to dissect any given landscape pattern and identify the dominant contributors to current diversity, as a step towards understanding the way future dynamics can be influenced.

Such models can try to integrate across four types of feedback between agents that change land cover and the consequences that this has for profitability and environmental services, such as carbon storage (Fig. 25).

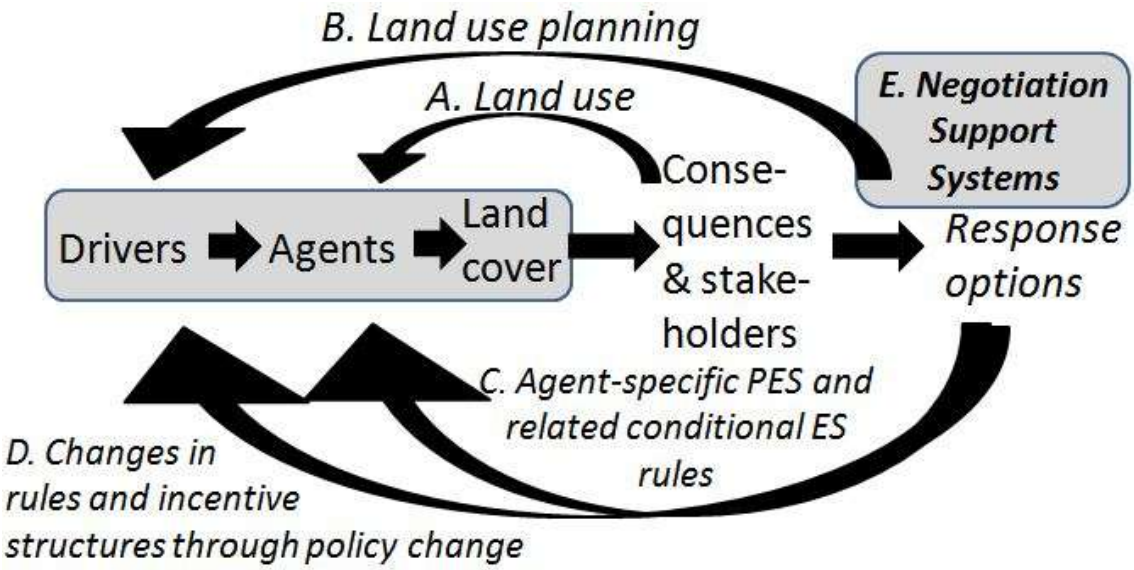


Figure 25. Four types of feedback that relate the consequences of land cover change to agents and drivers: A) on site productivity ('land use'), B) spatial restrictions on land use ('land use

planning'), C) performance-based payments or rewards for enhanced delivery of environmental services, D) changes in rules and incentive structures through policy change that will reduce the tradeoff between decisions based on production of goods' and that of 'services' (van Noordwijk et al., 2011; http://www.ecologyandsociety.org/vol16/iss1/resp1/)

A potentially generic way of describing any decision-making routine for agent-based models is that it considers the following (as depicted in Figure 25):

A) one or more options, that can be constant throughout the simulation or include new permutations or combinations
B) evaluation of the likely consequences of these options for one or more indicators of performance, which may relate to one or more of the 6 asset types
C) combination of the predicted consequences into an overall utility by some form or weighting or multiplication
D) choice for resource allocation to one or more options based on the utility scores, either going for the best or for some mixed portfolio of activities
E) implementation of learning at the level of expected consequences based on actual experience.

Review of published agent-based models that are spatially explicit (Villamor et al., 2010) reveals that the majority stays within a *homo economicus* paradigm of decision making that avoids the fundamental challenges to modelling diversity, which is the integration of non-economic motivations in the decision making of human agents.

If multi-layered decision making can be included, a level-IV model could potentially integrate the transaction and implementation costs of a local REDD+ implementation scheme and go beyond the opportunity cost analysis in a narrower sense. Multi-layered agent-based models where the rules are being negotiated as well as applied are, however, part of the unrealized potential of this approach and remain an option for future exploration.

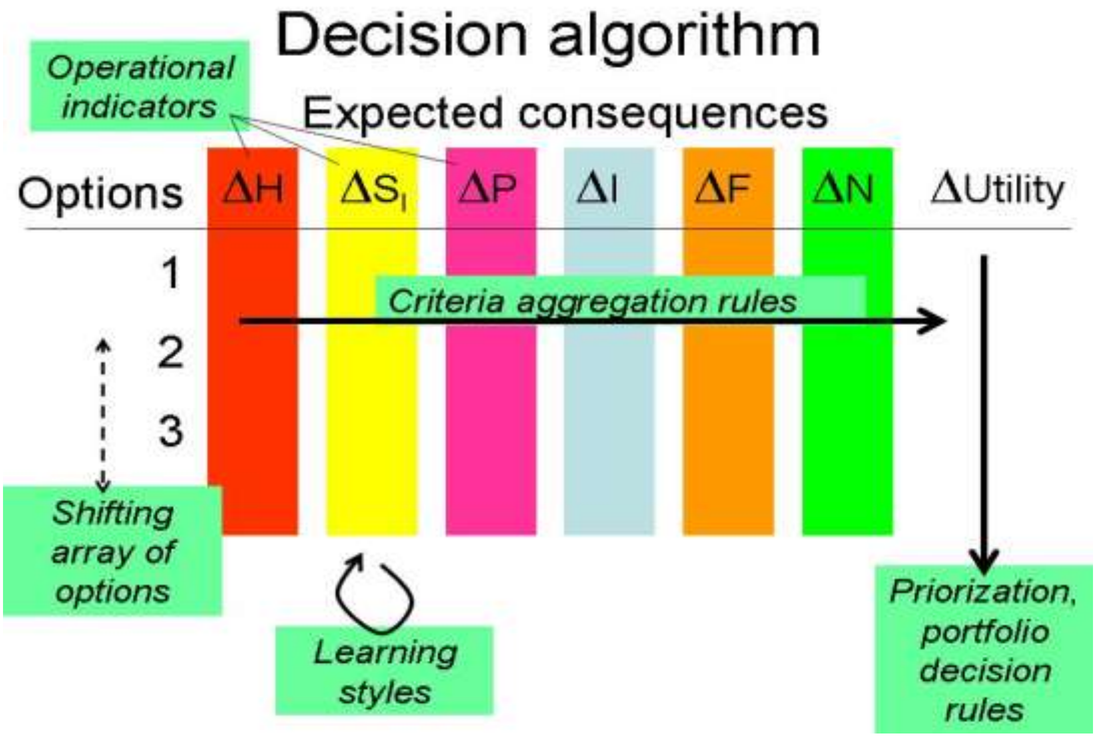


Figure 26. Generic decision algorithms for single or multiple layer multi-agent models, as reviewed by Villamor et al., 2010; Legend: H = human; S = social; P = political; I = infrastructure; F = financial; N = natural capital

4. Discussion and research priority issues

4.1 Connections between the four levels of opportunity cost analysis

In section 2 and Table 2 we tentatively linked the four levels of opportunity cost analysis to the various stages in a decision process around any local REDD+ implementation scheme, that requires increased knowledge of local stakeholders as well as investors/regulators. For levels I – III of opportunity cost as here described, the methods are operational and experience is building up of local applications. With appropriate attention to process as well as the uncertainties and biases of research methods, results can be obtained that support local negotiations and decision making.

No fully elaborated examples exist, however, of level IV approaches, and more qualitative short-cuts are probably needed to understand and support the negotiation processes in the final stages of contract specification.

Full accounting of opportunity cost might need to be performed to capture the foregone opportunities with the implementation of REDD+. At this point, opportunity costs beyond local farmers' direct monetary benefit from land uses are not yet accounted. Non-cash income is often important in forest livelihoods and can actually be included as total income in many studies. Foregone revenues and fiscal transfers from the central government to the local government should be considered. Multiplier effects and regional development that come along with some industrial enterprises that produce commodities such as oil palms are not yet included. Stakeholder analysis to map the direct and indirect beneficiaries of forest and land resources are necessary to capture a comprehensive analysis of benefit, transaction, implementation, opportunity cost that include co-benefit and safeguards.

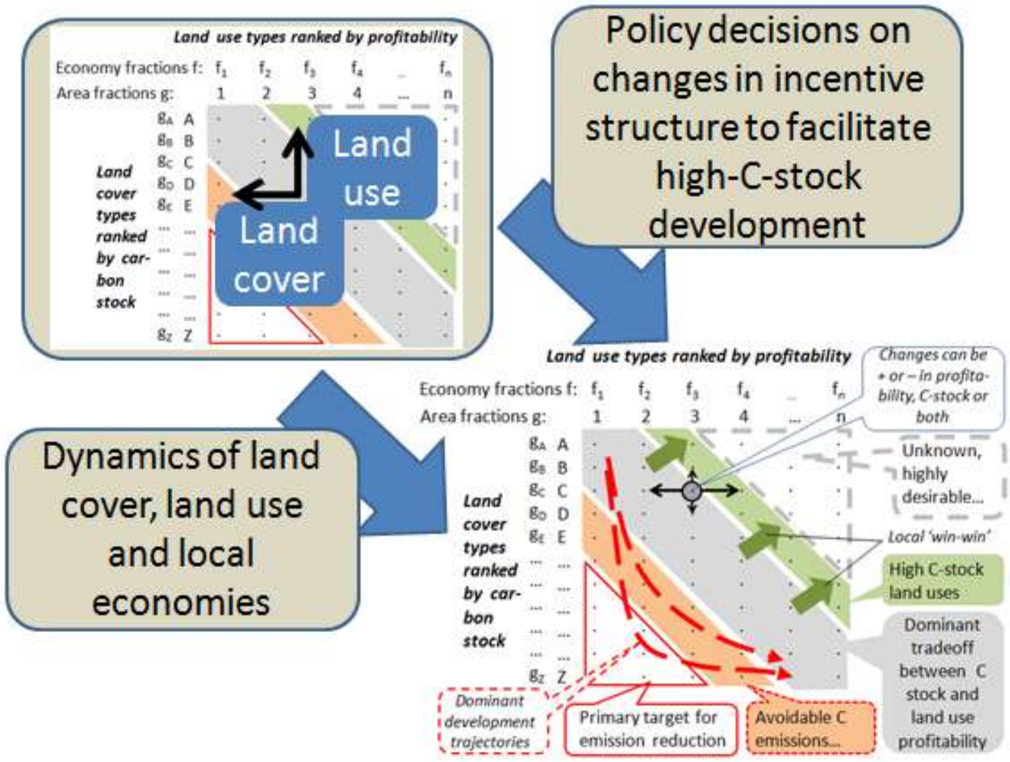


Figure 28. Fully elaborating the conceptual scheme of Fig 3 to the exploration of options for REDD+ implementation via opportunity cost analysis, depends on an effective and early congruence on a 'land use legend' that reflects the various interests, and on understanding of the local dynamics and policy options; early stakeholder consultation can make the resulting level-III model into a 'boundary object' that facilitates learning by all stakeholders in the process, rather than an externally generated tool for external use only

4.2 Other approached to opportunity cost analysis

A more complete overview of alternative approaches to the estimation of opportunity costs is provided in White et al. (2010), where the approach used here is described as 'bottom-up' and contrasted with 'top-down; approaches. For the purposes of generating national-level analysis of REDD+ opportunity costs, a bottom-up approach is recommended because they are based on local information and 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

The results of 'bottom-up' OpCost studies have, however, generally indicated lower opportunity costs than 'area-based' or 'global models' (Boucher, 2008).

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.

In future the feedback on prices of wide-scale REDD+ implementation will need to be reconciled with the 'bottom-up' approaches.

4.3 Embedding opportunity cost into a broader land use planning process

At a meso scale, rural land use planning aims to spatially allocate areas for particular functions, i.e., economic development and environmental protection, to achieve sustainable livelihoods. Within REDD+ scheme, this meso-scale, which is beyond REDD+ project implementation scale, is important for developing Reference Emission Level, safeguarding and monitoring leakage and displacement of activities. In developing countries, often land use planning is subcontracted to external agencies due to the lack of technical capacities at the local level. The planning process often is of limited scope, i.e, physical land suitability analysis only. Development planning is conducted in parallel to the land use planning and the two are not synchronized. The negotiation platform among stakeholders is either non-existent or not effective. The data, aspiration and understanding of ecological process and its interface with economic development and also the reality on the ground are scarcely used. Integrated, Inclusive and informed spatial land use planning should be promoted to evaluate, monitor and design land use planning process (Dewi et al., 2009).

Land use plan should target on achieving conservation-development objectives based on the reality, and revise/update the current land use plan under the available policies and regulations within which principles that lead to sustainability, fairness and efficiency, such as land sharing, integration, multifunctionalities, should be adopted. *Spatially explicit trade-offs analysis* of conservation-development, e.g., emission and economic return, should be embedded into the negotiation process of land use planning. The stepwise analysis of opportunity costs should logically feed into the process of land use planning, however the process of embedding the opportunity cost analysis into the meso-scale, regional land use planning process is not yet conducted.

4.4 Harmonizing land cover ⇔ land use legends

As emphasized above, clarifying the relationship between land cover and land use is probably the hardest nut to crack in applying the opportunity cost analysis. It requires a categorization of what is a continuous and fluid process in reality. A farmer clearing land to grow some crops may plant trees of different types, while selectively allowing spontaneously established trees to grow. Depending on how things develop in the plot, how the farmer reads market price changes and how the household labour supply is affected by diseases, decisions of family members to try their luck elsewhere or deaths, the plot may become a well-tended coffee garden, a multistrata agroforest with some coffee as understory or a secondary forest with a few planted trees. System perspectives are generally retrospective, not forward looking. No exiting model deals with the fluidity of this situation in sufficient detail, all require an early choice between the options that are recognized. The category of swidden or crop/fallow mosaics often is responsible for a disproportionate share in the classification error on remote sensing imagery, probably because of this type of fuzziness on the ground.

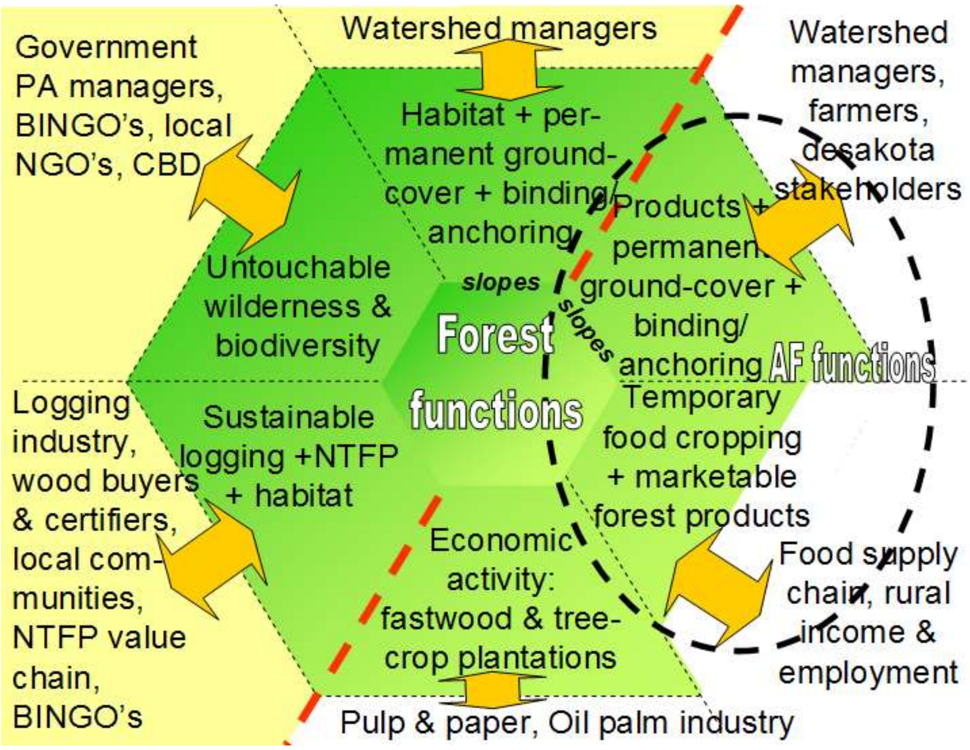


Figure 28. Functional distinctions between types of woody vegetation in the landscape that may provide 'forest functions' but may not be recognized under the existing forest definitions or institutional classification

The distinction between form and function is still very challenging in the broad categories of *woody vegetation* that can provide part of the 'forest functions' expected by society at large, but may not all be included in the institutional arrangements for REDD+ and similar efforts (Fig. 28).

Accuracy of existing opportunity cost curves is probably most constrained by the lumping of different forest types and the coarse scale used to describe logging impacts. Data quality is still an issue for the second D of the REDD+ acronym. Alternative approaches to carbon accounting combine 'gain - loss' estimates to the 'stock difference' approach of Tier-1 and Tier-2 accounting rules (Fig. [5]29).

