25 | Rapid carbon stock appraisal (RaCSA)

Meine van Noordwijk and Kurniatun Hairiah

The Rapid Carbon Stock Appraisal (RaCSA) assesses the status of carbon stocks in a given geographical area and develops scenarios of carbon sequestration or restoration resulting from potential land-use and management changes. RaCSA integrates procedures for developing land-use scenarios that can enhance carbon sequestration, prevent land degradation, promote sustainable land productivity and increase people's livelihoods.

Introduction

At the time of writing, about 10% of the emissions of carbon dioxide (CO_2) that cause global climate change are due to land-use changes in the tropics (Le Quéré et al 2013). The contribution of agriculture to other greenhouse gasses is up to 30%. While most policies have so far focused, rightly so, on the fossil fuels that cause the bulk of the CO_2 emissions, the land-use change can no longer be ignored.This land-based emission is the major part of emissions for many developing countries. Global mechanisms for providing economic incentives for maintaining and restoring carbon stocks are taking shape. The United Nations Framework Convention on Climate Change (UNFCCC) regulates the Clean Development Mechanism (CDM) that includes afforestation and reforestation activities. Under discussion is an approach to reducing emissions from deforestation and degradation in developing countries (REDD). Voluntary market mechanisms, which are not included in country commitments to reduce emissions, target various combinations of landscape restoration and protection of tree cover and carbon stocks.

Objectives

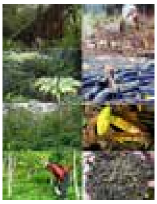
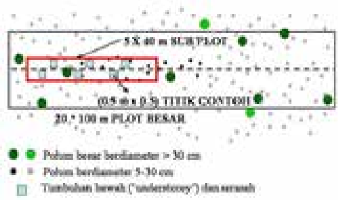
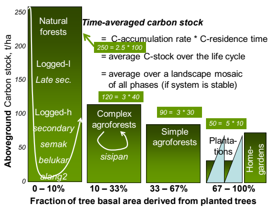
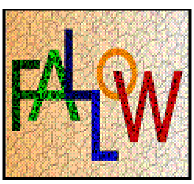
RaCSA is designed to provide a basic level of locally relevant knowledge to inform discussions on emissions reductions. It introduces a scientifically sound methodological framework of accounting for carbon sinks, while focusing on activities that can improve local livelihoods and alleviate rural poverty.

The purpose of RaCSA is to provide a cost-effective and time-bound (within 6 months) appraisal that:

- provides reliable data on carbon stocks in a defined landscape, historical changes and the impact of continuing land-use changes on projected emissions, with or without specific interventions to increase or retain carbon stocks;
- identifies the primary issues in the local trade-off between carbon stocks and livelihoods and the opportunities to achieve more sustainable development pathways; and
- enhances shared understanding between stakeholders as a step towards free, prior and informed consent in contracts to increase or retain carbon stocks.

Steps

Table 25.1. RaCSA activities and outputs

Activities	Objectives
1.  Initial appraisal of the landscape, focused on the dynamics of tree cover	To define the unit of assessment (integrated livelihoods/ landscape unit), its gradients in tree and forest cover, mineral and peat soils, land-use and land-cover types, major issues in the current debate
2.  Explore local ecological knowledge and the economics of local tree and forest management combined with a rapid household socio-economic survey	 To document livelihoods' strategies of the farmers pertaining to land-use practices and key drivers of change in the landscape
3.  Plot-level carbon data in representative land-cover units and; integrating from plot to time-averaged carbon stock of land-use types; an updated version of the ASB carbon stock protocol provides the tree and soil-level data	To assess the performance of existing land-use systems as carbon sinks and/or in preserving carbon stocks.
4. Combine remote-sensing imagery and ground-truthing data within a sufficiently sensitive 'legend' to provide spatial analysis of land-cover changes	To estimate carbon stocks of the main land-use practices at plot level as well as their integration at landscape level
5. Explore policy-makers' ecological knowledge of tree and forest management and spatial planning rules	To explore the opportunities to use or adjust existing policy frameworks to enhance carbon storage in the landscape
6.  Scenario studies of changes in carbon stocks and welfare through modelling land-use and carbon-stock dynamics in the landscape	To appraise landscape carbon-stock dynamics in relation to drivers of change as a basis for selecting interventions that enhance people's welfare and maintain or increase carbon stocks

The results need to be communicated in a simple format that focuses on the main trade-offs and decisions that can be made within a landscape. The primary data on carbon stocks can contribute to national databases and subsequently be used for national reporting. The ground-truthing and spatial analysis can similarly contribute to future analysis of the dynamics in larger areas, while the trade-off data and scenario models can be used for direct comparisons with other landscapes.

Case study of RaCSA application

RaCSA was applied in Nunukan district, East Kalimantan province, Indonesia, to monitor carbon stocks in an area where forest conversion, illegal logging and fire were causing substantial carbon emissions. Community-based forest management, such as agroforestry and low external input sustainable agriculture, were seen as options that could provide sustainable livelihoods for local farmers while increasing or maintaining carbon sequestration. Agriculture competed with logging as the most profitable activity.

According to a household survey, there were three main tree-based systems in the area: 1) smallholding plantations of oil palm and pepper; 2) 'jakaw' (an upland rice fallow rotation system); and 3) a fruit-based system where farmers planted fruit trees in logged-over forest between remnant trees of low-commercial value. These systems were estimated to store carbon as shown in Table 25.2.

Table 25.2. Mean aboveground carbon stocks of land-use systems sampled in Nunukan

Land-use systems	Carbon stock (Mg ha^{-1})
Primary forest	230
Logged-over forest aged 0–10 years	207
Logged-over forest aged 11–30 years	213
Logged-over forest aged 31–50 years	184
Jakaw aged 0–10 years	19
Jakaw aged more than 10 years	58
Agroforestry aged 0–10 years	38
Agroforestry aged 11–30 years	73
Imperata grass	4
Upland rice	5

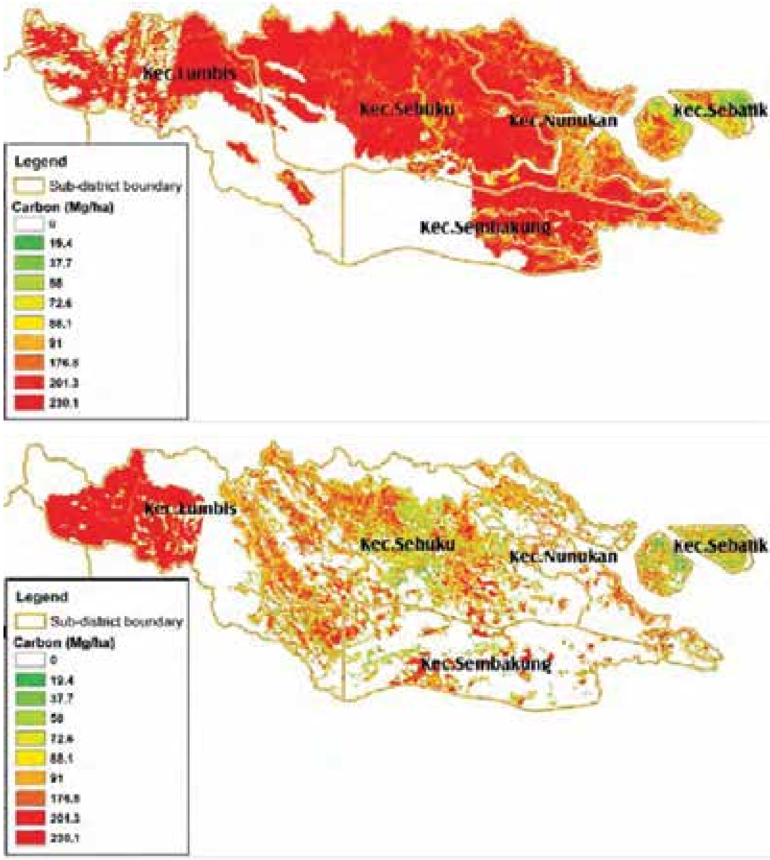


Figure 25.1. Distribution of land cover, Nunukan, 1996 (top) and 2003 (bottom)

An assessment of carbon stocks in the area estimated that carbon density in 1996 was 210 Mg ha^{-1}, while in 2003 it was 166 Mg ha^{-1}. During that period, primary forest was converted to other land uses at the rate of 3.9% $year^{-1}$. The estimated rate of carbon sequestration for the jakaw systems was 3.7 Mg ha^{-1} $year^{-1}$ and for agroforestry systems it was 2 Mg ha^{-1} $year^{-1}$.

Modelling exercises suggested that both income and landscape-level carbon stocks in Nunukan were decreasing, as non-sustainable logging remained the most profitable land-use option (Figure 25.1). Efforts to improve the profitability of agroforestry through better market development did not result in a greater adoption of the practice, since logging activities continued to provide better income (Figure 25.2). Thus, both per capita income and carbon stocks remained similar to the current trend. Reducing the timber market price by 25–50% reduced income without changing existing carbon stocks. If the market price was decreased 75–100%, people adopted agriculture and agroforestry to compensate for the income lost from logging.

The recommendation for policy in Nunukan was for promoters of agroforestry and community-based natural resource management to work together to achieve global and local benefits. A substantial increase in the profitability of agroforestry was needed before this practice could be considered an attractive alternative to illegal logging.

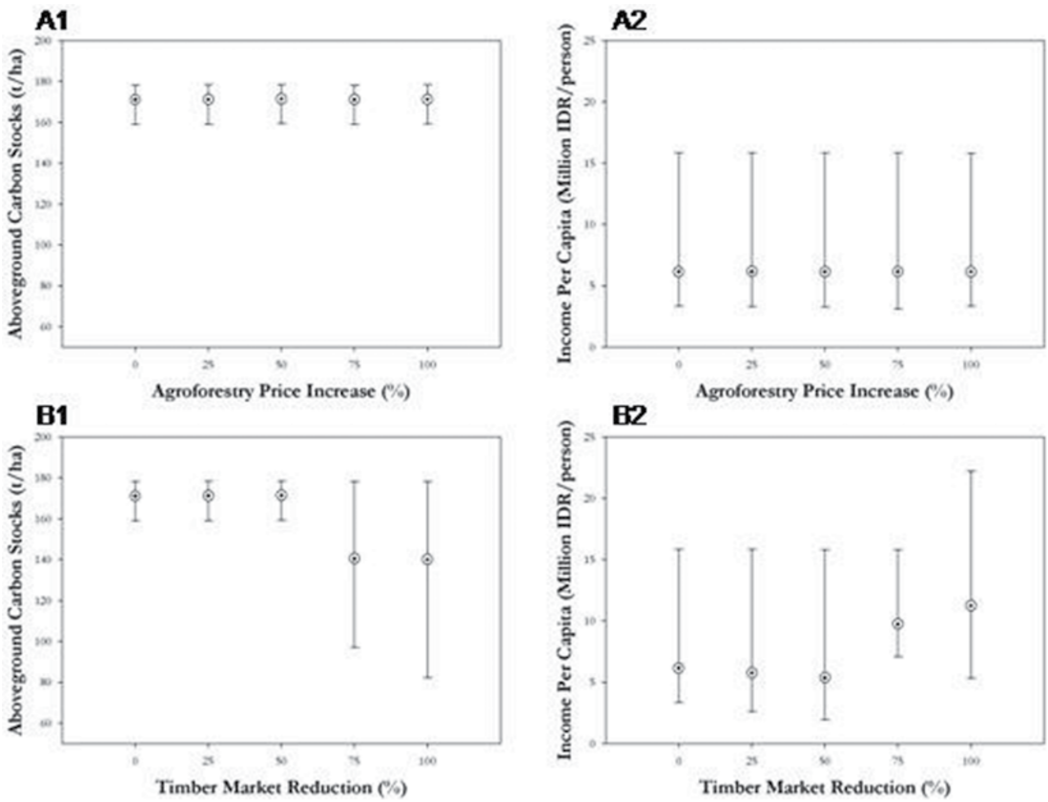


Figure 25.2 . Simulation results

Key references

Hairiah K, Dewi S, Agus F, Velarde SJ, Ekadinata A, Rahayu S and van Noordwijk M. 2011. *Measuring carbon stocks across land-use systems: a manual*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Hairiah K, Rahayu S. 2007. *Pengukuran karbon tersimpan di berbagai macam penggunaan lahan*. Measuring carbon stocks across land-use systems. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Hairiah K, Sitompul SM, van Noordwijk M, Palm CA. 2001. *Methods for sampling carbon stocks above and below ground*. ASB Lecture Note 4B. Bogor, Indonesia: International Centre for Research in Agroforestry.

Lusiana B, van Noordwijk M, Rahayu S. 2005. *Carbon stocks in Nunukan, East Kalimantan: a spatial monitoring and modelling approach*. Report from the carbon monitoring team of the Forest Resources Management for Carbon Sequestration project. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

26 | Reducing emissions from peatlands (REPEAT)

Maswar, Meine van Noordwijk and Fahmuddin Agus

Reducing Emissions from Peatlands (REPEAT) is a methodological tool designed to fill the gaps in our knowledge about peatlands. REPEAT simplifies collecting data and the subsequent consideration of land-use options.

Introduction

Peatlands accumulate plant matter over hundreds of years because decomposition is slower than organic inputs owing to lack of oxygen, low nutrient content and types of organic matter that are biochemically resistant to decomposition. These lands can store greater amounts of carbon than the best-stocked rainforest.

Most agriculture on peatland requires drainage of the land and use of fertilizers, both of which increase microbial breakdown of the peat, resulting in large carbon dioxide (CO_2) emissions. When fire is used to clear peatland, emission of CO_2 can be greater than from old, dense rainforest and conversion to monoculture tree crops, such as oil palm, also creates large amounts of emissions. However, some modification of peat swamp-forests—to increase the numbers of trees that are valuable to humans—produces little, if any, emissions but data on such types of agroforestry are scarce. REPEAT is designed to make it easier to collect these data.

Objectives

Practical ways to sample an undisturbed peat profile, and assess its carbon stock and emissions owing to changing the land use of the natural peatland ecosystem to a mostly agricultural one.

Steps

1. Assess the carbon stock in peatland soils based on depth, density and carbon content

The most popular and simplest way to sample undisturbed peat profiles is to use a peat auger, that is, a plate fin and a rotating half-circular sampler with a cutting edge along one side. Having reached the desired sample depth, the user turns the entire sampler 180° clockwise. During turning, the fin remains in position as the sampler completes the circle thereby forming an enclosed core sample. Figure 26.1 shows the full procedure for collecting peat soil samples to determine bulk density calculated by dividing the mass of the oven-dried sample by the volume of the core sample, ash and carbon content measured by 1) loss-on-ignition (LOI method); and 2) hydrogen peroxide digestion (Walkley and Black method).

Figure 26.1. Soil-sampling procedure and analysis for both bulk density and ash content

Note: a, b and c = peat-soil sampling procedure; d and e = bulk density determination; f, g and h = ash content determined by LOI method

2. Quantify the annual rate of CO_2 loss by measuring subsidence and compaction

Land subsidence is a symptom of the collapse of peat layers above the water table, owing to oxidation. Usually, subsidence is associated with an increase in the bulk density of the remaining peat and a correction factor is needed before subsidence data can be used for CO_2 emission estimates. Peat subsidence can be measured with a metal rod or other marker inserted into the underlying mineral soil (Figure 26.2). The distance between the soil surface and measuring point is recorded at three-monthly or yearly intervals. Adjacent to the stick, samples for bulk density need to be made at the start and end of the measurement period.

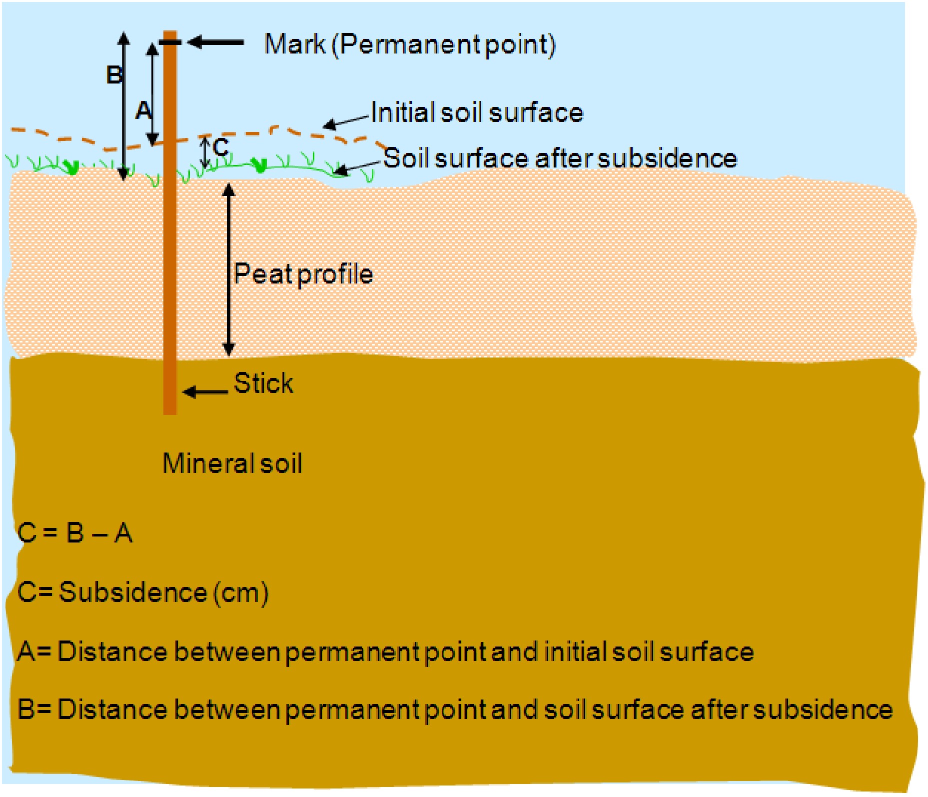


Figure 26.2. Conventional (field) method for measurement of peatland subsidence

3. Extrapolate to a broader spatial context through the use of ash content as internal tracer

In theory, carbon loss from peatland can be estimated from the progressive increase in mineral (ash) content after drainage, burning and/or a combination of both. This type of loss of the organic matter in the peat material sees the mineral fraction become more concentrated on the surface of peatland (Grønlund et al 2008, Turetsky and Wieder 2001, Maswar 2010). Carbon loss from the surface of peatland can be estimated based on the increase in ash concentration on the oxidation profile of peat soils.

4. Relate CO_2 loss to drainage, fertilisation and other aspects of agriculture or agroforestry

Carbon loss from the surface of peatland owing to fertiliser application can be quantified from the increase in ash concentration. By measuring subsidence and compaction in transects perpendicular to the drains and monitoring the groundwater table at measurement locations, emissions can be related to the deepest groundwater depth in a season or year. Carbon loss from peatland burning can be quantified based on the difference in ash concentration in the surface layers of burned and unburned peatland.

5.Identify 'best practice' and options for further improvement of low-emission peatland use

Maintaining peatland implies maintaining the conditions for low peat oxidation: wet and nutrient poor.

Example of application

Studies show that sites with a maximum depth of groundwater table of 20–40 cm have the lowest overall greenhouse gas emission rates, as shallower groundwater leads to methane emissions (Handayani 2009). In practice, the horizontal distance between drains is closely related to the depth of water table in the drain required to achieve sufficient drainage for all trees. A finely distributed network of shallow drains can allow good tree growth at low net emission rates.

Rubber trees on peatland can be grown without high fertiliser application rates, as the latex removed from the field has low nitrogen content, in contrast to oil palm, which has high fertiliser requirements. Rubber agroforests on peat in Aceh Barat were found to have low CO_2 emission rates. Other agroforestry systems, such as those with *Dyera* species ('jelutung'), have properties similar to *Hevea brasiliensis* (rubber) and returned similar results. Native fruit trees on peatland tend to be restricted to nutrient-enriched zones close to rivers.

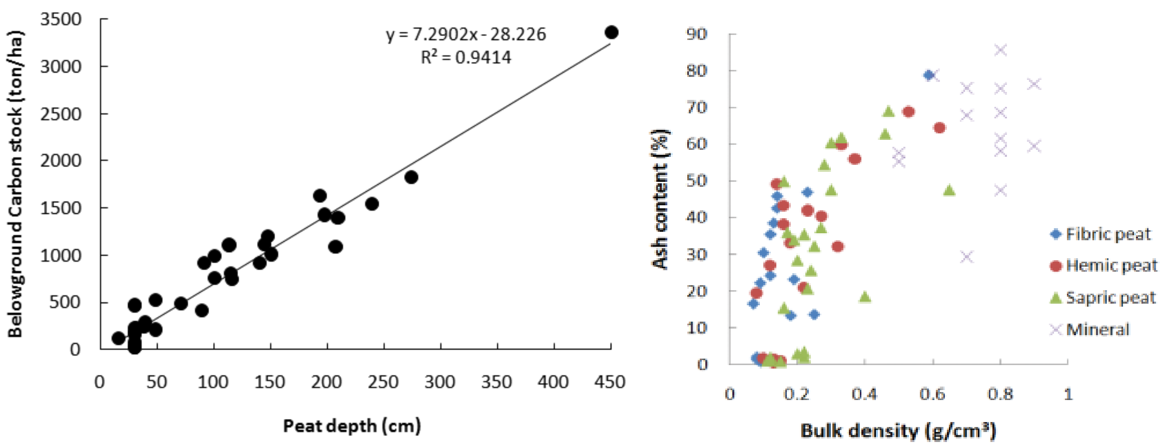


Figure 26.3. Example of the relationship between peat depth and total belowground carbon stock and the relationship between bulk density and ash content in samples from Lamandau, Central Kalimantan, Indonesia

Data source: Joshi et al 2010

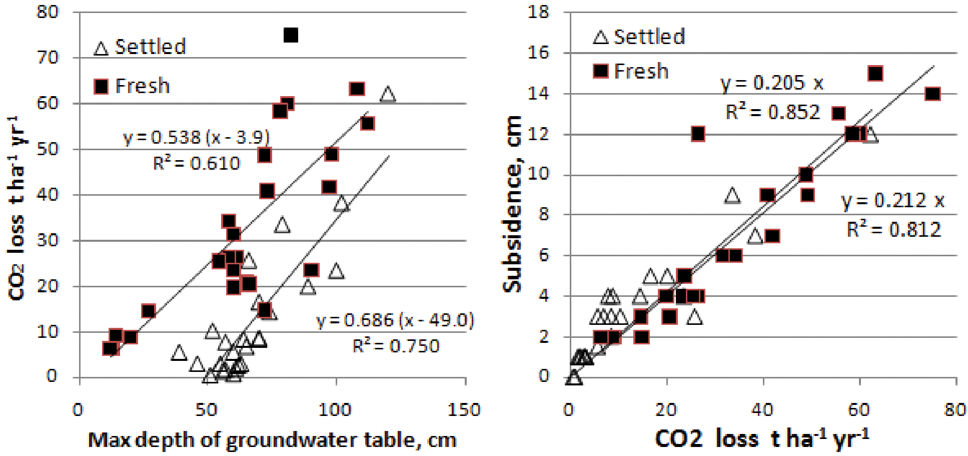


Figure 26.4. Example of the relationships between maximum depth of groundwater table and the calculated annual rate of CO2 loss owing to peatland decomposition

Note: For 'fresh' sites with recent (last two years) change in their drainage condition and 'settled' sites where drain depth was increased further in the past

Data source: Maswar 2010

Open questions

Because of the importance of reliable CO_2 emission estimates and the uncertainties in each of the methods, a triangulation approach that uses multiple methods is advisable. There are several important questions to consider.

- How variable are estimates of carbon loss or CO_2 emission when different tools and methods are used?
- How can point data be extrapolated to field and landscape scales by understanding the drainage and fertilisation patterns on top of the inherent variability of peat domes?
- What low-emission agroforestry practices can be further developed for supporting low-carbon-emission livelihoods options in peatlands?

Key references

Agus F, Hairiah K, Mulyani A. 2011. *Measuring carbon stock in peat soil: practical guidelines*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia; Indonesian Centre for Agricultural Land Resources Research and Development.

Maswar. 2011. *Kajian cadangan karbon pada lahan gambut tropika yang didrainase untuk tanaman tahunan*. Assessment of carbon stocks in tropical peatlands drained for annual crops. PhD Thesis. Bogor, Indonesia: Program Studi Ilmu Tanah, Sekolah Pascasarjana, Institut Pertanian Bogor.

[IPCC] Intergovernmental Panel on Climate Change. 2013. *2013 Supplement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Tokyo: IGES. http://www.ipcc-nggip.iges.or.jp/home/docs/1105_WetlandsToC.pdf.

27 | Re-assessing oxygen supply and air quality (ROSAQ)

Meine van Noordwijk and Betha Lusiana

A storyline that remains popular in public discourse and policy making is that trees provide oxygen. While scientists may argue that there is an excess rather than shortage of oxygen in the atmosphere, there are important issues of air quality that trees and forests interact with. The Re-assessing Oxygen Supply and Air Quality (ROSAQ) tool provides some pointers to how these can be tackled as part of a landscape approach.

Introduction

Tropical forests are often portrayed as the lungs of the world. Lungs of humans (common with all animals) interface with the atmosphere by reducing its oxygen and increasing its carbon-dioxide content (so forests might be the 'anti-lungs' rather than the lungs of the world). Among the positive roles of trees (and other vegetation) we often see 'provisioning of oxygen'. While technically correct (at least during the daytime in the growing season), this provisioning does not qualify as an 'ecosystem service' because these are based on 'benefits people derive from'. With over 20% of the global atmosphere consisting of oxygen—which plays a major role in fire events—there is no shortage of the gas. Even within closed buildings the purported 'lack of oxygen' is rather an excess of other gasses that have accumulated. Opening windows is the easiest way to solve that issue and provide the desired environmental service.

Yet, trees that are strategically placed do play important functions with respect to air quality. The ROSAQ tool was designed to shift the frequently asked questions about air quality into an exploration of the three interacting knowledge domains: local, policy-makers' and modellers' ecological knowledge, as used in other tools.

Objectives

Contribute to the identification of realistic roles of strategically placed trees and forests in improving air quality, while responding to commonly repeated concerns about oxygen supply.

Table 27.1. Air pollutants can affect air quality in many ways

<table>
<tr><th>Pollutant (http://en.wikipedia.org/wiki/Air_pollution)</th><th>Mechanism by which trees and forests may interact with the pollutant</th></tr>
<tr><td>Particulates, alternatively referred to as particulate matter, atmospheric particulate matter or fine particles, are tiny particles of solids or liquid suspended in a gas. In contrast, 'aerosol' refers to particles and the gas together. Sources of particulates can be human-made or natural. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged over the globe, anthropogenic aerosols—those made by human activities—currently account for about 10% of the total amount of aerosols in our atmosphere.</td><td>Deposition depends on wind speed, so effects of trees and tree rows on turbulence can influence local deposition.</td></tr>
<tr><td>Sulfur oxides (SOx), especially sulfur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulfur compounds, their combustion generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.</td><td rowspan="2">Wet leaf surfaces, for example, of trees, can lead to enhanced deposition of ammonium sulfate. Although trees thus clean the air, they may suffer from the 'acid rain' effect of this deposition.</td></tr>
<tr><td>Ammonia (NH_3) is emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odour. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilisers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.</td></tr>
<tr><td>Nitrogen oxides (NOx), especially nitrogen dioxide, are expelled from high temperature combustion and are also produced naturally during thunderstorms by electrical discharge. Can be seen as the brown haze dome above or plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of the several nitrogen oxides. This reddish-brown toxic gas has a characteristic sharp, biting odour. NO_2 is one of the most prominent air pollutants.</td><td>Leaves with wet surfaces and open stomata can absorb some nitrogen oxides on their way to the atmosphere.</td></tr>
<tr><td>Carbon monoxide (CO) is a colourless, odourless, non-irritating but very poisonous gas. It is a product of incomplete combustion of fuel, such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.</td><td></td></tr>
<tr><td>Volatile organic compounds (VOCs) are an important outdoor air pollutant. In this field they are often divided into the separate categories of methane (CH_4) and non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming.</td><td>Some tree-produced VOCs are implied in rainfall triggering as they form condensation nuclei for raindrops, potentially enhancing the air-clearing effect of rainfall.</td></tr>
<tr><td>Odors, such as from garbage, sewage and industrial processes</td><td></td></tr>
</table>

Steps

1. Exploration of local ecological knowledge (LEK)

The LEK component is straightforward as there is likely some recognition of what constitutes 'fresh' air but no specific knowledge of individual gasses, such as oxygen. Components that may be explored deeper are 'dust', 'smoke', 'haze', 'bad smell'.

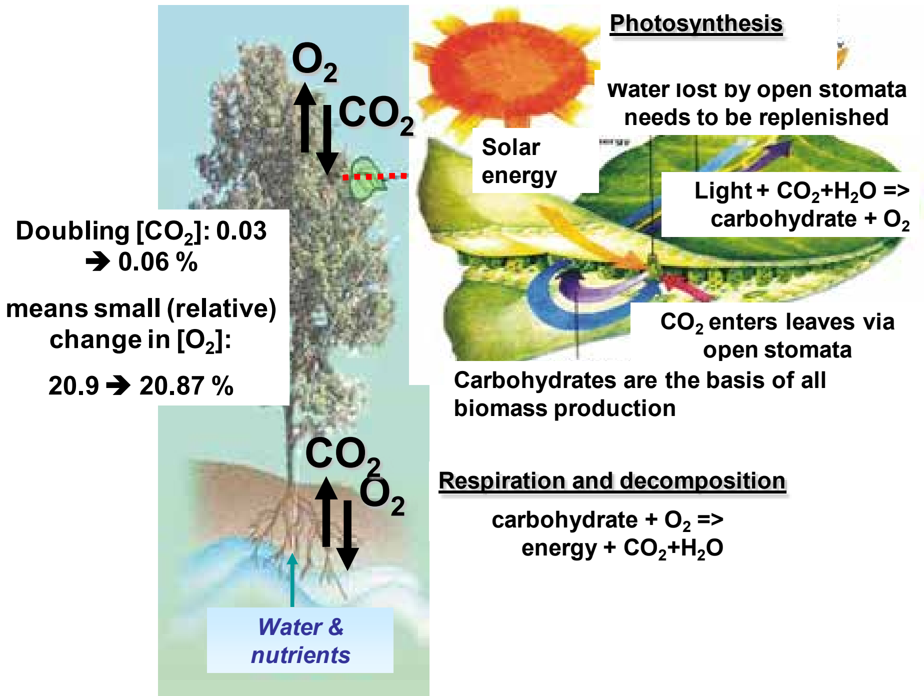


Figure 27.1. Leaf-level relationship between oxygen and carbon dioxide, with the consequences for both if the atmosheric CO_2 concentration doubles

2. Exploration of modellers' ecological knowledge (MEK)

Table 27.1 indicates possible mechanisms by which trees and forests can filter or increase deposition of air pollutants. Such effects have been documented for trees in urban environments but often require specialized equipment.