As extraction of wood products has a direct link between profitability and change in C-stocks, it is interesting to explore how a flow-based accounting can deal with 'opportunity costs' in a more direct way. Existing rules such as the Renewable Energy Directive (RED) of the EU define targets for the 'footprint' and carbon debt per unit product that crosses international boundaries. There are substantial challenges, however, to make a part-flow, part-stock accounting system work in practice.

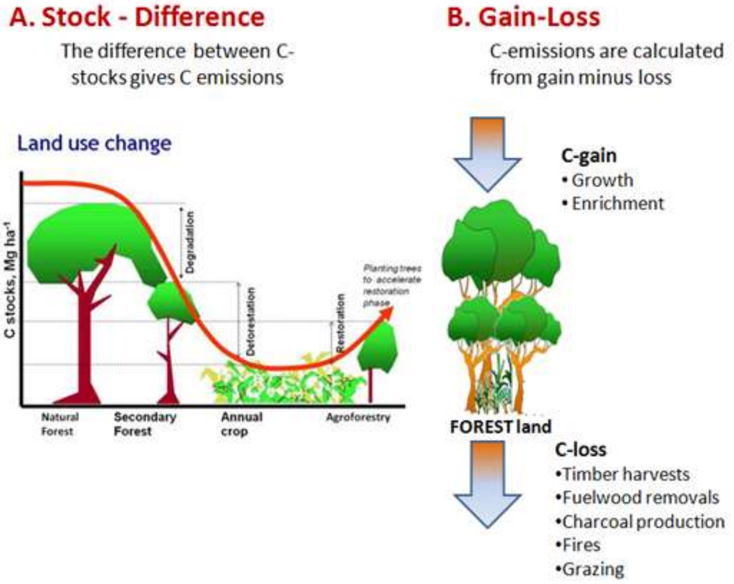


Figure 29. Stock and flow (gain – loss) based accounting rules for terrestrial carbon storage under the influence of extractive and restorative anthropogenic action on woody vegetation; IPCC Tier-1 and Tier-2 approaches are based on stock differences, while Tier-3 incorporate elements of a gain-loss approach

[5] There are three tiers of data for emission factors in the IPCC (2003) good practice guidance for LULUCF that are currently derived from ground measurements:

(a) Tier 1: uses IPCC default values such as for aboveground biomass in different forest ecoregions (six ecological zones in Africa, Asia, and Latin America) and new default values are included the IPCC Emission Factor Database. Tier 1 estimates provide limited resolution of how forest biomass varies sub-nationally and have a large error range (~ ±70 per cent or more of the mean) for aboveground biomass in developing countries;

(b) Tier 2: improves on tier 1 by using country-specific data (i.e. data collected within the national boundary) and by estimating forest biomass at finer scales through the delineation of more detailed strata;

(c) Tier 3: uses actual inventories with repeated direct measurements of changes in forest biomass on permanent plots. Tier 3 is the most rigorous approach and involves the highest level of effort. Tier 3 can also use parameterized models with plot data and can include model transfers and releases

4.5 Complementing stock-based national C accounting with flow based commodity footprints?

The ultimate objective of the Climate Change Convention (UNFCCC) is to achieve "... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Currently there are two basic approaches to counting and accounting for “anthropogenic interference with the climate system” based on net emissions of greenhouse gasses. ***The first*** uses countries (nation states) as the basic accounting units, closely linked to the decision making within UN bodies such as UNFCCC. Land areas add up nicely to the total terrestrial domain, with only minor disputes remaining over the exact location of international boundaries. Import/export data have conventionally been compiled at national scales as well, facilitating country level accounting of net greenhouse gas emissions. Responsibility for cross-border transport (‘bunker fuels’) is, however, more difficult to attribute and has been left out of international agreements on emission reduction. Country-level classifications of economic conditions have determined the path of international negotiations, ignoring the internal inequities and the fact that ‘the poor’ in ‘rich’ countries may have less anthropogenic interference with the climate system than ‘the rich’ in ‘poor’ countries. The ***second*** approach takes global trade in commodities as basis of human consumption as basis for emission accounting, identifying ‘footprints’ as based on population size multiplied with lifestyles, with lifestyles relating to the combination of consumption volumes across all currently existing commodities, and a typical emission intensity associated with each unit of any of the commodities.

Table 3. Area- and product-based accounting rules for emissions as basis of anthropogenic interference with the climate system

Product category	Land cover change ‘forest’		‘nonforest’			Land use	Transport and processing	Waste and end-user emissions	Emission intensity	Volume (de-mand)	Total
	1	2	3	...	n						
A		$e_{A,\Delta LU}$				$e_{A,LU}$	$e_{A,t\&p}$	$e_{A,w\&e}$	$e_A = \Sigma e_{A,j}$	V_A	$E_A=V_Ae_A$
B			$e_{B,\Delta LU}$			$e_{B,LU}$	$e_{B,t\&p}$	$e_{B,w\&e}$	$e_B = \Sigma e_{B,j}$	V_B	$E_B=V_Ae_B$
C		$e_{C,\Delta LU}$				$e_{C,LU}$	$e_{C,t\&p}$	$e_{C,w\&e}$	$e_C = \Sigma e_{C,j}$	V_C	$E_C=V_Ce_C$
...						...	...	...	...	...	...
Z			$e_{Z,\Delta LU}$			$e_{Z,LU}$	$e_{Z,t\&p}$	$e_{Z,w\&e}$	$e_Z = \Sigma e_{Z,j}$	V_Z	$E_Z=V_Ze_Z$
Total	RED REDD+ A/R CDM AFOLU accounting (LULUCF) ‘land-based emissions’ in production country					Agric	X-border transport outside current UNFCCC rules	Accounted in consu-mer country	Emission intensity per pro-duct at consu-mer level	Popu-lation * Life-styles	Total human ‘foot-print’

This second approach to accounting has no problem in accounting for international transport as part of the 'foot prints' and can integrate over emissions in production and consumption countries, without major difficulties. It can readily differentiate between lifestyles and alternate modes of production of comparable products. A 'footprint' approach has been popularized by NGO's and matches with the sense of individual responsibility that interacts with the usually much slower shifts in national policies.

The second approach, however, also has its share of challenges in providing comprehensive accounting of anthropogenic interference with the climate system. As many land uses contribute to multiple commodity flows, a convention in emission attribution is needed to avoid gaps and double counting. Where land use change is a multi-staged process, sharing of responsibility across commodity flows becomes more complicated, as a typical sequence of logging, overlogging and conversion to oil palm shows.

The potential use of commodities as source of bio-energy, with potential direct substitution of fossil fuel use, has sparked a debate and set of regulations on 'footprints' and emission profiles of sources of bioenergy, particularly those that cross borders in international trade. The current regulatory framework may look like Table 2, as an accounting system that covers parts of the rows (selected commodities), as well as part of the columns (selected area-based emissions), but includes both gaps and double-counting of cells. The three pathways that relate land use decisions in the tropical forest margins to global climate debate (Fig. 30) differ in the sense that one (world market) is directly linked to profitability (with consumer boycotts of certain products and response by the value chain to head off such responses), while two others (REDD+ and NAMA) are not (with REDD+ limited to 'forest' categories of land use).

Figure 30. Three ways in which land use decisions in tropical forest margins relate to ongoing international debate on reduction of land-based emissions: a) REDD+, b) NAMA, c) World markets, with increasing attention to 'footprint' standards

Conclusions

Our exploration of opportunity cost curves has shown that transparent data collection and processsing is possible to establish such curves and support a multi-stakeholder negotiation about the consequences of the data. Data collection, however, follows a normal quality/cost relationship, and efforts to contain transaction costs require scrutiny of the level of reliability of data that various stakeholders need in different stages of the negotiation process. A stepwise approach from Level-I to Level-III is feasible and may match the stepwise process of decision making around local REDD+ implementation arrangements. The incorporation of opportunity costs analysis at level I-III will also support the development of an Monitoring, Reporting and Evaluation (MRV) system, especially if the data are available in public domain and subject to scrutiny by stakeholders who know the 'ground truth'. Other aspects of implementation and MRV costs, however, need to be added to the opportunity costs, while acknowledging the 'fixed cost' nature of transaction costs (which can become a 'sunk cost' if the process does not reach the implementation stage of signed contracts).

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Appendix 1. Carbon trade-offs along tropical forest margins: Lessons from ASB work in Cameroon[6]

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Abstract

Reducing Emissions from Deforestation and Forest Degradation (REDD+) has become one of the pillars of international climate policy, but operational mechanisms to simultaneously achieve climate change mitigation, livelihood enhancement, and conservation objectives are lacking. The literature on the trade-offs between these multiple objectives is limited and expectations of win-win solutions may be inflated. This chapter presents a case of bottom-up analysis of trade-offs in the southern forest area of Cameroon drawing from more than a decade of research by the ASB (Alternative to Slash-and-Burn) Partnership. The data may broadly represent the land use options of the tropical rainforest zone of west and central Africa. Trade-offs are measured using indicators of carbon (time-averaged stocks), profitability (net present value), and plant biodiversity (species count, Plant Functional Types ("PFTs" or "modi" and the Vegetation Index "V" index.) at the tropical forest margins. Conversion from natural forests to mixed cropping systems leads to an initial loss of 220 t C ha^{-1} with biodiversity loss, but increase in profitability. Conversion to extensive cacao gardens provides benefits above 10 USD/tCO_2e of emisisons, while avoiding conversion to more intensive cacao systems would have even higher opportunity costs. Current REDD+ policies and market-compliant carbon pricing is unlikely to enable emission reduction under these conditions. Addressing the policy and institutional challenges beyond the forest and agriculture sectors and understanding landscape level interactions are important conditions for designing and implementing successful carbon projects in developing countries.

Introduction

Changes in forest and tree cover can lead to rapid and substantial carbon emissions, but recovery is relatively slow. Currently, about 7.3 million ha of forests are lost annually, releasing an estimated 5.8 Gt CO2 per year into the atmosphere, representing 12 - 17 % of human –generated green house gas (GHG) emissions. On the other hand, forests have the capacity to act as sinks (the ability to absorb and hold carbon dioxide for long periods). The IPCC Third Assessment report puts the total potential for avoiding or removing carbon emissions through aggressive forestry practice changes on 700 million ha of forest at about 60-80 billion ton or about 12-25% of the "business as usual" fossil fuel emissions over a period of 50 years.

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[6] In press as book chapter in**. in Wollenberg et al. (Eds)** ***DESIGNING AGRICULTURAL MITIGATION FOR SMALLHOLDERS in DEVELOPING COUNTRIES. Earthscan. In press***

As a corollary, forests and trees have been at the heart of strategies and negotiations for mitigating green house gas emissions in the last few years. The Clean Development Mechanism (CDM) and Reduced Emissions from Deforestation and forest Degradation (REDD+) are two key policy instruments that have emerged in the last few years to enable climate change mitigation through forests and trees. The CDM is a mechanism that has been employed within the context of the Kyoto protocol to enable carbon sequestration through afforestation and reforestation with little success so far in developing countries (Boyd et al., 2009). Meanwhile agreement was recently reached on the key principles for a REDD+ mechanism at the 16^{th} Conference of the Parties of the UNFCCC in Cancun (Decision 2/ CP.13; Decision 4/ CP.15 and Decision …/CP.16). The REDD+ idea suggests a mechanism in which countries that elect to reduce national level deforestation to below an agreed baseline would receive post facto compensation or rewards. These countries may also make commitments to stabilize and/or further reduce deforestation in the future. Such reductions can be obtained through "reducing emissions from deforestation," "reducing emissions from forest degradation," "conservation of forest carbon stocks," "sustainable management of forests," and "enhancement of carbon stocks" and must contribute to sustainable development.

How much sustainable development benefits, costs and / or trade-offs can be expected from a REDD+ type scheme remains a fundamental question as very little evidence currently exists, but expectations of win-win situations abound. In other words, at what point, or when, will carbon represent a good proposition to land users seeking to put land into alternative livelihoods and biodiversity / conservation uses? This chapter examines the trade-offs between carbon and alternative land uses in the Southern Forest zone of Cameroon. It uses evidence from long-term research from the Alternatives to Slash-and-Burn (ASB) Partnership for the Tropical Forest Margins.

In line with current global forest and tree climate mitigation strategies, the ASB Partnership has been working to reduce deforestation along tropical forest margins in ways that do not compromise agricultural productivity and the provision of environmental services through research on alternatives. It was created in 1994 as a partnership between international and national research organizations and universities, and is currently carrying out action research in a pan-tropical network of sites across the humid and sub-humid tropics. Based on analysis of land use dynamics related to deforestation and degradation, ASB research primarily focuses on the resulting sustainability impacts in terms of livelihoods, agricultural productivity and various environmental services, hence the trade-offs therein. Uniform indicators, methods and approaches have been applied in the quest to understand land use, carbon, biodiversity, agricultural productivity and livelihood impacts across a network of more than 12 sites (Palm et al. 2005). This chapter focuses on trade-offs between carbon, profitability and biodiversity in order to provide insights into the potential for REDD+ and other mechanisms to meet the triple objectives of climate, development and conservation using Cameroon as an example

The ASB Benchmark Site and Context in Cameroon

The Cameroon ASB site was selected to represent the agriculture, land use and population dynamics of humid tropical rainforest conditions of west and central Africa. The site is a 1.54M ha stretch spanning a population and land use gradient and varied market access conditions (Kotto-Same et al, 2002). Population densities range between 4 - 100 persons/ km^2 with a gradient from the north east (around the capital city Yaounde) to the southeast (south of Ebolowa / Ambam towns). Precipitation is bi-modal and ranges from 1,350 to 1,900 mm annually. Four varied soil profiles dominated by Orthic ferrosols with distinctive physiochemical properties form a north-south fertility gradient in the area. In terms of floral diversity, over 200 plant species have been recorded within a 1,000m^2 transect of natural forest in the area (Garland, 1989 in Kotto-Same et al, 2002). Forests in the area vary from dense semi-deciduous forests in the north to dense humid Congo basin forests in the south east.

Land use analysis constitutes the basis for trade-off analysis. Table 1 presents a summary of major land uses in the humid forest zone of Cameroon. Agricultural land use occupied about 24% of the area with cocoa being the dominant productive agricultural land use covering about 3.8%. In terms of trends, horticulture has been growing in the vicinity of the Yaounde urban area. This is characterized by intense cultivation of vegetables and maize for the growing urban market. However, its growth is slowly being limited by poor market infrastructure further away from the city. Smallholder oil palm has been growing but at a slower rate due to poor quality planting material access and poor processing infrastructure.

Carbon Stocks

In the trade-off analysis within the ASB benchmark sites, all alternative land uses were evaluated in terms of carbon stocks. Time-averaged carbon stocks (C stocks)for chronosequences of six land uses including original forest, two-year old cropland, a cocoa plantation, bush fallow - four years old, tree fallow - nine years old and secondary forest - 17 years old (Kotto-Same et al, 1997). The time-averaged C stock estimates the C content of a system over the rotation time of the system - taking into account C accumulation rates, maximum C stored in the system, time it takes to reach maximum C and the rotation time of the system as described in (Palm et al, 2005b). Estimates here were given from measurements of tree, understory, litter, root, and soil (0-50m) in 100m^2 quadrats at 36 sites for each chronosequence land use combination. Forests were used as the basis for comparison between land use systems. The carbon stocks (above-ground vegetation and litter) of 6 selectively logged forests in the area averaged about 228 t C ha^{-1}, ranging from 193 to 252t C ha^{-1}. A mature jungle cocoa stand contains about 43% of the C of the forest, ranging from 54 to 141 tC ha with an average of 89t C ha^{-1}. Traditional long fallows recorded the maximum C stocks for crop-fallow systems- about 167tCha. C accumulation rates varied with fallow age, ranging from 2.8t C ha^{-1} during the first two years with *Chromolaena* domination and increasing to 8.5 t C ha^{-1} for the next 6-10 years (Kotto-Same et al, 2002).

Profitability of Land Uses

Profitability was evaluated as a key determinant of adoption and hence land use change in the area. Net present values were estimated for the six alternative land uses of a 30 year period and a discount rate of 10% was applied at social prices (Kotto-Same et al, 2002). These calculations take account of price distortions and reflect social discount rates. Shaded intensive cocoa systems with fruit trees and short fallow intercropped food systems posted the highest and lowest social profitability respectively. However, it should be noted, that since per hectare profitability is measured on an annual basis and includes any non-productive fallow period, annual profitability of shifting cultivation is significantly reduced.