For oxygen, the MEK component is also straightforward. For example, the carbon dioxide (CO_2) emission estimates for Indonesia can be mole-per-mole converted to oxygen (O_2) consumption estimates (applying a factor or 32/44 for conversion), at least if we ignore the temporary storage in flows of organic products, which causes a time-lag between production and consumption of oxygen. The basic equation for photosynthesis (=>) and respiration/decomposition/fire (<=) is:

$$6CO_2 + 6H_2O + energy <=> C_6H_{12}O_6 + 6O_2$$

Because Indonesia is a net emitter of CO_2, its consumption of O_2 is greater than the O_2 that it produces. Spatial analysis can readily convert land-cover-change maps to O_2 consumption maps.

3. Exploration of policy-makers' ecological knowledge (PEK)

The PEK component is the most intriguing, as concerns over oxygen persist in the absence of evidence, or while the concepts are clearly challenged by science.

Air pollutant control, focused on point sources of industrial pollution, the domestic burning of organic fuel sources as well as biomass burning in relation to land use (and land-use change), has become a specialized part of environmental management. There is little explicit attention to filtering effects of trees and forests in most cases.

Case study: Forestry Ministry asks Japan to check air quality

In 2008, Indonesia challenged Japanese scientists to check the balance between the amount of fresh oxygen produced by its protected forests and amounts of forest fire haze affecting neighbouring countries. This information could be an important way to counter repeated international protests over Indonesia's haze problems.

Indonesia has the largest forested area in the region, with some 120 million hectares of tropical forests. Annual forest fires causing massive amounts of air pollution prompted protests from the Singaporean and Malaysian governments. The president of Indonesia formally apologized to the country's neighbours for haze incidents in 2006, the second most severe after the 1997 haze disaster that blanketed Singapore and Malaysia.

Responding to the Ministry's request, a Japanese researcher said that it was difficult but technologically possible to calculate the amounts of smoke emanating from Indonesian forest fires. Rather than requiring new measurement techniques, the totals can be estimated from the reported carbon balance:

$$\text{Net effect on atmospheric oxygen supply} = -32/44 \times \text{Net emissions of } CO_2 \text{ to the atmosphere}$$

Unfortunately for the Ministry, the researcher concluded that Indonesia is, and will be, a net consumer (not producer) of oxygen until it becomes 'carbon neutral'.

28 Biofuel emission reduction estimator scheme (BERES): land-use history, production systems and technical emission factors

Meine van Noordwijk, Ni'matul Khasanah and Sonya Dewi

The Biofuel Emission Reduction Estimator Scheme (BERES) is an integrated assessment method for estimating carbon dioxide and other greenhouse gas emissions related to biofuel production. It includes three different phases of crop production processes within lifecycle analysis and is in line with EU-mandated calculations. The phases are 1) land conversion; 2) crop production; and 3) post-harvest commodity transport and processing.

Introduction

Biofuels appeared to be such a nice way of facing the climate change challenge: they reduced political dependence on fossil fuel supply, could be used with minimal changes to engines and modes of transport, and provided new sources of income for rural economies. However, calculations of the area needed to make a dent in fossil-fuel use quickly showed that biofuels could not make a substantial contribution to 'clean' energy without using large areas of land and interfering with markets for food crops. If biofuel production extends beyond agricultural areas it will often increase emissions of carbon dioxide. The net effect will be a lower estimate of emission reduction than expected but if high carbon stock land is cleared then biofuel use can also increase net emissions. The debate on such emission enhancement has focussed on oil palm in the humid tropics of Southeast Asia, where forest and peatland conversion lead to large emissions, with or without a specific role for oil-palm expansion.

The public debate, however, has linked the two issues. The European Union provided guidance to countries on minimum standards that should be used when biofuels are included in national renewable energy plans. Until 2017, a minimum emission reduction of 35% has to be achieved for any fuel included in the scheme, shifting to 50% by 2017 and 60% beyond. Default estimates are given for major current or potential sources of biofuels. A procedure was established to calculate emission reduction factors, using a lifecycle approach for the supposedly typical production situation. Specific market flows of biofuels can apply for exception from this 'default' for the commodity but the procedures for that are not yet clear. These procedures, and their likely further development, create the need for exporting countries and entities to understand the steps in calculation and to do the research needed to get reliable data. Figure 28.1 shows examples of trees as biofuel sources in the tropics

Figure 28.1. Oil palm, coconut, jatropha and sugarcane: examples of biofuel feedstock sources

Objective

BERES was designed to provide a transparent approach to lifecycle analysis of the emissions associated with production of biofuel feedstocks, as a basis for calculating carbon footprints.

Steps

1. Identify and analyse time-series spatial data of land-cover changes combined with interviews with local witnesses

This includes negotiating the 'attribution' of the changes to various people (for example, legal, government-sanctioned and illegal logging; natural and human-induced fire). See ALUCT for details on the methods for reconstructing land-cover change.

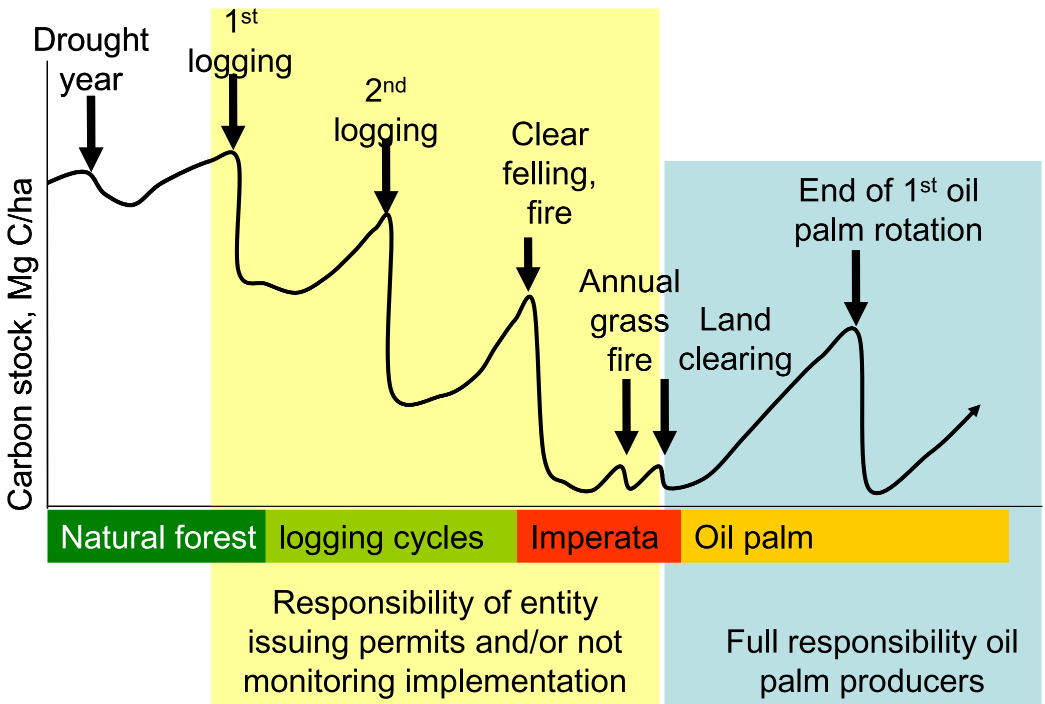


Figure 28.2. Trajectories of land uses and the dynamics of carbon stock

Note: Attribution is often contested more than what actually happened to aboveground vegetation

2. Estimate emissions due to crop production

a. Estimate time-averaged carbon (C) stock of existing land cover, including plantations and surroundings in different production environments (for example, peat and mineral soil types) and management regimes (for example, nucleus/company, plasma and independent).

The 'time-averaged C stock' is the sum of the average of five carbon pools (aboveground biomass, understorey vegetation, surface necromass, soil organic matter and roots) over a production cycle. When the preceding vegetation has a higher time-averaged C stock, the plantation starts with a 'carbon debt' with a 'payment time' or annualized draw on the biofuel carbon accounting. If it is lower, the calculation can reflect a net emission saving for the first production cycle. Methods for measurement of the pools are described in the RaCSA methodology and technical manuals.

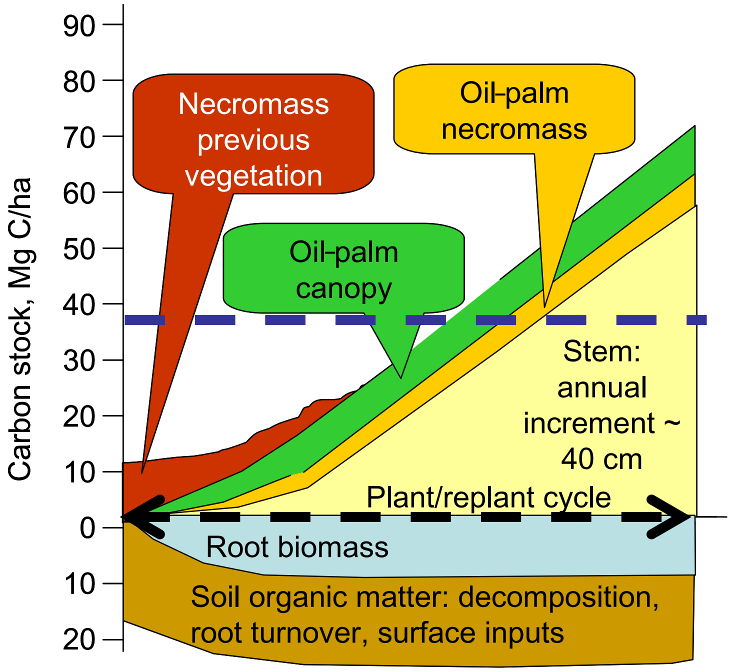


Figure 28.3. Components of C stock in oil-palm plantations, time-averaged over a planting cycle (schematic)

b. Estimate emissions due to use of fertilisers

This includes calculation of greenhouse gas emissions linked to fertiliser use. The Intergovernmental Panel on Climate Change's National Greenhouse Gas Inventory Guidelines suggest that 1% of N fertilizer is lost as N_2O from agricultural systems. Other literature suggests this can be 4%. In the absence of site-specific measurements, both assumptions can be compared for impact on the end result.

3. Estimate emissions due to post-harvest commodity transport and processing

Emission factors for transport and milling are based on fossil-fuel use and technical design of the mill and processing steps before the product reaches the end-user.

4. Conduct sensitivity analysis

The net result is very sensitive to the preceding vegetation. For the oil-palm example, a minimum emission reduction efficiency of 35% can only be reached in a second production cycle or when oil palm replaced vegetation of less than 40 t C/ha. Investment in CH_4 capture at the mill can improve the situation. Where peat soils are used, the effects of drainage on emissions usually means the target efficiency cannot be met. A third factor with considerable influence is the use of N fertiliser in relation to yield. Increase in N use efficiency can lower costs as well as help reach the fossil-fuel substitution efficiency.

Example of application

We applied BERES to 23 plantations in Indonesia that abided by what was considered 'good practice' and estimated whether the net emissions reduction of this 'good practice' was able to meet minimum European Union standards. The estimation of the net emissions included oil-palm lifecycle assessment (Figure 28.4).

Ten of the 23 plantations converted more than 60% of their area from forests to oil palm. In 91% of the plantations assessed, oil palm had replaced vegetation of more than 40 t C/ha thus incurring a carbon debt. The average net emissions rate of all sampled plantations owing to land-use conversion ranged 0–36 tonne of carbon dioxide equivalent per hectare per year (CO_2eq/ ha/yr).

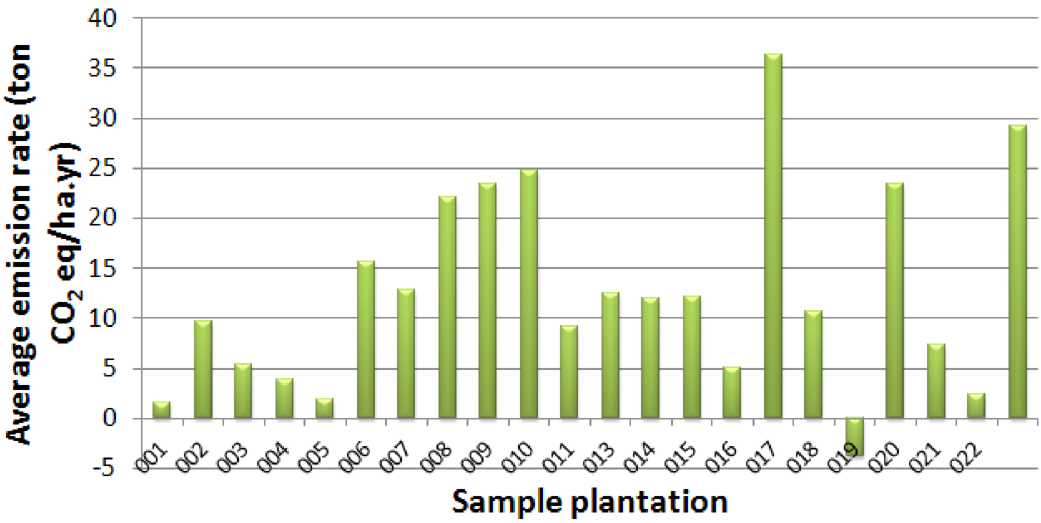
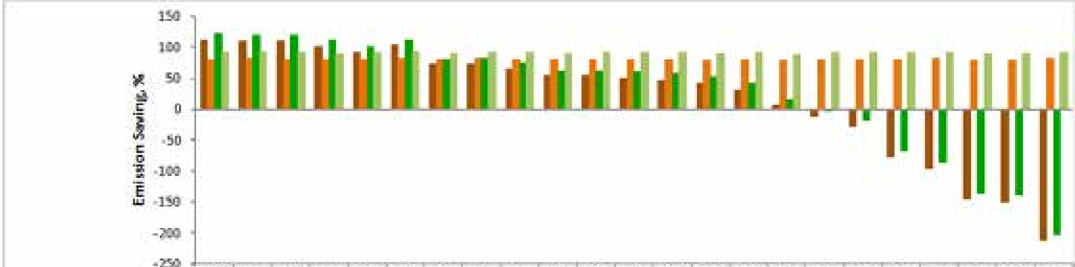


Figure 28.4. Average carbon dioxide emissions caused by land-use conversion

The average fresh fruit bunch production in Indonesia is approximately 18.8 t/ha/yr, which translates into an application rate for nitrogen fertiliser of 141 kg N/ha/yr (Figure 28.5 and Figure 28.6). The higher the yield, the more rapidly carbon debt can be neutralized and net emissions savings earned. However, higher yields depend on more than proportionally higher nitrogen fertiliser use. The additional nitrous oxide (N_2O) emissions need to be accounted for. Net effects depend on the assumed fraction of nitrogen fertilisers lost as N_2O.

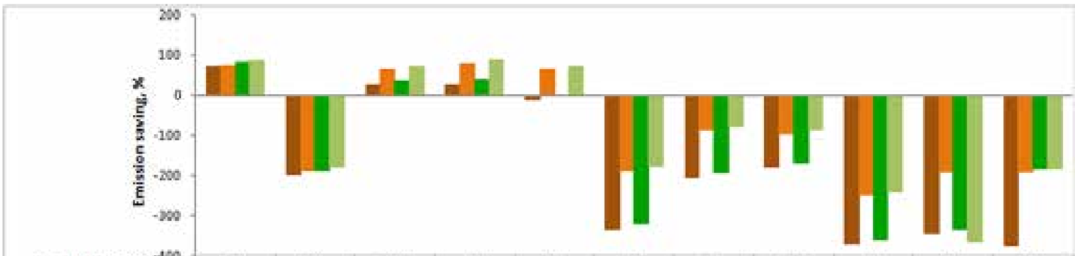
A substantial part of the current production of palm oil can meet the directive for minimum emissions savings. In 39% (first-cycle assessment) and 78% (second-cycle or subsequent assessment) of the plantations, palm oil used for biodiesel can lead to emissions savings (calculated per standard European Union procedure) of at least 35%. Intensification and good management practices will increase emissions savings and decrease the product's carbon footprint.



N fertilizer, Kg N/ha	110	77	110	137	152	77	127	110	154	114	128	114	199	257	140	252	164	164	136	67	104	178	178
Initial C-stock, ton C/ha	10	16	17	21	27	27	50	53	59	62	71	71	77	94	96	132	155	167	196	216	229	274	276
Plantation ID	019b	022b	019a	021b	011b	022a	021a	005	011a	016b	015b	016a	004	018	014	007	020a	020b	009	010	017	023b	023a
1st cycle - w/o CH4 trap	111.9	110.0	109.8	101.4	91.27	102.4	72.09	72.52	65.23	53.02	52.91	50.16	47.71	42.33	32.24	6.61	-12.8	-27.5	-76.7	-95.7	-145.	-149.	-211.
2nd cycle - w/o CH4 trap	81.80	82.47	81.80	80.24	80.77	82.47	80.41	82.14	80.84	80.46	81.25	81.65	81.25	79.56	81.43	79.03	81.19	81.19	81.11	82.38	80.06	80.06	81.94
1st cycle - w/ CH4 trap	121.5	119.6	119.5	111.1	100.9	112.0	81.73	82.15	74.87	62.65	62.55	59.79	57.34	51.96	41.87	16.25	-3.19	-17.9	-67.1	-86.1	-136.	-139.	-202
2nd cycle - w/ CH4 trap	91.43	92.11	91.43	89.88	90.40	92.11	90.05	91.78	90.48	90.10	90.89	91.29	90.89	89.19	91.07	88.66	90.82	90.82	90.74	92.02	89.70	89.70	91.58

Figure 28.5. Attributable emissions savings in relation to former carbon stock and nitrogen fertiliser application

Note: For plantations established on mineral soil and nitrogen loss as N_2O is 1%. (Plantation ID with a = large company as a 'nucleus'; b = 'plasma' (satellite smallholding plantations))



N fertilizer, Kg N/ha	145	136	128	128	128	91	91	122	124	136	136
Initial C-stock, ton C/ha	46	49	67	95	101	119	123	123	137	164	195
Area of peat	0.02	0.78	0.01	0.01	0.04	0.66	0.38	0.58	0.99	0.79	0.73
Plantation ID	001	003	013b	015a	013a	006b	006a	002	008	012a	012b
1st cycle - w/o CH4 trap	71.96	-199.18	26.27	28.77	-10.98	-332.83	-204.42	-178.47	-369.79	-343.07	-375.16
2nd cycle - w/o CH4 trap	74.57	-188.05	63.60	79.26	63.60	-187.97	-86.73	-95.79	-250.24	-191.50	-191.50
1st cycle - w/ CH4 trap	81.60	-189.54	35.91	38.51	-1.35	-320.49	-194.78	-168.83	-360.16	-333.43	-181.87
2nd cycle - w/ CH4 trap	84.20	-178.42	73.23	89.00	73.23	-175.64	-77.10	-86.15	-240.60	-365.52	-181.87

Figure 28.6. Attributable emissions savings in relation to former carbon stock and nitrogen fertilser application

Note: For plantations established on mixed peat and mineral soils and nitrogen loss as N_2O is 1%. (Plantation ID with a = large company as a 'nucleus'; b = 'plasma' (satellite smallholding plantations))

■ Key reference

Khasanah N, van Noordwijk M, Ekadinata A, Dewi S, Rahayu S, Ningsih H, Setiawan A, Dwiyanti E, Octaviani R. 2012. *The carbon footprint of Indonesian palm oil production.* Technical Brief 25: palm oil series. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://worldagroforestry.org/regions/southeast_asia/publications?do=view_pub_detail&pub_no=PB0047-12

29 | Generic river flow (GenRiver) at landscape level

Ni'matul Khasanah, Lisa Tanika, Betha Lusiana and Meine van Noordwijk

Generic River Flow (GenRiver) is a semi-distributed, process-based model that extends a plot-level water balance to sub-catchment level. It was developed for data-scarce situations and is based on empirical equations. The model can be used to explore the basic changes of river flow characteristics across spatial scales: from patch, sub -catchment to catchment. GenRiver is a simple river flow model that can be used to explore our understanding of historical changes in river flow owing to land-use changes.

Introduction: why model river flow?

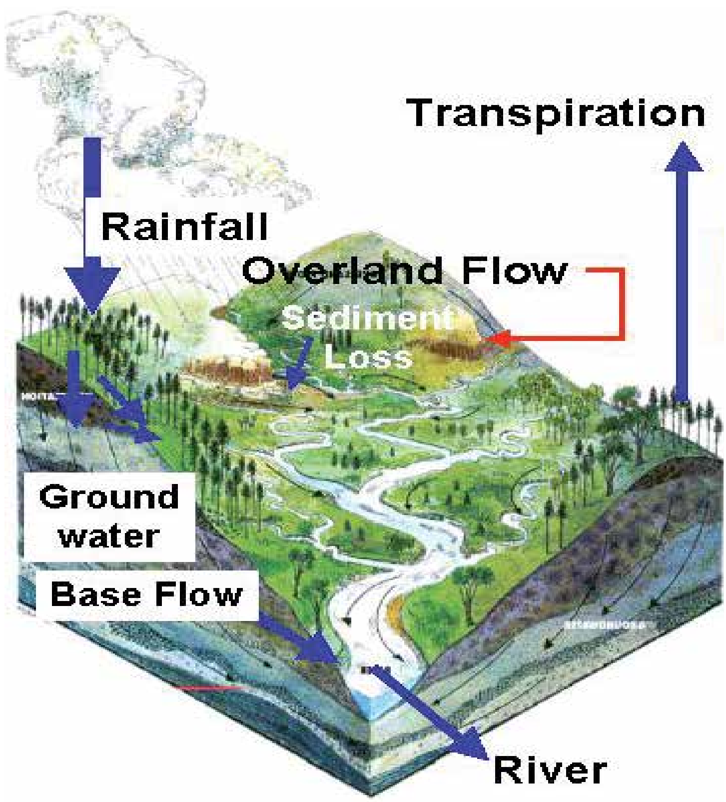


Figure 29.1. Schematic diagram of water flow in a catchment

Changes in land cover can significantly affect watershed functions. For example, they can change the amount of rainfall that reaches the ground and, consequently, the pathways of water flow over and through the soil, as well as affecting the rate of water use by plants. Most of the impacts on river flow can be explained by characteristics of the vegetation and soil. Empirical assessments of the dynamics of water flow as a function of changes to land-cover and soil properties require time and resources and need to take the temporal and spatial variation of rainfall into account. A model based on 'first principles', which integrates changes of land-cover and soil properties as driving factors of changes in river flow, can be used to explore scenarios of land-use change, provided it passes a 'validation' test against observed data.

GenRiver

GenRiver is a generic model for analysing river flow. As is common in hydrology, it starts with the accounting of rainfall or precipitation (P) and traces the subsequent flows and storage in the landscape that can lead to either evapotranspiration (E), river flow (Q) or change in storage (ΔS):

$$P = Q + E + \Delta S \quad \text{......................................} (1)$$

Hydrological models differ in the relations between the different terms of the balance equation and in the way they account for the 'slow flows'. Slow flows derive from water that infiltrates the soil but that takes a range of pathways (with various residence times) to reach the streams and rivers, depending on landform, geology, and extractions along the way.

The core of the GenRiver model consists of a 'patch'-level representation of daily water balance driven by local rainfall and modified by the land cover, land-cover changes, and soil properties of the patch. The patch can contribute to three types of stream flow: 1) surface quick flow on the day of the rainfall event; 2) soil quick flow on the next day; and 3) base flow via the gradual release of groundwater.

A river is treated as a summation of streams, each originating in a sub-catchment with its own daily rainfall, yearly land-cover fractions, and constant total area and distance to the river outflow (or measurement) point. Interactions between streams as they contribute to the river are considered to be negligible (that is, there is no 'backflow' problem). Spatial patterns in daily rainfall events are translated into average daily rainfall in each sub-catchment. The sub-catchment model represents interception, infiltration into the soil and rapid percolation into the subsoil as well as surface water flow and rapid lateral subsurface flow into streams, with parameters that can vary between classes of land cover.

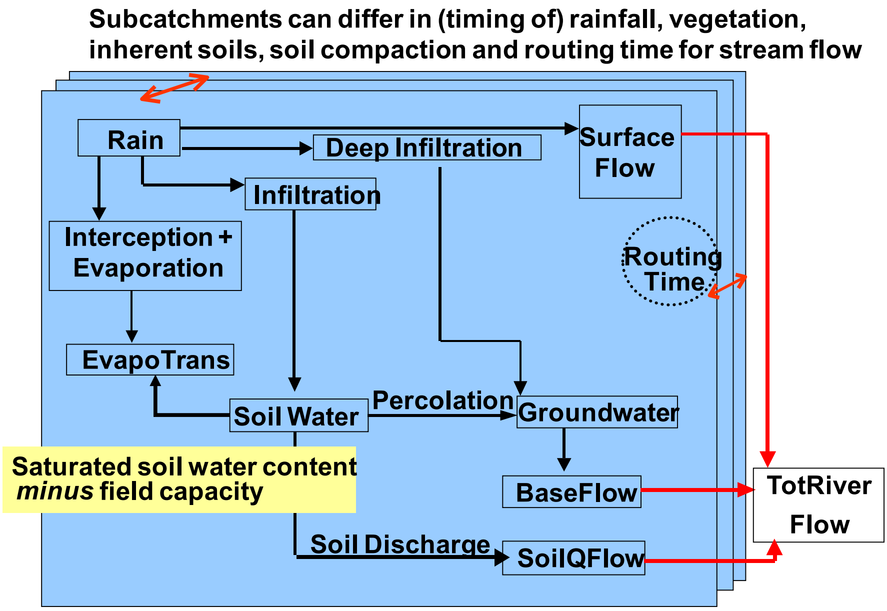


Figure 29.2. Schematic of the model aligned with the basisc plot-level water balance equation

The model has been built on the STELLA platform, with an accompanying Excel file to store input parameters; a NetLogo version of GenRiver is also available.

Objectives

To help to simulate the effects of land-cover and climate changes on the hydrological functions of a watershed.

Steps

Modeling is carried out using the following steps.

1. Data preparation and model parameterization.
2. Model calibration including evaluation on model performance.
3. Assessment of hydrological situation of the watershed.
4. Scenario development.
5. Model simulation based on scenarios developed in Step 4 to understand the impact of land-use changes on water balance and river flow.

Example of application

GenRiver was used to analyze the response of Bialo watershed (11 417 km^2) to land-cover changes. The watershed is situated in Bantaeng and Bulukumba districts, South Sulawesi, Indonesia. Model simulations used rainfall data from 1989 to 2009. Annual rainfall ranged 1142–2668 mm per year.

In general, more than 58% of Bialo watershed area was dominated by agroforests (such as mixed-tree, clove, cocoa and coffee systems). Forests (primary and secondary) and rice covered 22.5% and 11% of the area, respectively. The remaining cover was shrub, grass, cleared land and settlements. The percentage area of each land-cover type in Bialo in 1989, 1999, 2005 and 2009 are presented in Figure 29.3.

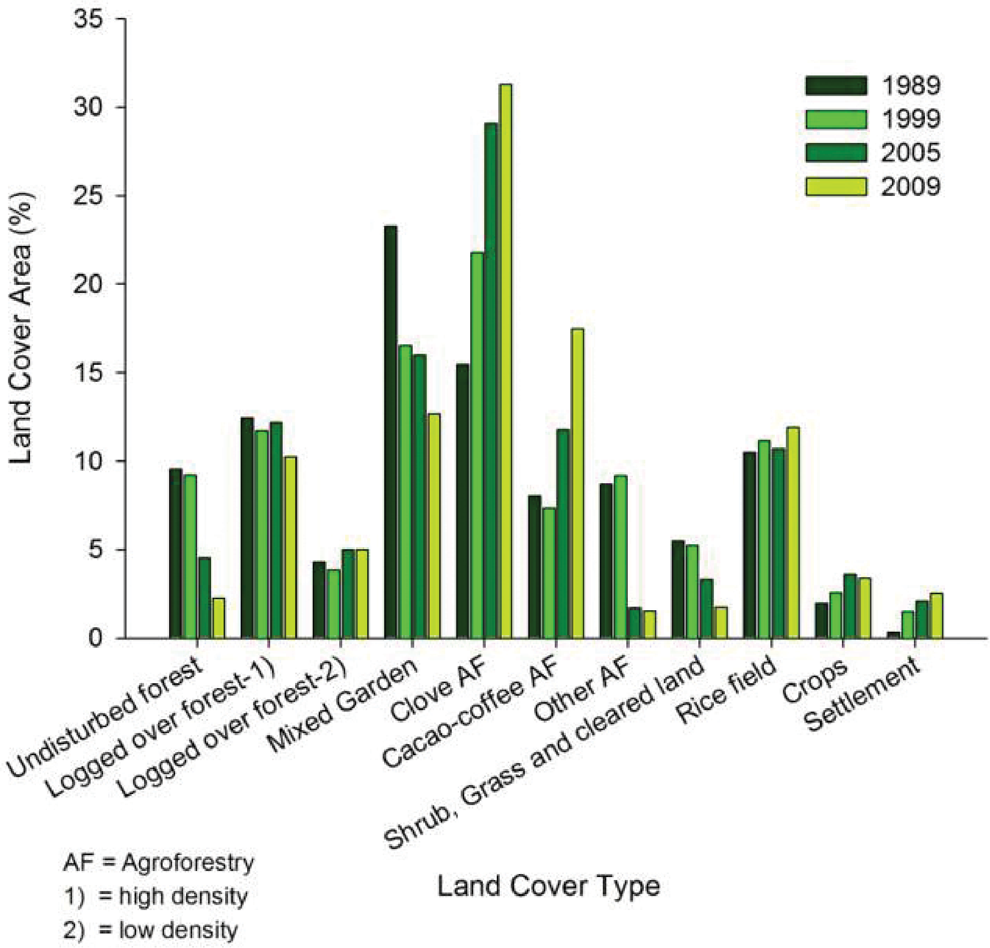


Figure 29.2. Land-cover percentages in Bialo watershed

Calibration and validation was carried out using river flow data from 1994–1995 and 1998–1999. The results showed that the hydrograph from GenRiver captured the patterns of observation data in the Bialo watershed with NSE values 0.55 and 0.63. According to Moriasi (2007), these NSE values are satisfactory criteria and can be used to simulate river flow of the watershed.

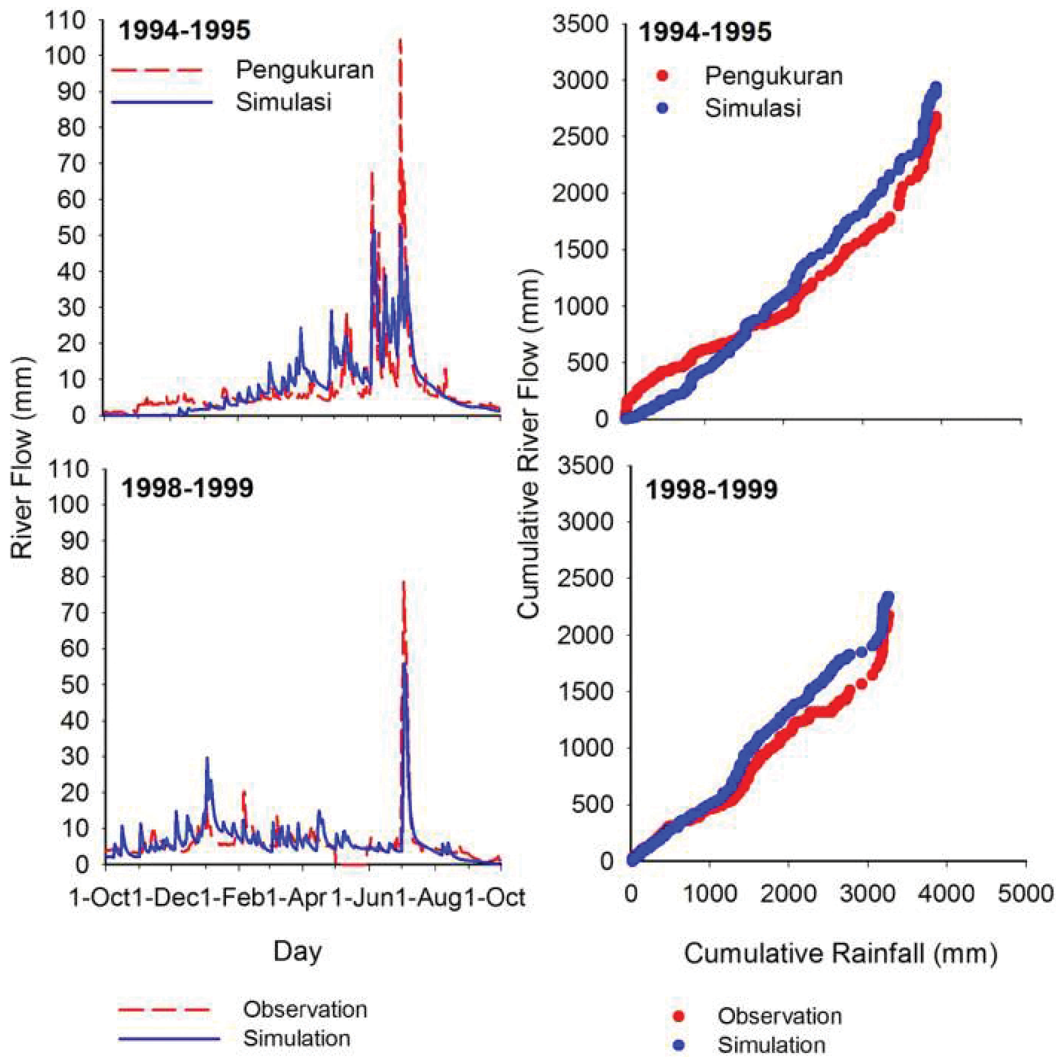


Figure 29.3. River flow simulations by GenRiver with actual observation

The results of the simulation of the impacts of land-cover changes on the water balance in Bialo watershed, using GenRiver, can be divided into three transition periods: 1) 1989–1999; 2) 2000–2005; 3) 2006–2009.

The first period (1989–1999) enjoyed annual rainfall ranging 1142–2668 mm and land-cover changes, such as the deforestation of 39 hectares, a decrease in mixed-tree gardens from 23.3% to 16.5%, a decrease in coffee and cocoa agroforestry from 8% to 7.3% and an increase of 6.3% and 0.5% of clove and other agroforestry, respectively. This led to an increase in evapotranspiration of 12.16% per year and a decrease in river discharge of 12.13% annually. The decrease was caused by the decline in surface flow (12.14% per year) and base flow (0.1% per year).

The second (2000–2005) and third (2006–2009) periods had annual rainfall ranging 1392–2194 mm and 1184–2365 mm, respectively. The main land-cover transition that occurred in these periods was in forests and clove agroforests. Forests decreased from 9.25 to 4.5% and then from 4.5% to 2.3%. Clove agroforests increased from 21.8 to 29.1% and then from 21.9 to 31.3%. This led to increased evapotranspiration of 0.53% per year and a decrease in river discharge of 0.43% annually. This change of river discharge featured increasing baseflow and decreasing surface flow.

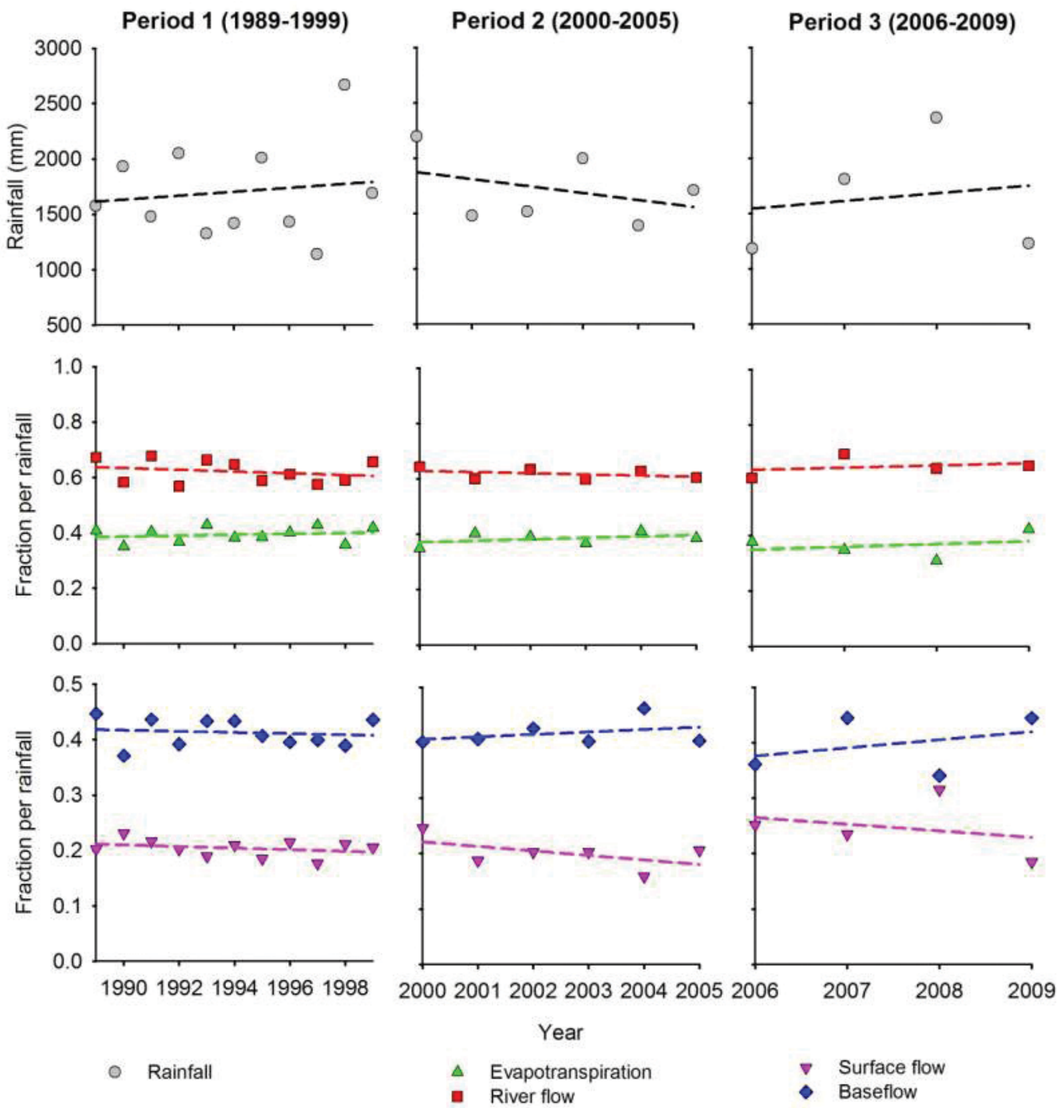


Figure 29.4. Simulation result of water balance in Bialo watershed using GenRiver model for each transition period

The assessment of the hydrological situation of a watershed is determined by the criteria and indicators of water transmission (total water yield per unit rainfall), buffering capacity (relationship of peak river flow and peak rainfall, linked to flooding risk) and gradual release of groundwater in the dry season, based on recharge in the rainy season (Table 29.1). These indicators all relate the flows of water to preceding rainfall and by doing so allow the analysis of relatively small land-use effects, superimposed on substantial year-to-year variation in rainfall.

To capture the impact of land-use changes, the indicators were scattered over the 21-year simulation period (Figure 29.1). The main effect of the changes seems to have been an increase in evapotranspiration and a decrease in total water yield as a fraction of total rainfall. The buffering capacity (buffering indicator, buffering relative, and buffering peak events) tended to be stable until 2009. The buffering indicator and relative buffering indicator had a negative correlation to the discharge fraction (fraction of river flow per rainfall) over the year (Figure 29.1).

Table 29.1. Average of indicators of watershed function

	Observed			Simulated		
	Min.	Average	Max.	Min.	Average	Max.
Total discharge fraction	0.32	0.57	0.77	0.57	0.63	0.69
Buffering indicator	0.58	0.74	0.90	0.58	0.68	0.76
Relative buffering indicator	0.17	0.54	0.75	0.35	0.50	0.61
Buffering peak event	-0.68	0.51	0.91	0.72	0.84	0.91
Highest monthly discharge relative to mean rainfall	1.36	2.30	3.61	1.62	2.38	3.18
Overland flow fraction				0.16	0.21	0.32
Soil quick flow fraction				0.00	0.00	0.00
Slow flow fraction				0.33	0.41	0.47
Lowest month fraction				0.01	0.18	0.44

.

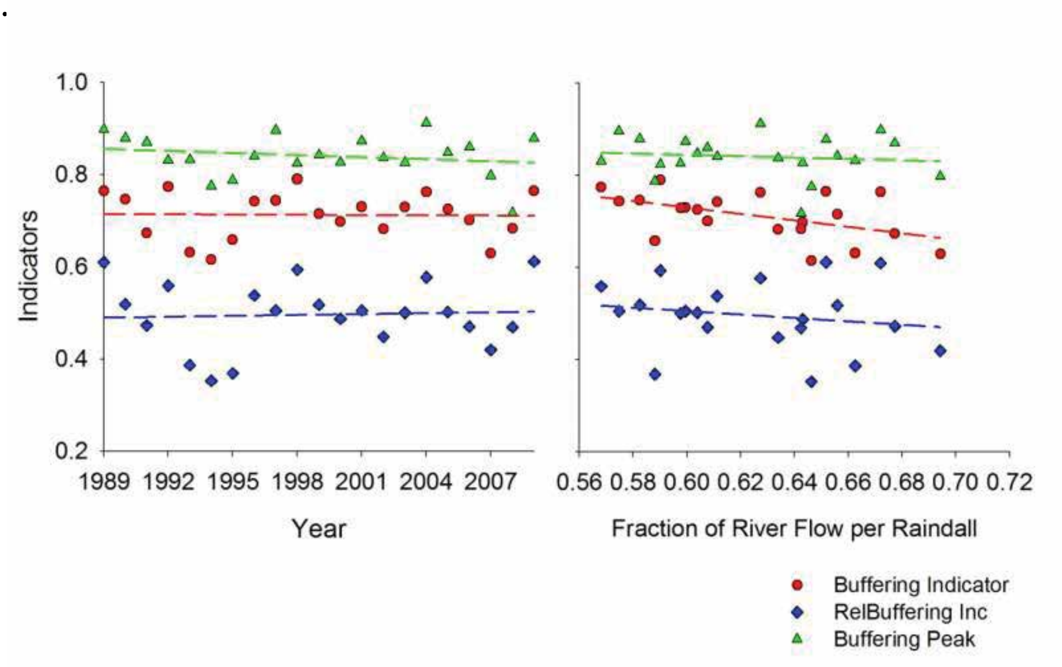


Figure 29.5. Trend of buffering capacity indicator over 21 years (1989–2009) and to discharge fraction

Key references

Van Noordwijk M, Widodo RH, Farida A, Suyamto DA, Lusiana B, Tanika L, Khasanah N. 2011. *Generic River and Flow Persistence models. User Manual Version 2.0*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestry.org/sea/publication?do=view_pub_detail&pub_no=MN0048-11.

Moriasi DN, Arnold JG, Van Liew MW, Bingner RL, Harmel RD, Veith TL. 2001. *Model evaluation guidelines for systematic quantification of accuracy in watershed simulations*. American Society of Agricultural and Biological Engineers 20(3):885–900.

30 | Flow persistence (FlowPer)

Lisa Tanika and Meine van Noordwijk

The Flow Persistence (FlowPer) model produces an indicator that summarizes the relationship between rainfall and river flow and current (today) with previous (yesterday) river flow. The flow persistence value can indicate how well the watershed is buffering rainfall and thus avoiding flash floods. Flow persistence values of above 0.8 may reflect good watershed conditions, while values below 0.4 indicate a poorly buffered watershed. The values can be used as a basis for conditional environmental services' rewards.

Introduction

Analysis of watershed functions deals with complex factors that influence processes and patterns in the landscape that ultimately translate a temporal pattern of rainfall into a temporal pattern of stream flow, which aggregates to become a river. The Flow Persistence (FlowPer) model uses information from a time series of river-flow data to deduce what may happen upstream in the absence of knowledge on 'anthropogenic' intervention that could have occurred as well as the geological and climatic background.

The FlowPer model provides a parsimonious null-model that is based on temporal autocorrelation or an empirical 'flow persistence' in the river-flow data. The basic form is a recursive relationship between river flow (Q) on subsequent days:

$$Q_{t+1} = f_p Q_t + Q_{add}$$

where Q_t and Q_{t+1} represent the river flow on subsequent days, f_p is the flow persistence value ([0< f_p <1]) and Q_{add} is a random variate that reflects inputs from recent rainfall.

Q_{add} and f_p are related, as $\Sigma\, Q_{add\,i} = (1 - f_p)\, \Sigma Q$. Thus, if $f_p = 1$, $Q_{add} = 0$ and river flow is constant, regardless of rainfall (the ideally buffered system. If $f_p = 0$ there is no relation between river flow on subsequent days and the river is extremely 'flashy', alternating between high and low flows without temporal predictability within the frequency distribution of Q_{add}.

The term $Q_{add,i}$ can be described as a statistical distribution with a probability of a non-zero value, a mean and a measure of variance, plus two parameters that describe a seasonal pattern (peak and shape of the distribution, for example, Weibull[1]).

If we partition the total flow Q_{tot} into water flow by three pathways (surface runoff, interflow and groundwater flow), we can obtain $Q_{tot} = Q_{runoff} + Q_{interflow} + Q_{gwflow}$. Each type of flow pathway will typically have a different flow persistence, $f_{p'runoff}$, $f_{p'interflow}$ and $f_{p'gwflow,}$ respectively.

[1] Weibull distribution is a continuous probability distribution (in probability theory and statistics)

$$Q_{tot,t+1} = (f_{p',runoff}(Q_{runoff,t}/Q_{tot,t}) + f_{p',interflow}(Q_{interflow,t}/Q_{tot,t}) + f_{p',gwflow}(Q_{gwflow,t}/Q_{tot,t}))Q_{tot,t} + Q_{add,t}$$

As we can expect values for $f_{p'runoff}$, $f_{p'interflow}$ and $f_{p'gwflow}$ of about 0, 0.5 and close to 1, respectively, we can interpret the relative contributions of the three flow pathways from the overall f_p value.

Objectives

1. FlowPer provides indicators of how well a watershed is provisioning the stability of river flow.
2. FlowPer serves as a parsimonious (parameter-sparse) null model that allows quantification of the increments in model prediction that is achieved with spatially explicit models.

Steps

1. Gather daily river-flow data and rainfall data in addition to calculating flow persistence value (f_p).
2. Calculate f_p and Q_{Add} value using 'Preparation Input FlowPer.xls'.
3. Assess the hydrological function based on f_p and rainfall data.
4. Run FlowPer to predict other daily river discharges based on f_p value.

Case study: Bialo watershed

Bialo Bayang-Bayang discharge station is located in upper Bialo watershed, South Sulawesi, Indonesia. This station covers 5020 hectares, 44.9% of Bialo watershed, which is mainly dominated by forest. However, from during 1989 to 2009, the forest area (both primary and secondary) in Bialo watershed decreased from 49 to 36%. The area was largely converted to clove agroforestry.

We analyzed the buffering capacity of the Upper Bialo watershed using FlowPer. The purpose was to make a quick assessment of the watershed condition based on river discharge behaviour. The result showed that the flow persistence values tended to increase with an average value of 0.8, reflecting good watershed conditions (Figure 30.1).

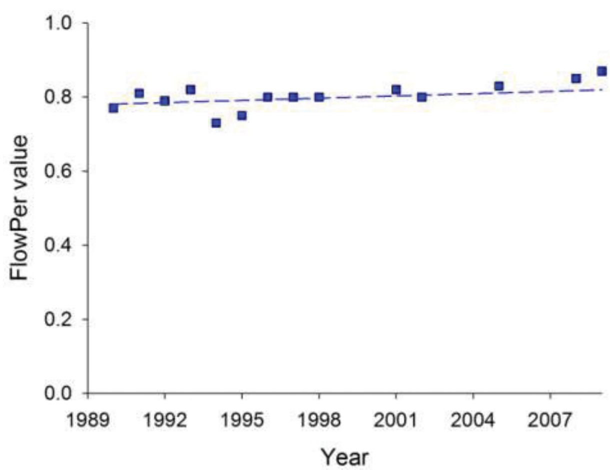


Figure 30.1. FlowPer value in Bialo Bayang-Bayang station over a 21-year simulation

The example of river discharge prediction using FlowPer is shown in Figure 30.2. The generation of this river discharge is based on f_p value 0.75 and Q_{Add} 0.4. The model evaluation between observed and simulated shows that both river discharges has a daily correlation 0.49 and 0.86 for monthly correlation. It means that the FlowPer can predict river discharge using a simple parameterization.

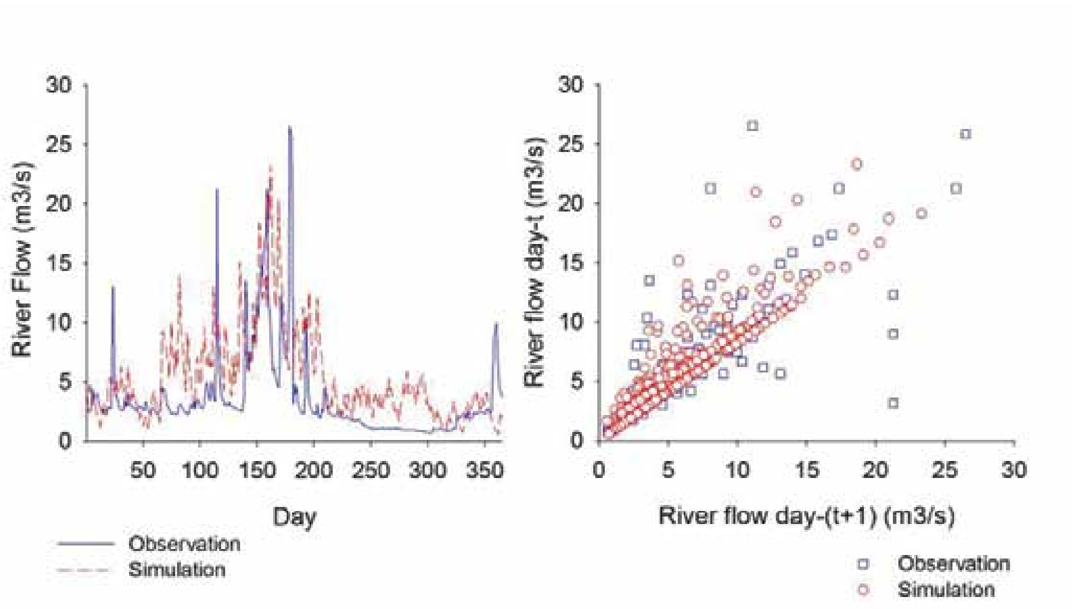


Figure 30.2. Example of the type of 'fit' that can be achieved for the six parameter null-model. This simulation used Upper Bialo watershed data for 1993

■ Key reference

Van Noordwijk M, Widodo RH, Farida A, Suyamto D, Lusiana B, Tanika L, Khasanah N. 2011. GenRiver and FlowPer: Generic River and Flow Persistence models. User manual version 2.0. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestry.org/sea/publication?do=view_pub_detail&pub_no=MN0048-11.

31 | Rainfall simulator (RainyDay) and spatial rainfall (SpatRain)

Meine van Noordwijk, Lisa Tanika, Desi A. Suyamto, Rachmat Mulia, Betha Lusiana and Ai Farida

Rainfall Simulator (RainyDay) generates daily rainfall based on annual rainfall characteristics and an assumption that rainfall patterns follow statistical distribution functions, such as Weibull and Gamma. The model takes into account day-to-day variations in rainfall events as well as different patterns of rainfall across time or seasons. The model operates in MS Excel.

Spatial Rainfall (SpatRain) is a statistical tool to generate event-level rainfall maps across a watershed that represent the observed partial spatial correlation between daily rainfall at multiple locations. The results can be used by hydrological models that assess the influence of rainfall at watershed level on the scaling of river flow and its degree of buffering and flow persistence.

Introduction

Most hydrological and ecological models need daily rainfall data as input. Such a dataset is, however, not always readily available because, for example, the high cost of buying daily data from a weather-recording institution, human error in reading the daily rainfall amount from installed equipment in the field or a rainfall record that tends to produce rainfall data over several days so wet and dry days tend to be clumped together. Some studies can also need an extrapolation of rain events, for example, for simulations of hydrological process over 100 years into the future. An appropriate method to generate daily rainfall data is thus necessary.

RainyDay generates daily rainfall based on two main steps: 1) simulating rainfall occurrence, that is, determining whether or not a day is a rainy day; and 2) if rainfall occurs, determining the amount of rainfall on that wet day. Rainfall occurrence is simulated using a Markov chain model, while amount of rainfall is determined using Weibull and Gamma distribution functions.

Variations in river flow tend to decrease with an increasing area of consideration, partly owing to a decrease in temporal correlation of rainfall events across space. Patchiness of rainfall can contribute to an increase of crop-yield stability over space. To what degree does rainfall variability enhance stability of river flow? How do land cover and spatial patterns of rainfall interact in preventing flashiness of river flow? Being able to answer these questions is important for watershed management. The answers can determine how much changes one can expect from land rehabilitation efforts improveme watershed functions.

A hydrological model can answer these questions. However, a model requires the availability of rainfall data based on a dense network of rain gauges across a watershed. In the absence of such data, which is usually the case, especially in developing countries, a rainfall generator that can produce realistically resampled rainfall maps across a watershed is essential. Existing rainfall simulators, such as the ones included in WaNuLCAS and GenRiver, focus on station-level time series, not on the space/time autocorrelation that matters at higher scales.

Objectives

The objective of RainyDay is to generate daily data from monthly rainfall data.

The objective of SpatRain is to generate time series of rainfall that are fully compatible with existing station-level records of daily rainfall but yet can represent substantially different degrees of spatial autocorrelation. Using semivariance as as a function of increasing distance between observation points, SpatRain is also able to characterize the resulting rainfall patterns accumulated over specified lengths of time (days, weeks, months, years).

Steps in RainyDay

1. Prepare a minimum of one year's daily rainfall data as an input. These data are used to extract the characteristics of rainfall, that is, the wettest month, the month with the highest daily rainfall, the number of wet days, the monthly wet fraction, the monthly relative wet persistence and parameters for Weibull distribution.
2. Parameterize the model.
3. Generate daily rainfall data that has the closest characteristics to actual rainfall data.

Steps involved in SpatRain

Calculations start from the assumed spatial characteristics of a single rainstorm pathway, with a trajectory for the core area of the highest intensity and a decrease of rainfall intensity with increasing distance from this core. The model can derive daily amounts of rainfall for a grid of observation points by considering the possibility of multiple storm events per day but not exceeding the long-term maximum of observed station-level rainfall. Options exist for including elevation effects on rainfall amount.

SpatRain adheres to the following rules.

1. The simulated rainfall for any point in the landscape must be consistent with existing data on the frequency distribution of daily rainfall.
2. SpatRain must allow for spatial trends in the rainfall average (mean), for example, due to elevational effects.
3. SpatRain analyzes semivariance as a function of increasing distance between observation points as a way to characterize the resulting rainfall patterns accumulated over specified lengths of time and identify the storm-level parameters that lead to specified degrees of spatial correlation.
4. For use in combination with a hydrological model, SpatRain should allow for the
   a. identification of sub-catchments in a watershed area and allow averaging the point grid; and
   b. pattern to derive the daily average rainfall per sub-catchment.

The following steps are carried out prior to running SpatRain.

1. Calculate assumed storm (rain) properties.
2. Synchronize spatial pattern with temporal pattern.
3. Generate multiple storm events.
4. Calculate storm events probability.
5. Calculate patchiness indicator using semivariogram.

Case study: RainyDay in Sumberjaya

We applied RainyDay in Sumberjaya catchment, Lampung, Indonesia. Land use in the area was mostly (70%) coffee plantations. A reservoir for a hydroelectric plant was located downstream. The plant's management were concerned that the coffee plantations, which had been converted from forests, would disrupt the stability of river flow. They were interested in using a model to assess the hydrological function of the watershed. However, multi-year rainfall data were not available and so we used RainyDay to generate the data for the area. We tested the performance of RainyDay in generating rainfall by comparing its results with actual observations for a 1-year period.

Analysis of the rainfall data was carried out to create input parameters required to generate rainfall (tables 31.1 and 31.2). In general, the rainfall of Sumberjaya has one peak event. Thus, we could use uni-modal parameters. The offset value was smaller than -1 because in Sumberjaya there were no dry months (monthly rainfall is always larger than 0). The high Weibull value showed that the daily rainfall tended to be uniform.

Table 31.1. List of parameter inputs for RainyDay in Sumberjaya

Parameters	Value
Uni or bimodal?	1
Wettest month of rainy season	1
Peakiness of season	1
Probability	0.5
Offset (influence number of dry months)	-30.00
Weibull value	0.93
Average of wet fraction	0.81

Table 31.2. Monthly time series input for RainyDay in Sumberjaya

	Jan	Feb	Mar	Apr	May	Jun	Jul	Agt	Sep	Oct	Nov	Dec
Number of wet days	29	27	30	26	26	22	22	16	20	23	26	29
Montly rainfall	334	297	321	306	208	153	103	119	163	239	273	315
Relative wet per-sistence	1.01	1.00	1.00	1.02	1.07	1.15	1.19	1.45	1.27	1.15	1.08	1.01

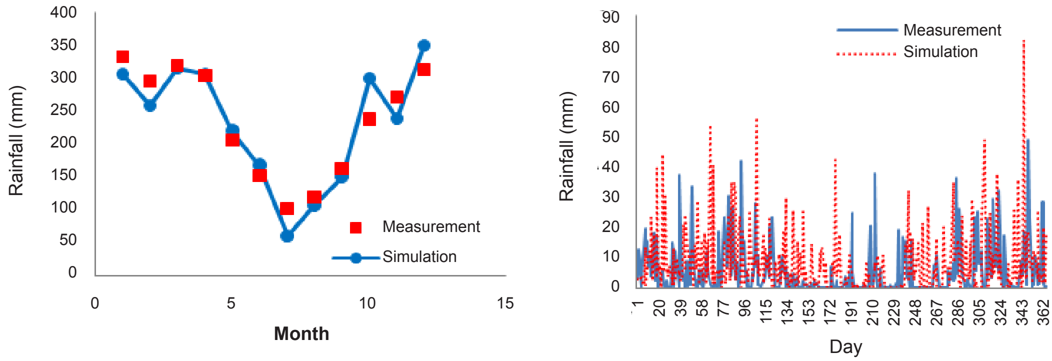


Figure 31.1. Comparison of simulated and observed rainfall data, total monthly rainfall (upper figure) and daily rainfall data (lower figure)

The comparison between simulated and actual rainfall showed that RainyDay was able to generate rainfall similar to actual rainfall with correlation above 80% and bias smaller than 8 mm.

Case study: SpatRain in Sumberjaya

SpatRain was used together with GenRiver to simulate the river flow of Way Besai River in Sumberjaya watershed, Lampung, Indonesia. The study tested the hypothesis that spatial variability of rainfall becomes increasingly important with increasing size of catchment areas in influencing the volume, seasonality and regularity of river flow.

A series of spatially explicit daily rainfall patterns was constructed that matched the monthly mean as derived from rainfall records on the site (Figure 31.2) with differences in pattern, homogeneity, intermediateness and patchiness (Figure 31.3). The fractal dimension (Bian 1997) of each rainfall type was 1.44, 2.34, and 2.90, for H ('homogeneous'), I ('intermediate') and P ('patchy'), respectively.

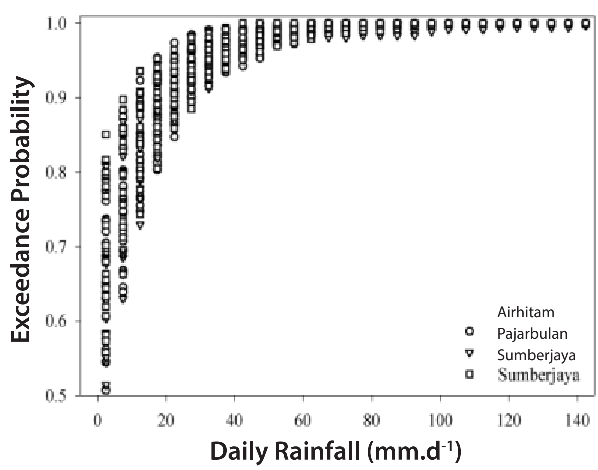


Figure 31.2. Probability of rainfall in Sumberjaya based on three rainfall stations

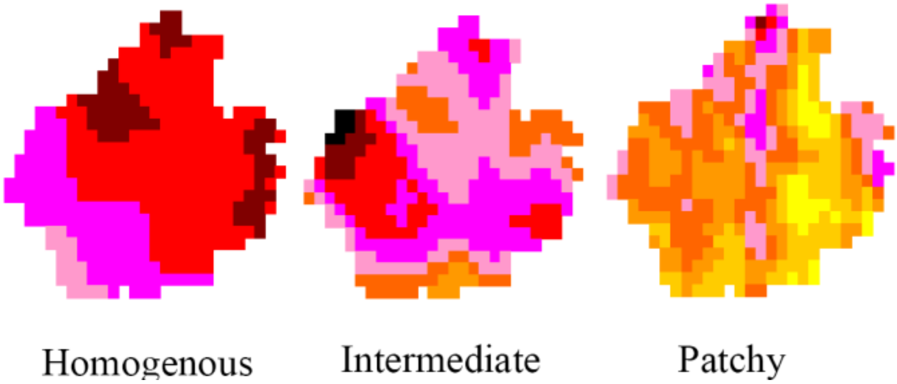


Figure 31.3. Example of the spatial distribution of rainfall on a single day for settings that are indicated as 'homogenous', 'intermediate' and 'patchy'

Using the rainfall patterns of SpatRain, we simulated river flow for the Way Besai River over 20 years to reveal the way annual rainfall is partitioned over evapotranspiration, groundwater discharge, surface and soil quick flows, showing some changes in response to land-use changes (Figure 31.4).