Table 1: *Main land uses at the forest margins of southern Cameroon*

Land Use	Description
Natural forests	Undisturbed dense semi-deciduous or humid Congo basin forests. This is the reference point for all land uses.
*Community forests	Forest systems of no more than 5,000 ha (ranging from natural to degraded) that is the subject of a management agreement between "a community" and government as defined in the 1994 forest law. A community forest could be subsequently exploited as a sale of standing volume
*Commercial logging	Either a concession (up to 200,000ha) or a sale of standing volume (2,500 ha maximum)
Extensive Cocoa with Fruit tree shade - Long fallow	Complex multistrata agrofrestry shaded cocoa system with fruit trees (mango, avocado, African prune - *dacryodes edulis*, oranges). Normally established on forested land or long fallows and intercropped with plantain, melon seed and cocoyams in the first 3 years. Fungicide use is about 50% of intensive coco systems and yields average 265 kg ha^{-1}. Farm sizes average 1.3 ha.
Intensive Cocoa with fruit trees shade- short fallow	Complex miltistrata agrofrestry shaded cocoa system with fruit trees (mango, avocado, African prune -*dacryodes edulis*, oranges) with high input practices. Normally established on 4 year fallow. Yields average 500 kg ha^{-1}. Average farm size is 1.3ha.
Oil Palm Long Fallow	Small holder monoculture of oil palm planted at density of 143 trees/ ha. Established on forests and intercropped with plantain, cocoyams and melonseed during the first two years. Yields average 8000 Kg/ ha at maturity. Average farm size is 1 ha
Intercropped food crop field-short fallow	Crop / Fallow system planted into a 15 year fallow of *Chromollaena ordorata* fallow consisting of melonseed *(cucumeropsis mannii*), plantain, maize and cocoyam. Mainly for subsistence. Average farm size is 0.25 ha
Intercropped food crop field-long fallow	Crop / Fallow system planted into a 4 year fallow of *Chromollaena ordorata* fallow consisting of groundnuts, cassava, maize, cocoyams and plantai. Mainly for subsistence. Average farm size is 0.25 ha
NB: * denotes a land use that has not been subject to evaluation within ASB work in Cameroon though present in the landscape.	

Biodiversity

ASB explored three indicators of plant biodiversity including species counts, Plant Functional Types ("PFTs" or "modi") and the Vegetation Index "V" index . The number of plant species was counted for each standard plot (40m x 5M) and for each land use in Cameroon in six replicates. Plants were further classified through coding into functional groups (what they do and how they do it) and adaptive characteristic including leaf size class, leaf inclination, leaf chlorotype, leaf morphotype and plant live-form as a basis for PFT or Modi- numbers of PFT in land use as described in (Gillison, 2000b; Gillison and Carpenter, 1997). The "V" index represents the relative position of each plot in terms of increasing structural complexity and richness in both species and PFTs. It is derived by seeking the single best eigenvector solution from multi-dimensional scaling analysis using the following attributes: mean canopy height, basal area, vascular plant species count, PFT and species/PFT ratio -a measure of taxonomic and functional heterogeneity (Gillison 2000b; Williams et al, 2001). The index is standardized between 0.1 – 1.0 with 1 being the value of the forest. The PFT and V-index are not standard textbook biodiversity measures but were developed within ASB to address mosaic land use / plot level biodiversity dynamics and were found to highly correlate with land cover type, plant and animal richness and soil nutrient availability in Indonesia, Cameroon and Brazil, hence a potentially useful index (Gillison 2000).

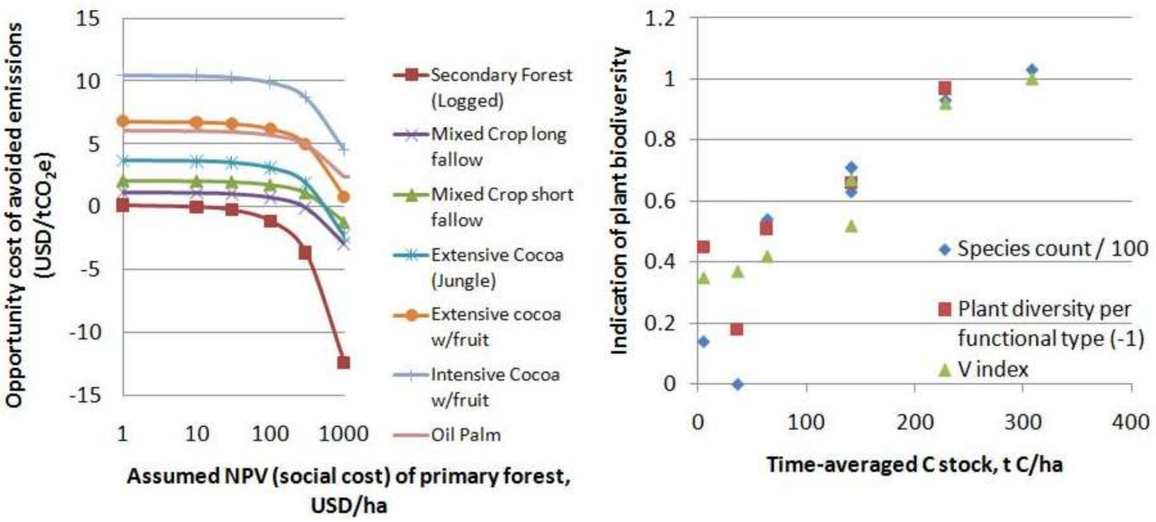

Figure 1A. *Opportunity cost of avoiding emissions by conversion of natural forest to a a range of land uses, expressed as the difference in Net Present Value divided by the difference in time-averaged C stock (multiplied by 44/12 as CO_2/C ratio); values are given for a range of Net Present Value estimates of natural forests, as this was not assessed by the ASB Cameroon report; 1B. Correlation of aboveground C stock with indicators of plant biodiversity for land use systems in Cameroon*

Trade-offs

The assessment of trade-offs in ASB studies was given by a set of multiple indicators across the humid tropics. We have addressed one indicator each time-averaged carbon stocks for carbon, net present value for profitability of land uses and three indicators for biodiversity (species count, PFT/modi and the "V" index). Figure 1 shows the indicators for each of the land uses and their trade-offs. Fig. 1B shows that scores for the three indicators are related to aboveground C stocks for the range of land uses found in Cameroon.

In a typical cycle in Cameroon, forests are cleared for mixed crop systems first in short fallow rotation and then in long fallow. In cases where cocoa plantations are established, mixed crops do not go into fallows but are planted with cocoa and crops phased out slowly. Where landsis left to fallow long enough (> 20 years) it eventually returns to forested land (secondary forest). This transformative cycle entails various trade-offs.

Transformation from natural forest to mixed crop systems constitutes the greatest loss in terms of carbon and biodiversity. More than 200 t C ha^{-1} and great amounts of biodiversity is lost. While returns on land increase, it remains the least profitable of all land use conversions. While these conversions continue to grow in the area, limitations on inputs and relatively low population densities in most parts of the study area continue to favor its practice. Intensification occurs in home garden systems near urban areas where market conditions and infrastructure are favourable. However this intensification does not bring any carbon or biodiversity gains.

The second most significant system change with best benefits for carbon, biodiversity and profitability is the conversion of short fallows into intensive cocoa with fruit tree systems. With such conversions, C stocks increase from 6 to over 100 t C ha^{-1}. However, there are questions about sustainability of such systems owing to susceptibility to pest attacks. Such systems have not been growing significantly in the area due to high input requirements - notably labour and pesticides. Labour is scarce in the region and capital and associated infrastructure to support input supply is limited. On the other-hand, extensive cocoa systems planted in long-fallows or remnants of forests do not require high inputs, are fairly manageable in terms of pests and are moderately profitable. They also come with considerably lower losses in carbon stocks and biodiversity during establishment. These features make the extensive cocoa system a widespread practice and potentially beneficial for carbon management in the region with possible slight improvements (Gockowski and Sonwa, 2011). These systems could be part of potentially workable REDD strategies if well designed.

Key Lessons and Conclusions

Looking at ASB's work in the last decade and a half in Cameroon and globally, a number of lessons emerge that could be of relevance to current emission reductions policy discussions and practice in developing countries.

First, current prices in the compliance carbon market are unlikely to ensure emission reductions as they will not meet the opportunity costs of conversions in the forests landscape in southern Cameroon. Conversion of forests or long fallow to extensive cacao gardens provides benefits above 10 USD/tCO_2e of emissions, while avoiding conversion to more intensive cacao systems would have even higher opportunity costs (Figure 1A). That opportunity costs represent only part of the carbon project costs makes it even more unlikely.

Secondly, that conversions within non-forest land use classes hold some of the best opportunities for emission reductions and co-benefits implies it is unlikely REDD alone will enable the warranted emission reductions. Studies in both Indonesia and Cameroon show that trade-offs are more beneficial in terms of carbon, profitability and biodiversity gains in areas that do not currently fall under the definition of a forest within the UNFCCC REDD+ framework, for example, conversions from mixed crops to intensive cocoa agroforestry (van Noordwijk and Minang, 2009; van Noordwijk et al, 2009; Ekadinata et al, 2010). Moving beyond the current REDD + framework within the UNFCCC (which is mainly about forests) to a broader framework for reduced emissions from all land use change is thus imperative.

Furthermore, ASB studies in Cameroon have highlighted the importance of institutional and policy issues as crucial factors for success in the design of emission reduction projects. We have learnt from Cameroon that a key strategy for reducing emissions such as the intensification and diversification of cropping systems with trees - resulting in agroforestry with huge potential carbon, economic and biodiversity benefits - can be hampered by labour, market, infrastructure and land tenure challenges. Strategies for addressing drivers of deforestation as well as emission reduction strategies outside of REDD will need serious analytical work and investments in institutions and policies to ensure success.

Lastly, the trade-off analysis in Cameroon demonstrates the need to understand whole landscape systems in order to develop a complete picture of how REDD+ and other emission reduction mechanisms might work. Economic analysis was not done for community forest and logging systems hence judging opportunity costs against a natural forest with little or no economic benefit presents only part of the picture. ASB work in Indonesia and Peru showed that with conservative values for logging, opportunity costs for REDD are potentially very high and therefore requiring a high C price to off-set any potential conversion (Tomich et al., 2002; Swallow et al, 2007). This indicates that more work is required in understanding trade-offs within logged forests and also under regimes such as reduced impact logging that are likely to be applicable for emission reductions in the context of "degradation" within the REDD+ framework.

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Appendix 2. REDD-ABACUS manual

http://www.worldagroforestrycentre.org/sea/projects/allreddi/softwares

REDD-Abacus is a computer program that facilitates the creation of cost curves. Carbon and profit data of numerous land uses and sub-national regions can be examined entered within the program for analysis (Figure 1). 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). The ease of data management and calculations helps to speed the process of sensitivity and scenario analyses.

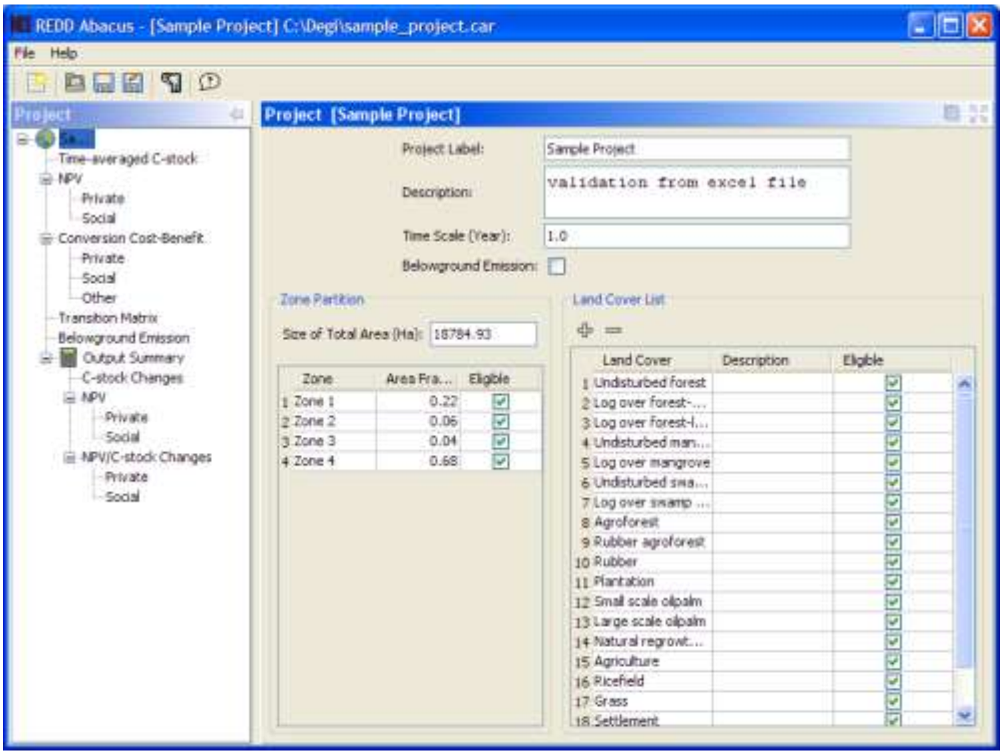


Figure 1. Land uses and regions of a sample analysis within REDD-Abacus

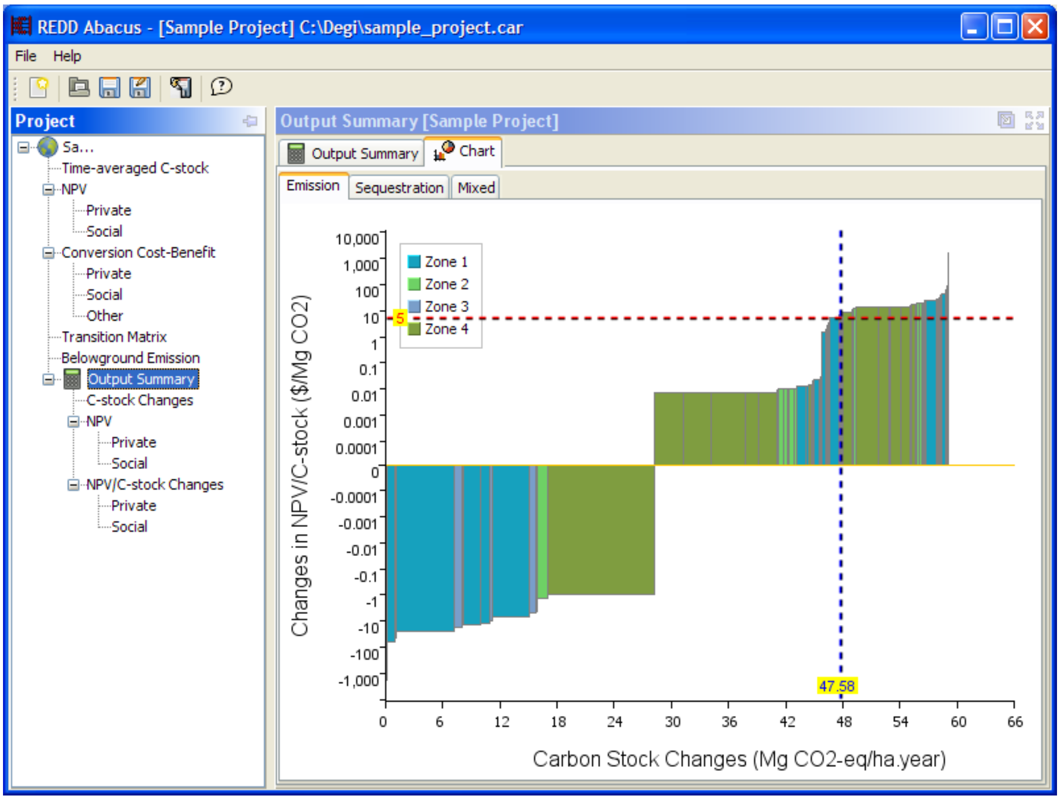


Figure 2. An opportunity cost curve per land use change and sub-national region

Example analysis using REDD Abacus

1. On the REDD Abacus website, a sample file representing a context in Indonesia (http://www.worldagroforestry.org/sea/projects/allreddi/products/sample_project.zip) can be examined within the REDD Abacus program. 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

2. 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).