The difference between the three rainfall patterns, however, was larger than the land-use change signal, with an increasing surface quick flow fraction for more patchy rainfall events. The latter was due to higher local rainfall events in parts of the landscape exceeding infiltration capacity during the time available. The frequency distribution of river flow clearly corresponded with the simulations for 'patchy' rainfall much more closely that it did with those for homogeneous or intermediate rainfall types (Figure 31.5).

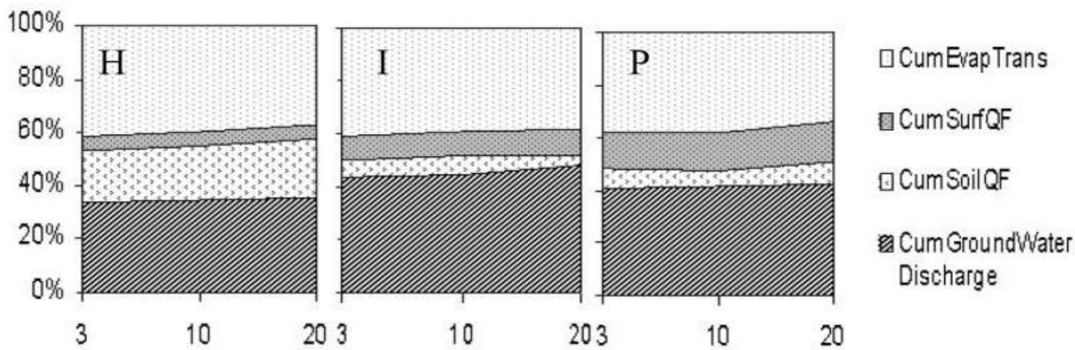


Figure 31.4. Water balance for homogenous (H), intermediate (I) and patchy (P) rainfall type

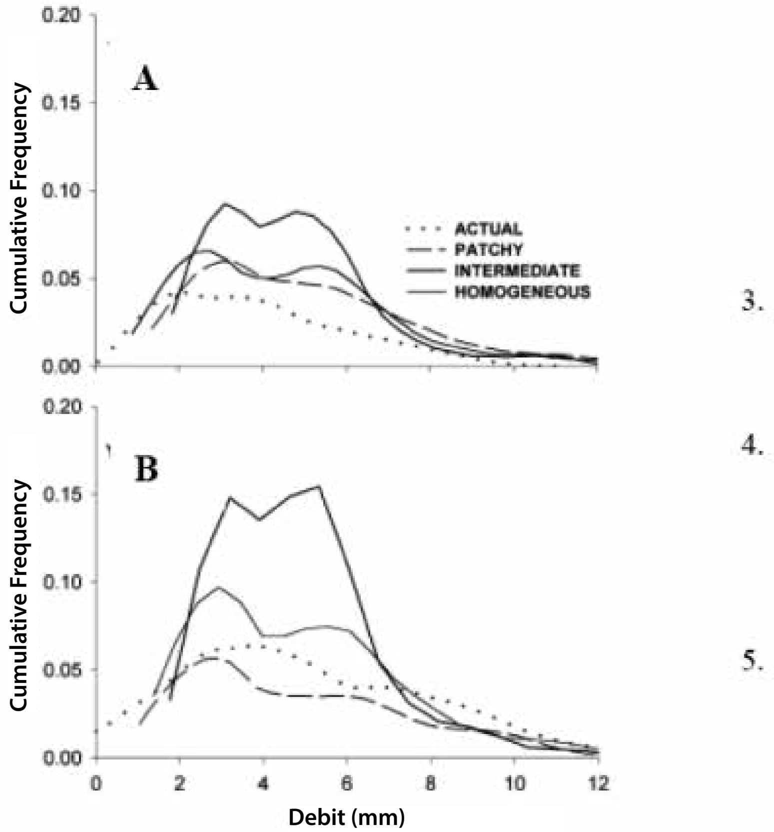


Figure 31.5. Probability/frequency distribution of the river debit

Note: Actual and as simulated by GenRiver driven by homogenous, intermediate or patchy rainfall patterns for year 3 (A) and year 20 (B)

■ Key references

Van Noordwijk M, Widodo RH, Farida A, Suyamto D, Lusiana B, Tanika L, Khasanah N. 2011. *GenRiver and FlowPer: Generic River and Flow Persistence models. User manual version 2.0*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestry.org/sea/publication?do=view_pub_detail&pub_no=MN0048-11.

Van Noordwijk M, Farida A, Suyamto D, Lusiana B, Khasanah N. 2003. Spatial variability of rainfall governs river flow and reduces effects of land use change at landscape scale: GenRiver and SpatRain simulations. In: Post DA, ed. *Proceedings of MODSIM 2003: International Congress on Modelling and Simulation*. Townsville, Australia: Modelling and Simulation Society of Australia and New Zealand. p. 572–577.

32 | Land-use change impact assessment (LUCIA)

Carsten Marohn, Georg Cadisch and Betha Lusiana

The Land-Use Change Impact Assessment (LUCIA) model can be used to assess impacts of land-use changes on soil productivity and fertility, biomass production, watershed functions and environmental services. It operates at high spatial and temporal resolution but can so far only handle small mountainous catchments. It help scientists and land-use planners simulate mid- to-long-term effects of land-use management and changes on environmental degradation and rehabilitation. It is explicit in the consequences of plot-level decision making by farmers and thus operates between the reach of detailed tree–soil–crop interaction models and models that operate at more aggregated watershed scale.

Introduction

Peoples' decisions with respect to agricultural land use and management have a major impact on natural resource degradation. Soil degradation is largely caused by the activities of land-use decision makers and has substantial feedback effects on both human and environmental systems. Particularly in mountainous areas, degradation is largely due to flow of matter from upstream to downstream areas in the form of water (runoff) that also brings along soil (erosion, deposition) and nutrients. The use of a simulation model such as LUCIA can help land-use planners to assess the impact of landscape management in order to reduce soil degradation.

LUCIA integrates different processes related to soils, water and plants thus allowing a user to assess the benefits and trade-offs of land-use changes and management. These processes are represented in a spatially explicit way so that the effects of positioning of each land use and activity in the catchment are taken into account and can be considered when designing management strategies. Applications of the model encompass the decline and recovery of soil fertility, changes in the water balance, surface runoff, erosion and sedimentation processes, yield levels, as well as food security, biomass and carbon stocks. Scenarios can represent the consequences of local farmers' short-term management decisions (such as fertilization, ploughing or burning), land-use and land-cover changes, or longer-term changes such as climate.

Objectives

LUCIA was designed to represent processes of water balance, erosion and sedimentation as well as nutrient balance and yield formation in a small catchment responding to plot-level management decisions.

Steps

LUCIA combines daily time steps for crop growth and hourly sub-time step for infiltration, runoff and erosion. It is a spatially explicit landscape model written in PCRaster, a combination of dynamic modelling language and GIS developed at the University of Utrecht.

LUCIA consists of five main modules: 1) Hydrology/soil water; 2) Soil nutrients; 3) Organic matter and decomposition; 4) Plant growth; and 5) Land-use and management options. The soil water, organic matter and plant modules are built on concepts of established models, namely KINEROS (Woolhiser et al 1990) and SPAW (Saxton and Rawls 2006), CENTURY (Parton et al 1987) and the Crop Growth Monitoring System CGMS (Supit 2003), which is based on the World Food Studies (WOFOST) model.

Input parameters required and outputs produced by LUCIA are provided in the user manual (Hörhold and Marohn 2012) and theoretical background in the documentation (Marohn and Cadisch 2011). An online distance learning course is offered that includes lectures and exercises with the model (https://openilias.uni-hohenheim.de).

The LUCIA model has been successfully coupled with MP-MAS, a model that simulates farm decision making, to explore the impacts of several soil conservation measures on erosion and yields in northern Viet Nam. Currently, LUCIA-Choice is also being developed: a decision-making module, which can be coupled with LUCIA. LUCIA-Choice contains a decision algorithm based on household resources, crop preferences and plot quality. The latter includes top-soil carbon contents and other indicators of soil fertility and it is up to the farmers (as parameterized by the user) how much importance they attribute to these factors. This will allow a reflection of farmers' levels of local knowledge on plot-specific characteristics in terms of their land. A simple tool for building land-cover-change scenarios is the rule-based LUC generator.

Case study: LUCIA in Viet Nam

Soil degradation is largely caused by the activities of land-use decision makers and has substantial feedback effects on both human and environmental systems. To capture these feedback effects and the resulting human–environment interactions, LUCIA was used to assess the potential impact of low-cost soil conservation methods on maize cultivation in upland areas. The study was carried out in Chieng Khoi in Son La province, Viet Nam, an area which represents the ongoing trend toward intensified maize-based agriculture in parts of northwestern Viet Nam. The combination of heavy rain and mostly steep terrain makes soils highly susceptible to erosion once permanent vegetation cover is removed. With increasing population in the area and stronger market integration, fallow periods have shortened or even disappeared, leading to severe soil degradation.

Average crop yields were calibrated using a household survey of 490 farms (Quang 2010) and validated based on field data by Schmitter et al (2010) and Rathjen (2010) for paddy rice, maize and cassava, respectively. Pixel size in the Chieng Khoi model was set at 25 by 25 m, which corresponds to the size of an average smallholding plot. Maize fields in Chieng Khoi are slashed and burned between November and March; fields are ploughed at the start of the wet season (April to October) and maize is sown in May. Model scenarios were based on the above data, comparing farmers' practices as a baseline scenario to three alternative scenarios (Table 1). Under these scenarios, the introduction of different soil conservation options in the maize fields was tested.

Table 32.1. Scenarios tested for plots under maize cultivation

Scenario	Management options			
	Burning	Tillage	Cover crop	Description
Baseline: current practice	Yes	Yes	No	Fallow vegetation or crop residues are slashed and burned in the dry season prior to ploughing and sowing
B: Zero tillage without cover crop	No	No	No	Fallow vegetation is not burned but mulched; maize is planted in untilled soil
C: Zero tillage with cover crop	No	No	Yes	Same as (B), but a perennial legume is inter-planted with maize to reduce erosion; suppress weeds and fix atmo-spheric nitrogen
D: Cover crop plowed under	No	Yes	Yes	Same as (C), but the cover crop is ploughed into the soil to improve soil fertility and ease planting

Source: Marohn et al 2013

Three fertilizer levels were implemented for each scenarios: 1) zero fertilizer; 2) farmers' practice which is 75/50/75 kg of N/P/K per hectare; and 3) levels recommended by the fertilizer manufacturer (double the farmers' practice). Fertilizer levels per pixel were not varied between scenarios and years. Legumes were implemented as soil cover not competing with the crop for nutrients.

The objective of the study was to assess 1) whether soil conservation measures under maize were able to directly reduce soil degradation and indirectly reduce it under other land uses on lower slope positions; and if so 2) how far yield levels would be positively affected by soil conservation measures in the long run.

It was found that soil conservation effectively reduced erosion. After the first year, soil conservation on maize plots under no tillage (Scenario B) resulted in 0–7.3 Mg ha^{-1} less sediment loads per pixel as compared to the baseline, while the legume scenarios C and D achieved between 0 and 18.8 Mg ha^{-1} less sediment loads (Figure 32.1). Land uses other than maize showed only minor differences between scenarios. After 25 years, reduced sediment loads on maize plots reached up to 365 Mg ha^{-1} for Scenario B and 1680 Mg ha^{-1} for Scenario C and Scenario D. The most substantial reduction was found in the lowland areas, which receive sediment from the entire catchment. Cumulative reduction ranged from 0 to 780 Mg ha^{-1} for Scenario B and from 0 to 2,150 Mg ha^{-1} for scenarios C and D. Topsoil depth after 25 years was analysed as well. On a few of the pixels (approximately 20% of the entire catchment), topsoil thickness was slightly greater in the baseline as compared to the other scenarios. In all other cases, topsoil was up to 5.3 cm thicker under Scenario B and up to 20 cm under scenarios C and D, as compared to the baseline. Separating these effects between maize and other land covers showed that other land uses were hardly affected, revealing that top-soil loss affected mainly the source cells and that sediments travelled through the lowlands but did not cause a major entrainment of soils under other land-cover types.

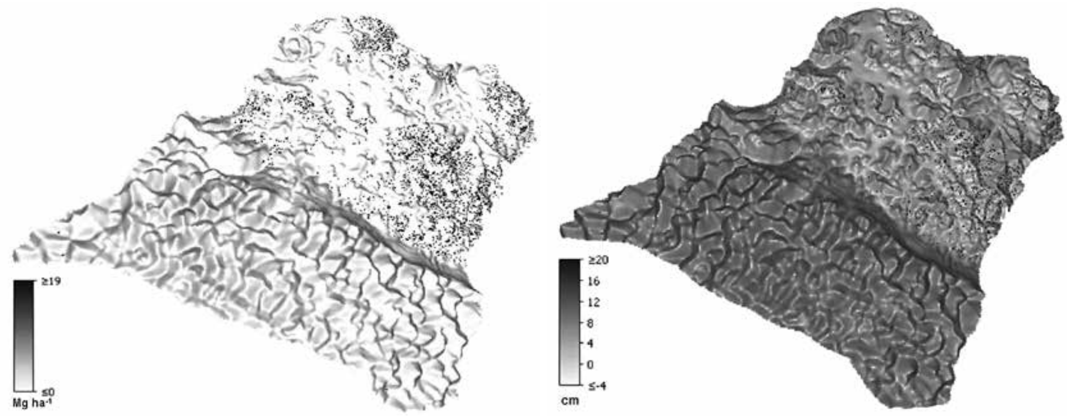


Figure 32.1. Difference in sediment loads and topsoil depth

Note: Baseline minus scenario D after year 1 (left) and difference in top-soil depth scenario D minus baseline after year 25 (right)

Source: Marohn et al 2013

The analysis of yields after 25 years showed that it was mainly maize that was affected by soil conservation measures, as expected (Figure 32.2). Owing to landscape-related factors, both maize-derived erosion rates and maize yields showed large spatial variability, as shown in Table 32.2.

Table 32.2. Descriptive statistics of yields

Descriptor	Maize yield F0, year 5	Erosion, year 1
Mean [Mg ha^{-1}]	4.20	13.6
St.dev. [Mg ha^{-1}]	2.40	30.2
Coeff. Var. [%]	57	222

Note: On unfertilized (F0) maize pixels for the fifth year of simulation, and erosion across all maize pixels for the first year of simulation, baseline, (n = 3,665)

Source: Marohn et al 2013

Clear differences in average maize yields appeared between fertilizer levels, regardless of the soil conservation measures used. Under farmers' practice of continuous fertilizer inputs (F1 treatment in Figure 32.2, left chart) average maize yields started around 6 Mg ha^{-1} and then increased up to 7 Mg ha^{-1} under the baseline and no tillage scenarios, while yields of maize combined with legumes slightly decreased and dropped below the baseline in year 8. As nutrient competition between crop and legume was not modelled, this might have been caused by indirect nutrient insufficiency owing to water stress in the crop (caused by the higher water demand of crop plus legume). Yields under high fertilizer input (F2 treatment; Figure 32.2, right chart) came close to potential yields during years without water stress. Under soil conservation and high fertilizer inputs, yields remained clearly above the baseline at all times, however, during years of extreme weather (for example, 7 and 17) the difference in yields between legume and non-legume treatments shrunk.

Significant effects of ploughing between the two legume treatments were not observed in the simulations.

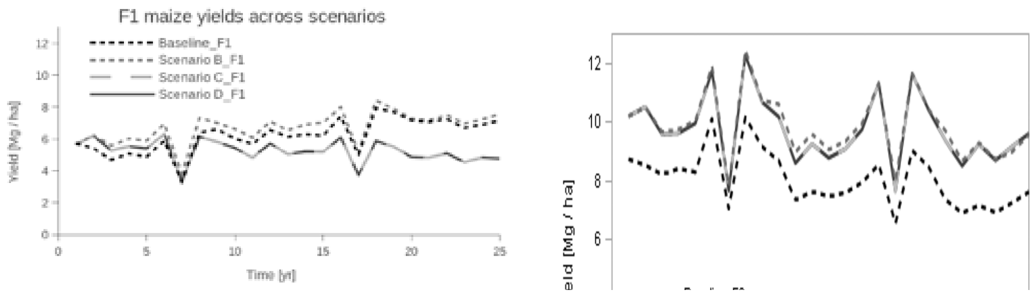


Figure 32.2. Average maize yields

Note: At farmers' practice (left) and high fertilizer levels (right) under all scenarios over the 25 years of simulation

Source: Marohn et al 2013

At the plot level, the magnitude of soil eroded from maize plots (Table 32.2) was in the range of that found in the reference experiments carried out on similar slopes and soils in Chieng Khoi (Tuan, personal communication). Simulated soil conservation measures on maize plots were effective at reducing soil erosion on these plots and also on other plots downstream. The reduced erosion rates had a positive effect on maize yields in the first years after implementation of the measures.

In combination with the MP-MAS model, LUCIA maize yields led to two different land-use and management strategies by farmers: 1) Intensification, that is, adding more fertiliser when maize yields decreased; and 2) extensification, that is, omitting fertiliser on plots that were not profitable. Consequently, a sensitivity analysis showed that fertiliser prices had a strong impact on soil conservation measures: where fertiliser was cheap, waning yields were compensated by increased fertiliser levels, else soil conservation was practised.

At the landscape level, soil conservation measures in maize fields had limited effects on the sediment loads leaving the entire catchment, as deposition accounted for filtering and delayed delivery. Although absolute quantities of eroded soil at the catchment outflow differed clearly between scenarios, these differences remained small in relative terms, owing to the fact that the large areas under forest and tree plantations that contribute little to erosion remained unchanged between scenarios. Seemingly larger erosion reduction effects in paddies, as compared to maize plots, stemmed from the fact that the model simulated sediment loads and thus did not distinguish between eroded soil originating from a pixel and such passing through a pixel (except for pixels without an inflow, for example, next to a ridge). As sediment from the entire catchment passed the lowland and outflow cells, total amounts were always higher than in the upland source cells.

The LUCIA standalone model captured the spatial variability in erosion and crop yields observed in the field (Lippe et al 2011). The high temporal and spatial resolution of the model allowed identification of erosion hotspots (in terms of reduced topsoil thickness), distribution of sediment loads and patterns of soil fertility (for example, high fertility along previously forested footslopes, outputs not shown) and their development over time. The unchanged land cover and management practices over 25 years, even though not a necessarily realistic scenario, facilitated the tracing back of causal relationships between variables.

■ Key references

Hörhold S, Marohn C. 2012. *User manual for the Land Use Change Impact Assessment tool LUCIA*. Hohenheim, Germany: Hohenheim University. https://lucia.uni-hohenheim.de/fileadmin/einrichtungen/lucia/lucia_user_manual.pdf.

Marohn C, Cadisch G. 2011. *Documentation and manual of the LUCIA model version 1.2*. Stuttgart, Germany: Institute for Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim. https://lucia.uni-hohenheim.de/

Marohn C, Cadisch G, Jintrawet A, Buddhaboon C, Sarawat V, Nilpunt S, Chinvanno S, Pannangpetch K, Lippe M, Potchanasin C, Dang VQ, Schreinemachers P, Berger T, Siripalangkanont P, Thanh TN. 2013. Integrated modeling of agricultural systems in mountainous areas. In: HL Fröhlich, P Schreinemachers, K Stahr, G Clemens. *Sustainable land use and rural development in Southeast Asia: innovations and policies for mountainous areas*. p. 367-432. New York: Springer.

Marohn C, Schreinemachers P, Quang DV, Berger T, Siripalangkanont P, Nguyen TT, Cadisch G. 2013. A software coupling approach to assess low-cost soil conservation strategies for highland agriculture in Vietnam. *Environmental Modelling and Software* 45: 116–128.

33 | Polyscape

Fergus Sinclair and Timothy Pagella

Polyscape is a GIS framework designed to explore spatially explicit synergies and trade-offs amongst ecosystem services to support landscape management (from individual fields through to local landscapes of 1000 km^2 scale). Polyscape currently maps the impacts of land-cover change on surface runoff, habitat connectivity, erosion, carbon sequestration and agricultural productivity. The tool also incorporates trade-off algorithms that allow visualisation of the impact of different land management decisions and, thus, can be useful for land-use planning at local landscape scales.

Introduction

Bagstad et al (2013) recently reviewed 17 ecosystem services' tools against eight evaluative criteria that gauged their readiness for widespread application in public- and private-sector decision making. There is scope for further exchange of concepts and algorithms between these models, while there is a clear need for greater user-friendliness and options for exchange between models based on common definitions and concepts. Most of the models are currently framed as 'decision support', aiming for a best-current-science representation of the likely consequences of actions. As discussed before in many of the tools herein, it is relevant to complement such models with approaches that are more directly cognizant of the negotiation context, where knowledge, aspirations and skills are not (yet) shared between the various stakeholders.

The Polyscape approach provides a spatially explicit framework for different stakeholders to explore impacts of land-use options for a range of ecosystem services and to identify synergies and trade-offs amongst them. Negotiation of ecosystem services is likely to involve interaction at the plot, farm and local landscape scale and the tool was designed to work at these scales (typically 10 to 1000 km^2). Stakeholders are engaged from the outset, with the representation of ecosystem services' maps iteratively developed and drawing heavily on local and expert stakeholders' knowledge and feedback. This ensures local legitimacy of outputs. This participatory mechanism facilitates in the negotiation of land-use options and in the evaluation of their impact on the provision of ecosystem services. The core of the Polyscape approach is a GIS toolkit that uses generally available data to map:

1. where interventions are most and least desirable with respect to single ecosystem services (currently, agricultural production, water flow, sediment flow, biodiversity conservation and carbon storage; these layers would need to be customised for each landscape);
2. trade-offs and synergies amongst impacts of land-use change on a range of ecosystem services, pinpointing win-win options and areas where incentives may be required to manage trade-offs; and
3. how changes in landscape structure have an impact on the provision of ecosystem services.

Given the emphasis on participation and the difficulties of operating in data sparse environments, the process of developing the maps is likely to be more important than the final maps.

Objective

The objective of Polyscape is to represent the basic physical structure of a landscape along with the key spatial processes that influence ecosystem functions and create spatial dependencies between cause and effect. This is to be done in a way that is intuitive and communicates well with local stakeholders. The tool captures additional information and insights into the current situation before exploring future changes.

Steps

1. Obtain a working version of the model and the software needed to run it. Polyscape is in the proof-of-concept phase. Initial development used Python scripts that were hardwired into the tools. Polyscape runs in ESRI™ ArcMap™ 9.2 (or 9.3) with Spatial Analyst™ and Arc-Hydro extension. The tool is currently being ported to QGIS.
2. Develop specifications for the ecosystem services being considered (see Figure 33.1) Parameterize the model with existing spatial information.
3. Present the initial model version to a group of stakeholders, obtain their suggestions for refinement and improvement and observations on how realistic the model is; adjust to the degree possible.
4. Bring the adjusted model to further meetings of landscape actors (including farmers) and explore with them how a wide range of alternative future configurations would affect the performance measures in agronomic, economic and environmental perspectives.
5. Capture the main contrasts, trade-offs and choices that emerge from the 'what if' scenarios of local stakeholders, and bring them into local negotiations.
6. Validation with local stakeholders and experts.

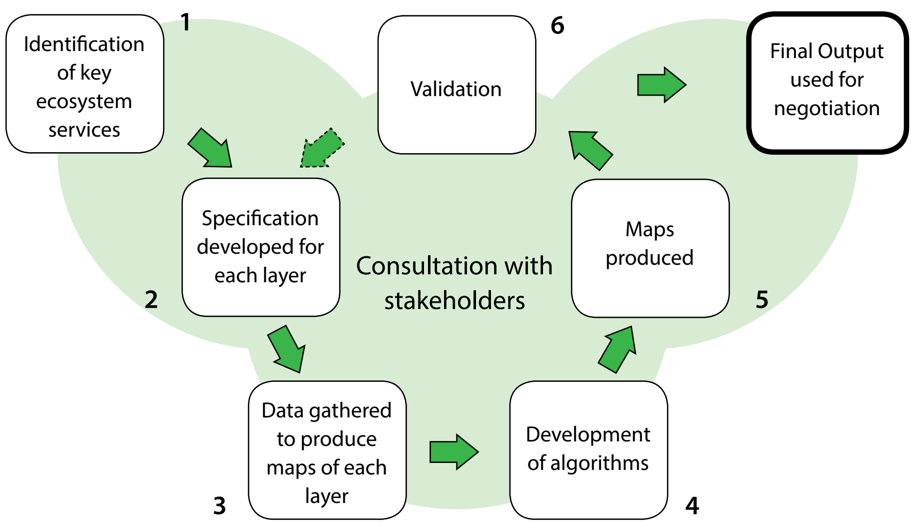


Figure 33.1. Iterative cycle of map development for Polyscape

Example of application

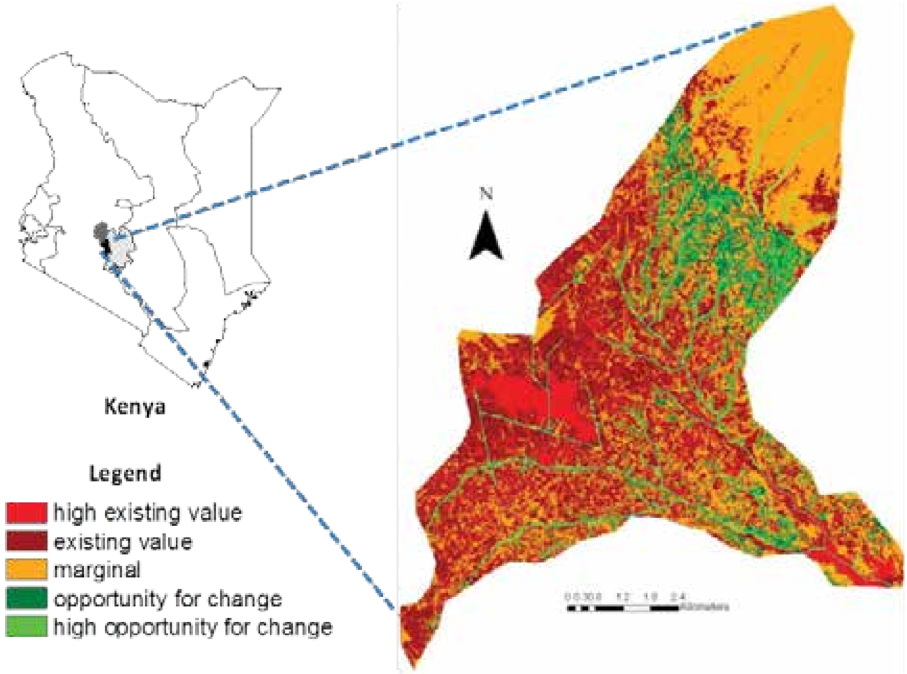


Figure 33.2. Example of Polyscape output for the Sasumua watershed in Kenya, trading-off flood mitigation and agricultural productivity services

Polyscape produces spatially explicit outputs in the form of maps showing areas where different ecosystem services either show a trade-off or have synergies at landscape scale. Polyscape was applied in the Sasumua watershed in upland Kenya. The trade-offs shown explore interactions between two separate ecosystem services (flood mitigation and farm productivity). The research interest here was to explore where best to place trees in the landscape (Figure 33.2). Areas where tree planting did not interfere with agricultural production but would intercept surface runoff are shown as light green; areas where a single ecosystem service is good and another ecosystem service is neutral are shown as dark green. The areas coloured red or maroon show where there was a trade-off between agricultural production and hydrological regulation, possibly requiring incentives to promote tree planting.

Key references

Jackson B, Pagella T, Sinclair F, Orellana B, Henshaw A, Reynolds B, McIntyre N, Wheater H, Eycott A. 2013. Polyscape: a GIS mapping framework providing efficient and spatially explicit landscape-scale valuation of multiple ecosystem services. *Landscape and Urban Planning* 112:74–88.

34 | Forest, agroforest, low-value landscape or wasteland (FALLOW)

Desi A. Suyamto, Rachmat Mulia and Betha Lusiana

Forest, Agroforest, Low-value Landscape or Wasteland (FALLOW) is a spatially explicit model that simulates the consequence of agents' land management decisions on overall landscape dynamics. It is useful for exploring how the changes in the landscape have an impact on carbon sequestration, biodiversity and watershed functions. FALLOW is particularly suited to simulate rural or peri-urban landscapes where land-based activities (that is, agriculture, forest extraction) are still the main livelihood. FALLOW proceeds in annual time steps at watershed scale.

Introduction

Growing populations and market-based development accelerate changes in parts of the developing world. In areas where new land is no longer available and accessible, intensification may lead to conflicts. Trade-off analysis of the impact of land-use changes on livelihoods and environmental services can help evaluate options for current land-use and future management. If scenario analysis is based on a credible landscape simulation model, we can assess various options and their consequences for livelihoods, carbon stocks and water flows, with various incentives and rules to enhance environmental service provisioning.

FALLOW can be used to explore the likely trajectories and impacts of development strategies. FALLOW simulates the dynamics of land-use and land-cover changes that are local responses to external drivers, with various feedback loops (Figure 34.1), and assess the consequences of the resulting land-use mosaics on economic utilities (welfare and food security) and environmental services (for example, carbon stocks).

FALLOW PORTRAYS SEVERAL LOCAL RESPONSES.

- How farmers adjust their expectations about the economic utility of each available option on land-based and non-land-based investments through learning.
- How farmers allocate their capital (labour, money and land) to each available option of investment.
- How farmers perceive the attractiveness or otherwise of a plot to expand a particular land-use system, with regard to some spatial factors determining potential benefits (soil fertility, suitability and attainable yield) and potential costs (transportation, maintenance and land clearing).
- Succession, growth, fire and land conversion.
- Laws of diminishing and increasing marginal utilities on soil fertility and land-use productivity.

The main external drivers incorporated in the model include:

- market mechanisms and relevant regulation interventions, articulated through commodity prices, costs and harvesting labour productivities;
- development programs, articulated through extension, subsidies, infrastructure (settlements, road, market, processing factories) and land use productivities; and
- conservation programs, articulated through forest reserves as prohibited zones for farmers.

Objectives

FALLOW can be used to project landscape dynamics and the consequence of changes on ecosystem services and people's livelihoods.

Steps

1. Installation of FALLOW, PCRaster and NutShell programs to run the model.
   a. The FALLOW model can be obtained from http://worldagroforestrycentre.org/regions/southeast_asia/resources/fallow-forest-agroforest-low-value-landscape-or-wasteland.
   b. PCRaster is open source environmental modelling software developed by Utrecht University, The Netherlands, targeted at the development and deployment of spatio-temporal environmental models: http://pcraster.geo.uu.nl/downloads/.
   c. NutShell is a Windows shell for PCRaster that facilitates the running of PCRaster commands and edits and runs PCRaster models (scripts): http://nutshellqt.sourceforge.net/.
2. Preparation of data
   a. FALLOW input data are categorized into three types: 1) spatial data; 2) arrays; and 3) time series . The spatial data required by FALLOW are information on initial land cover, information to differentiate qualities, such as soil fertility, slope, distance to market, roads and rivers and, if they exist, a suitability map for each agricultural system/livelihood option. FALLOW also requires information on profitability, input (labour and cash) and output (yield) for each livelihood option, which can be based on a farm survey. Landscape-level information, such as size of population, percentage of labour force and income per capita, are initial information required to run the model.
3. Development of scenarios
4. Run the model

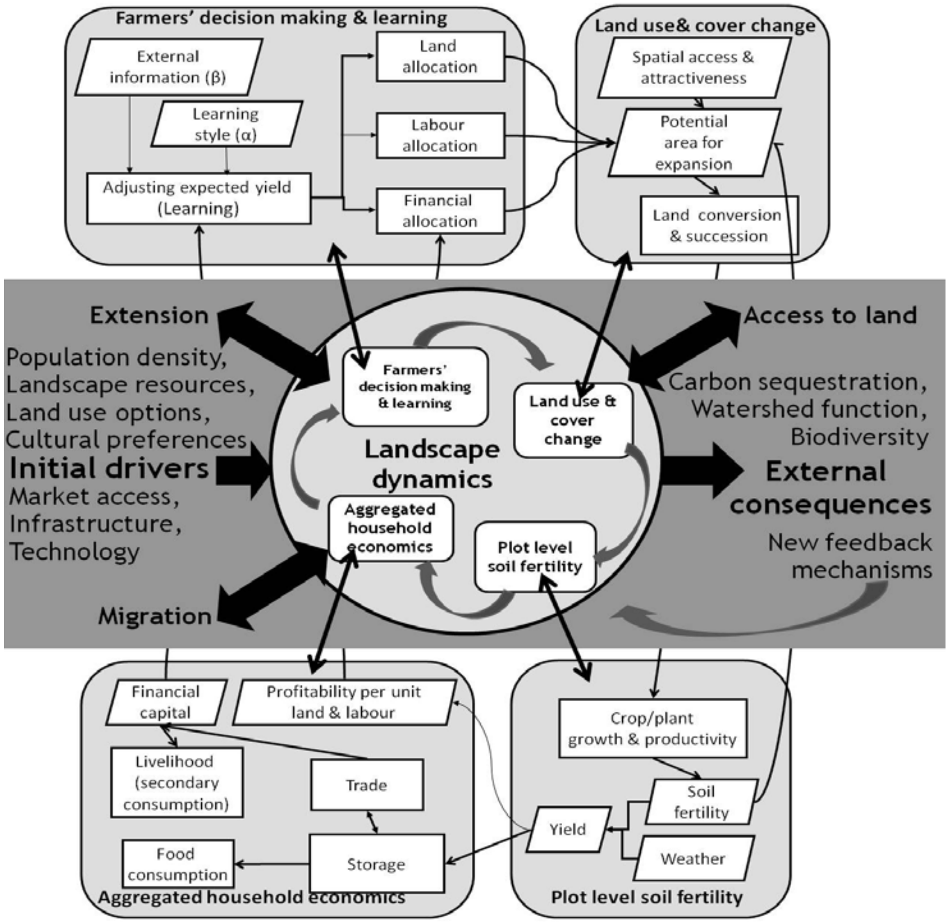


Figure 34.1. The four core modules of FALLOW that simulate dynamic changes in land-use and land-cover due to local responses to external drivers, with various feedback loops

Case study: FALLOW in Upper Konto catchment

FALLOW model was used to explore the effect of land zoning on farmers' livelihoods and aboveground carbon sequestration in the Upper Konto catchment, East Java, Indonesia. The watershed presents a landscape of mixed agroforests and rice fields with forest remnants, which is typically found in Southeast Asia, where horticulture in a peri-urban setting lead to rapid land-use change and forest conversion. Conflicts over access to land have occurred in the past as two-thirds of the land was allocated as forests for production and conservation purposes. Thus, farmers could access only a third of the watershed for settlement and agricultural activities. We explored 1) the impacts of changes to the forest zone policy; 2) the potential of further integration of fodder production in forest areas; and 3) the impact of open access to all land on farmers' welfare and aboveground carbon sequestration in the entire landscape. We developed five scenarios representing the current situation ('business as usual' or BAU) and four hypothetical questions related to changes in land zoning, including access to harvest fodder (Table 34.1).

The FALLOW simulation was run for a 20-year period. We evaluated how the model performed in simulating the BAU scenarios. The spatial validation showed good results and we are confident the model can be used to explore scenarios (not depicted here, refer to Lusiana et al 2012). The model projected that under the current policy, forest cover will be maintained with intensive agriculture (horticulture) dominating the agricultural system. However, in terms of contribution to income, dairy cattle was the highest contributor, followed by agriculture and agroforestry.

Table 34.1. Scenarios (business-as-usual and prospective) of landscape dynamics in the Upper Konto catchment developed for FALLOW

Scenarios	
I	Business as usual
II	Agroforestry access to plantation forest
III	No fodder harvesting allowed in plantation forest
IV	No planting of monoculture Napier grass
V	Open access to land

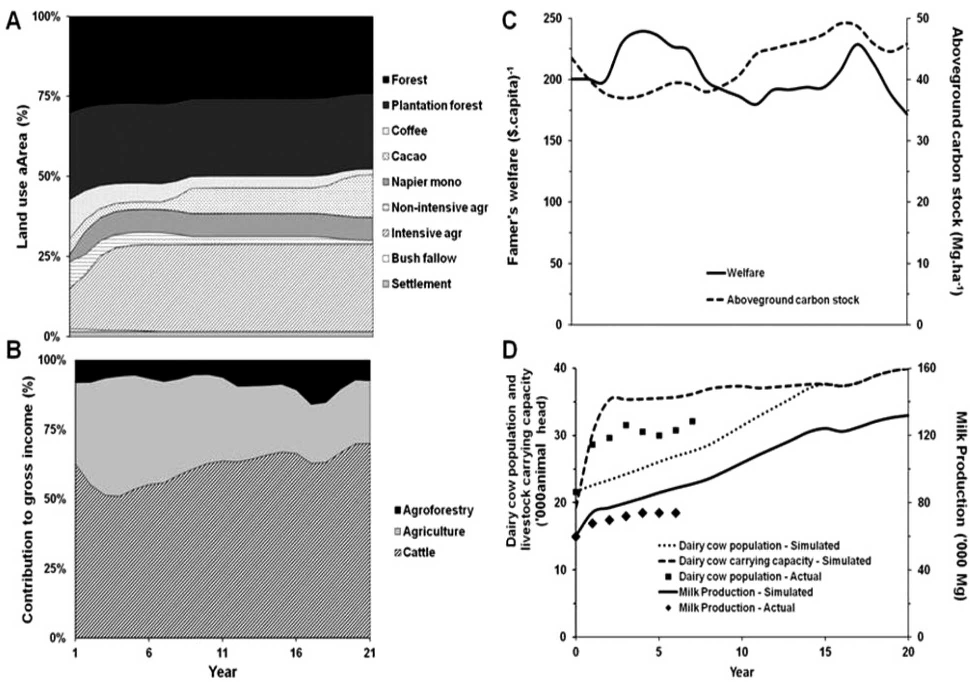


Figure 34.2. Business-as-usual scenario from FALLOW for the Upper Konto catchment

Note: (A) landscape dynamics (% area); (B) contribution of main livelihood options on catchment gross income (%)

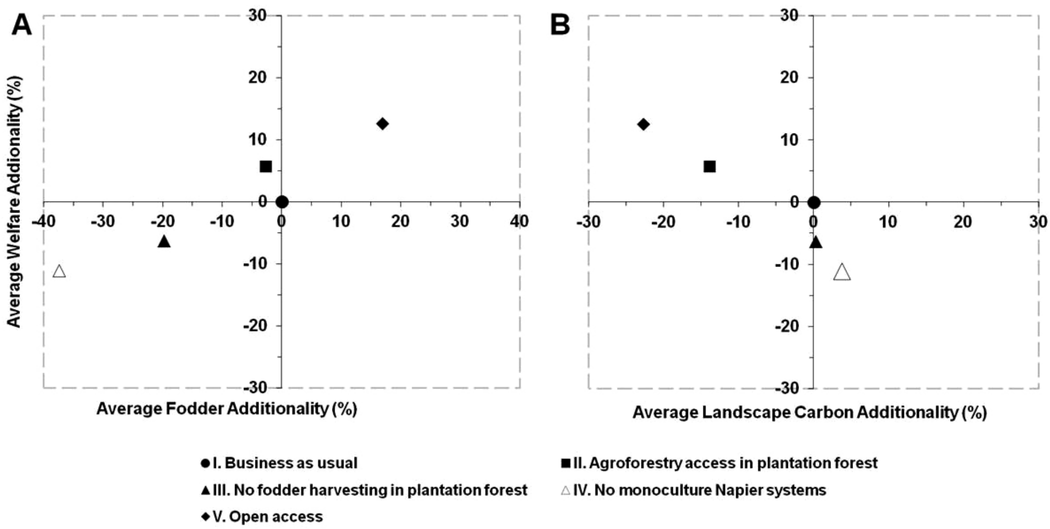


Figure 34.3. Trade-offs

Note: A) average fodder additionality versus landscape aboveground carbon stocks; and B) farmers' welfare versus landscape aboveground carbon stocks relative to business as usual. Results of prospective scenarios (I–V) of the FALLOW model averaged over 20 years

Comparing the four scenarios (II – V) with BAU (I) showed that welfare/income are positively correlated with availability of fodder. Increases in welfare were projected to be obtained through the open-access scenario (Figure 34.3A). However, the model suggested that the current policy appeared to be the best for balancing livelihoods and environmental objectives (Figure 34.3B). Although open access would increase welfare by around 33%, carbon stocks would be decline in the landscape by 23%.

■ Key references

Lusiana B, van Noordwijk M, Cadisch G. 2012. Land sparing or sharing? Exploring livestock fodder options in combination with land-use zoning and consequences for livelihoods and net carbon stocks using the FALLOW model. *Agriculture, Ecosystems and Environment* 159:145–160.

Suyamto DA, Mulia R, van Noordwijk M, Lusiana B.2009. *Fallow 2.0.* Manual and Software. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M. 2002. Scaling trade-offs between crop productivity, carbon stocks and biodiversity in shifting cultivation landscape mosaics: the FALLOW model. *Ecological Modelling* 149:113–126.

35 | Ecological corridors (ECor): a distributed population model with gender specificity

Meine van Noordwijk, Rachmat Mulia and Sonya Dewi

To counteract the effect of habitat fragmentation, the concept of restoring ecological corridors is popular in conservation circles. The expected effectiveness of such corridors depends strongly on the dispersal characteristics, which for species such as orangutan are strongly dependent on gender. A distributed population model allows ex ante impact predictions of various corridor designs.

Introduction

Habitat fragmentation is a major cause of loss of biodiversity, as populations of plants and animals may get too small to survive and recover from the shocks that tend to occur with climate variability and other stress factors. Reconnecting remaining small habitat fragments through 'ecological corridors' through which plants and animals can disperse is a response to the fragmentation challenge. However, the effectiveness of such corridors must be weighed against the costs and alternative uses of conservation funds so an ex ante impact predictor is needed. We found that existing tools did not handle gender-specific dispersal yet male and female individuals of a species such as orangutan have very different dispersal distances.

The ECor model MetPop001 was developed by the Ecological Modeling Unit of the World Agroforestry Centre Southeast Asia Regional Program in September 2010 to provide options to analyze ecological connectivity in landscape mosaics, as the next step in dynamic land-use-change models such as FALLOW. This is a beta version of a landscape mosaic and corridor meta-population model. It is based on simple principles of population dynamics in a number of separate populations that are linked through dispersal. The default application is for orangutan (OU) population dynamics in a small forest patch with or without active corridors to a 'stable reservoir' population in a large protected area. Other species can be added to the database and then evaluated. The model is initially described for discrete (default: yearly) time steps and a continuous variable population density rather than discrete individual counts.

Meta-populations can be described through local birth rates and mortality plus an annual transfer coefficient matrix. Corridors can play a significant role through the transfer coefficient matrix even if their mortality exceeds birth rates. Within the confines of this model, habitat quality can be translated into a carrying capacity concept, capping off local population increase. Connectivity with corridors implies both gains and losses and the net effects depend on access to (relatively) large source areas. For an organism such as orangutan, the dispersal behavior differs between males and females and this affects corridor effectiveness. The following life-history traits have to be provided as parameters to the model: sex ratio at birth, average inter-birth interval, litter size, juvenile mortality multiplier, pre-productive years, adult annual mortality rate (%/year), male dispersal and female dispersal. These jointly determine the natural increment rate feasible for the population in the absence of disturbance.

Objectives

Objective of the model is to allow details of life history at species level, including male and female dispersal traits, to be related to a land-use mosaic with time-dependent habitat types to explore effects on sub- and total population size. The tool can be used to explore the likely effectiveness of alternative ecological corridor designs.

Steps

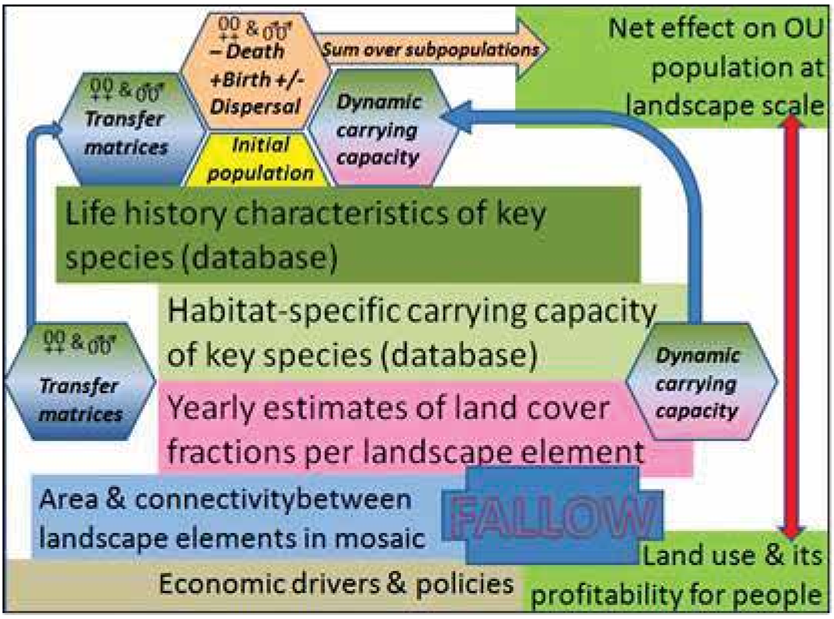


Figure 35.1. Logical flow of the MetaPop model

Case study: ECor in Indonesia

In line with broader efforts to restore ecological connectivity in landscape mosaics, the potential relevance of restoring connections between the habitats of (sub-) populations of Sumatran orangutan is expected to support survival of the species. One of the last chances to do so may be in the Tripa swamp where a (sub-) population of over 100 individuals has become separated from the main population in the Gunung Leuser National Park as a result of the conversion of peat swamp-forest into oil-palm plantations. While there may be opportunities to use funding mechanisms linked to the United Nations-mandated mechanism for Reducing Emissions from Deforestation and Degradation plus conservation (REDD+) for both protecting remaining forest and restoring (ecologically) the surrounding landscape, the effectiveness of such efforts on orangutan survival forms a key argument for seeking broader investment beyond the issues of avoided carbon-dioxide emissions and net carbon sequestration. The expected functionality of landscape corridors must be weighed against their costs and local acceptability.

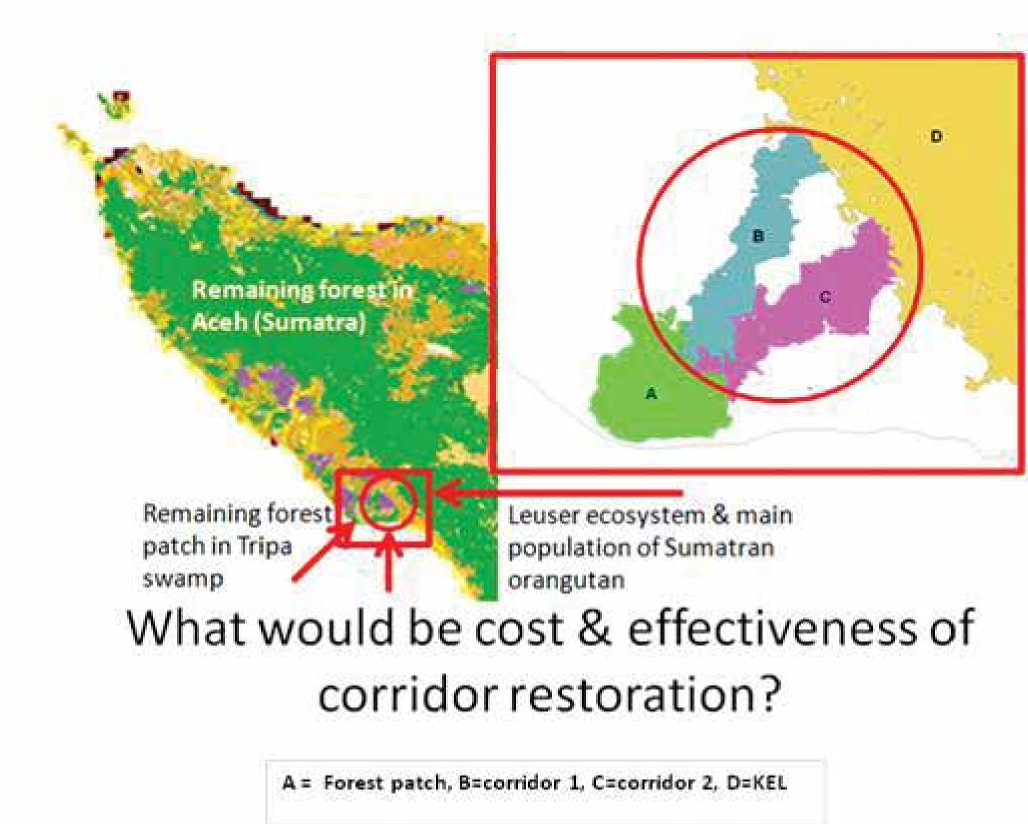


Figure 35.2. The model explored potential corridors B and C, singly or in combination, between forest remnant A and the national park

Key references

Tata MH, van Noordwijk M, Mulyoutami E, Rahayu S, Widayati A, Mulia R. 2010. *Human livelihoods, ecosystem services and the habitat of the Sumatran orangutan: rapid assessment in Batang Toru and Tripa*. Project Report. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Download ECor: http://www.worldagroforestry.org/sea/files/MetaPop001BV.zip.

36 | REDD abacus SP

Degi Harja, Sonya Dewi, Meine van Noordwijk, Andree Ekadinata, Arif Rahmanulloh and Feri Johana

REDD Abacus SP is the short name for Reducing Emissions from Deforestation and Forest Degradation Abatement Cost Curves and Simulator for Scenarios of Policies, a tool to estimate emissions from land-use and land-cover changes, which takes into account the dynamic heterogeneity of soil types, elevations, climate and other biophysical characteristics in a landscape. The tool can easily produce abatement cost curves and the resulting opportunity cost analysis of trade-offs between emission reduction and economic benefits.

Introduction

Carbon emissions' reduction and storage incentive schemes, such as the United Nations-mandated Reducing Emissions from Deforestation and Forest Degradation plus Conservation (REDD+), are part of climate-change mitigation in the agriculture, forestry and other land-uses sector. Implementing such schemes has been high on the agenda of many forest-rich developing countries. Some countries, like Indonesia, have made specific emissions-reduction commitments. As the mechanism takes shape, the question of how to relate national commitments to local contexts and effective implementation is more important than ever. Implementation at the sub-national level needs to be equipped with an appropriate planning platform. The platform must allow development of a multiple stakeholder decision-making process to establish land-use plans for sustainable development, which can reduce greenhouse gas emissions from land-based activity while simultaneously maintaining economic growth.

REDD Abacus SP can assist such a platform by simulating emissions-reduction scenarios within specific zones or across an entire landscape in order to produce ex ante emissions-reduction and opportunity-cost forecasts. REDD Abacus SP is one suite of tools that can analyze emission-related components, including historical and projected emissions and economic trade-offs. In REDD Abacus SP, intermediate and final results are easily extracted so that the process is not a 'black box' and information can easily be traced. The tool uses Java programming language and can be run in any operating system (Windows, Mac, Linux etc). The user interfaces can be easily translated into other languages.

Objectives

- Estimate emissions from land-use and land-cover changes allowing for dynamic heterogeneity of soil types, elevations, climate and other biophysical characteristics in the landscape.
- Analyze trade-offs between emissions and financial gain (opportunity-cost analysis) and produce abatement cost curves to project ex-ante emissions and financial gain of business-as-usual scenarios for setting the reference emission level.
- Simulate zone-specific policies and other emissions-reduction scenarios within landscapes and estimate the potential reductions and opportunity costs.

- Project ex-ante emissions and financial gain of business-as-usual scenarios for setting the reference emission level.

REDD Abacus SP can serve as the main tool for

- developing land-use plans for low-emissions development strategies at provincial or district levels;
- assessing carbon efficiency of a large-scale, land-based enterprise; and
- estimating the abatement cost of emissions from land-use and land-cover changes at a regional level.

Steps

The tool performs four steps.

1. Converts differences in carbon stocks into estimated emissions.
2. Constructs a table of opportunity costs for every type of land-use change from the differences in net present value and carbon stocks.
3. Determines the actual emissions for each cell in the matrix from the area involved and the emissions per unit area.
4. Presents the cumulative emissions total after sorting by opportunity cost.

Together these four steps lead to a two-dimensional graph charting the opportunity costs of avoiding deforesting land-use changes against the volume of carbon-dioxide equivalent emissions.

REDD Abacus SP requires four types of data.

1. A legend that represents land-use changes from the perspectives of economic ('land use') and carbon storage ('land cover') and which allows land-use change data to be compiled by a combination of land-cover-change detection and economic constraints (for example, labour requirements in relation to human population density).
2. Typical carbon-stock data for each legend unit (RaCSA).

   Net present value for each land-use type, typically using private or social accounting (LUPA).
3. A matrix of land-use-change values, which are internally consistent and represent either historical change or a forward-looking scenario (ALUCT).

Example of application

REDD Abacus SP has been used extensively within LUWES activity. It was applied in Tanjung Jabung Barat district, Jambi province, Indonesia, to estimate opportunity-cost curves during the periods 1990–2000, 2000-2005 and 2005-2009 (figures 36.1–3). Using the threshold of USD 5 as the potential price of 1 ton CO_2 equivalent, the curves showed how much emissions could have been compensated or abated. During 1990–2000 (Figure 36.1), emissions below the threshold of USD 5 were 4.49 ton CO_2e/ha/year and increased to 10.28 ton CO_2e/ha/year for 2000–2005 (Figure 36.2) . The increase of eligible emissions demonstrates the higher emissions from conversion to lower net present value land uses. During 2005–2009, the amount of emissions below the USD 5 threshold decreased slightly to 9.53 ton CO_2e/ha/year (Figure 36.3). From the total annual emissions, the proportion of emissions that could have been avoided in Tanjung Jabung Barat district increased over the period of analysis. For 1990–2000, the proportion was 42%, for 2000–2005 it was 58% and for 2005–2009 the proportion was 64%. These increasing figures demonstrate that emissions reduction efforts could have been successful. A higher proportion of emissions could have been avoided with a similar price of carbon. This also shows potential for future emissions reduction in Tanjung Jabung Barat district.

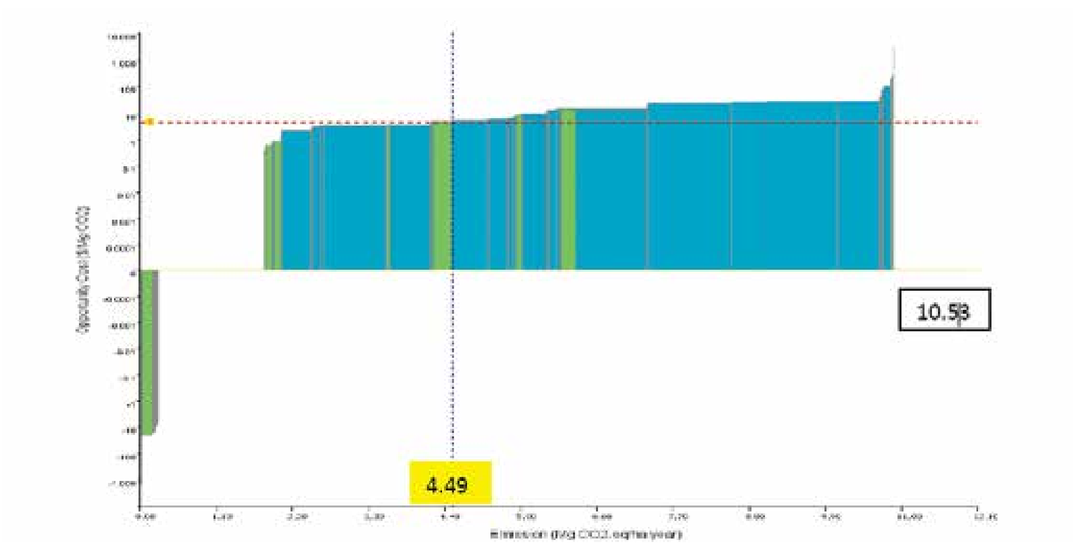


Figure 36.1. Opportunity-cost curve for Tanjung Jabung Barat, 1990–2000

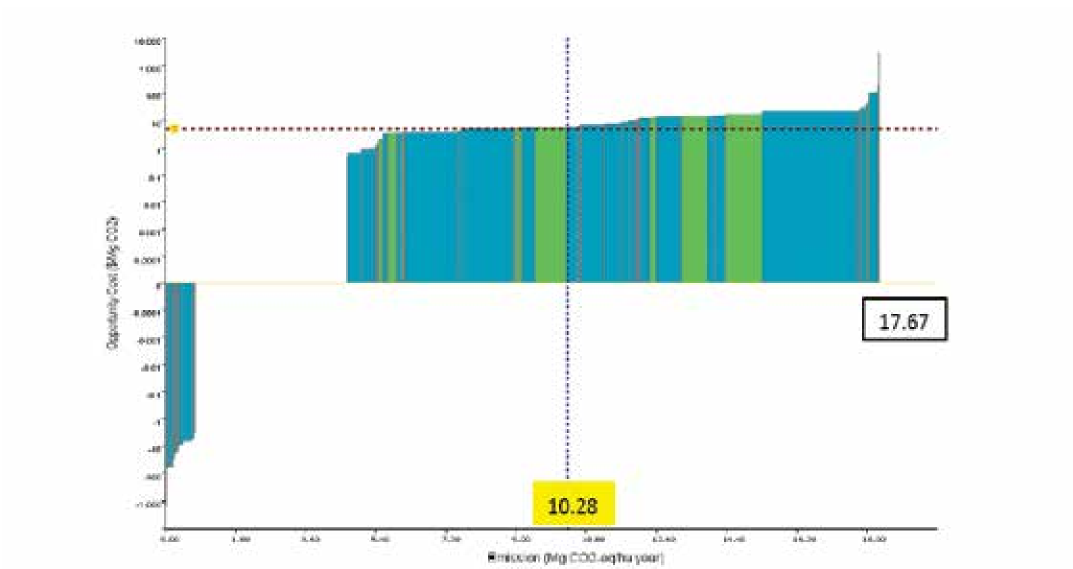


Figure 36.2. Opportunity-cost curve for Tanjung Jabung Barat, 2000–2005

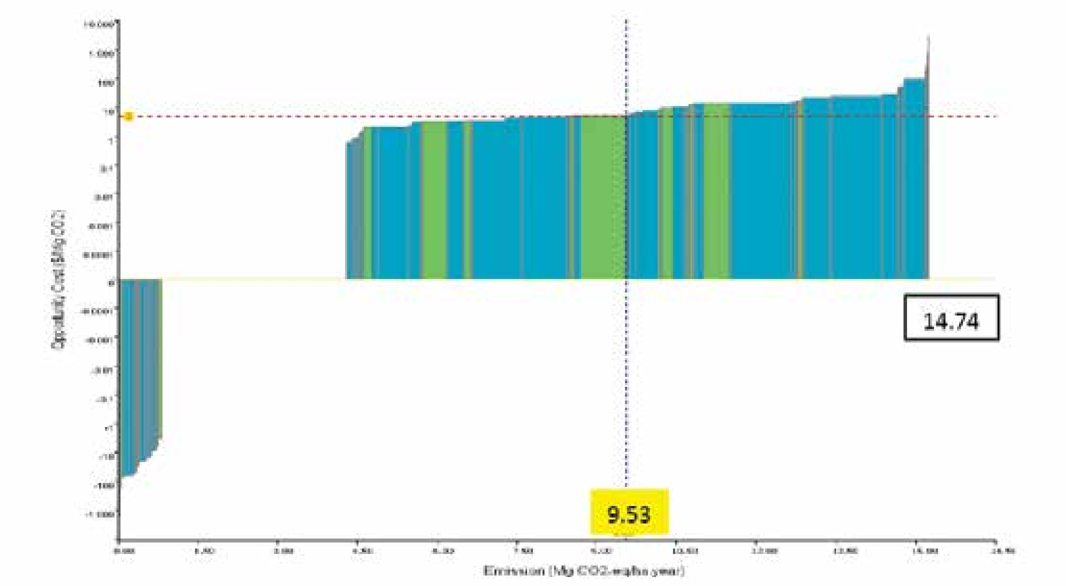


Figure 36.3. Opportunity-cost curve for Tanjung Jabung Barat, 2005–2009

Key references

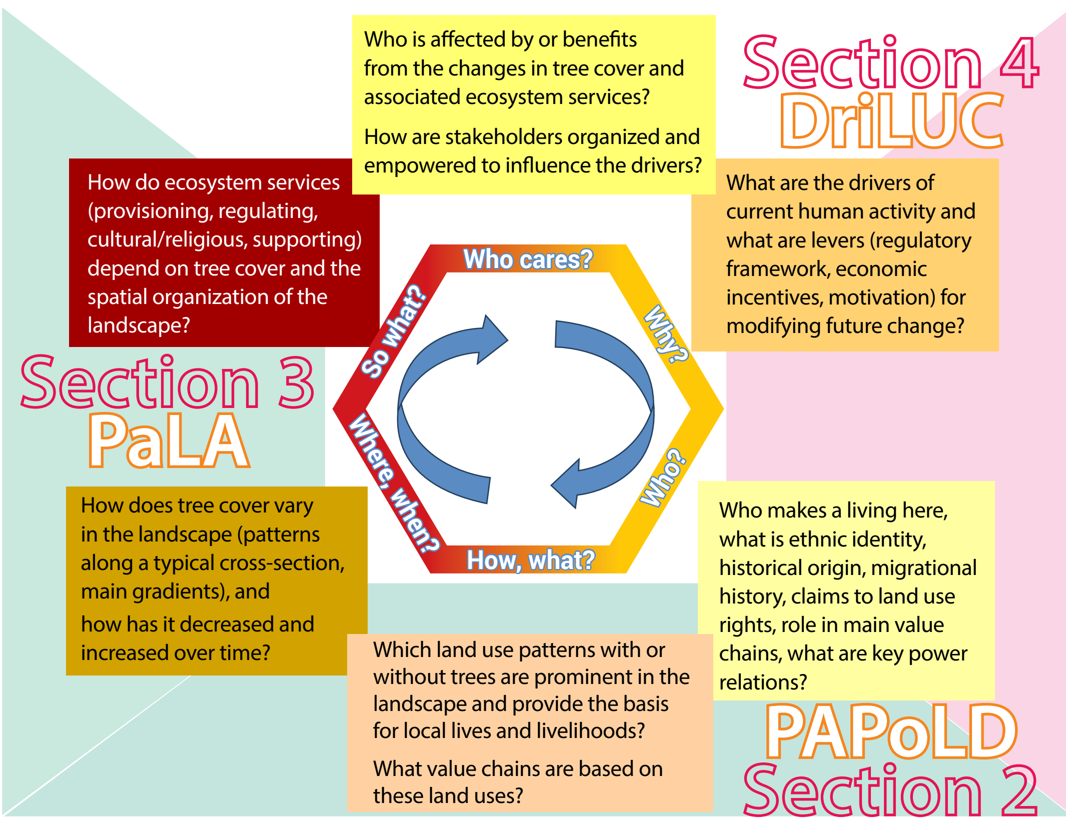
Harja D,Dewi S, van Noordwijk M, Ekadinata A, Rahmanulloh A. 2011. *REDD Abacus SP: User Manual and Software*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Widayati A, Suyanto S, van Noordwijk M. 2011. *Towards reduced emissions in a high-stake district. REALU project design for Tanjung Jabung Barat (Tanjabar), Jambi, Indonesia.* Version 2.0. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Tool download: http://worldagroforestrycentre.org/regions/southeast_asia/resources/redd-abacus-sp

SECTION 04

Transformations: governance, rights



37 Rapid land tenure assessment (RaTA): understanding land tenure conflicts

Gamma Galudra, Martua Sirait and Ujjwal Pradhan

Rapid Land Tenure Assessment (RaTA) delves deeply into the nature of competing claims over land-use rights and access among stakeholders who hold different rights and interests. RaTA clarifies the institutions and rules governing the management of natural resources and analyses the links between various claims and customary land laws and policies. RaTA seeks policy options and interventions to resolve land conflicts.