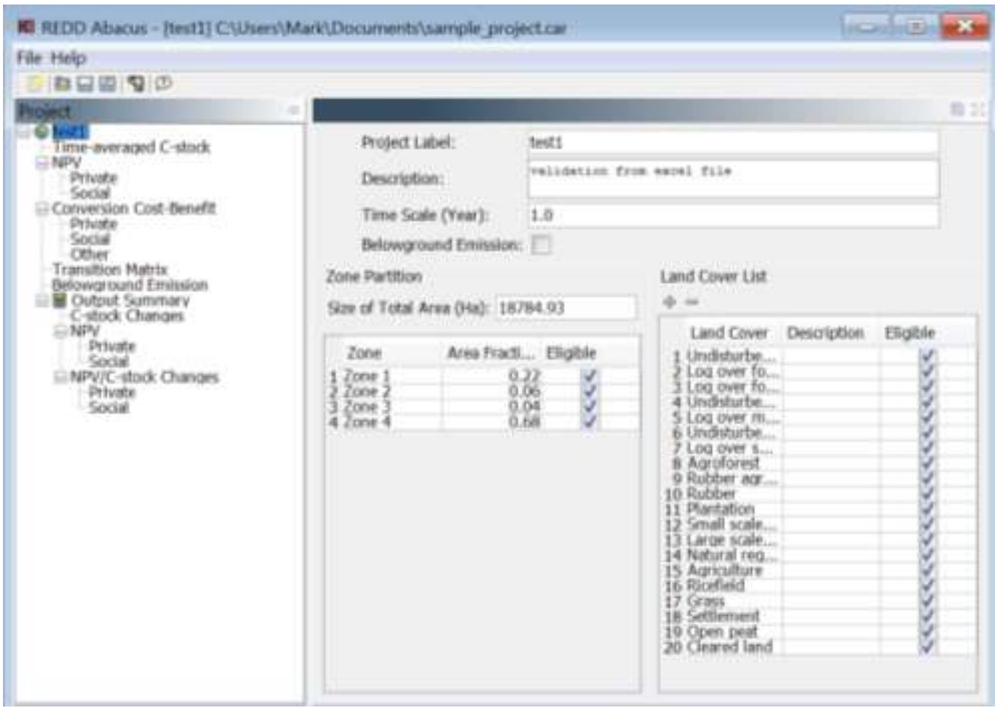


Figure 3. Context description screen of REDD Abacus example

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

- title
- description
- number of zones
- total area

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

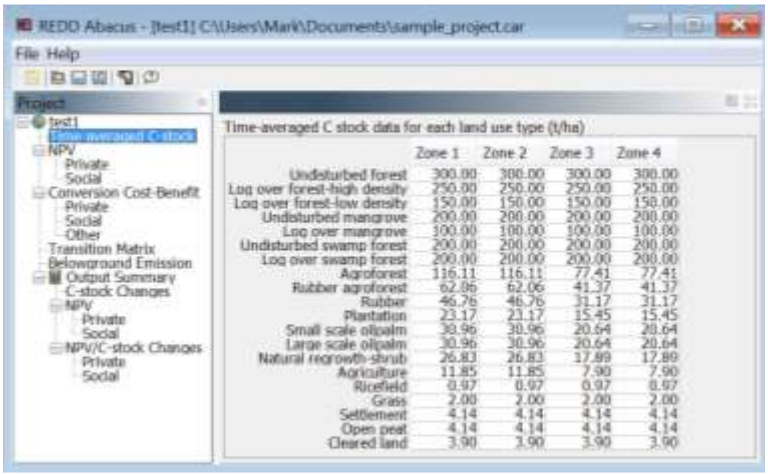


Figure 4. Time-averaged carbon stock of REDD Abacus example

5. Profit data from land uses are entered in the third screen (in NPV - net present value terms). 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).

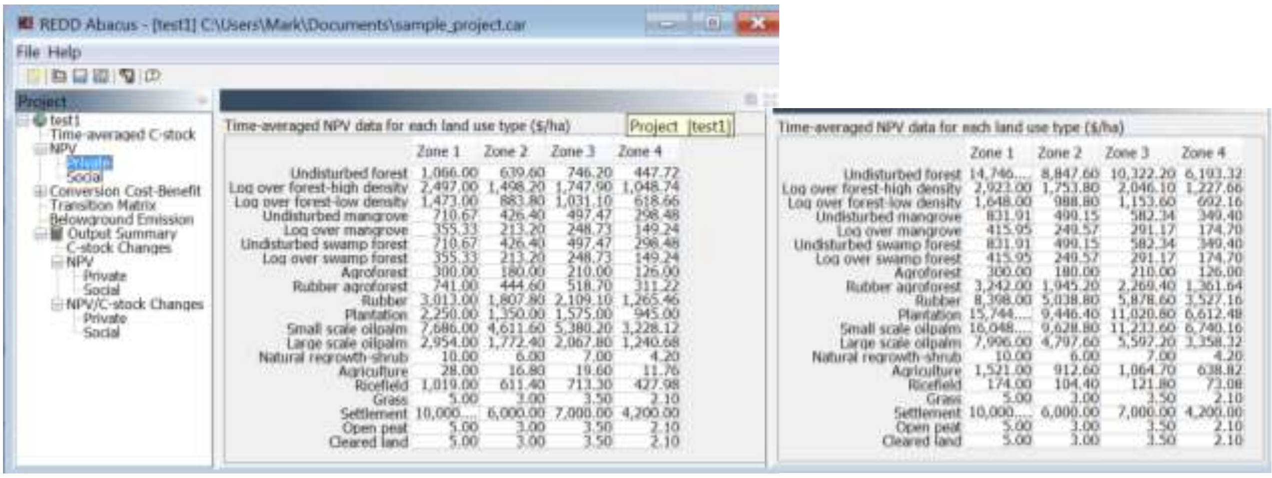


Figure 5. NPV estimates (Private and Social) for REDD Abacus example

6. The fourth screen, *Conversion Cost-Benefit*, calculates the per hectare opportunity cost of each land use change.

7. The fifth screen, *Transition Matrix*, is a summary of each type of land use change within the area of analysis (Figure). This is the same as the **Land use change matrix**, mentioned within this manual. 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.

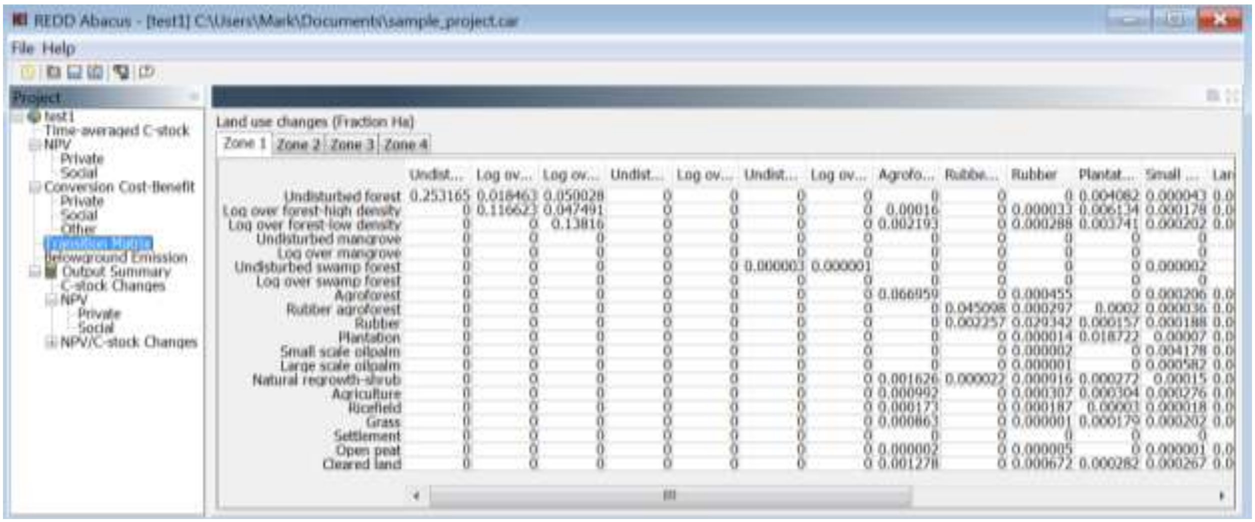


Figure 6. Transition matrix for REDD Abacus example

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

Analysis results

9. 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).

10. 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.

11. 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.

12. In Figure , 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.

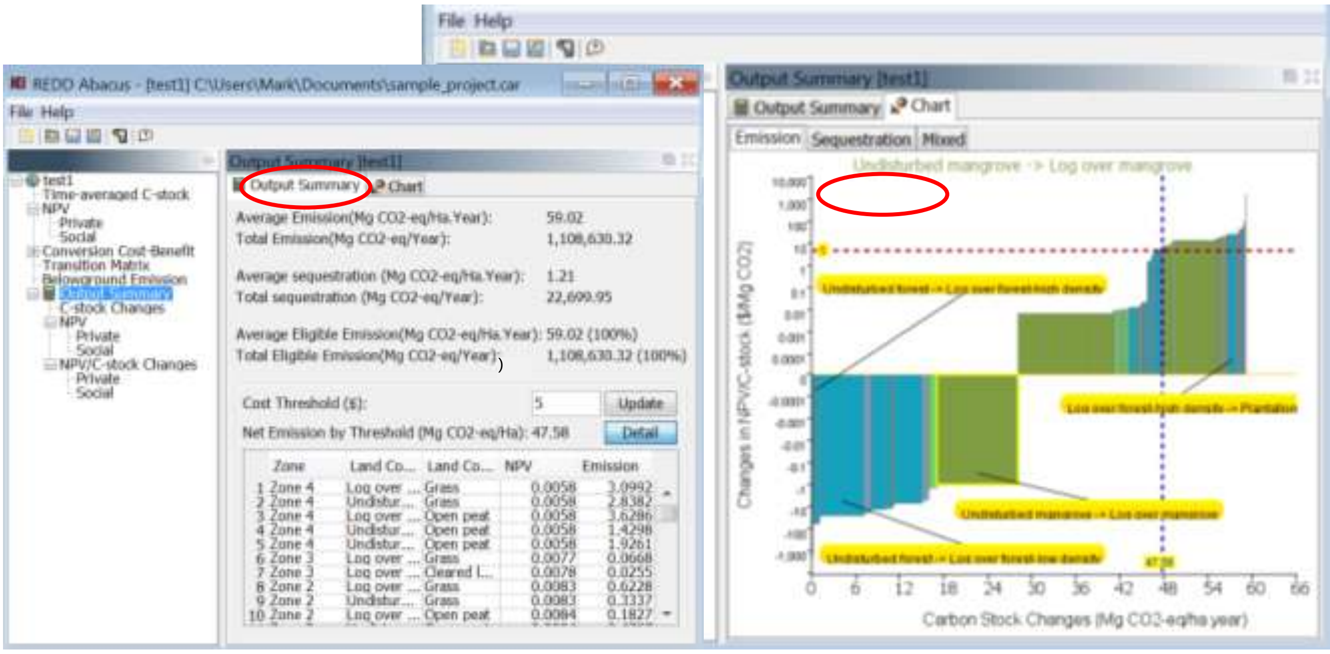
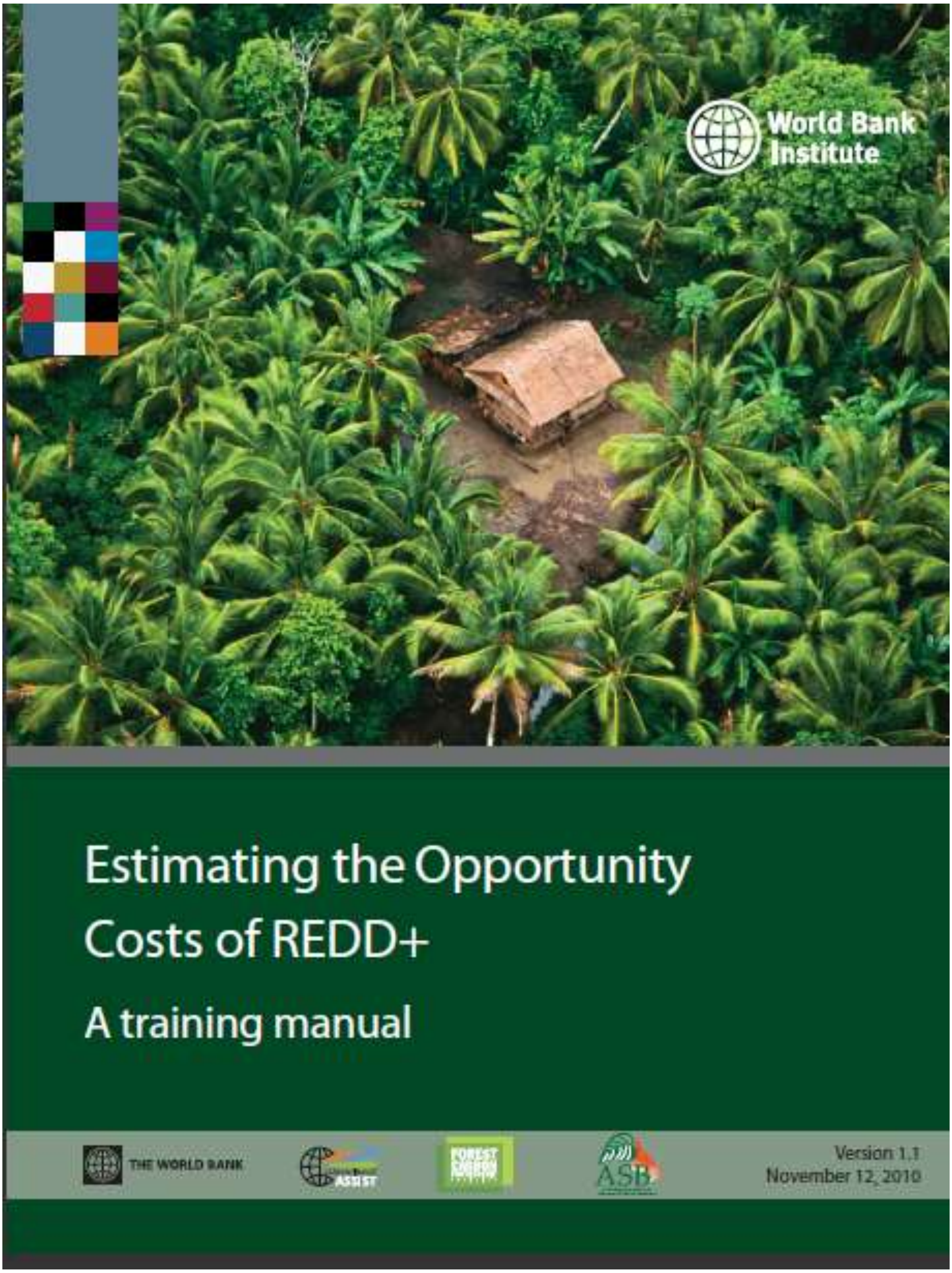


Figure 7. Output Summary and associated Chart from REDD Abacus example

Appendix 3. Outline of Training material on Opportunity Cost analysis for REDD+ developed by ASB in cooperation with World Bank Institute and FCPF, used for a series of regional trainings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A training manual
THE WORLD BANK
ASSIST
FOREST CARBON
ASB
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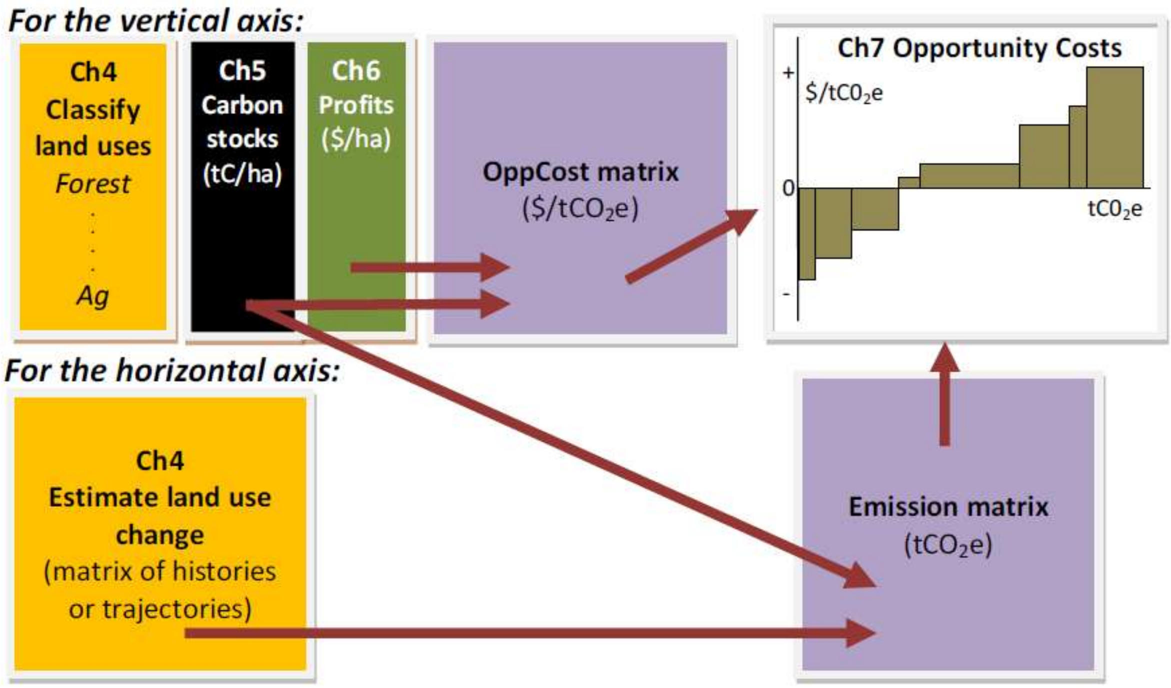
For the vertical axis:
Ch4
Classify
land uses
Forest
Ag
Ch5
Carbon
stocks
(tC/ha)
Ch6
Profits
($/ha)
OppCost matrix
($/tCO2e)
Ch7 Opportunity Costs
+
$/tC02e
0
-
tC02e
For the horizontal axis:
Ch4
Estimate land use
change
(matrix of histories
or trajectories)
Emission matrix
(tCO2e)