Introduction: land access: rights, conflicts and cooperation

Deforestation, forest fire, illegal logging and land conflicts with indigenous people are often major problems in forest management. These problems are associated with land tenure, mostly stemming from a lack of clarity, legitimacy and legality of land tenure policies (Box 37.1), which leads to competing claims of access to, and use rights over, forests. 'Legality' refers to alignment with constitutional rights and principles while 'legitimacy' refers to the full involvement of stakeholders in discussions and legal reform. Land tenure conflicts often arise from the different understanding that people have about their rights over forestland and resources; these claims of rights often arise from the evolution of land tenure policies.

We have identified ten sources of competing claims over land tenure.

1. The historical transformation of governance from local communities to colonial rule, which mixed support for local rulers and external control of the economic and political interests of the state, to integration in a unified state with formal law, which has left a patchwork of claimants to rights over various part of the landscape.
2. The duality of tenure systems between formal state laws (incompletely understood and implemented) versus informal or customary claims, which are largely unresolved.
3. Lack of recognition of customary and informal rights in government development projects.
4. Unclear land registry records leading to multiple possession of titles for the same land.
5. Land border disputes owing to unclear ownership or management status or different understandings of land ownership.
6. Overlapping rights of different parties over the same land owing to differing objectives, interests and jurisdictions of various government departments or under different legal regimes.
7. Increased commercial agricultural and extensive land use leading to competition over land access.
8. Inequality in land access, associated with extreme poverty and vanishing opportunities, causing fierce competition for land.

9. Migration to areas with established communities and land tenure systems, leading to conflict and misunderstanding over the rules of access to land and exposure to local entrepreneurs who sell non-legitimate claims to land.
10. Displacement and return of populations caused by conflicts, war or forced resettlement by governments.

RaTA engages with a range of such issues.

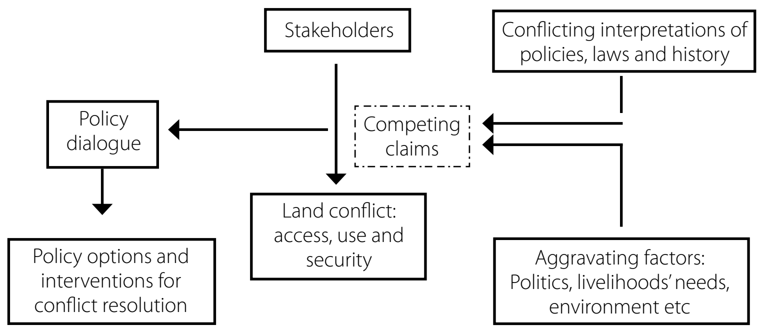


Figure 37.1. Analytical framework for RaTA

Objectives

RaTA aims to reveal the competing historical and legal land tenure claims among stakeholders holding different rights and interests. Five actions are required to resolve land tenure conflicts: 1) exploring the reasons for the conflict; 2) stakeholder analysis; 3) addressing various forms of perceived historical and legal claims; 4) linking these claims to policy and (customary) land laws; and 5) adopting mechanisms for conflict resolution (see Table 37.1).

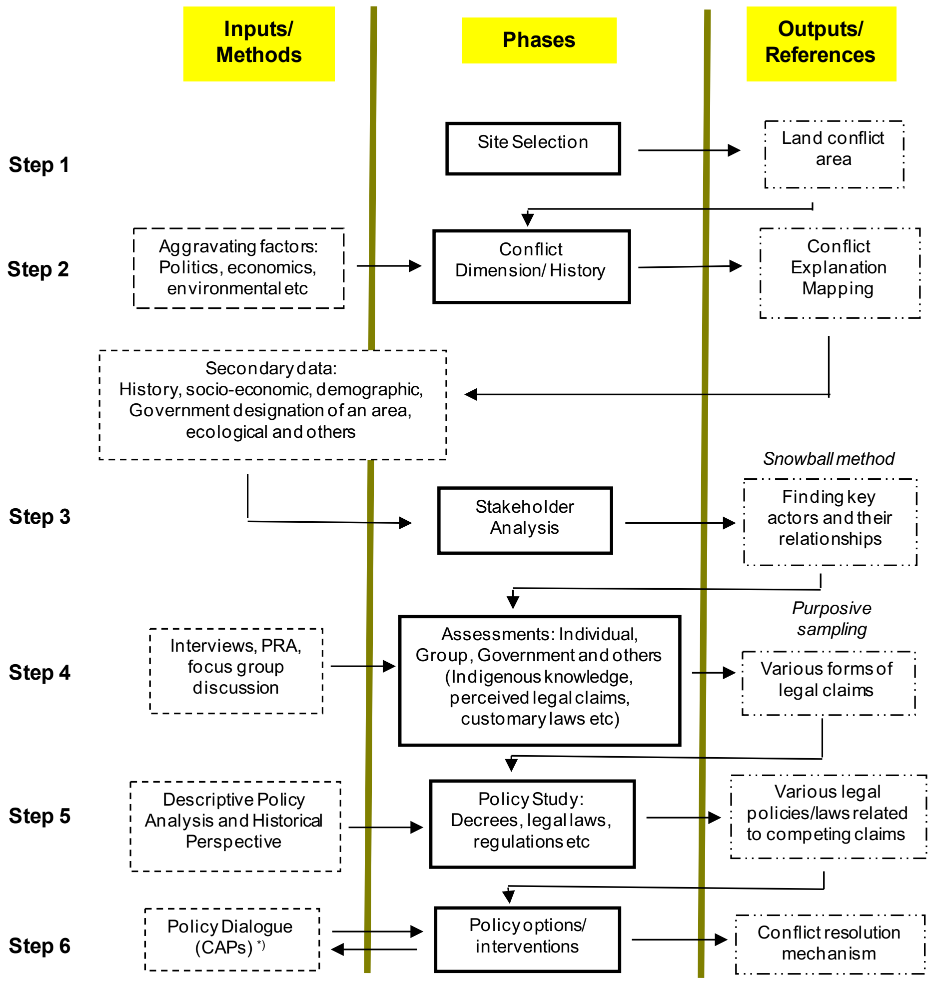
Table 37.1 Aims and questions in the various steps of RaTA

	Aims	Questions
Step 1	Explore the reasons for the land conflict and their links to the political, economic and environmental context.	Where are the main conflicts? When did these conflicts begin? How did they begin? What are the driving factors that led to the conflicts?
Step 2	Identify and analyse stakeholders.	Which actors are directly involved or have influence in this conflict? How do these stakeholders interact and relate to each other? What are the land tenure conflicts genuinely about?
Step 3	Identify perceived historical and legal claims by stakeholders.	What types of evidence do stakeholders use or are considered acceptable to prove their claims? Do they believe their land interests and rights are enforceable? Do they know of any legal organizations that are protecting their interests?
Step 4	Identify the institutions and rules governing the management of natural resources and analyse the links between various claims and customary land laws and policies.	What are the customary laws and policies governing land and property matters? Do rights holders have the support of existing policies? Are there any contradictory policies and legislation?

	Aims	Questions
Step 5	Determine policy options and interventions for conflict resolution.	Are there any existing policies governing the management or resolution of land disputes? What types of conflict need to be addressed? What level of intervention is required?

As an analytical framework (see Figure 37.1), RaTA offers guidance on the important things that policy-makers/mediators need to consider when developing conflict-resolution mechanisms. RaTA consists of six steps (see Figure 37.2). Different techniques, participatory rural appraisal, stakeholder analysis and the establishment of legal policies and laws are among the methods that have been taken account of in the different phases of RaTA.

Steps



*) CAPs: Collaborative Analytical, Problem-Solving Process or Approach

Case study: RaTA in the misty mountain of Halimun Salak: a confusion of legal rights from multiple historic claims

An area covering 113 357 hectares on Mount Halimun-Salak in Indonesia was declared a national park in 2003 owing to the richness of its forest ecosystems and hydrological functions. Signposts for the national park were placed near its boundaries, which caused much concern among the people who claimed to have traditional access rights to the land. The dispute was not only between the national park authorities and the local communities but also with the district government of Lebak, which claimed about 15 000 hectares of national park land for mining operations, estate-crop plantations and infrastructure development.

According to interviews, legal documents and policy analyses, the claims by the national park authority were based on gazettal and delineation processes during the Dutch colonial period and the 1950s, 1970s and 1980s. Only 11 000 hectares of 128 000 hectares of designated land had not yet been gazetted and delineated; the rest was legally protected.

Nevertheless, local people had claims to the land based on history, livelihoods and traditional legality. Starting in the 1920s, the designated land was used by local people for shifting cultivation until the Dutch colonial government declared it state land. Since that time, the government had rejected local claims over the land.

In addition to historical claims, some people also had land ownership certificates, which were issued by the National Land Agency in the 1960s as part of national land reform. Others viewed their dependence on the land for livelihoods as proof of their legal claim. To understand the conflicting claims, RaTA used participatory rural appraisal tools in four villages in the national park area. It found that a very large proportion (70%) of the livelihoods of local people depended upon their access to the national park, a reason why they defended their claims so strongly.

The district government of Lebak also had claims to the area based on historic and legal interpretations. The area had been controlled by a state mining company since 1958 under Government Regulation no. 91 of 1961. This law did not mention a state forest zone and, therefore, it was considered that the land was under the control of the state but not as a state forest zone. Based on RaTA's findings, it seemed clear that unless these differences in both claims and policy interpretation were resolved and the needs and interests of all stakeholders were accommodated, conflicts were likely that would jeopardize the rich biodiversity in the park.

Key reference

Galudra G, Sirait MT, Pasya G, Fay CC, Suyanto S, van Noordwijk M, Pradhan U. 2010. *RaTA: a rapid land tenure assessment manual for identifying the nature of land tenure conflicts*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

38 | Why No Tree? (WNoTree) Analysis of agroforestry constraints

Meine van Noordwijk, Endri Martini and Suyanto

A Why No Tree? (WNoTree) analysis examines five constraints to a re-greening revolution based on agroforestry.

1. Property rights linked to land tenure and land-use restrictions.
2. Lack of access to high quality planting material of proven suitability.
3. Inadequate management skills and information often constrain production for high market values.
4. Over-regulation often restricts access to markets for farmer-grown timber and tree products, partly due to rules intended to curb illegal logging in natural forests or government plantations.
5. Lack of reward mechanisms for the environmental services provided by agroforestry and/or high discount rate and lack of investment.

Introduction

Agroforestry provides productive and protective forest functions, such as sheltering biological diversity, keeping ecosystems healthy, protecting soil and water resources and storing carbon. Yet, the trees planted in agroforestry systems are excluded from formal definitions of 'forest' and are often overlooked in legal and institutional frameworks for sustainable forest management.

The relationship between agroforestry and plantation forestry can be complementary, neutral or competitive depending on the effectiveness of policies supporting forest functions. Substantial government subsidies favouring large-scale plantations reduces the capacity of agroforestry to provide ecological benefits and services (Figure 38.1).

Objectives

WNoTree surveys generally have three objectives.

1. To identify the most significant constraints to tree management and domestication (including planting and harvesting) in the local context through focus-group discussions with farmers and local government agencies.
2. To test the hypotheses that emerge from these consultations, in combination with spatial analyses of actual tree presence in the landscape, through follow-up surveys.
3. To address the primary constraints and test the preceding analysis by enaging in action research with local communities and governments.

Steps

1: Checklist of issues to pursue in focus-group discussions

LAND TENURE AND LAND-USE RESTRICTIONS

- Physical or economic access to land for tree planting is linked to use rights over tree products; a lack of clarity on future use rights stops farmers from planting trees.
- Conflicts over land may enhance the use of fire in the landscape and/or create a reluctance to protect trees that are not bringing direct benefits.

LACK OF ACCESS TO HIGH QUALITY PLANTING MATERIAL OF PROVEN SUITABILITY

- Inadequate high-quality planting stock adapted to soil, climate, pests and disease, intercropping systems, local preferences and markets.
- Poor delivery mechanisms for high-quality planting material.

MANAGEMENT SKILL AND INFORMATION OFTEN CONSTRAIN PRODUCTION FOR HIGH MARKET VALUES

- Underperforming trees due to drought, floods, grazing animals, pests, diseases, suboptimal thinning and pruning.
- Lack of knowledge, labour or inputs for managing tree growth in intercropping or on monoculture plantations.

OVER-REGULATION OFTEN RESTRICTS ACCESS TO MARKETS FOR FARMER-GROWN TIMBER AND TREE PRODUCTS, partly due to rules intended to curb illegal logging from natural forests or government plantations

- Lack of local demand and/or physical and institutional access to markets for tree products.
- High transaction costs (permits, formal and informal taxes) for harvesting trees and tree products.

LACK OF REWARD MECHANISMS FOR THE ENVIRONMENTAL SERVICES PROVIDED BY AGROFORESTRY

- Lack of perception and appreciation of non-economic or cultural benefits.
- High opportunity costs: treeless land-use options are more profitable than tree-based ones; in fact this may be the only 'economically valid' reason for a lack of trees in a landscape unless high discount rates and lack of investment are the primary hurdles to otherwise profitable tree-based land use.

An example of WNOTree analyses for Indonesia and the Philippines is provided in Roshetko et al 2008 and van Noordwijk et al 2008.

2: Detailed surveys to test hypotheses generated in Step 1

Box 38.1. Analyzing underlying causes of fire

After the 1997/1998 forest fires in Indonesia, a rapid analysis suggested that 'fire as a tool' and 'fire as a weapon' were major reasons behind the conflagrations (Tomich et al 1998a). Subsequent research tested these hypotheses and documented location-specific causes (Chokkalingam et al 2005, Suyanto 2005). One of the case studies, which studied the fires in Trimulyo, West Lampung (Suyanto et al 2004), found that, even with the use of military force, forest policy and management had largely failed to protect forest resources when local communities were not involved. The burn scar pattern in 1994 was similar to the burn scars in 1997; both scars were very large and contiguous. A major reason for the 1997 fires had been tenure conflicts: fires had been intentionally caused by discontented villagers as revenge for government efforts to relocate them. Since then, the area had been an unproductive grassland (*Imperata cylindrica*) that was prone to annual fires. The analysis suggested that providing more secure land rights through which livelihoods' expectations could be realized could lead to more sustainable land management by local communities. Subsequent experience has confirmed this hypothesis. Burn scars became small, indicating fire control.

3. Action research engagement to address constraints

Box 38.2. Lessons learnt from national tree-planting campaigns

The Indonesian movement for forest restoration and tree planting, *Gerhan*, has provided substantial funding for tree planting in areas identified as 'critical land'. Implicit in the program design has been the recognition that the lack of trees derives from a lack of availability of tree seedlings and other planting material. The limited success rate for tree survival and establishment suggests that other reasons for the lack of trees in the landscape are at least as important. The success rate for tree planting under conditions where land tenure and future benefit flows are clear is substantially higher than in conditions where the trees are seen either as public or as a government controlled good on land that has multiple claims of ownership and use rights.

Box 38.3. Experience in stability of a forest–village gradient in Batang Toru

Positive incentives for appropriate land management are needed to counter incentives for damaging the landscape. Working with community members and other local partners to develop new ways for them to earn income without disturbing the forest or its inhabitants may provide a win-win solution in the orangutan conservation program in Batang Toru, Indonesia. Results of surveys by the World Agroforestry Centre and Winrock International identified a number of non-timber forest products that were produced in Batang Toru which have the potential to diversify and secure viable livelihoods in a landscape with orangutans and other biodiversity. In all the land-use systems (mixed tree gardens, agroforests and natural forests), planning and management are limited. Improving crop management and developing market links could benefit the productivity, profitability and sustainability of these systems. Community strategies were developed to provide technical approaches that enhanced the productivity and/or profitability of non-timber forest products in agroforestry systems while protecting orangutan habitats and helping the communities to market those products. A series of training events built the farmers' capacity to manage their agroforests in more productive, market-oriented and environmentally friendly ways (Martini et al 2008, Roshetko et al 2007).

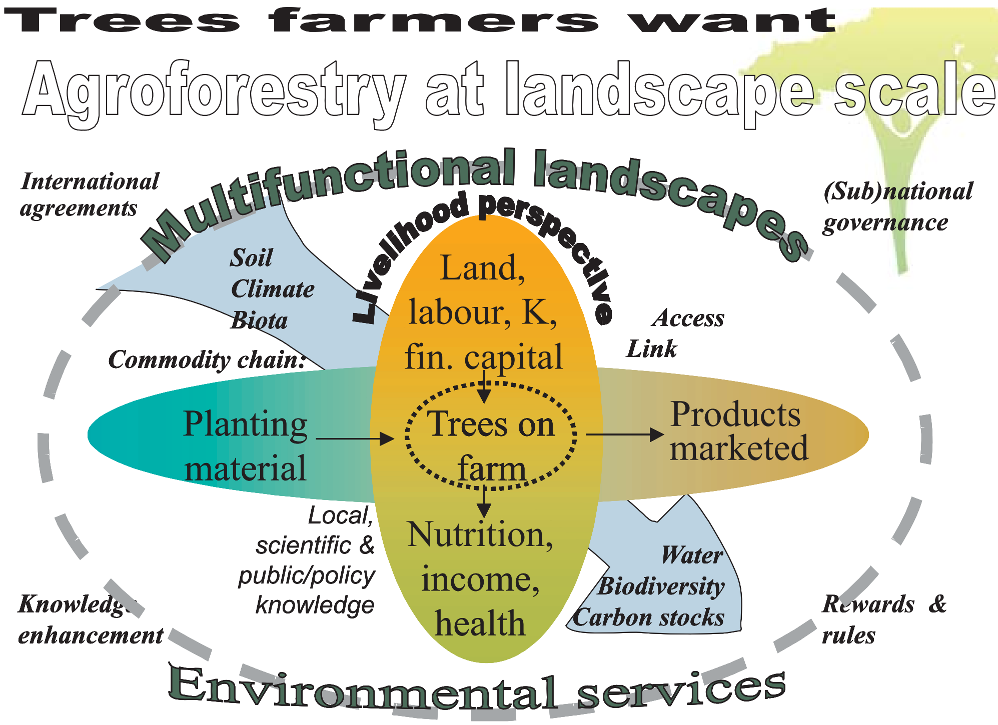


Figure 38.1. Interrelationships in a landscape that bear on farmer's decisions to manage trees or not

Barrier analysis

In technical terms the WNoTree protocol clarifies the 'barriers' that an external support project can address in forms of the Clean Development Mechanism of the United Nations. Removing a barrier provides for 'additionality' of landscape carbon stocks.

Key reference

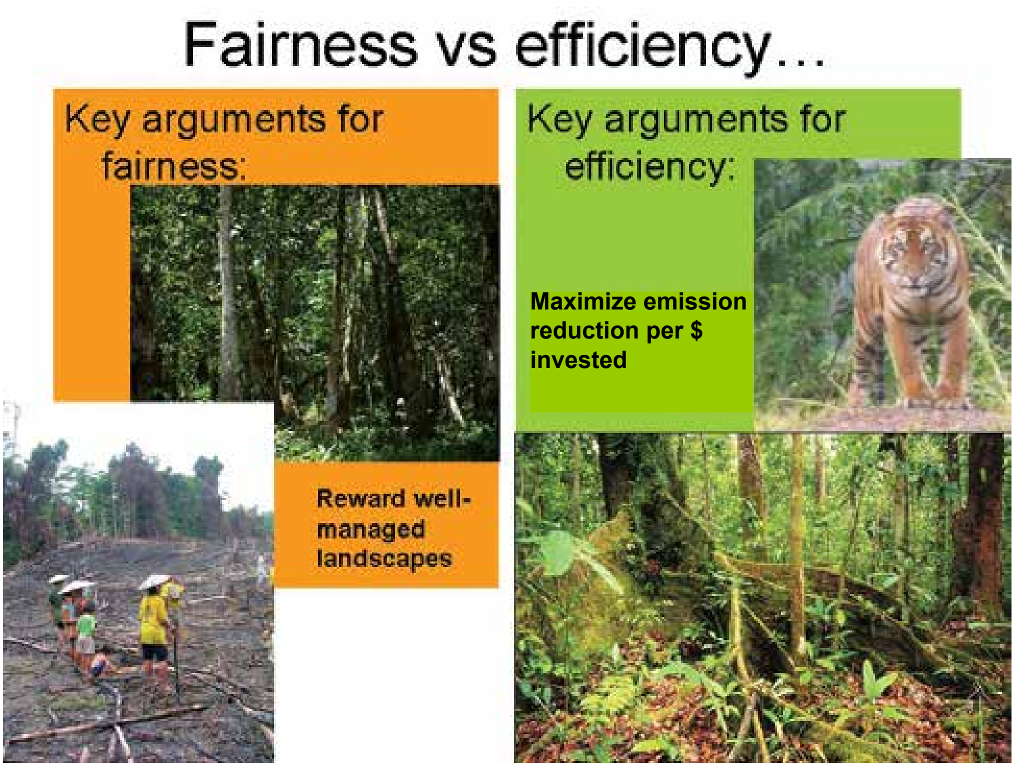
Roshetko JM, Snelder DJ, Lasco RD, van Noordwijk M. 2008. Future challenge: a paradigm shift in the forestry sector. In: Snelder DJ, Lasco RD, eds. *Smallholder tree growing for rural development and environmental services*. New York, USA: Springer Science and Business Media. p. 453–485. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=2044.

39 | Fair and efficient REDD value chains allocation (FERVA)

Meine van Noordwijk, Suyanto and Sandra Velarde

Fair and Efficient REDD Value Chains Allocation (FERVA) is based on focus-group discussions with different stakeholder groups to combine efficiency and fairness principles in reducing emissions from deforestation, peat land and forest degradation, and other land-use changes in developing countries.

Reducing emissions from deforestation and forest degradation (REDD) is a United Nations-backed mechanism that uses market incentives to reduce greenhouse gas emissions. Combining efficiency and fairness principles is a major challenge for REDD efforts in developing countries. Successfully reducing emissions while also stimulating the creation of sustainable livelihoods and development pathways requires the right combination of policy instruments and the ability to find a middle ground among stakeholders. The FERVA method was designed to help with this process.



Typical arguments for fairness		Typical arguments for efficiency	
1.	Moral imperative: the people that effectively guard the forests in their landscapes deserve rewards	1.	Maximize CO_2 emissions reduction per dollar invested; focus on real threats only
2.	Poverty reduction as a key Millennium Development Goal, mandates a pro-poor approach	2.	Markets seek the 'right' price, if protected from monopolies
3.	Avoid perverse emission- enhancing incentives by rewarding forest destruction	3.	We need to show success in emissions reduction to maintain public support
4.	Respect for the traditional practices of local communities	4.	Use local institutions and resources

Figure 39.1. Key arguments for fairness and efficiency

Objectives

- To highlight arguments between fairness and efficiency in reducing emissions from the land-based sector.
- To capture different perceptions from stakeholders of fair and efficient value chains.

Steps

FERVA is based on focus-group discussions with different stakeholder groups. The approach should be adapted to suit the local context.

Participants are given an introduction to climate change and the role of greenhouse gases. Roughly 90% of emissions stem from use of fossil fuels and the remaining 20% from the loss of forest and peatland carbon stocks. Depending on the stakeholders' degree of exposure to carbon markets and their expectations of easy money, the audience may recognise itself in one of the stages of the ignorance/hype/crash/reality cycle (Figure 39.2). At this stage, we do not know for whom the reality stage will have negative, neutral or positive consequences.

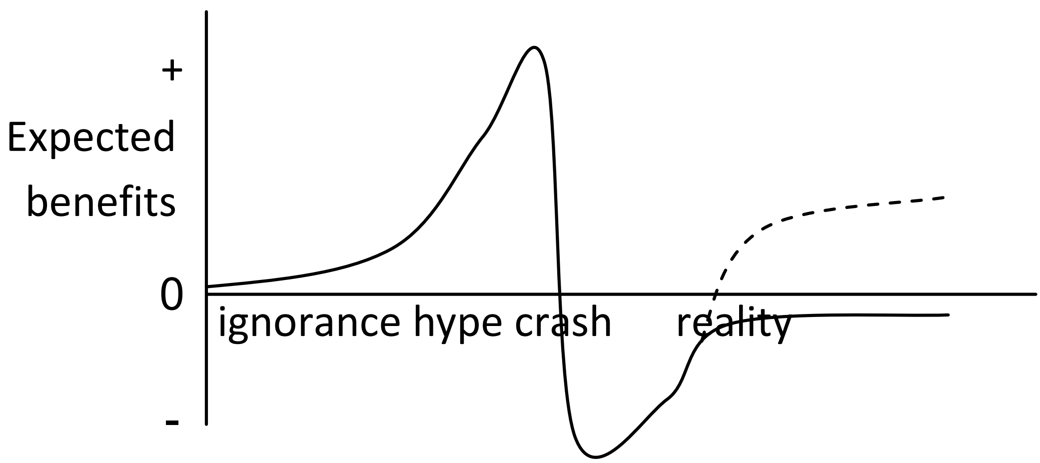


Figure 39.2. Stages of a hope-hype-crash-reality cycle in expected benefits from new options

1. Once the local context and data on land-use changes have been clarified, the discussion can focus on opportunities for reducing emissions in areas that have a track record of high emissions as well as on the usefulness of providing positive incentives for long-term forest and peatland conservation. The stakeholders can be split into two groups and a debating club format can be used to tease out the arguments for efficiency and fairness.
2. Next, the concept of a value chain can be introduced, using the example of a local agricultural commodity (for example, coffee, rubber or timber). The different steps in the chain add value from the perspective of the end user but the share of the net benefits that they receive may be disproportionate to the effort they put in. We can identify at least eight functions that need to be fulfilled before an end user will be willing to buy a unit of certified emission reduction (named' 1 CREDD' or otherwise). Depending on the local context, the discussion can focus on which parts of this value chain already exist.
3. A major test of how the fairness plus efficiency issue is handled is how the benefits—the difference in price between legitimate opportunity costs for current CO_2 emitters and the going price for certified emission reductions—will be shared along the value chain. The fourth step of FERVA involves asking participants to allocate 100 units of value over the eight steps of the value chain identified in Step 3 (Table 39.1). This can be done by distributing 100 beans, pebbles or other items into eight bowls. Participants can be asked to do this twice: the first time to show what they expect to happen (based on their experiences with other mechanisms) and the second time to show what they would consider to be a desirable outcome.

Table 39.1. Eight functions required for reducing emissions from deforestation and degradation in developing countries and the way stakeholders see benefits allocated along the value chain

	Current situation: reality	Desirable situation: hope	Difference
1. Actual emission reduction by protecting existing carbon stocks and off-setting legitimate opportunity costs for options foregone voluntarily			
2. Support sustainable livelihoods' pathways with less dependence on land use that results in emissions			
3. Guarding against leakage through integrated natural resource management at the local scale			
4. Securing additionality through clear baselines developed as a result of spatial planning			
5. Certifying credits for emissions reduction by national standards			
6. Setting up conducive regulatory frameworks for multiscale governance			
7. Verifying emissions reduction by international standards			
8. Securing buyers for carbon credits and providing investment when and where needed			
Total	100	100	

FERVA sample results

Figure 39.2, below, shows the results obtained during a workshop with environmental NGOs and government agencies interested in developing forest conservation projects within a REDD context.