Appendix 4. Commodification, compensation or co-investment as basis for avoiding carbon emissions from peat swamp conversion to oil palm in orang-utan habitat: the case of Tripa (Sumatra, Indonesia)

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Abstract

Current international efforts to mitigate climate change aspire market-based instruments to compensate right-holders for foregoing economic opportunities of land use change that would cause high emissions per unit economic gain. The social dimensions of current market-based efforts to reduce emissions from deforestation and degradation (REDD+) depend on the perspectives on rights to pollute and rights to land that exist at local, national and international scales. Three paradigms relate to the REDD+ debate: Commodification of the Environmental Services (CES; with price a resultant of supply and demand and the ES a direct commodity (CES1) or part of the branding of existing value chains (CES2)), Compensation for Opportunities Skipped (COS; with bargaining over who is eligible for obtaining a share of standardized price levels) and Co-Investment in Stewardship (CIS; with investment in a green economy judged on a ratio of its economic benefits and emission reduction). The paradigms differ in roles for markets, in social dimensions, and in balance of fairness and efficiency across scales. Our case study of Tripa considers the last remaining peat swamp forest that harbours a potentially viable Sumatran orangutan subpopulation outside formally protected areas. Natural forest cover declined from 54% in 1995 to 18% in 2009 and aboveground C stocks from 148 t/ha in 1990 to 61 t/ha in 2009, while oil palm increased from 4 to 39% of the study area. The peat contains 419 tC/ha per m of peat depth, with an average of 3.2 m and 1350 tC/ha. Most of the remaining forest ha is part of existing oil palm concessions. As the forest area has been degazetted from its previous protection forest status, the direct application of REDD+ rules is problematic within the Indonesian context, although additionality of emission reduction would be uncontested. Rather than positive REDD+ incentives, shifts in the international value chain of palm oil in response to consumer concerns (CES2) have, however, so far been the immediate cause of shifts of company behaviour and declaration of a voluntary moratorium on conversion. Simulations with a dynamic landscape model (FALLOW) helped to define CIS targets for alternative employment generation as part of high C stock development, addressing the non-linear baselines of both emissions and development expectations. A combination of rules that clarify land use rights and facilitate attractive environmentally friendly local development alternatives will be needed to achieve lasting conservation and emission reduction combined with economic development.

Keywords: Avoided deforestation, Carbon market, Eco-certification, Nationally Appropriate Mitigation Actions (NAMA), Scenario studies, Simulation model

Introduction

In a market-based approach to enhancing environmental quality through freely negotiated forms of Payments for Environmental Services (PES), bargaining position is crucially important (Perrot-Maître 2006). The opportunity to receive or claim financial compensation for not exercising a right to inflict environmental damage is at the core of the debate on PES (Tomich et al. 2004; Van Noordwijk et al. 2004; Leimona et al. 2009; Swallow et al. 2009). It is also central to the international debate on modalities for Reducing Emissions from Deforestation and Degradation (REDD+) (IFCA , 2007; Karsenty et al. 2008; van Noordwijk et al. 2008a; Angelsen et al. 2009; Pagiola and Bosquet 2009; Verchot and Petkova 2009) , supported by the United Nations Framework Convention on Climate Change (UNFCCC) since its 13th Conference of Parties in Bali in December 2007. At national scale, developed countries claim this right based on status quo and developing countries claim it based on lower per capita emissions in their economies and by referring to the earlier and more extensive damage done to the atmosphere by 'developed' countries. At subnational scale implicit emission rights are linked to rights to change land cover and land use (Suyanto et al. 2009a; Akiefnawati et al. 2010; Galudra et al. 2011), causing emissions of greenhouse gasses as an unintended side effect. Within the high-emission country Indonesia is, provinces differ substantively in track record. Both at national and subnational scale the 'shame' of high emissions (being called the third global emitter) is linked to an opportunity to benefit from a high reference emission level.

There is a difference between 'having a right' in a legal sense and 'being right to use it' from a moral/ethical, economic, social or ecological perspective. Lam and Pauly (2010) addressed the question 'Who is right to fish' expanding the legal debate on fishing rights into domains of social and ethical values. Similar questions apply on forest issues, deforestation and carbon emissions play a role in public debate, but have largely stayed outside the scientific literature. Yet, the clearer the arguments are on 'having the right', the stronger the bargaining position is to voluntarily forego such rights. The weaker the 'being right' perception is, the weaker the bargaining position.

Critiques of the direct bargaining approach to PES have emerged (Porras et al. 2008; Swallow et al. 2009; Gómez-Baggethun et al.2010; Kosoy and Corbera, 2010; Lele et al. 2010; Pascual et al. 2010; Peterson et al. 2010, Gregersen et al. 2010), challenging applicability, efficiency and fairness of such approaches. Van Noordwijk and Leimona (2010) identified three paradigms that differ in underlying assumptions, in the way conditionality of ES enhancement incentives is constructed and in perceptions on fairness and efficiency:

- Commodification of the Environmental Services (CES; with price a resultant of supply and demand),
- Compensation for Opportunities Skipped (COS; with bargaining over who is eligible for obtaining a share of standardized price levels) and
- Co-Investment in Stewardship (CIS; with investment in a green economy judged on a ratio of its economic benefits and emission reduction).

The authors argued that lack of clarity of land tenure and associated rights, and existing regulations that declare most activities that affect environmental services to be illegal form major obstacles to a pure market-based approach in commoditizing environmental services in most developing countries. Further major obstacles exist at local level when the deforestation is done by agriculturally dependent people who don't perceive a modest financial transfer as an alternative to continued forest conversion as their livelihood strategy (Gregersen et al. 2010). A softer form of co-investment in stewardship may well have to be the entry-level form of PES. To gain and maintain broad support, incentive mechanisms have to balance 'perceived fairness' and 'efficiency' at all levels (Suyanto et al. 2009b). Co-investment gives more weight to 'being right' than most markets currently do.

A further refinement of the CES paradigm is to distinguish between situations where the ES a direct commodity (CES1) and those where it becomes part of the branding in existing value chains (CES2), with or without formal 'ecocertification'. CES2 approaches are beyond the purview of current REDD+ negotiations which focus on agreements between nation-states and not international trade flows. In the global economy, however, consumer concerns over environmental issues ('being right') are increasingly influencing decisions what to buy or not to buy. Perceptive international companies respond by 'voluntarily' accepting norms of behaviour that can claim to be environmentally friendly, with or without backup of such claims through forms of ecocertification (Teisl et al. 1999, van Kooten et al. 2005). For example, in 2010 a number of food processing companies announced that they cancelled contracts with oil palm companies publicly associated with ongoing deforestation in Indonesia. Orangutans as flagship species for conservation became iconic in this debate on oil palm (Koh and Wilcove 2007; Butler et al. 2009; Venter et al. 2009; Nantha and Tisdell 2009; Gaveau et al. 2009; Wilcove and Koh 2010; Yule 2010). As a consequence of public pressure, it may no longer be economically right for an oil palm company that wants to maintain market share in Europe or North America to convert primary forest on deep peat swamp that is habitat for the highly endangered Sumatran orang-utan, even if the company has the formal right to do so and if that action would be outside the reach of international REDD+ arrangements. Informally the 'Emissions Embodied in Trade' (EET) have started to influence value chains, in addition to REDD+, but without clarity on the interface of CES2 and REDD+ (Minang et al. 2010).

In fact a third relation exists between international stakeholders of emission reduction and local land users whose actions might enhance or decrease net emissions. The realization that per capita emissions, when land use and energy-based emissions are combined, in Indonesia are at par with Europe, undermined the moral stand and bargaining position of Indonesia to secure international finance for efforts to reduce emissions. By articulating its framework for Nationally Appropriate Mitigation Actions (NAMA) and specifying an associated reference emission level, Indonesia regained moral standing and obtained commitments for international co-investment. The subnational translation of this NAMA and its consequences for effective emission rights remains to be elaborated. A public announcement of a 'moratorium' on further peatland conversion, may apply only to new development plans, or might have consequences for companies who have obtained part of the series of permits required to convert forest. Consequences for companies that completed the set of permits but not converted the forest are unclear.

In the international debate of REDD+ the delineation of the scope of the arrangements has been problematic, as it hinges on the forest definition which itself is unclear and which may be more linked to forestry institutions rather than to woody vegetation and emissions (van Noordwijk et al. 2008a; van Noordwijk and Minang 2009; Ekadinata et al. 2010; Sasaki et al. 2010). Conversion of tropical peatlands to agricultural use is a major source of emissions, with emission rates that can be tenfold those of forests on mineral soils and last beyond the direct 'deforestation' events (Sorensen 1993; Page et al. 2002, Jauhiainen et al. 2005). The NAMA articulation and bilateral agreements between Indonesia and Norway have been able to step beyond these constraints by explicit reference to peatlands as source of (avoidable) emissions, at par with forests in importance.

Outside of the national parks and formally protected areas in North Sumatra and Aceh, the Sumatran orangutan (*Pongo abelii*) and people still share landscapes that consist of remaining natural forest, forests that have been modified by human use, agroforests created by farmers, open farm land and settlements (Tata et al. 2010; Wich et al. 2008). In the case study of the Tripa swamp (Ruysschaert et al. 2009) described here, oil palm conversion has indeed been the major threat. In our study multiple perspectives on 'rights' and 'right/wrong' or desirable/undesirable emerged. As the formal REDD+ negotiations at international level have not yet clarified the attribution for reductions in emission that derive from self-regulation in international trade, the Tripa swamp is a case study to explore the potential for synergy across multiple incentives, positive and negative, to achieve global benefits while satisfying legitimate demands for rural development.

Key questions for the case study were:

1. What is the formal basis of the companies' rights to convert forest and what are the options for government at local, provincial and national level to revoke licenses and/or support land swaps?

2. What are the carbon stocks in the area, what are historical emission levels and how much emission can be avoided?
3. How profitable is the land use that causes emissions and hence what would be opportunity costs of avoiding emissions?
4. What other environmental services are involved and could be enhanced to provide co-benefits to avoided forest conversion? Which stakeholders of such environmental services could be expected to co-invest?
5. What alternative options for 'high C stock development' exist that could provide attractive local employment options? What resource use rights do local communities claim to have, on a formal and/or informal legal basis

For the broader discussion , we focus on:

6. How is current repositioning of agents in the international value chain interacting with the options to provide positive economic incentives through REDD+ and achieve the national goals for emission reduction set in the NAMA debate?

Questions 1-5 will be answered on the basis of recent fieldwork in the Tripa area and extensive YEL and PanEco support for local negotiations in the area since 2006, while question 6 will be addressed in the discussion, in relation to a set of hypotheses posed in the theoretical framework.

2. Theoretical Framework

As a theoretical framework we recognize multiple scales and multiple incentive paradigms (commodification, compensation and co-investment), as introduced by van Noordwijk and Leimona (2010). Applicability, fairness and efficiency are the overarching concepts. The efficiency aspect can be seen as an exchange of a quantifiable environmental service for a negotiated financial flow, which can be expressed in different ways at different scale transitions under the different paradigms. The fairness aspect involves a social exchange of respect, image, knowledge and 'free and prior informed consent' by sovereign decision makers, which can again be expressed in different ways at different scale transitions (Fig. 1).

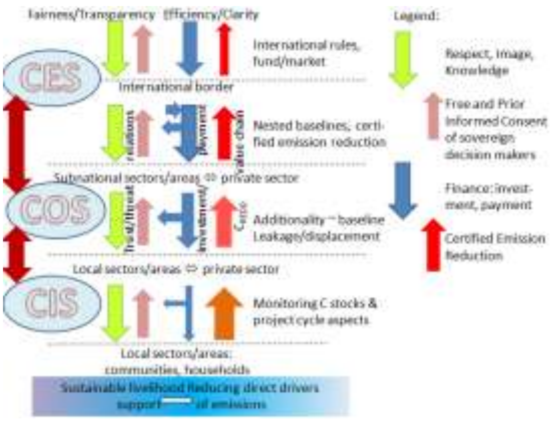

Figure 1. Conceptualization of the cross-scale exchanges in the 'fairness' and 'efficiency' domains of rewards for reducing emissions cause by land use change; we hypothesize that the applicability of co-investment (CIS), compensation (COS) and commodification (CES) paradigms of van Noordwijk and Leimona (2010) varies with scale

The figure shows the parallel two-way exchanges from local to global scales in the fairness and efficiency domains, with a linkage between the two at every scale level. At the local level dealing with the drivers of emissions is the short-term efficiency focus, while securing sustainable livelihoods is the primary focus of fairness concerns. At intermediate scales in the REDD+ value chain, buyer/seller identities switch and the necessity to show respect for lower steps in the chain and demanding it from higher up complicate bargaining positions (Minang and van Noordwijk, *submitted to this issue)*. The figure suggests that multiple CES/COS/CIS paradigms can be used at various scale levels, with translations of language and exchange in currencies at intermediate scales. Expressed as a formal set of hypotheses this implies:

H1. Cross-scale mechanisms for fair and efficient reduction of land-based greenhouse gas emissions (or a forest-related subset) need to acknowledge differences in clarity of rights and performance measures between local, subnational and national scales.

H2. At national borders an international form of 'commoditized environmental services' is feasible that links performance on verifiable emission reduction below internationally agreed reference levels, to financial flows (CES1 paradigm).

H3. International trade will include voluntary and mandatory standards for emission reduction linked to commodity value chains that provide incentives for reduced emission land use (CES2 paradigm)

H4. From national to sub-national entities a form of compensating for opportunities skipped is appropriate, using 'proxies' such as forest cover in relation to human population density (COS paradigm).

H5. At local level, property rights and outcome-based performance criteria are a challenge to a ***"$ per t CO_2"*** exchange and co-investment in environmental services (interpreted across water, biodiversity and C-stocks) and the human and social capital that support them is appropriate as a start (CIS-paradigm).

H6. Transparency and free and prior informed consent (FPIC) ***can*** be achieved ***despite*** shifts in currency, language, time-frame and conditionality between scales, associated with the paradigms used.

3. Material and methods

Location

The Tripa swamp (Ruysschaert et al. 2009) is on the western coast of Aceh (Nanggroe Aceh Darussalam) province (Fig. 2) and split over two districts, Nagan Raya and Aceh Barat DayaTripa. Tripa comprises a total area of 102,000 ha, which includes 62,000 ha is peat swamp within the boundary of the Leuser Ecosystem (a Strategic National area for its biodiversity and water catchment value), and an additional 5 km surrounding buffer area. Tripa is adjacent to the Gunung Leuser National Park that is part of a UNESCO World

Heritage Site. The Tripa swamp consists of three separate peat domes (Wahyunto et al. 2003).

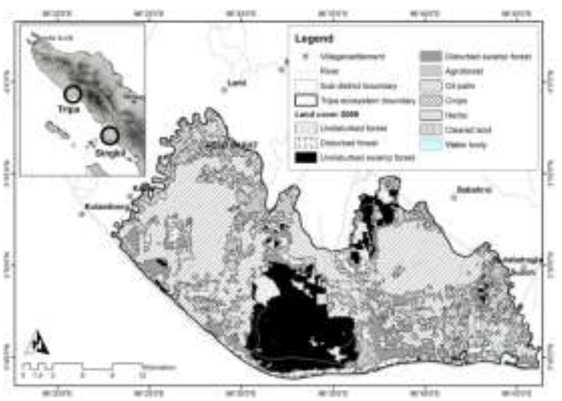

Figure 2. Location of the Tripa swamp on the west coast of Aceh at the northern tip of Sumatra

Land use history and rights

Methods akin to participatory rural appraisal and the Rapid Land Tenure Assessment were used to identify local perspectives on the landscape, land use patterns in their historical context and the potential presence of conflicts over land tenure (Galudra et al. 2010). Existing spatial data set on administrative boundaries, concessions and land cover (Minnemeyer et al. 2008) were combined. Earlier results of YEL/Paneco (2008, 2010) were cross-checked in focus group discussions at village level and interviews with local government and NGO's.

Economic benefits of land use options

The main land use systems of the area were characterized in their agricultural calendar, labour requirements for different phases of the system, use of external inputs and yield levels. A spreadsheet model was used to derive Net Present Value (USD/ha) as sum of discounted future cash flows at a discount rate of 6.5 %/year (Tomich et al. 2001; White et al. 2010). Further details are provided in Tata et al. (2010).

Carbon stock assessment

Five carbon pools are to be assessed according to the Intergovernmental Panel on Climate Change (IPCC, 2006): aboveground biomass (tree and understorey), dead wood, surface litter (necromass) and belowground biomass (roots) and necromass (soil organic carbon and peat). The sampling method used in this survey refers to the ASB protocol (Hairiah et al. 2001, 2010). Three nested sub-plots were established in each sample plot depending on vegetation: 40 m x 5 m sub-plot for counting trees and dead wood between 5 to 30 cm diameter; 100 m x 20 m plots for measuring trees and dead wood of more than 30 cm diameter; quadrant of 2 x 0.5 m x 0.5 m set up inside the sub-plot used to count understorey, litter and soil. A total of 23 plots were measured in undisturbed peat forest, disturbed peat forest and secondary peat forest of Tripa, including reanalyzed data from 14 plots studied by van Belle and Hennin (2008). Peat depth, classification, bulk density and carbon content were estimated from a previous study in the area (Agus and Wahdini, 2008). Tree diversity data from the measurement plots were used for calculating a Shanon Wiener diversity index:

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Where p_i is the number of individuals in species i relative to the total in the sample and S is the number of species encountered.

Opportunity cost curves

Opportunity costs where first calculated for every pixel (or map unit) that had changed land cover over a time step, using the typical C stocks (t C/ha) and Net Present Value (USD/ha) of each land use type distinguished (Swallow et al. 2007).

$$OpCost = \Delta_{t=>t+1}(NPV)/\ (a\ \Delta_{t=>t+1}\ (Cstock))\ \ [USD/tCO_2e]$$

where

$\Delta_{t=>t+1}()$ indicates a change over the time period t to t+1,

NPV = Net Present Value (or discounted sum of cash flow over assessment period), in USD/ha,

Cstock = Time-averaged carbon stock of land use system, in t C/ha,

a = conversion factor from carbon to CO_2e (= 44/12).

The frequency distribution of these OpCost values, expressed against the average emissions from the landscape was calculated as 'OpCost curve', using a land use change matrix as well as the OpCost value for any type of land use change. The ABACUS tool developed by the Allreddi project (http://www.worldagroforestrycentre.org/sea/projects/allreddi/softwares) was used to generate such cumulative OpCost curves.

Alternative options for 'high C stock development'

Dynamic land use change scenarios were developed using the Fallow model (van Noordwijk 2002; van Noordwijk et al. 2008b; Suyamto et al. 2009), which represents farmer decision making among land use systems and labour allocation, on the basis of learning from the performance of such land use systems in the local context. Results can be expressed as changes in total landscape carbon stock and farmer income. The parametrization was derived from earlier applications of the model to Aceh's west coast (Lusiana et al. 20011).

Table 2. Brief history of land use in Tripa ecosystem(further details in Tata et al. 2010)

Period		Description	Livelihood changes
1930s	Plantations established by Dutch colonial government (rubber and oil palm)	Introduction of plantation crops such as oil palm (in Sukaraja), cocoa (in Seunaam, Seumayam settlement area), or rubber (Babah Leung and Ladang Baru area) outside the peat swamp.	From swidden agriculture, people became more involved in oil palm plantation

1991–8	Transmigration program Degazettement of forests for oil palm plantations	SP 1, 2, and 3 in Seunaam, along with oil palm expansion Five oil palm concessions were established on peat land	Oil palm expansion Citrus (*Citrus sinensis*) production in some transmigration areas (in particular Seunaam 4)
1998–2004	Ecological recovery during heightened military conflict	Farming activity decreases significantly	Farming activity decreases: frequency of farmers accessing forest and farm areas decreases owing to safety issues
2005	Tsunami (Dec. 2004) rebuilding program, peace agreement	Natural forest opening movement: wood extraction	People involved in logging to get raw material for tsunami rebuilding program
2008	End of rebuilding period, oil palm plantations expand	Land conversion to plantations (oil palm) increases	People return to farming; some move to off-farm activity such as oil palm harvesting
2008–09	'Thousand hectare of oil palm' program in Nagan Raya and Aceh Barat Daya	Land conversion to plantations (oil palm) increases	

Results

Land use history and formal basis of the companies' rights

The western coast of Aceh, a strip of up to 5-30 km wide between the Indian Ocean and the mountains of the Bukit Barisan mountain range that runs along Sumatra, has been a backwater of development throughout history. About a quarter (26%) of its

although the latter category can include logged-over forest. The area does not have easy access to its mountainous hinterland, and has in Meulaboh a port of limited importance. During the colonial period some rubber and oil palm plantations were established around the peat swamp forest relying on road transport to Medan (N. Sumatra). According to local history recounted by local stakeholders not much happened on the peat swamp itself beyond providing some livelihood (e.g. fishery, timber, plants) and protecting people from extreme events (e.g. water regulation, watershed protection), before transmigration programs opened up this area in the 1990s. Large-scale oil palm concessions began converting the peat swamp forest. This oil palm expansion period ended in 1997-98 during a phase of intensified conflict between the Acehnese independence movement and the national army. Most of the transmigrant population left the area, and natural ecological restoration started in abandoned oil palm plantations (Table 2).

Table 3. Monthly household income by occupation

Occupation	Household sample N	Household sample %	Range of income per month (Rp 000)	Median (Rp 000/month)	Standard Deviation
Fishing	10	14.29	115–750	199	111
Agriculture	32	45.71	108–486	167	126
Mixed garden	32	45.71	30–3000	125	526
Smallholder oil palm	12	17.14	160–5500	1,233	2045
Non-farm: oil palm workers	31	44.29	120–2800	450	585

The boxing day Tsunami of December 2004 caused a lot of damage to lives and property on the West Coast of Aceh. In Tripa, only the communities adjacent to Tripa and on Tripa were affected. All the communities further inland were effectively protected due to the efficient buffering action of Tripa itself. The Tsunami induced an intensive process of negotiations between the two sides in the conflict and a comprehensive peace agreement in 2005 cleared the way for new economic development activities.

Politically, the two regencies (districts) that share the Tripa swamp slightly differ in land-use and development policies. In Nagan Raya, expansion of oil palm plantations has been fast and was promoted by the District Government. Under the program 'Nagan Sejuta Sawit' (Nagan 1 million oil palms), approximately 200,000 oil palm seedlings were distributed to local communities in 2009. Within the Tripa peat swamp, despite an official commitment by the District Government to protect the peat swamps forest, conversion to oil palm plantation within concessions was rapid. Large-scale oil palm concessions re-started their operations using their existing concession rights to rehabilitate the oil palm concessions and to convert the remaining peat forest into oil palm. An additional large-scale oil palm concession was established. Obtaining their concession rights from the government, the three main oil palm companies encountered land conflicts with local communities that have customary rights claims. Sometimes violent, these conflicts lead to a joint petition by the 21 villages in and around Tripa, requesting Government to assist them to regain control over Tripa, to manage it sustainably and to conserve the remaining approximately 20,000 ha of primary forest.

At individual smallholder level the reality to prevent oil palm expansion is somewhat different. Oil palm had become the number one commodity planted by local villagers with higher income (which seems logical as oil palm plantation is capital intensive and an approximately eight year time to positive cash flow), with cocoa being the second most frequently planted. Most farmers (about 65%) within surveyed villages had oil palm plots of at least 1–2 ha each, with different ages of oil palm planted. Many of the oil palm plantations were already producing. Within the Tripa swamp, farmers establish their plantation within the remaining primary forest between plantations and compensate the local villages for land loss by payment, often for community development. In some cases, smallholders even establish oil palm concessions on the forest land under oil palm concession in an attempt to get a customary right on this land.

In Aceh Barat Daya, the District Government also had a 1 million oil palm programme but it focussed on support to smallholders through the so called "special autonomy fund", providing planting materials and fertilizer. In addition, the District Government took over the main oil palm concession that was left abandoned (8,492 ha) and ruled that community members could establish oil palm plots of up to 2 ha per household. The second large-scale oil palm concession is only partly operating and not expanding. In addition, along the Seumayam river, which separate the two Districts, a new large scale (2,740 ha) oil palm concession has been established on the Aceh Barat Daya side. In addition to these large-scale concessions, oil palm plantation smallholders are also expanding, converting the remaining forest outside the concessions.

Summarizing the findings on the two districts, the large-scale oil palm plantations are still driving land-use change in Tripa and are holding about 80% of the peat swamp (figure 3). However, the richest smallholders from the local villages are increasingly driving land-use change in Tripa, expanding into the remaining forest between the large-scale oil palm concessions, with active support (through subsidies and policies) from the District Governments. This discrepancy and paradox between official stance from village leaders to save Tripa and practical reality with destruction by local people may be in the long-term the greatest potential threat to the remnant peat swamp forest of Tripa and, thus, to the Orangutan. Indeed, even if large-scale oil palm concessions could be stopped, local societal reality will have to be taken into account.

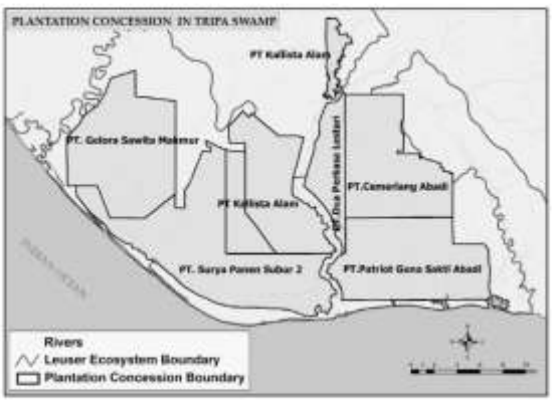

Figure 3. Oil palm concessions within the Tripa (former) peat swamp forest (62,000 ha)

However, awareness of the protection the remaining forest had provided during the Tsunami (Cochard et al. 2008) plus new evidence of the biodiversity value of the remaining swamp forest, initiated actions by local and international NGO's to conserve the area. In addition, the carbon emissions from peat swamp forest conversion to oil palm became an international issue of concern, but also more specifically in Aceh Province. The Aceh Governor is promoting "Green Aceh" to get access to carbon finance and Tripa is certainly currently the area with highest emissions rates in the province. As such, the Aceh Province declared in 2007 a Moratorium of forest conversion and established a team to review the legality of all type of concessions (e.g. forest and agricultural land). In its 2010 spatial planning plan presented to the Indonesian Ministry of Forestry, the Aceh Government included Tripa as a conservation area to be protected.

Options to cancel large-scale concessions seem, however, difficult as their owners hold a legal document from a Central Ministry, something the local villages with customary claims do not possess. Options to 'swap' land from existing oil palm concessions in Tripa to alternative degraded land is possible as there is at least 200,000 ha of such land of low current use value in Aceh (Aceh Green, 2008). But, this land is divided in different small areas of only few hundred hectares each. In addition, these lands have unclear land right status making this investment little attractive, technically more costly and socially potentially risky.

Carbon stocks, historical emission levels and potential emission that can be avoided

Forest in Tripa decreased dramatically to more profitable but low-carbon stock tree cover, that is, oil palm (both plantations and smallholder plots), while annual crops and agroforest remained constant. Natural forest cover declined from 54% in 1995 to 18% in 2009. Three types of forests could be distinguished: primary forest of high density, primary forest of low density and secondary forest, which consisted of regenerated vegetation and forest burnt in 1996. Average density in each type of forest was 193 ton ha^{-1} from undisturbed peat forest of the YEL/ PanEco/ICRAF 2007 and ICRAF 2010 survey, 84 ton ha^{-1} from disturbed peat forest YEL/PanEco/ ICRAF 2007 and ICRAF 2010 survey, 112 ton ha-1 from disturbed forest of ICRAF 2010 survey and 28.5 ton ha^{-1} from agroforest in peat of YEL/PanEco/ICRAF 2007 survey, respectively (Fig. 4).

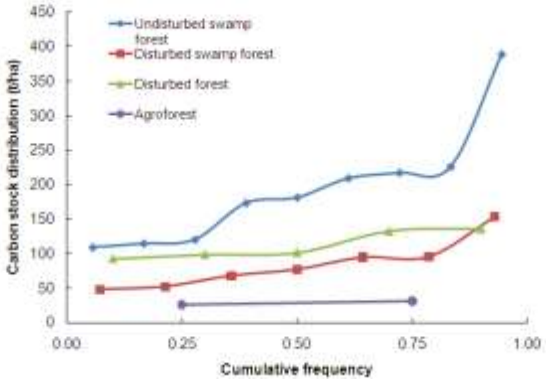

Figure 4. Cumulative frequency of aboveground carbon stock based on land cover classification in Tripa area

Peat density in Tripa was measured to be in the range 0.01–0.03 g/cm^3 with a carbon content of 12–63%, resulting in an average of 419 tC/ha per m of peat and a carbon stock that ranged from 382 t/ha for a 130 cm depth profile to 2240 t/ha for a location with a depth of 390 cm (Agus and Wahdini, 2008). Peat domes in Tripa have an average depth of 3.2 m and 1350 t/ha as average belowground carbon stock.

At landscape level, the average aboveground carbon-stock density in the 1020 km^2 assessed in Tripa decreased from 148 t/ha in 1990 to 61 t/ha in 2009, while for the 480 km^2 subset of this that is conceded to oil palm plantations, carbon density decreased from 114 t/ha in 1990 to 48 t/ha in 2009. The annual emission rates owing to land-use conversion in the study area ranged between 0.94 MtCO_2e/yr and 2.2 MtCO_2e/yr, with the highest value in the period 1990–1995 when forest conversion to oil palm plantations peaked. The lowest rate, during 2001–2005, was because of a slowdown of activities during the conflict. The post-tsunami peace agreement, lead to an increase in emissions. Over the whole observation period, average annual emissions were 14.45 tCO_2e ha^{-1} yr^{-1}.

A total of 92 tree species were identified in 23 plots (4.6 ha) in the Tripa area. In undisturbed peat forest (4 plots), a total of 20 species were encountered, with average species numbers in each plot at 8. Secondary peat forest had less species, with 11 species found in 5 plots with an average of 5 species per plot. Species numbers in disturbed forest on mineral soils was higher: 79 species in 14 plots with an average of 12 species per plot. *Eugenia jambos, Eugenia curtisii, Litsea cubeba and Laurus nobilis* were the most common species in the Tripa area, dominating all types of forest (Fig. 5). Ten dominant tree species found in Tripa (including *E, jambos* as most common species) were identified as sources of orangutan food by Russon et al. (2007).

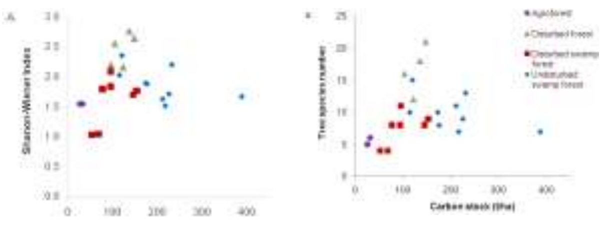

Figure 5. Relationship between aboveground carbon stock and tree diversity, expressed in the Shannon-Wiener index and as tree species number per observation plot

Economic benefits of land use options and opportunity costs of avoiding emissions

Results of a livelihood and economic analysis confirmed oil palm as the driver of the local economy. In both districts, within every smallholder plot there were 120–150 oil palms per hectare, with a gross production valued at Rp 600 000–1 500 000 (±USD 67–168) per month per hectare. In 2010, prices for fresh fruit bunch fluctuated from Rp 700 000 to 1 050 000 (±USD 80–110) per tonne.

Working for an oil palm company is another alternative livelihood that was very important within the surveyed areas. There were two types of work that we identified:

- Contract labourers, usually called *buruh syarat kerja umum* (SKU), were permanent mid to top level workers of oil palm companies. However, most of the workers, especially the field workers, have no permanent contracts, their contracts being short term and paid for the volume or time spent. These contracts are locally known as JAKON (or JAwa kONtrak). The contract systems have been used since the first plantation came to Sumatra during Dutch colonial times. The majority of labour came from Java, forming the initial period of in-migration to Aceh. Their main responsibilities were garden maintenance and harvesting. Wages labourers should be above or at least equal with provincial minimum labour payments (*Upah buruh Minimum Provinsi* or UMP*)*, which, in 2011 in Aceh province was Rp 1 350 000 per person per month. They worked six-day weeks, seven hours per day. Within the surveyed villages, the labour force was dominated by Javanese and Sundanese. labour from outer areas were provided with a small house inside the plantation. Some of the labourers came directly from Java or were descendants of previous contract labourers who came to the region when the company was first established many years ago. The rest are transmigrants or their descendants who were not successful enough at farming.
- Daily wage labourers, usually work on specific tasks. Women are predominant in work such as fertilizer application, weeding, pesticide or herbicide spraying and collecting bunches. Men usually built or fixed roads, drainage systems and bridges. Most such workers were not equipped with safety equipment. Daily wage labourers worked five-hour days, starting at 6 AM, for a wage of Rp 25 000–40 000 (±USD 2.80–4.45) per day. Daily labourers usually came from the surrounding villages. Interviews with some native Acehnese showed that they were not interested in working for an oil palm company as contract labour because they mostly had farms. Working as daily wage labourers was not part of their culture or habit because the oil palm concessions took away their land. However, to get quick cash, they would agree to work as daily wage labourers in their spare time.