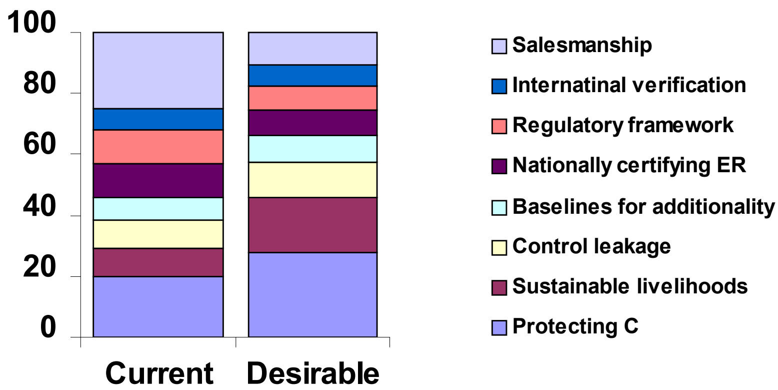


Figure 39.2. Example of result from focus-group dicussions with environmental NGOs and government agencies of fair value chains of REDD

In the lead-up to the 13th Conference of Parties of the United Nations Framework Convention on Climate Change in December 2007, in Bali, a group of national and international researchers of the Indonesian Forest Climate Alliance (IFCA) expressed the hope that transaction costs (categories 3–8 listed in Table 39.1) could be kept to less than one-third of the value chain and that the efforts would otherwise be split between direct emission reduction (efficiency) (category 1) and long-term livelihoods' options (fairness) (category 2) (Figure 39.3).

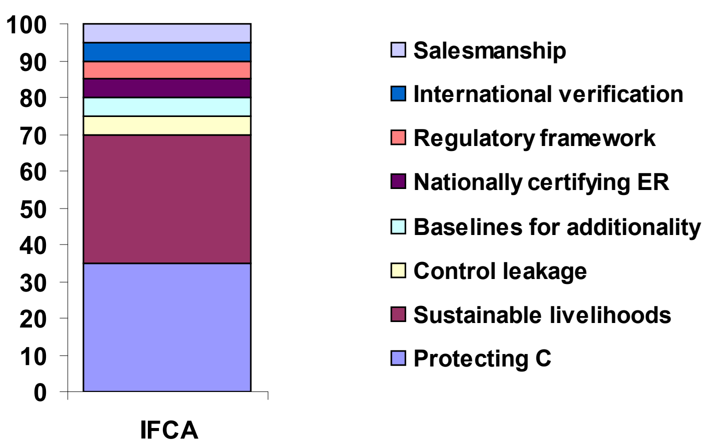


Figure 39.3. Results of the application of FERVA with national and international researchers of IFCA

We are interested in compiling the results of FERVA discussions with different stakeholder groups, and would like to receive reports on FERVA exercises carried out in different countries and contexts.

■ Key references

Van Noordwijk M, Dewi S, Swallow BM, Purnomo H, Murdiyarso D. 2007. *Avoided deforestation with sustainable benefits (ADSB) in Indonesia*. 1. Policy research brief. Avoided. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

40 | Rapid assessment of institutional strengths, networks and actors (RISNA)

Retno Maryani, Gamma Galudra, Reny Juita and Ujjwal Pradhan

Rapid Assessment of Institutional Strengths, Networks and Actors (RISNA) assesses the capacity of local institutions to respond to changes and opportunities in their external environment, including policy changes at higher levels. Identification of authorities to make decisions to adapt and change, and of existing modifiable rules for benefit distribution and conflict resolution are particular foci of RISNA.

Introduction

The ongoing degradation of natural resources cannot be solved by a purely technical approach. Efficient and fair governance is a prerequisite for sustainable natural resource management. Assessment of institutional capacity offers a comprehensive and holistic perspective on likely achievement of Sustainable Development Goals.

There are success stories of sustainable resource management by adaptive traditional rules, as well as evidence of landscape degradation when external exploitation overrides local institutions. Under globalized economies, local institutions face challenges from outside (exogenous) as well as from within the institution itself (endogenous). Changes in the political, economic and social contexts influence institutional strategies in the use of natural resources. Broad and dynamic social networks have been built by actors through coalition or cooperation with various parties for exploitation of natural resources.

It is imperative for institutions that are in charge of natural resource management to be responsive and adaptive to the changing environment and needs. To analyze the capacity to respond and adapt, it is necessary to understand institutional structures and components, the locus of decision-making authority regarding the use of natural resources, benefit distribution and conflict resolution. Furthermore, strategies of the institutions to deal with the dynamic environment need to be identified and assessed.

Objectives

1. Identify strengths and weaknesses of existing local institutions in charge of natural resource management to face policies and environmental changes;
2. Identify particular structures and components within the institutions that should be strengthened to increase agilities in conserving and managing natural resources;
3. Provide tools for policy-makers that can be used to determine the capacity of an institution

Steps

1. Rapid assessment of changes in the landscape and environmental services (water, biodiversity, forest and land) and the drivers of changes. Choice of tools: RHA, RABA, DriLUC.

2. Rapid assessment of existing rules and regulations of utilization of natural resources, particularly in
   a. ownership and rights of use;
   b. sharing and distribution of benefits; and
   c. transfer of rights and ownership of the resources.
3. Gaps between formal and informal rules, as well as competing claims and conflicts over lands. RaTA method can be used here.
4. Rapid assessment of actors who use the natural resources in order to find out the role of the actors in terms of
   a. planning and using natural resources, including
      i. implementation and utilization of resources
      ii. processes in formulation and enforcing rules; and
   b. methods: stakeholder analysis, power analysis.
5. Rapid assessment of network development, in terms of cooperation and capacity building.
6. Analysis of institutional capacity to adapt and adjust to the changing environment.

Case study: RISNA in Indonesia

The village of Lubuk Beringin in Jambi province, Indonesia, is situated at the edge of the Kerinci Seblat National Park and its buffer zone. Road access was only recently developed. The main sources of livelihoods are traditional rubber agroforestry and rice production. The very first permit for a 'Hutan Desa' (village forest agreement) in Indonesia was given over a forested area of 3517 hectares of Lubuk Beringin in 2009. Under this permit, the community has the right to manage the area (Akiefnawati et al 2010), demonstrating the institutional capacity of the village, with support from NGOs and local government, to handle the administrative procedures, among other things. Since then, the Hutan Desa at Lubuk Beringin has become a showcase for various types of community-based forest management, including efforts to reduce deforestation and forest degradation (REDD).

Conflicting local and formal rules, local and formal institutions

However, the formal recognition, which aimed to strengthen and empower local institutions, appears to have undermined the informal rules and arrangements that guided local practices in managing natural resources. The rules of the Hutan Desa permit impose numerous formal procedures that are not be familiar to the villagers nor are they manageable under local conditions.

The risks and benefits associated with such interventions will benefit from an analysis of institutional strengths, network and actors. Application of RISNA aimed to increase understanding of the local institutional capacity. In so doing, it was clear that there was a complex network of customary and formal government rules at work, as outlined below.

The 'rio' (local title for the head of the village) played an important role in regulating the use of land, water and fish since customary rules were still followed by the people of the village. Disputes which resulted in the death of humans and livestock would be settled according to custom. There were 12 types of cases that were resolved under customary rule, including stabbing, killing or poisoning cattle. Law enforcement was carried out through the rio with reference to customary rules as applicable. Punishments included slaughtering a buffalo slaughter and forgiveness, all of which were entered into the village records.

A Kelembagaan Hutan Desa (KHD/Village Forest Institution) was established through mutual agreement between the Consultative Agency of Lubuk Beringin and the rio. The sub-district government approved the institution and members were directly elected by all citizens of the village. Stewardship by the chair, secretary and treasurer was exercised for 1) village forest protection; and 2) use of the village forest. Stewardship of the institution itself was under the Village Board of Trustees, which governed the use of village assets. Stewardship was valid for a period of three years, after which an open election was held.

Even though the customary institution played an important role related to social interaction and use of natural resources, the KHD still needed to increase capacity, such as through introducing an administrative model to deal with the process of forest management from planning until profit distribution. Involvement of the KHD in discussions both at the national and regional levels was necessary to increase individual capacity as well as institutional networking. Documentation and administration will be needed, especially in the negotiation process with other parties, such as other levels of government, companies, NGOs and neighbouring communities.

No later than two years after the establishment of a Hutan Desa agreement, a Village Forest Working Plan (RKHD) and Annual Plan of Forest Village (RTHD) had to be submitted in the form of documents endorsed by the district government. RKHD includes aspects of regional governance, institutional governance, business management and human resources management while the RTHD includes a boundary work plan, planting plan, maintenance, utilization and protection.

However, RISNA revealed that the boundary work plans could not be fully implemented owing to the rules on the use of government funds for boundary activity, which stated they could only be used for determining the outer boundary, which separates the non-forest area from forest. Further, it seemed that in the protected areas, the budget for works would be the responsibility of the organization that has the permit, which must be financed from the rights holders (KHD). Clarification by the Ministry of Forestry was requested by the district forestry office, however, at the time of writing there had been no concrete suggestions from the central government to resolve the problem.

Conclusion

1. Rapid assessment of the strength and weaknesses of the village forest institution provided information on the gap between the formal provisions of village forest management and its implementation.
2. The forest management regulations are unclear and give rise to debate that impedes implementation.
3. The right to manage the forest given to community is treated equally with the rights granted to large investors. It is feared that these requirements would impede the village forest scheme of achieving its intended goal of forest protection.
4. Through rapid analysis of institutional resistance, RISNA, structural problems that exist in the field can be identified.

Key reference

Akiefnawati R, Villamor GB, Zulfikar F, Budisetiawan I, Mulyoutami E, Ayat A, van Noordwijk M. 2010. Stewardship agreement to reduce emissions from deforestation and degradation (REDD): case study from Lubuk Beringin's Hutan Desa, Jambi Province, Sumatra, Indonesia. *International Forestry Review* 12:349–360.

41 | REDD/REALU site-level feasibility appraisal (RESFA)

Laxman Joshi, Meine van Noordwijk and Janudianto

REDD/REALU Site-level Feasibility Appraisal (RESFA) assesses the feasibility of dealing with the direct drivers of land-use change that reduce carbon storage and supporting sustainable livelihoods' options that are compatible with high carbon-stock landscapes with trees that provide goods and services as any of them can become a bottleneck when full project design, approval and implementation are attempted, which is a process that costs considerable time and investment and needs to have a reasonable probability of success to justify such investments.

Introduction: would a targeted effort to reduce emissions bring local livelihoods' benefits?

Land-use and land-cover changes are a relevant part (about 15%) of the total human-induced emissions of greenhouse gasses that lead to global climate change. While most of the attention has so far gone to reductions in the other 85% that relate to fossil fuels (and some other industrial processes), no opportunity to reduce emissions can be left ignored if targets are to be met, such as keeping global warming below 2 °C. Reducing land-based emissions usually requires two things: 1) dealing with the direct drivers of land-use change that reduce carbon storage, for example, through forests or conversion; and 2) supporting sustainable livelihoods' options that are compatible with high carbon-stock landscapes with trees that provide goods and services.

To get such efforts recognized, a further set of steps is needed, which we group here under monitoring, evaluation and transaction costs. Since the discussion on 'carbon markets' has started, there are high expectations that engaging in emission reductions and/or enhancing carbon storage can help provide funding for rural development. Much of that hope may be hype but there are opportunities for real benefits if intentions are genuine and projects are designed well. The international rules are still under discussion. Figure 41.1 captures the interlinked process of different actors at different levels and the meaning of CO_2 benefits to each.

Box 41.1. Any design for reducing net emissions of CO_2 and other greenhouse gasses needs to balance between

a. dealing with the local representations of drivers of land-cover change by protecting high carbon-stock density areas (effectiveness and, when expressed per unit investment, efficiency); and

b. promoting sustainable development pathways that provide livelihoods (welfare and wellbeing) at reduced net emission levels (fairness);

while linking opportunities to reduce emissions locally with those at other scales, through the concepts:

C1. Additionality (How do 'with project' emissions differ from 'without project' ones?)

C2. Leakage (How do 'within project' actions relate to 'out-of-project' emissions?)

C3. Permanence (What is the expected emissions trajectory after the project ends?)

C4. Accounting rules (How will emission reductions be quantified and verified?)

C5. Rights to co-invest and share in future net benefits, within national sovereignty to set rules

C6. Certification (clarifying local emissions reductions as part of national-scale achievements)

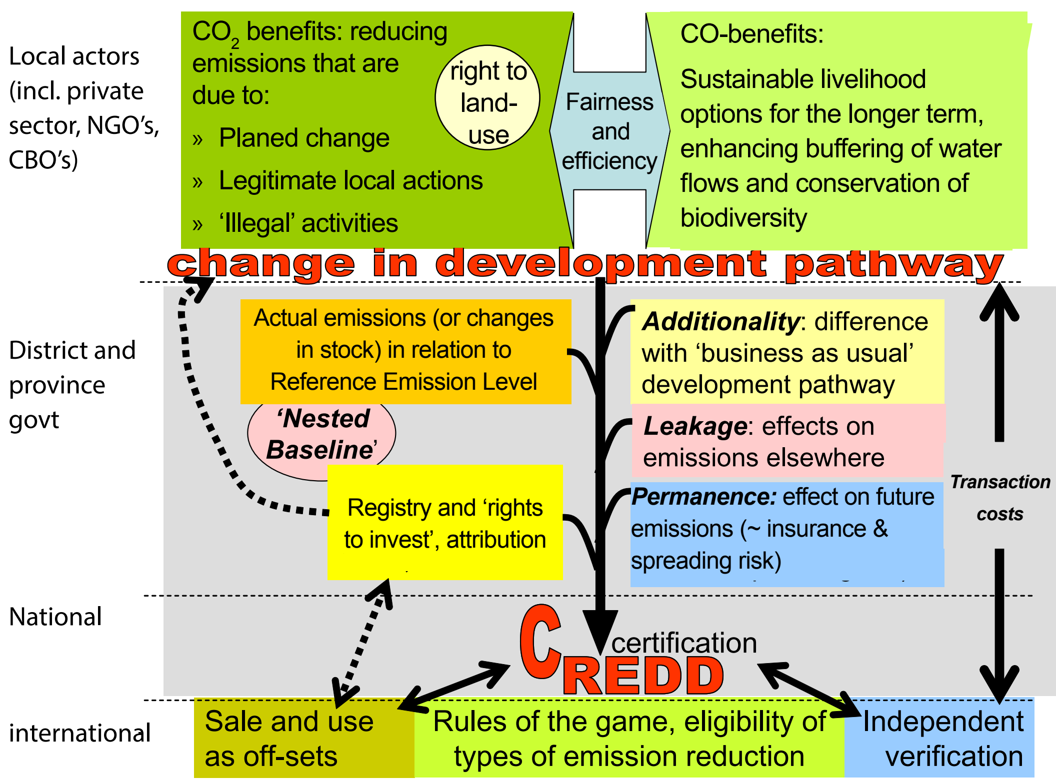


Figure 41.1. Interlinked process of multiple actors at multiple levels with multiple views of reduced CO_2 emission

Objective

RESFA integrates a number of negotiation-support tools to lead to a decision point for local communities and proponents of activities under the mechanisms for reducing emissions from deforestation and forest degradation (REDD) and reducing emissions from all land uses (REALU), answering 1) Is it worthwhile to pursue a project to reduce net emissions from land use (including forest) for this area or will it be too complex, too costly or low in co-benefit returns? 2)If so, what directions can best be pursued in project design?

Steps, key questions and tools in the assessment

1. What is the current carbon stock of the system? What other environmental services does the system provide?
2. RaCSA to provide protocols for carbon-stock assessment in the landscape

   What are the driving factors and threats that lead to reduction in carbon stocks (increase in carbon emissions)?
3. DriLUC to analyze the local drivers of land-use change, linked to analysis of actual time-series of land cover (ALUCT)
4. What is the dependency of local people on the system?
5. WNoTree, RAFT and PAPoLD can be combined to explore current land-use options within a livelihoods' perspective (which includes in- and out-migration and off-farm employment)
6. How clear are the tenure arrangements?
7. RaTA to analyze the tenure claims and history of policies that gave rise to claims and conflicts about them
8. What are the possible scenarios and what is the potential carbon stock increase or decrease under these scenarios?
9. Scenario models (either TALaS based on FALLOW or LUWES using ABACUS can explore business-as-usual trends and scenarios that are within (or just beyond) the 'plausible' domain for with/without project developments
10. What are the implications of these scenarios on livelihoods, institutions and equity? What are the opportunity costs, both financial and social? What about additionality, leakage and permanence issues?
11. How can the benefits of REDD/REALU be shared or distributed equitably? Who will benefit and who will suffer?
12. FERVA can analyze the perceptions on fairness and efficiency, within the institutional setting and emerging rules for investment in emission reduction ('carbon markets')

Decision point: 1) is it worthwhile to pursue a project to reduce net emissions from land use (incl. forest) for this area, or will it be too complex, too costly or low in co-benefit returns? **2)** if so, what directions can best be pursued in project design?

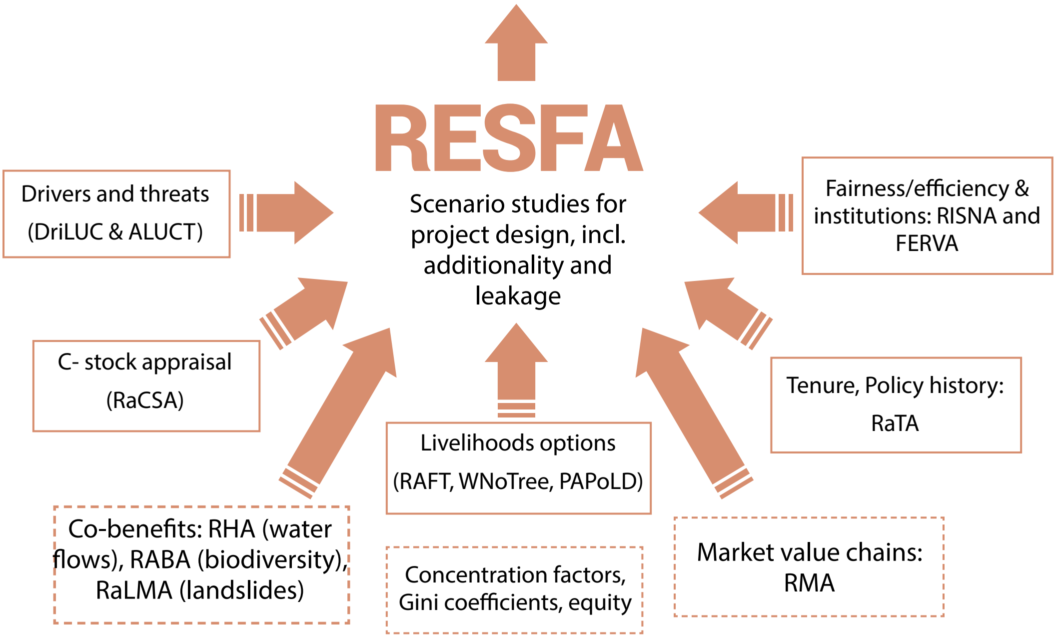


Figure 41.2. RESFA scheme, comprised of steps and applications of available tools

■ For example of application see:

Joshi L, Janudianto, van Noordwijk M, Pradhan UP. 2010. *Investment in carbon stocks in the eastern buffer zone of Lamandau River Wildlife Reserve, Central Kalimantan province, Indonesia: a REDD+ feasibility study.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://worldagroforestrycentre.org/regions/southeast_asia/publications?do=view_pub_detail&pub_no=RP0268-11.

Janudianto, Mulyoutami E, Joshi L, Wardle DA, van Noordwijk M. 2011. Recognizing traditional tree tenure as part of conservation and REDD+ strategy: feasibility study for a buffer zone between a wildlife reserve and the Lamandau River in Indonesia's REDD+ pilot province. ASB Policybrief 22. Nairobi: ASB Partnership for the Tropical Forest Margins.

42 | Trade-off analysis for land-use scenarios (TALaS)

Rachmat Mulia, Betha Lusiana and Meine van Noordwijk

Trade-off Analysis for Land-use Scenarios (TALaS) is based on a suite of tools that carry out ex-ante analysis of the impact of development strategies on the trade-offs between livelihoods and ecosystem services. The tool combines the use of a spatially explicit land-use-change model, a land-use profitability analysis tool as well as other tools that aim to quantify ecosystem services, that is, biodiversity, carbon and hydrological functions. TALaS is useful for exploring suitable development strategies that can balance growth in the economy and livelihoods while maintaining or enhancing ecosystem services.

Introduction

Development strategies sometimes need to consider both economics/livelihoods and ecological aspects. Very often, development strategies were planned solely for economic benefits without concern for the negative impact they might have on the ecological values of the landscape.

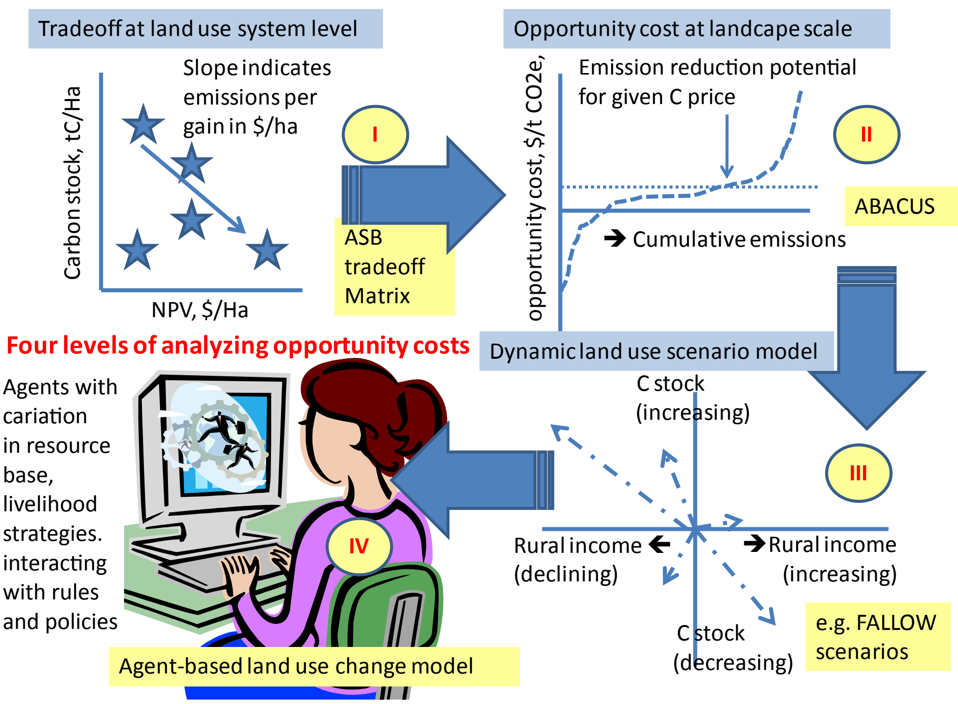


Figure 42.1. Four levels of complexity in analyzing trade-offs: TAlaS (a type III method) builds on tools of type I (trade-off matrix) and type II (Abacus), making use of the FALLOW model

There are four possible directions where implementation of a land-use strategy can lead (Figure 42.1). For example, emphasizing the economic aspect will lead the future of the landscape to have better economic aspects relative to the baseline but most likely will bring a decline in ecologic values ('red development' strategy). An ideal development strategy should bring improvement both in economic and ecologic aspects ('green development').

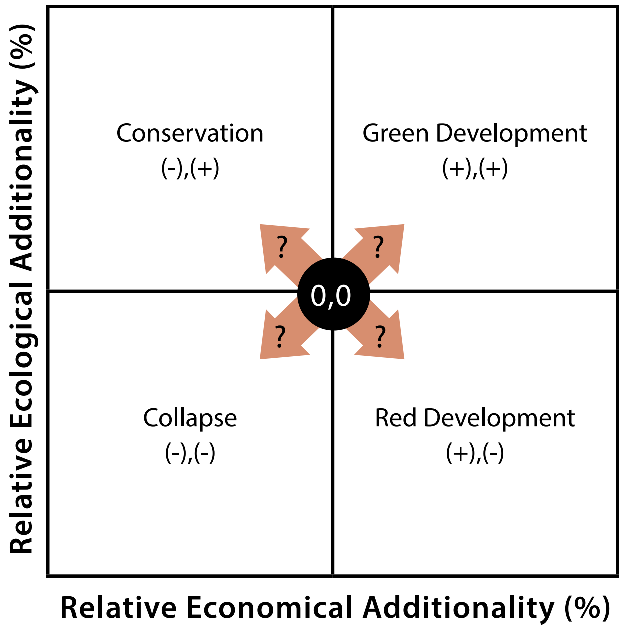


Figure 42.2. Conceptual diagram depicting plausible impact of development strategies

Note: Economic (X axis) and ecological value (Y axis) relative to the initial condition before implementing the strategies (baseline, central point of the diagram)

An ex-ante analysis of several plausible development strategies will help policy makers and natural resource managers understand the impact of their strategies on the landscape. Such an analysis could support the establishment of 'green' development strategies. TALaS was developed for that purpose. It is based on a spatially explicit, land-use-change model (FALLOW), an ex-ante analysis based on scenarios of development strategies (that can be derived from LUWES activities) and combined with land-use profitability analysis (LUPA) and ecological values of the various land-use systems (see RaCSA, QBSur and RHA).

Objectives and steps

TALaS offers a suite of tools that can be used to assess the impact of development on trade-offs between livelihoods and ecosystem services. Steps involved in carrying out each tool are available within each section of the tool.

Example of application

Ex-ante analysis was carried out in Tanjung Jabung Barat district, Jambi province (Mulia et al 2013). The development strategies explored are listed in Table 42.1. The district is located in the eastern part of Sumatra with total area of about 500 000 hectares. The landscape is complex, with peat and mineral soils, the Bukit 30 National Park, former Kesatuan Pengusahaan Hutan Produksi (KPHP/production forests), industrial forest plantations with acacia trees and large-scale oil-palm plantations (Figure 42.3a). For agricultural crops, smallholders in the district cultivate maize and rice as staples as well as soy beans, cassava, groundnut and other vegetables. Different types of tree-based systems also exist, consisting mainly of rubber (*Hevea brasiliensis*) agroforests. Other important tree-based systems include coffee and coconut agroforests and oil-palm plantations, which was the new commodity introduced into the landscape that quickly drew attention owing to its higher economic returns. Product diversification in the landscape could help to maintain the income of smallholding farmers when they are faced with a harvesting or marketing problem in relation to one specific commodity. Coconut and betel nut are common multipurpose tree species that are often introduced into the system, either as important products or as a 'live fence' or marker of land tenure.

Table 42.1. Four land-use scenarios for FALLOW model simulation that consider the present and future of the rural landscape in Tanjung Jabung Barat, Jambi province

No.	Scenario	Description	Remarks
1	Business as usual	No protection for trees outside the Bukit 30 National Park (BTNP); for conversion into smallholding plots Illegal conversion of protected peat forest (Hutan Lindung Gambut/HLG) into smallholding plots Six types of tree-based system and two types of agricultural crops simulated as livelihoods' options for local people	No new concessions for oil, coal and natural gas exploration are assumed for 30-year simulation No change in road and settlement distribution and market price is assumed during 30-year simulation
2	Protected peat forest	Protection of the HLG No protection for trees outside the legally protected forests (HLG and BTNP); for conversion into smallholding plots	Other conditions are the same as business as usual
3	REALU	Protection of rubber and coffee systems: no conversion is allowed to other livelihoods' options. Post-production rubber and coffee systems are rejuvenated Protection for trees inside HLG, BTNP and ex-KPHP	Supporting low carbon emission development and product diversification Other conditions are the same as business as usual
4	Green REALU	Similar to REALU scenario, plus: New oil-palm plantations can only be established in non-productive non-peat soils (that is, shrub or grass lands on non-peat soils) Post-production rubber systems are not rejuvenated but are instead allowed to naturally develop into secondary forest	Oil palm is introduced on shrub or grass lands to increase profitability and carbon stock Other conditions are the same as business as usual

The FALLOW model was run for 30 years. The land-use profitability data was based on Sofiyuddin et al (2012). Simulation results showed that implementation of three development scenarios that considered protection of remaining peat forest and/or local agroforestry resulted in lower economic levels relative to the baseline scenario (Figure 42.3b). The baseline scenario allowed conversion of remaining peat/mineral forests and agroforestry plots into smallholding oil-palm plantations that give higher economic returns. Scenarios that considered a larger protection area to prevent conversion into oil-palm plantations resulted in lower economic levels compared to the baseline. On the other hand, carbon stock levels in the baseline scenario were the lowest because of massive conversion of remaining peat/mineral forests and local agroforests to oil palm.

Other examples of TALaS application are given by Suyamto et al (2005), van Noordwijk et al (2008), Lusiana et al (2012) and Tata et al (2013).

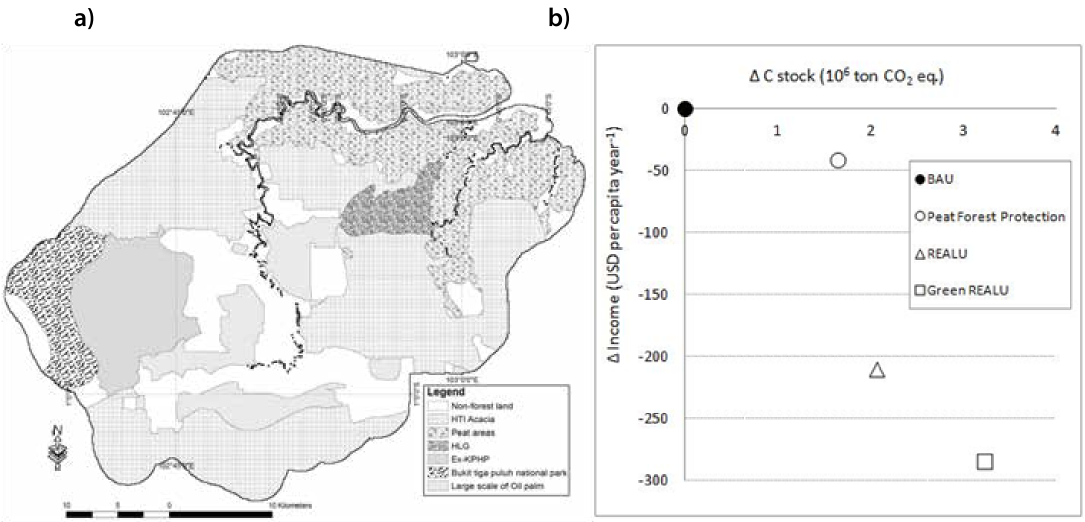


Figure 42.3. a) Area boundaries in the district; and b) impact of each scenario application relative to the baseline scenario

Note: Ecological impact is represented by standing carbon stock in the landscape and economic impact by income per capita measured as the average over the 30-year simulation

■ Key references

Lusiana B, van Noordwijk M, Cadisch G. 2012. Land sparing or sharing? Exploring livestock fodder options in combination with land use zoning and consequences for livelihoods and net carbon stocks using the FALLOW model. *Agriculture, Ecosystems and Environment* 159: 145–160.