Extra labour was usually deployed for harvesting. They either already worked for the oil palm company or on smallholder oil palm plots. Some were paid a daily wage, others through a profit-share system.

Forest conversion to oil palm plantations in Tripa produced high average annual emissions, due to the use of fire in land clearing with 575 fire hotspots recorded during the last 10 years (between November 2000 and January 2011) (Fig 6; NASA/University of Maryland, 2002). The drainage of peat causes ongoing annual emissions associated with the subsidence of peat (rates of 5-10 cm/year have been reported).

Table 4. Return to labour and land per land-use system in Tripa;

Land-use system	Return to labour (Rp/pd*)	Return to land (Rp 000/ha)	Labour requirement (pd/ha/yr)
Cocoa agroforestry	46 934	20 521	93
Smallholder oil palm	139 881	88 134	57
Home garden	56 804	5972	77
Irrigated rice paddies	32 433	2229	73

*Note: Prices based on 2010 prices and expressed in June 2010 rupiah (Rp 9199 = USD 1). *pd = person day*

Table 5. Emission, sequestration and net emission from 1990 to 2009, based on aboveground carbon stock changes within the KEL (Kawasan Ekosistem Leuser) boundaries and the Tripa study area which includes a 5 km zone around KEL

	1990–1995	**1995–2001**	**2001–2005**	**2005–2009**
Emission: Study area				
Total emission (tCO_2e)	11 008 417	9 310 972	3 775 111	7 591 064
Annual emission (tCO_2e /yr)	2 201 683	1 551 829	943 778	1 897 766
Ave. ann. emission (tCO_2e/ha/yr)	21.58	15.21	9.25	18.60
Sequestration: Study area				
Total sequestration (tCO_2e)	929 925	1 057 174	740 446	1 652 640
Annual sequestration (tCO_2e /yr)	185 985	176 196	185 112	413 160
Ave. ann. sequestration (tCO_2e/ha/yr)	1.82	1.73	1.81	4.05
Net emission: Study area				
Total net emission (tCO_2e)	10 078 492	8 253 798	3 034 664	5 938 424
Annual net emission (tCO_2e/yr)	2 015 698	1 375 633	758 666	1 484 606
Ave. ann. net emission (tCO_2e/ha/yr)	19.75	13.48	7.43	14.55
Emission: KEL				
Total emission (tCO_2e)	7 169 491	7 177 397	2 353 612	5 252 623
Annual emission (tCO_2e/yr)	1 433 898	1 196 233	588 403	1 313 156
Ave. ann. emission (tCO_2e/ha/yr)	23.77	19.83	9.76	21.77
Sequestration: KEL				
Total sequestration (tCO_2e)	181 525	642 028	343 573	641 864
Annual sequestration (tCO_2e/yr)	36 305	107 005	85 893	160 466
Ave. ann. sequestration (tCO_2e/ha/yr)	0.60	1.77	1.42	2.66

Net emission: KEL				
Total net emission (tCO_2e)	6 987 965	6 535 369	2 010 039	4 610 759
Annual net emission (tCO_2e/yr)	1 397 593	1 089 228	502 510	1 152 690
Ave. ann. net emission (tCO_2e/ha/yr)	23.17	18.06	8.33	19.11

When comparing carbon stock and profitability four groups of land use can be identified in Tripa (Fig 7): 1) High carbon and low profitability (for example, forest); 2) Medium carbon and medium profitability (for example, logging and agroforest); 3) Low-carbon stock and low-to-medium profitability (for example, annual crops and agroforest); and 4) Low-carbon stock and high profitability (for example, oil palm).

The slope of the line connecting natural forest (group 1) to oil palm (group 4) represents an opportunity costs of avoiding such emissions (or 'abatement costs') slightly over 10 USD/tCO_2e. If such a conversion is a stepwise process, the opportunity costs of converting natural forest and natural peat swamp forest to other land use (group 2 or 3) are higher, while that of converting other land use (group 2 or 3) to to oil palm plantations is lower. By taking into account peat emission during land-use conversion, the average emission in Tripa was estimated to be 20 tCO_2e ha^{-1} yr^{-1}. It is made up of contributions of multiple conversion steps, that differ in their opportunity cost (Y axis) and emission total in the landscape (X-axis) (Fig. 8).

Using the threshold of 5 USD/tCO_2e, the emissions from land-use conversion that could have been avoided ranged between 6 tCO_2e ha^{-1} yr^{-1} to 15.3 tCO_2e ha^{-1} yr^{-1} over different periods of observation. Approximately 41% of the aboveground carbon-stock emission, totalling 5.88 tCO_2e ha^{-1} yr^{-1} could have been avoided if a carbon

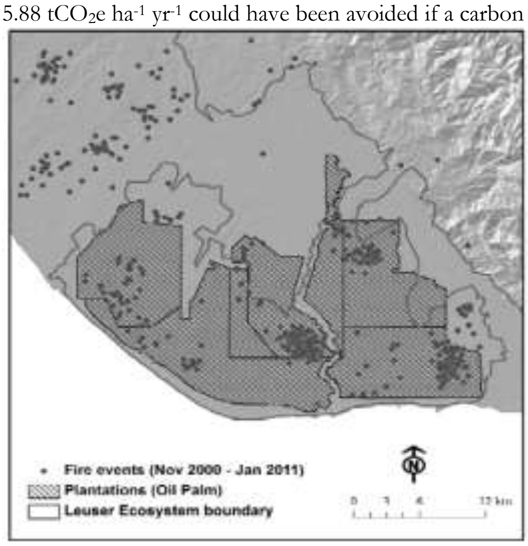

Figure 6. Fire events recorded in Tripa

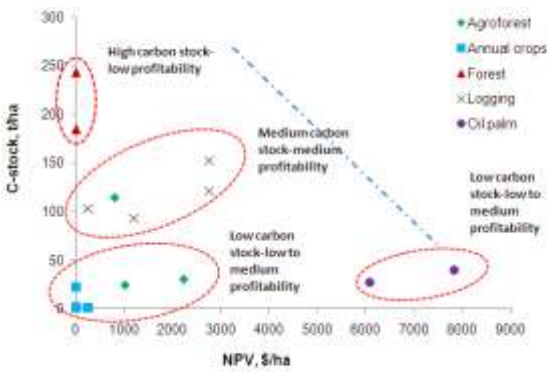

Figure 7. Trade-off between profitability (net present value = NPV) and typical carbon stock of the land-use systems encountered in Tripa

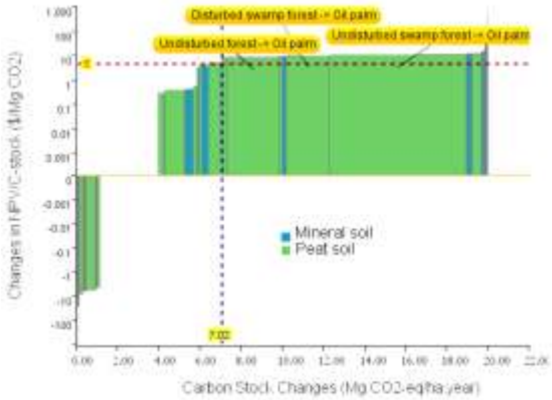

Figure 8. Apparent opportunity or abatement-cost curves for CO_2 emissions of peat and mineral soil throughout the entire period of analysis (1994–2009) in Tripa

price of 5 USD.tCO2e would ally only for aboveground losses and a lower fraction (35%), but higher total amount (7.03 tCO_2e ha^{-1} yr^{-1}) if belowground emission from peatland conversion are taken into account.

Biodiversity and environmental services

The area is one of only three significant tracts of coastal peat swamp forests (Tripa, Kluet, Singkil) remaining on the entire west coast of Sumatra and the overall Aceh Province as there is hardly any peat swamp on the East coast of Aceh. These peat swamps are quite distinct from the remaining swamp forests on Sumatra's East coast, and therefore they hold a unique biodiversity value (Yel/Paneco, 2010), the primary reasons for which the three of them are integral part of the Leuser Ecosystem.

Tripa is the habitat of the Sumatran orangutan (*Pongo abelii*; IUCN 'Critically Endangered') outside protected areas in its highest world densities. It also supports Sumatran tigers (*Panthera tigris sumatrae*; IUCN 'Critically Endangered'). In addition, the existence of Tripa and the other swamps swamps is crucial for the survival of numerous swamp specialist animal species. Otter civets (*Cynogale bennetti*), Storms' stork (*Ciconia stormii*), the white-winged wood duck (*Cairina scutulata)* and the masked finfoot (*Heliopais personata*) are especially noteworthy and very much restricted to swamp habitats. They are also important for aquatic and marine species, including the remarkable saltwater crocodile (*Crocodylus porosus*) and several marine turtle species that nest on the adjacent beaches. Most of these species appear on the IUCN Red List of Threatened Species. In addition, Tripa and the other swamps form the only natural ecological corridors linking the Indian Ocean to the mountainous interior of the Leuser Ecosystem and the Gunung Leuser National Park. As such they play a key role in the adaptation of many of the wildlife species that inhabit them to climate change. If sea levels and temperatures rise as predicted, forest corridors such as these will be critically important, and the only routes for species forced to migrate due to changing vegetation and climatic factors. Tripa is also important for its vegetation. The area is singled out as high-priority conservation area for maintaining floristic diversity (Laumonier et al. 2010).

Beyond biodiversity and carbon values as global goods, Tripa also provide crucial environmental services to local economy by providing livelihood and securing lives. The Tripa peat swamp forest provides food (wild food and fisheries), fresh water for household and agriculture, timber for construction, fibre from rattan species (*Calamus manan*) used to make furniture, fuel wood, natural medicines and ornamental plants. Collecting shellfish (*Polymesoda* sp.) and fishing is may be the single most traditional source of livelihood from the swamp. The main fish species sought are catfish known as lele (*Clarias nieuhofii*). Farmers often catch this species using traps made from bamboo and rattan. However, fishermen report that fish harvests have generally declined by almost half, to just 60% of former levels, due to the massive land conversion (Tata et al. 2010).

A well functioning peat swamp provide also regular supply of fresh water that is necessary for drinking, cooking, bathing and irrigating agricultural lands. Rice production – the main staple food of the region – depends heavily on a stable water supply. This situation is rapidly changing when drying out the peat swamp lowering the water table for oil palm expansion, with water shortage and contamination reported.

The coastal peat swamp forests are peat domes that maintain a high water table, preventing sea water intrusion into the swamp itself and preventing fires (Wösten and al 2006, 2008). When peat swamps are drained for plantations, and the peat dries and oxidizes, it shrinks, resulting in subsidence of around five centimetres per year, according to even the most conservative scenarios (Hooijer, et al. 2006, Wösten and Ritzema, 2002). Subsidence near the coast leads to the serious problem of increasing land salinity, which will eventually preclude agricultural production, even on the oil palm plantations themselves.

The local communities in Tripa already increase in freshwater flow due to reduced peat capacity of water retention. They have consistently reported a marked increase in both the frequency and extent of floods since 2000 with the extension of the oil palm concessions (Paneco 2008). In 2010, peat areas in Tripa where thousands of people live were flooded, with flood depths between 1 and 1.5 m, isolating the communities living in and around Tripa (Serambi, 2010).

Increased in fires on dried peat is another major problem. Although the burning of peatlands is forbidden by Indonesian law, 575 fires were recorded by satellite (fires of at least as large as 20m*20m) in the Tripa peat swamp alone between November 2002 and February 2011 (Nasa/University of Maryland, 2002).

The Tripa peat swamp forest regulates the micro-climate that benefits adjacent agriculture, including large-scale oil palm plantation. In fact, the highest palm oil yields in the world, more than eight tonnes of crude palm oil per hectare per year, are recorded in this very region (Jacquemard, 2010).

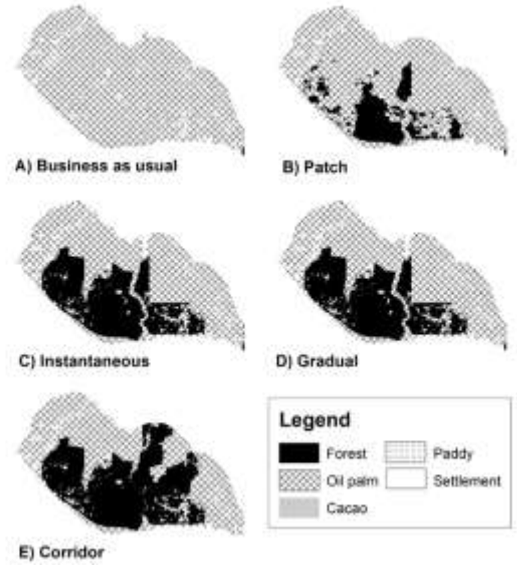

Figure 9. Landscape mosaic in Tripa after 30 years. Simulation of five different scenarios by the FALLOW model: A) Business As Usual (BAU); B) conservation of remaining forest ('patch'); C) instantaneous restoration of all oil palm plantations into forests ('instantaneous'); D) gradual restoration ('gradual'); and E) establishment of two corridors to support orangutan preservation ('corridor'). The total simulated area was 104 000 ha, including 40 000 ha in all HGUs combined. (Abbreviations used in the legend: set=settlement, pfor=pioneer forest, ysec=young secondary forest, osec=old secondary forest, prim=primary forest, pion=pioneer stage, early=early production stage, late=late production stage, post=post-production stage, OP=oil palm.)

Alternative options for 'high C stock development' and employment generation

FALLOW modelling scenarios in Batang Toru and Tripa highlighted the need to consider both livelihood and emission levels as dynamic baselines. A 'business as usual' scenario for the landscape suggests that all remaining forest can be converted to oil palm within a few years, as labour and capital to do so are available in the landscape and oil palm is the system of choice for local agents.

A number of 'ecological restoration' scenarios were evaluated (Fig. 9) that differ in their time frame ('instantaneous' for revoking all existing permits, versus 'gradual' for allowing existing oil palm to last its concession permit but not renewing the permit) and spatial extent (whole landscape within the Leuser Ecosystem boundaries (KEL) or focus on a corridor to connect the remaining swamp forest to the Gunung Leuser national park).

The various scenarios can be compared in their effects on local income and changes in C stock (Fig. 10). Compared to the current situation, which is taken as the origin in the graph, a business as usual scenario adds approximately 1 M Rp per capita per year for all inhabitants of the area, and lose about 0.3 M ton of CO_2e per year. The various restoration scenarios lead to loss of income compared to current, but will lead to a net sequestration of CO2, approximately proportional to the loss of income.

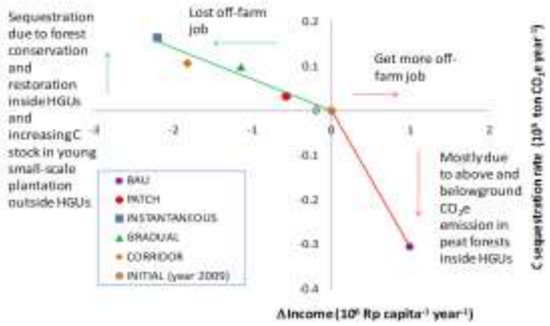

Figure 10. Difference in annual income and annual CO_2e sequestration rate calculated with the FALLOW model for each simulation scenario for 30-year simulation over the simulated landscape in Tripa relative to the condition measured in year 2009 (i.e. income of Rp 3.5 x 10^6/capita or Rp 6.5 x 10^6/labour with a labour fraction of 0.54 from total population in Tripa) and total aboveground carbon-stock of 5.5 x 10^6 tonne in the landscape); the wage rate as laborer in big-scale oil palm plantations used to calculate income was Rp 1.2 x 10^6/month).

The tradeoff described by the slopes of the lines in Fig. 8 can be compared to that in Figures 7 and 8, but it now refers to a predicted outcome of multiple decision makers. The scenarios include the response options farmers have in the presence or absence of new oil palm development or ecological restoration. The size of this response can be calculated as follows. The difference between BAU and year 2009 was 17 000 ha of oil palm. At 57 person-days/ha/yr and a 'return to labour' of Rp 71 000/day, this oil palm area could generate USD 7.5 million/yr. However, in the absence of oil palm development, the 17 000*57 person-days could be spent in other ways, generating income. Within the parameter value of the model, apparently 4.5 million of the USD 7.5 million could be internally compensated, leaving a difference of USD three millions, or approximately one Million Rp per capita per year, given a projected 2030 population for the 102 000 hectare area (Tripa peat swamp and its surrounding) of 29 000 persons and a human population density of 25 persons km^2 (certainly much less within the peat swamp, but most likely much more on the buffer zone) While in Fig. 7 and 8 the implication was that the USD value of opportunity costs would have to be paid to a rights-holder, the interpretation now is that somehow investments in the area have to generate an equivalent level of income opportunities. In that sense the scenarios are not prescriptive of how to achieve such goal, but they do quantify a required bottom line.

Discussion

Answers to questions 1-5 position the Tripa area at the heart of the current REDD+ debate: in an area of high above- plus belowground C stock, with forests that still represent globally important biodiversity (several percent of global population of critically endangered Sumatran orangutan and one of the last remaining habitat for several endangered plants, birds and other animals), privately profitable economic activities take place, mostly in the form of forest conversion to oil palm plantations and associated drainage of peat domes, that lead to high carbon emissions but also create jobs and provide local income. After many centuries of sharing the landscape of the northern half of Sumatra, human populations and orangutan appear to become incompatible in the 20th century. Economic incentives are needed before any of the actors involved in current emissions would voluntarily change behavior. Before any one will provide the necessary economic incentives to change the current pattern, however, the legality of status quo and business as usual need to be asserted. Presidential Decree No. 32/1990 and Indonesian Government Regulation No 26/2008, state that all peat land with a peat of depth exceeding three meters should automatically be assigned protected status and its water retention and regulatory functions should be maintained. The degazettement of Tripa as protection forest and issuance of concessions was not aligned with these rules as the core of each peat dome has more than three meters of peat. Direct payment of compensation to concession holders may not be appropriate for this reason. But other local stakeholders who expect to benefit from oil palm expansion through jobs (e.g. local people) and taxes (e.g. different levels of Government, and especially the local Government) do need consideration.

Providing economic incentives at the local level is probably efficient in a global perspective on the economy, as its costs may well be lower and more efficient than other actions currently undertaken elsewhere as part of globally appropriate mitigation actions to reduce net emissions to a level compatible with less than two degrees warming. In addition this direct support may have positive win-win impact on the over-arching issue of talking local poverty of people living at forest margin and therefore the first Millennium Development Goal (MDG1), which is at the core of development assistance (Gregersen et al. 2010).

The necessary economic incentives to protect the remaining peat swamp forest does not necessarily mean direct cash payments to all people living in the district. Part of the funds can be used to finance activities to enhance or secure the different environmental services (e.g. carbon stock, biodiversity conservation, fish pond, water retention, wood supply) that the peat swamps provide. When it relates to biodiversity for example, the activities may be to promote tourism or undertake further research. Rehabilitation of the peat swamp for fish pond, water retention of fish pond could be done by careful water table management and selective reforestation.

Another part of the apparent need for funds can be internally generated by the direct contribution, unaccounted for in the current comparison, of the peat swamp forest to the local economy (e.g. fish, freshwater supply, buffer zone against tsunami). As for who should then pay for securing the area it may refer back to who is responsible for it and who most benefit from it. When it comes to biodiversity and carbon preservation, international donors may have to be the biggest contributors. When it comes to provide and secure local livelihoods, government agencies may be ultimately responsible, along with local communities and private sector who benefit from the well functioning ecosystem, for example for the micro-climate important for agriculture, including large-scale oil palm concessions.

Between the potential relevance and applicability of economic REDD+ incentives, however, stands a complex network of institutions, history, politics and stakeholders with rights, expectations of rewards, needs for recognition and articulation of sovereignty Based on the study, CES, COS, CIS paradigms may need to be combined to provide economic incentives for different development pathways in Tripa: commoditization of carbon (CES1) may work at the national border, while international market signals linked to existing commodity trade (CES2) has been effective so far. COS at the subnational planning level and in approaches such as land swaps, need to support and synergize with CIS approaches at local scale. These tentative conclusions based on the Tripa case are likely to have broader application in Indonesia and similar countries. The six hypotheses of the theoretical framework will be used to structure the final discussion of question 6: How is current repositioning of agents in the international value chain interacting with the options to provide positive economic incentives through REDD+ and achieve the national goals for emission reduction set in the NAMA debate?

Hypothesis 1 stated that "Cross-scale mechanisms for fair and efficient reduction of land-based green-house gas emissions (or a forest-related subset) need to acknowledge differences in clarity of rights and performance measures between local, subnational and national scales."

Land rights issues are prominent and largely unresolved across Indonesia, as customary rights and the formal legal systems have not been effectively reconciled (Galudra et al. 2010). Private sector rights, derived from government permits, are often overlapping with local claims. By contrast, boundaries between subnational entities (districts, provinces) and the national border are generally uncontested. The pendulum swings of centralization-decentralization-recentralization of government system since independence, however, has left overlapping mandates and a need for reconciliation and cooperation, especially in some of the hot spots of emissions in peat land areas (Galudra et al. 2011).

'Having rights' and 'being right to use them' are indeed different issues. For a fair and efficient reduction of green house gazes, at local level, performance measures, beyond monitoring of carbon stocks, will have to be linked to effective practical measures to provide environmentally friendly development alternatives with a pro-poor agenda that preserve and enhance the different ecosystem services. Carbon emission reduction is then an additional positive effect from an efficient development assistance. On the opposite end of the spectrum at national scale, efficient green house gas reduction is more linked to the effective functioning of institutions and of implementing regulatory frameworks to reduce carbon emission.

Hypothesis 2 stated that "At national borders an international form of 'commoditized environmental services' is feasible that links performance on verifiable emission reduction below internationally agreed reference levels, to financial flows (CES1 paradigm)."

At national scale there is no doubt on the sovereignty of Indonesia (except for a few islands contested with neighbors) to manage its economy and negotiate emission reduction agreements with other sovereign nations in a form of CES1, where national scale C credits (within agreements that are yet to be finalized) can be exchanged for money at a price that reflects supply and demand for such credits. Indonesia ratified the UNFCCC convention and Kyoto protocol. It is a UN-REDD partnership country and is likely to support international REDD+ agreements if these come at an attractive carbon price. The basic conditions for CES are thus met at this scale. At sub-national scale, however, the issue of right-holders is substantially more complicated. Regional autonomy, spatial planning and forestry laws have yet to be reconciled in a number of key provinces (especially those with high emission track records).

Hypothesis 3 stated that "International trade will include voluntary and mandatory standards for emission reduction linked to commodity value chains that provide incentives for reduced emission land use (CES2 paradigm)"

In the short term, at least, the CES2 paradigm has been the most effective in reducing emissions from the area. The main company with an 'agreement in principle' for oil palm establishment in the best remaining forest block in Tripa has declared a moratorium on its plans for forest conversion, which aligns with the rules of the Roundtable on Sustainable Palm Oil (RSPO) and the intentions of the Government of Indonesia. The company realises that there is international attention on the area and that their actions are scrutinised. If it withdrew from their concessions, however, without clarity on the future of the area, a vacuum might appear in which local actors or new buyers might see opportunities for direct gain. The unresolved tenurial claims and contest in the area will need to be resolved as part of a comprehensive conservation plan.

In addition to the issue of conserving the remaining forest with societal stake on it, one should not also forget that from a biodiversity perspective ecological connectivity from the Indian Ocean to the inner part of the Leuser Ecosystem needs to be maintained for many plants and animal species (see biodiversity section). This is especially true from the perspective of orangutan conservation as this species needs a large home range. Therefore, securing an interrupted corridor between the remaining orangutan habitat in the swamp and the Gunung Leuser National Park is probably the biggest concern.

Hypothesis 4 stated that "From national to subnational entities a form of compensating for opportunities skipped is appropriate, using 'proxies' such as forest cover in relation to human population density (COS paradigm)."

Considerable discrepancies between parts of the country in economic performance and emission history, suggest that an efficiency driven approach of focusing on the high emission provinces only will not be perceived as 'fair'. Domestic emission displacements by shifts in the plantation industry are likely, and would have to be accounted for at national scale. The process of selecting a single REDD+ pilot province under the Norway-Indonesia agreement suggests that negotiations use an informal bidding process, where prospects of success, local commitment and severity of the issues are combined in the decision-making. The sub-national process matches a COS paradigm at the provincial level. At the sectoral level, however, a preference by the Ministry of Forestry to focus REDD+ activities on areas in which it has a direct stake, has lead to a situation where a case such as Tripa is not a national priority as it is already defined as legally 'deforested'. It is outside the legally defined forest area and classified as APL (Area Penggunaan Lain = Other Use Area) and thus also outside the scope of responsibility of the Ministry of Forestry as the primary government agency involved in REDD+. Existing public policy commitments to support conservation in the Leuser Ecosystem have not had tangible impacts on the ground and a strong case can be made for 'de facto additionality' of new efforts to reduce emissions, even though on paper the area already is protected. Earlier, a similar situation became an obstacle in the development of afforestation/reforestation projects under the Clean Development Mechanism development in Indonesia (van Noordwijk et al. 2008b).

To understand these eligibility issues better, a comparison is needed of international and Indonesian perspectives on, and definitions of, 'forest'. The internationally agreed definition of 'forest' has four components: canopy cover, tree height, minimum area and expected recovery from an 'unstocked' condition. Based on the UNFCCC forest definition, forest can include 'areas normally forming part of the forest area which are temporarily unstocked and are expected to revert to forest'. In Indonesian forestry law, 'forest' is defined as an ecosystem with multiple functions (Law no. 41 of 1999) but the concept of 'forest without trees' is possible as well. Ultimately, 'forest area' in both international and Indonesian definitions is an institutional designation that does not depend on the presence of trees. This categorisation can help explain why official statistics of deforestation show much smaller areas than remote-sensing data on loss of tree cover (van Noordwijk and Minang, 2009). Equally, however, non-forest can contain trees and recent data for Indonesia (Ekadinata et al. 2010) suggest that emissions from change in woody vegetation outside institutional forest are equal to those inside the institutional forest area. The way the REDD+ debate in Indonesia has so far been interpreted as necessarily focused on the 'forest area' is not mandated by international rules, but based on Indonesia's interpretation of these rules. In a comprehensive approach to land-based emissions that do not depend on an institutional forest definition, the emission reduction feasible in Tripa can match international rules for REDD+ and the 'forest plus peat' interpretation that has been used for the Letter of Intent between Norway and Indonesia.

Hypothesis 5 stated that "At local level, property rights and outcome-based performance criteria are a challenge to a ***"$ per t CO_2"*** exchange and co-investment in environmental services (interpreted across water, biodiversity and C-stocks) and the human and social capital that support them is appropriate as a start (CIS-paradigm)."

As indicated above, legality of existing use rights is open to multiple interpretations and a CIS focus on the levels of investment needed to provide alternative income and employment, rather than on CES or COS issues of who should be paid what may have more chances to blend fairness and efficiency at local level. Local government and decision makers need to understand the various components involved in the calculation of trade-offs between economic and ecological aspects of development. Managing the trade-offs involves review of the overall development strategy, as land, labour, capital, knowledge and markets interact in creating economic opportunities, while the fractions of land and their spatial configuration determine the ecological outcomes. The FALLOW model can be used to measure the impact of certain development strategies on the economic and ecological prosperity of local people living in a rural landscape, but model outcomes are sensitive to parameter values and assumptions. The relative ranking of scenarios is likely to be more robust than the absolute values of the results.

The primary lever on the oil palm economy is the external labour demand. Although the companies try to offer locally competitive wage rates they still rely on seasonal external labour and their historical connection with transmigration that added a labour force to the area. Current expansion is dependent on such labour and on companies who can organise it. A further restructuring of oil palm production to local agents, with oil palm companies focussing on their comparative advantage in the mill and downstream processing rather than primary production, may achieve local-livelihoods-plus-conservation goals if it removes the demand for an external labour supply. Clarification on land tenure, especially on the degraded land, and reform in subsides of oil palm expansion focussing more on the local farmer than large-scale plantations (e.g. technical know to farmers, access to market) will make alternative development on degraded land much more attractive and would pave a way for a new relationship between the smallholders and the large-scale companies.

According to our analysis, a major constraint faced by smallholders who may be attracted by the possible returns of oil palm systems is the lack of capital for investment, the time lag for return on investment (return from investment takes at least eight years, with the first four years dominated by expenditure), price uncertainty and low intensity of management and specific knowhow on the crop. For cacao, many farmers are constrained by lack of technical guidance with management, with pest control a major issue. Increased availability of investment capital and knowhow may increase attractiveness of the crop, while it could also be part of a 'guided intensification' process that allows forest conservation and emission reduction. The main issue ('Pandora's Box', as discussed in Tomich et al. 2001), is whether or not the landscape will continue to attract external labour and migrants.

Hypothesis 6 stated that "Transparency and free and prior informed consent (FPIC) ***can*** be achieved ***despite*** shifts in currency, language, time-frame and conditionality between scales, associated with the paradigms used."

The appropriate combination of CES, COS and CIS paradigms at different scales is still a rapidly moving target. The way the incentives reach the local economy can still be open to discussion: our opportunity-cost analysis only provides a target for a bottom line. Past policies (since early 2000) of the local government to promote smallholder oil palm for local households may have increased the number of households in the area; further growth may not be compatible with a high carbon-stock development pathway. Promotion of oil palm plantation by increasing yields (intensification) and development on already degraded land may be two attractive options. However, if policies induce people to move elsewhere then emission displacement rather than emission reduction may be the consequence.

The target should be to find population-neutral development alternatives that consider oil palm development, but also includes environmentally friendly alternative that maintain and restore the different eco-system services that the forest provides and secures. In short, at local level striving of a low carbon economy refers to and development agenda where poverty alleviation is central. It closely refers to what defines as being a green economy "as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011).

The institutional translation of the REDD concept has proved to be substantially more complex than initially thought and the way any REDD scheme will interact with land-use planning, the local economy and conservation outcomes still depends on multi-level negotiations (Van Noordwijk et al. 2008b, 2009; Suyanto et al. 2009b).

Such negotiations require a common understanding among the parties of the exact understanding the situation with the different environmental services that are at stake and who benefit from it. These negotiations also require a common understanding of the various options, including analysis and exploration of scenarios that reflect various types of change.

It seems that with Governmental support, broad stakeholder's good will and modern technology (that allows for increasingly easy, cheap and accurate information flows) transparency and free and prior informed consent (FPIC) ***can*** be achieved ***despite*** shifts in currency, language, time-frame and conditionality between scales, associated with the paradigms used. A similar discussion by Leimona *et al. (submitted to this issue)* of multi-scale rewards enhancement of for watershed services in Indonesian landscapes also concluded that multi-scale, multi-paradigmatic approaches are feasible, and may in fact be necessary to achieve success.

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World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

REDD-ALERT

ASB Partnership for the Tropical Forest Margins

SEVENTH FRAMEWORK PROGRAMME

Abatement curves summarize the costs that are involved in reduction of pollution, in this case net greenhouse gas emissions, based on the volume of various types of emissions and the expected cost per unit emission reduction. Such representations support policy development, identifying an initial focus on the low-cost high-volume emission categories. Four approaches are described and compared to do such analysis for tropical forest margins in the context of Reducing Emissions from Deforestation and (forest) degradation. The four methods, of increasing complexity and costs of data collection are appropriate in different steps along the pathway to negotiated agreements that can meet 'Free and Prior Informed Consent' standards, while reducing overall transaction costs by early warnings for cases that are unlikely to lead to mutually beneficial agreements. In early screening of potential cases, a comparison of profitability and time-averaged carbon stock of the different landuse options within an area can be used to confirm that there are no high C stock + high profitability land uses (if there are the question shifts to why these are not universally adopted) and that there generally is a tradeoff. The presence of low C stock + low profitability land uses, can direct the focus on prevention of degradation and possibilities of win+win restoration. For a Project Information Note (PIN) this may give sufficient initial clues. In landscapes where tradeoffs are confirmed, a further quantification and spatial study of the emission pattern can use pixel-level ratios of change in C stock and profitability as basis for C price estimates ('OpCost curves'). Such curves give an indication of baseline emissions and the opportunity for economic incentives to shift away from emissions that yielded low benefits in terms of profitability increases in land use. Such information can inform Project Design Documents (PDD). For further negotiations of contracts, forward looking landscape scenarios can further support the negotiations, as they can help define the bottom-line levels of alternative livelihood provisions that will be needed to make low C emission scenarios equivalent in terms of local economy to high C stock emission business as usual scenarios. Finally, further detail on the scenarios by inclusion of agent-based variation in resources and preferences may add further detail, but for this class of methods further tests are needed to judge their predictive value and relevance in the negotiation processes.