Mulia R, Lusiana B, Suyamto D. 2013. *Manual of FALLOW model*. Version 2.1. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Mulia R, Widayati A, Suyanto, Agung P, Zulkarnain MT. 2013. Low carbon emission development strategies for Jambi, Indonesia: simulation and trade-off analysis using the FALLOW model. *Mitigation and Adaptation Strategies for Global Change*. doi: 10.1007/s11027-013-9485-8.

43 | Scenario tools: land-use planning for low-emissions development strategies (LUWES)

Sonya Dewi, Feri Johana and Andree Ekadinata

Land-based actions to mitigate climate change, which are 'pro-poor' and oriented towards 'green' development, need spatially explicit land-use planning processes that are inclusive, informed and integrative. Bringing multi-stakeholder processes to life, beyond rhetoric, needs a breakthrough in political willingness, multi-stakeholder buy-in and technical capacities that allows negotiation platforms to operate. Land-use Planning for Low-emissions Development Strategies (LUWES) provides a mechanism for this.

Introduction

At the national level, common but differentiated responsibility for climate-change mitigation has been agreed among parties within the United Nations Framework Convention on Climate Change. The implementation of climate-change mitigation should recognize the specificities of local needs and circumstances.

Because land-use planning is pivotal between local (sustainable development) and global (in this case, land-based, climate-change mitigation) agendas, there is a huge need for a tool that can support a negotiation process that promotes inclusive, integrated and informed land-use planning. Figure 43.1 illustrates the links between development and land-use planning with land-based climate-change mitigation actions at the local level.

The LUWES framework takes a landscape approach rather than a project-based one. A sustainable development plan at the local level, especially in rural areas where the land-based sector is a primary source of revenue, income and livelihoods, is a reflection of past land uses and land-use changes, as well as existing needs and constraints. This plan, without prejudice against early mitigation actions or intervention in climate change, can be taken as the baseline or business-as-usual scenario. A development plan should detail the number of people involved and economic growth; it should be linked to land-use planning that details the respective size of areas and the location of specific, planned activities. The projected emissions (in CO_2-eq) using the baseline scenario on current land use and cover is the Reference Emission Level (REL, used for gross emissions) and the Reference Level (RL, used for net emissions). For areas in the forest margins where a mechanism to reduce deforestation and forest degradation plus conservation (REDD+) is more applicable and profitable, REL is usually more important as sequestration is generally low.

When planning for lower emissions development, an analysis of the portfolio of land-use changes that drive the projected emissions, the emission shares and the opportunity costs of the reduction is required. Strategies and targets for reducing emissions can be developed and simulated to ascertain ex ante emissions. These strategies are formulated to note the size of affected areas, locations and standard practices, all of which can eventually be used to estimate how many people will be affected, the costs of compensation for those people and the means of implementing that compensation, the effects on tenure, and what environmental services can be delivered.

An action plan and revised development and land-use plans can then be established. From the global perspective, with its emissions-reduction agenda, the performance or success of climate-change mitigation action is measured relative to the reduction of future CO_2-eq emissions from the REL, using a transparent and acceptable method. Depending on the modalities and strategies, the costs of reducing emissions (comprised of transaction, opportunity and implementation costs) can either come from the national level, multilateral funds or the private sector, as in carbon markets.

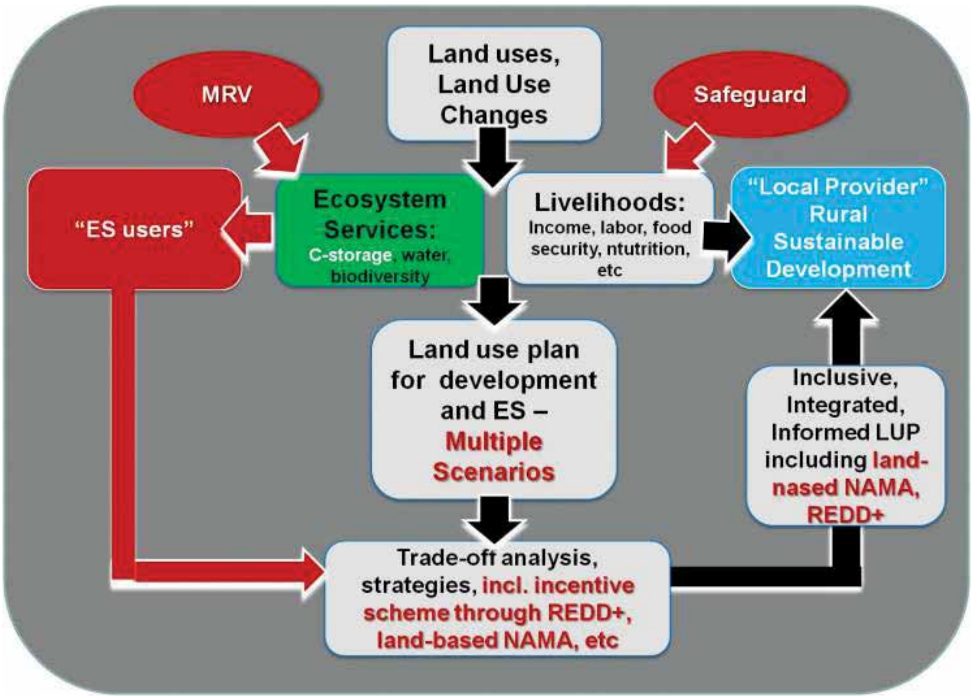


Figure 43.1. Aligning conservation and development issues and internalizing the externalities through land-use planning for low-emissions development strategies

Objectives

- Provide a framework, guided steps and tools for local stakeholders to negotiate a low-emissions development strategy through land-use planning based on formal and informal allocations and actual biophysical status.
- Accommodate 'what if' scenarios and trade-off analyses as a basis for negotiations over best scenarios for climate-change mitigation.

- Assist the formulation of action planning to achieve low-emissions development targets.
- Serve as educational tools for concepts and applications of reducing emissions from land-based sectors at the local level.

LUWES in six steps

1. Develop planning units that reconcile current socio-economic conditions, development and spatial plans, biophysical and functional zones and multiple views of land tenure and management.
2. Estimate historical land-use changes and their consequences for carbon storage.
3. Develop a baseline scenario for future land-use and –cover changes and project the reference levels of emissions.
4. Develop mitigation scenarios and projected emissions.
5. Conduct a trade-off analysis between mitigation and economic goals, financial and other benefits to inform the negotiation process.
6. Formulate action plans, including necessary instruments for implementation.

Steps 2-5 are assisted by the REDD Abacus SP tool described elsewhere in this book.

Case study: LUWES in Indonesia

The tool has been applied in several districts in Indonesia. A subset of LUWES (steps 2–4) has been applied in most provinces to develop the provincial, land-based, local action plan for reducing greenhouse gas emissions, which is a requirement of sub-national operationalization toward the National Action Plan for Reducing Greenhouse Gas Emissions. At the project level, training and workshop activities for LUWES have been conducted in Cameroon, Viet Nam and Peru. The concepts and tools are relatively easy for practitioners and academics to grasp. Application is illustrated using the case of Tanjung Jabung Barat district, Jambi province (Johana et al 2013).

Step 1. Develop planning units

Heterogeneity within a landscape reflects existing land uses and users under formal land allocation, tenure regimes, pluralities of social settings, local and regional economic strategies and varying biophysical characteristics. Overlap of land-use permits may occur as a result of lack of transparency and poor coordination of issuance processes.

LUWES does not aim to solve land tenure problems per se but rather to clarify planning units that allow specific policy interventions o be applied and feasible action plans to be implemented. Reconciliation of plans with existing conditions that link to land managers provides a basis for developing planning units that address consequences and potentialities of zone-specific mitigation activities. This zonation is conducted on the basis of discussions with stakeholders about land-use plans and allocation maps. Figure 43.2 presents the reconciled planning units from several data layers in Tajung Jabung Barat district.

Developing the zone is a very appropriate way to integrate all existing planning documents into single template. A planning unit is defined as a 'zone' where any land-use-change process was recorded and the zone contains factors affecting the activity and preparation in developing appropriate mitigation actions. The zone is developed based on spatial-based integration between various planning documents such as the District Spatial Plan (RTRW), Long-term Regional Development Plan (RPJP)/ Medium-term Regional Development Plan (RPJMD), forestry land status, land-use permits and bio-physical elements (peat).

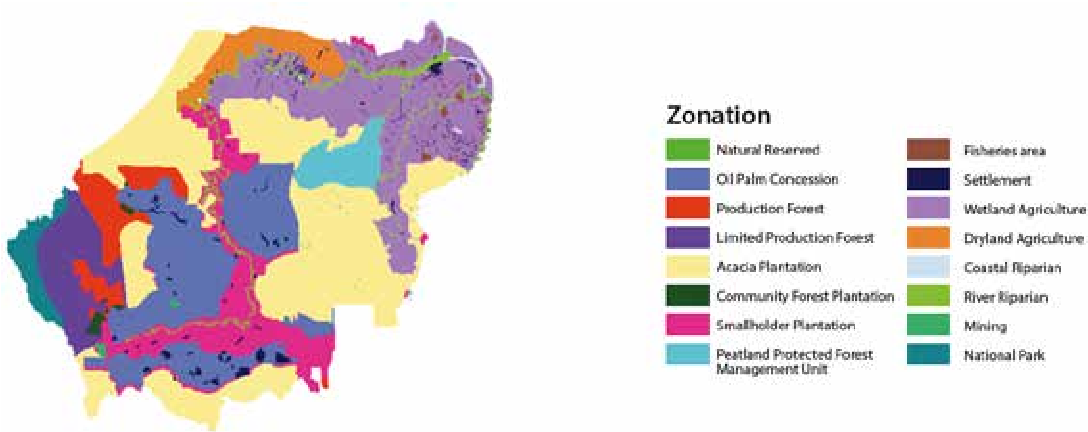


Figure 43.2. Planning units as a result of a reconciliation process of data layers and stakeholder discussions

Step 2. Estimate historical emissions

The stock-difference method is used to estimate emissions (Figure 43.3). Using activity data, which in this case is land-use and land-cover maps of 2005 and 2010 of Tanjung Jabung Barat (Figure 43.4) and the emission factors of Tier 2 of the United Nations Framework Convention on Climate Change, provided by the Ministry of Forestry, the historical emissions for each planning unit listed in Figure 43.2 can be calculated (Figure 43.5).

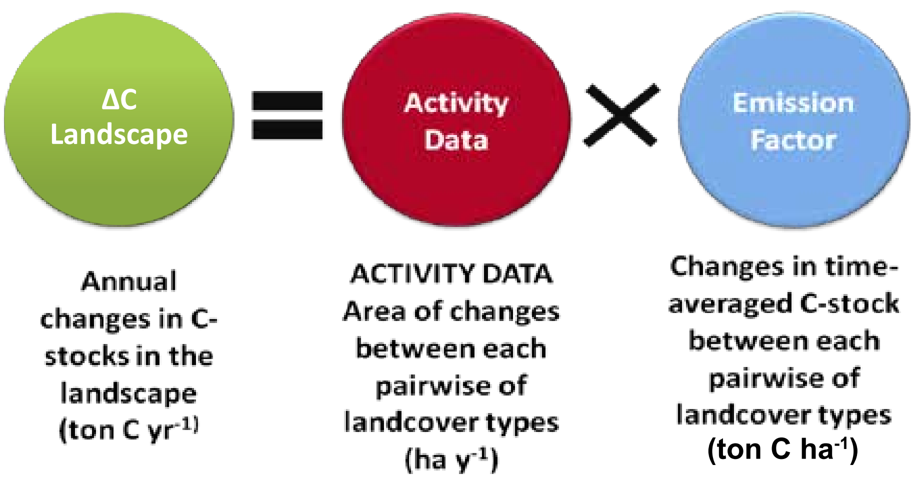


Figure 43.3. Stock-difference method

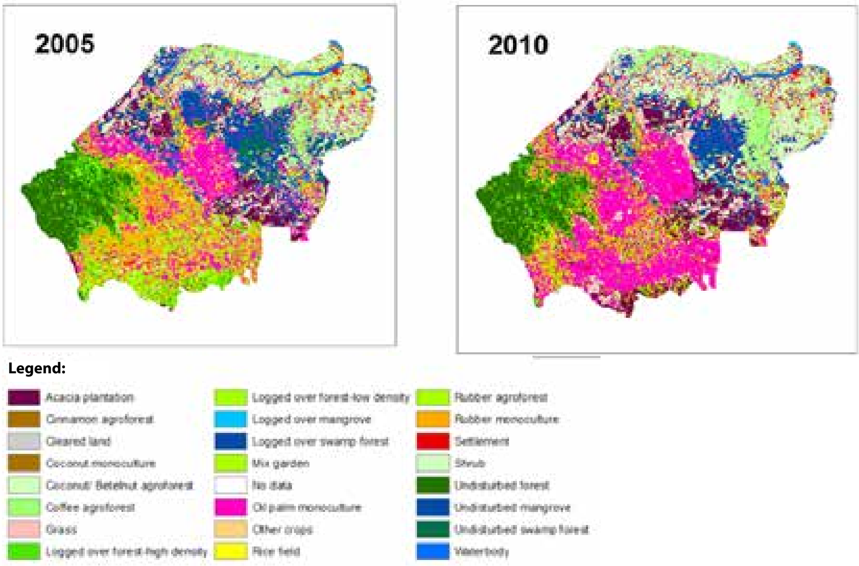


Figure 43.4. Land-use and land-cover maps of 2005 and 2010, Tanjung Jabung Barat district

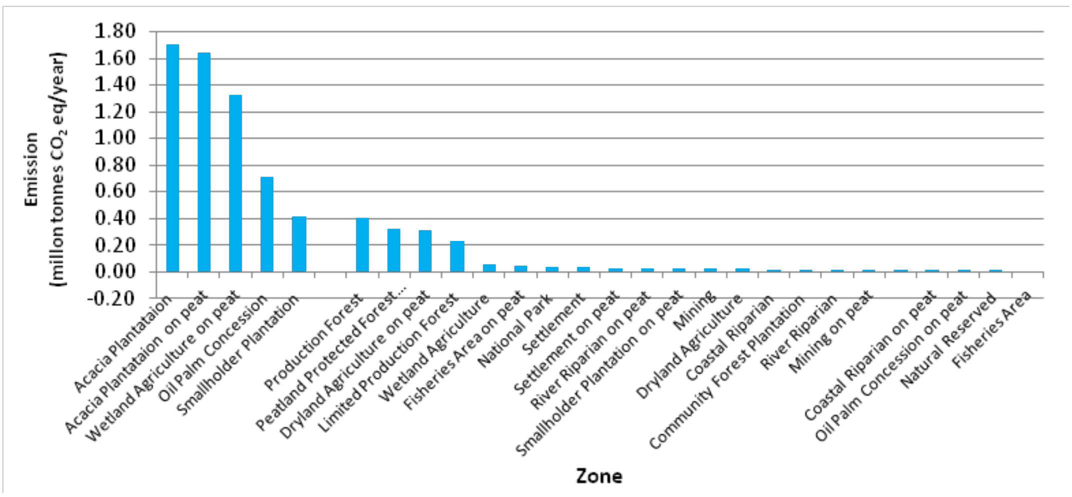


Figure 43.5. Mean annual emissions from each planning unit of Tanjung Jabung Barat, 2005–2010

Step 3. Develop baseline scenario

The REL is the projected emissions in the future if there were to be no mitigation actions. The annual historical emission rate in the district for 2005–2010 was around 14.8 tonnes CO_2 eq/ha/year. Since rates of future emissions are projected based on the rate of land-use change from the historical period, the annual emission rate for 2010–2015 was estimated to be 9.6 tonnes CO_2 eq/ha/year and the emission rate for 2015–2020 was about 8 tonnes CO_2 eq/ha/year (Figure 43.6).

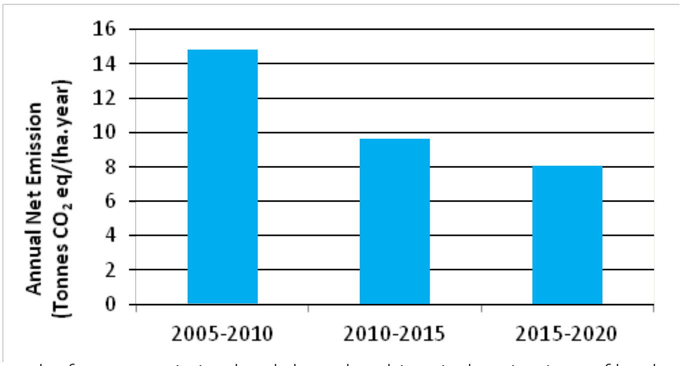


Figure 43.6. Projected reference emission levels based on historical projections of land-use and land-cover changes using 2005–2010 as the base period

Step 4. Developing mitigation scenarios

Figure 43.7 presents scenarios for six planning units, including avoiding loss of carbon stock and enhancing it. The projected emissions reductions are presented in Figure 43.8.

Zone	Scenarios	Planned Activities
Acacia Plantations (S1-AP)	(1) Avoid conversion of primary forest to acacia (2) Maintain existing smallholders' tree-based systems (3) Expedite planting acacia in bush fallow and grassland areas within the concession zone	• Persuade concession holders to maintain primary forest by promoting HTI and HCVF (High Conservation Value Forest) spatial regulation • Implement results of agreement between the district government, community and concession holders on forest boundaries • Implement moratorium on use of wood from natural forests for pulp and paper industries
Oil Palm Concession (S2-OPC)	Prohibit conversion of forest to oil palm (± 8759 ha)	• Persuade concession holders not to convert high-density forests and primary forests to oil palm systems in support of the Government's commitment to reduce emissions by 26%
Peatland Protected Forest Management Unit (S3-PPFMU)	(1) Maintain existing forest area (2) Establish systems with jelutung (*Dyera* sp) to rehabilitated oil palm area.	• Promote the concept of Conservation/Protected areas and their purpose to communities around the KPHLG. • Request more Forest Police from the Ministry of Forestry. • Establish relevant local institutions to support KPHLG. • Promote the value of jelutung (*Dyera* sp) to the local community and explore access to its national and international markets
Production Forest (S4-PF)	(1) Maintain primary forest area (2) Establish rubber systems in non-forested areas	• Promote the concept of Conservation/Protected areas and their purpose to communities around the KPHLG • Provide rubber seedlings to establish rubber systems in the area
Limited Production Forest (S5-LPF)	(1) Maintain primary forest area (2) Establish rubber systems in non-forested areas	• Promote the concept of Conservation/Protected areas and their purpose to communities around the KPHLG • Provide rubber seedlings to establish rubber systems in the area
Wetland Agriculture on Peat (S6-WA_OP)	Preserving existing forest	• Issuing recommendation and prioritized agriculture activities in non-forested land

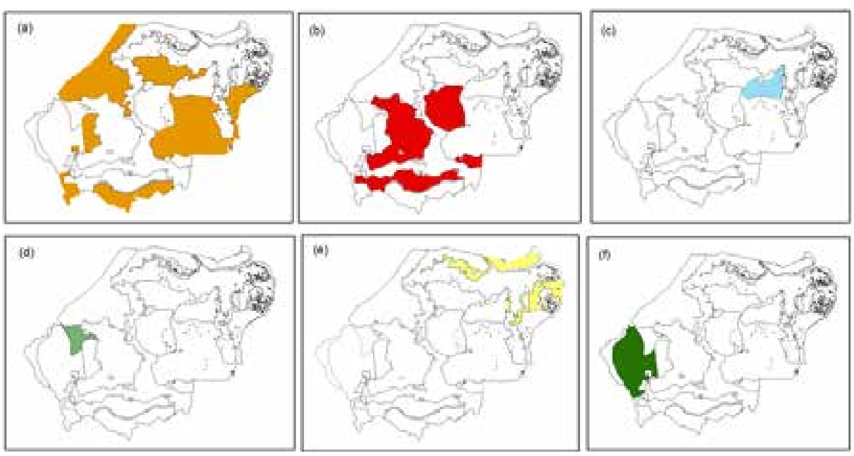


Figure 43.7. Planning unit-specific scenarios: (a) S1-AP; (b) S2-OPC; (c) S3-PPFMU; (d) S4-PF; (e) S5-LPF; (f) S6-WA_OP

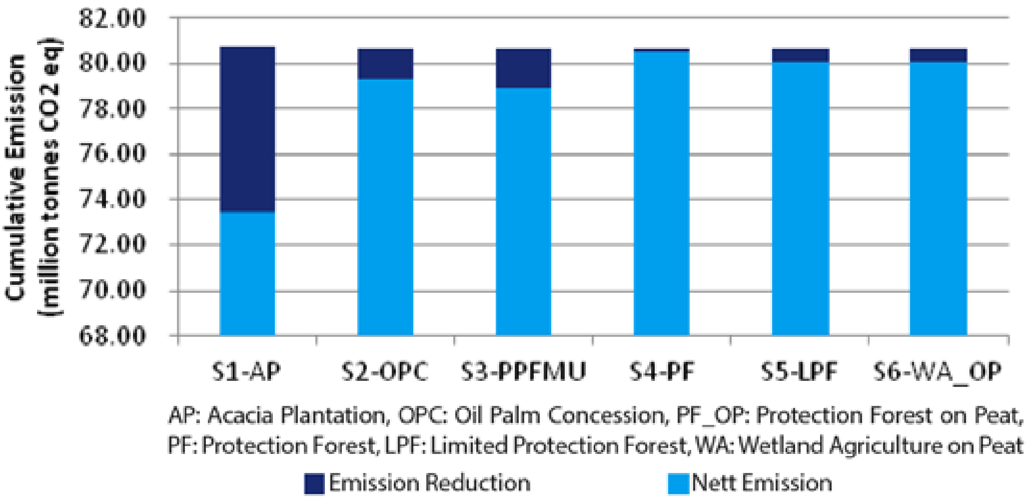


Figure 43.8. Projected emissions reduction from the mitigation scenarios

Step 5. Trade-off analysis

Land and forest-based activities that generate economic benefits and produce food often cause carbon loss from the landscape. Halting these activities to reduce emissions by conserving carbon stock can potentially have a negative impact on economic growth and food security if it is not properly planned (Figure 43.9). Regional economies, livelihoods and food securities, and land-use profitability can serve as indicators of benefits from land uses and land-use changes within a trade-off analysis in planning for low–emissions development.

Identification of potential scenarios for low-emissions development strategies include:

1. identification of types of land uses and land-use changes that associate withlow emissions–low economic benefits, low emissions-high economic benefits, high emissions–low economic benefits, high emissions–high economic benefits and those that associate with low removal-low economic benefits, low removal–high economic benefits, high removal–low economic benefits, high removal–high economic benefits; and
2. prioritization of emissions reduction and carbon–stock enhancement in suitable planning units through reducing high emissions-low economic benefits land uses and land-use changes that have been contributing a lot in the past and will potentially be dominant sources of emissions in the future and promoting high removal-high economic benefits land uses and land-use changes that are biophysically and socio–culturally suitable for the area.

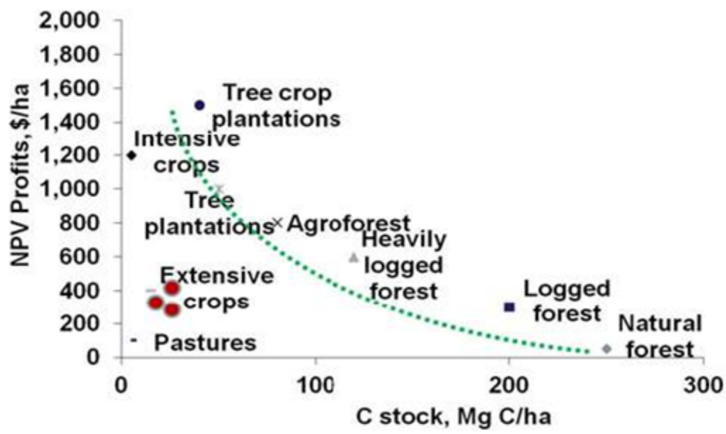


Figure 43.9. Trade-offs between conserving carbon stock and making benefits from low carbon-stock land uses

Source: adapted from White et al 2010

Step 6. Formulate action plans

In Tanjung Jabung Barat, three major actions were identified.

1. Reducing emissions in the oil-palm sector would require commitment from concession holders to optimize the use of abandoned and degraded land rather than opening land with high carbon stock. A land-swap policy would be needed.
2. On peat land, the local government and communities must work together to restore and maintain the protection function. Conversion of oil palm to jelutung (native tree species that produces resin and can grow well without any drainage system) systems could increase carbon stocks. However, commodity conversion needs careful consideration because it has an impact on farmers' income.
3. Communities need clear legal status and tenurial access in order to effectively manage the land. The local government should consider providing 'village forest' permits for community forests or other forms of cooperation that could strengthen the collaboration between the government and communities.

■ Key reference

Dewi S, Ekadinata A, Galudra G, Agung P, Johana F. 2011. *LUWES: Land-use planning for low emission development strategy*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

44 | Capacity-strengthening approach to vulnerability assessment (CaSAVA)

Sonya Dewi, Ni'matul Khasanah and Atiek Widayati

The Capacity-Strengthening Approach to Vulnerability Assessment (CaSAVA) synthesizes local and scientific knowledge to identify existing livelihoods' assets (human, social, financial, physical and natural capital) and deficits at multiple landscape scales. The information for the synthesis comes from multiple stakeholders (for example, farmers, government officers and scientists) and is designed to enable local stakeholders (female and male farmers) to buffer and adapt to both economic (that is, fluctuating prices) and climate-related (for example, extreme weather events) shocks and hazards. CaSAVA is tailored for participatory approaches to collect information disaggregated by gender and, most importantly, to strengthen farmers' awareness of, and capacity for thinking about and articulating, otherwise latent problems. CaSAVA further facilitates the assessment results to develop conservation and livelihoods' strategies to increase farmers' resilience to shocks and hazards.

Introduction

An agro-socio-ecological landscape might experience shocks and hazards[1] that act as stressors to the landscape and its inhabitants. The stimuli are mostly external and are beyond the control of landscape managers. There are two types of shocks and hazards: biophysical, caused by natural processes; and those that are socio-economic and political. The biophysical shocks and hazards can be in the form of extreme rainfall, prolonged drought, pests and diseases, hurricanes, fire, earthquakes or volcanic eruptions. The socio-economic and political shocks and hazards encompass sudden price changes, market uncertainty and tenure regulation.

In most tropical countries, rural livelihoods are vulnerable to climate-related shocks and hazards, which are often intertwined with socio-economic and political ones. Fluctuations in the prices of agricultural products and climate-related events that affect productivity are the two most likely shocks and hazards that will increase farmers' vulnerability. As elaborated in van Noordwijk et al (2011), buffering and filter functions of landscapes and institutions shield people from the direct impact of such shocks and hazards, with complementary roles for buffering across the various assets (capitals) and some opportunity for substitution. Vulnerability is due to both shortfalls in buffering and the intensity of a shock or hazard that exceeds the buffering but the buffering part is potentially under the control of local people while the shock or hazard is not.

[1] A 'shock' is defined herein as a sudden, dangerous event and a 'hazard' as an unavoidable dangerous event that might or might not be sudden.

There are several key questions regarding buffering, filtering and resilience.

- Which households and communities are more vulnerable than others? Why?
- Which tree species, crops, farming systems, forest management practices are contributing to buffering and resiliency?
- Are the buffering and filtering capacities of the landscape decreasing? If so, what is degrading them?
- Can barriers to buffering and filter functions be identified and removed to promote enabling conditions for enhanced resilience?
- What are the capacity deficits that restrict actions and strategies to increase resilience? How to overcome them?

Figure 44.1 shows the flows of a vulnerability assessment, featuring some of the causal links that shape an agro-socio-economic landscape in respect to resilience. The assessment requires landscape-level capital (human, social, financial, physical and natural) to be identified and ecosystem services measured and development of the links between the two to the buffering and filtering processes. Constraints and limitations to taking more aggressive responses are also identified. The roles of trees—particularly, tree diversity—and land-use management are studied as part of natural capital and livelihoods' strategies and as responses that can reduce vulnerability and increase adaptive capacity.

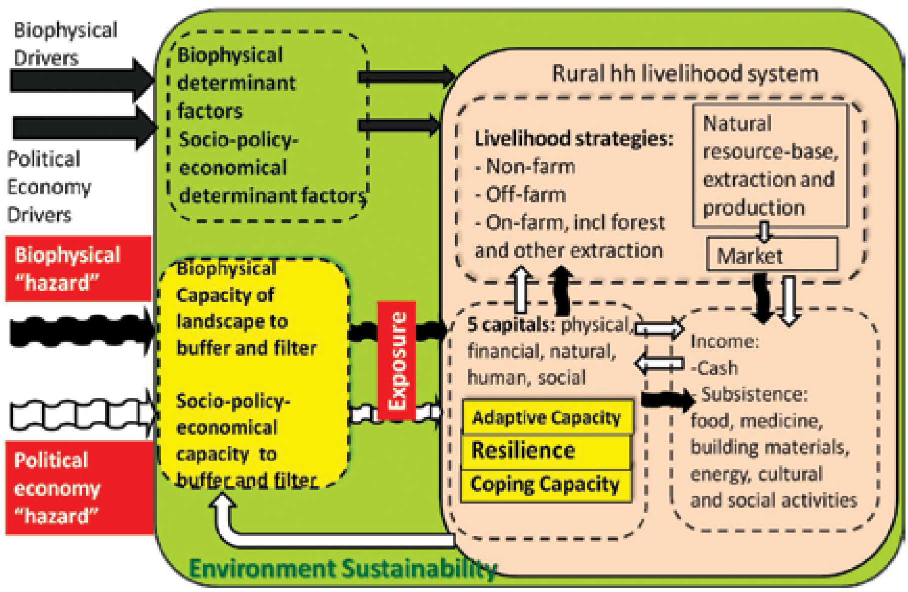


Figure 44.1. Conceptual framework of vulnerability assessment

Note: Rural livelihoods are vulnerable to hazards caused by external biophysical factors and political economy and to changes to a household's internal capital, which affects their agroecosystem's productivity and profits. Source: modified from van Noordwijk et al 2012

Objectives

CaSAVA aims to:

- understand the multiple-scale causalities and decision-making processes in agro-socio-ecological landscapes that shape land use, presence of trees and associated buffer and filter functions;
- unearth the local knowledge that can be the basis of adaption and reducing vulnerability;
- assess, in a participatory manner, the landscape, societal and human capacities to cope with, and adapt to, environmental and socio-economic and political changes; and
- strengthen the capacity of local people to develop strategies and manage their landscape sustainably.

Steps

To build scientific knowledge, CaSAVA draws on other tools described earlier. There are five main steps of CaSAVA (Figure 44.2).

1. Conduct a vulnerability assessment of landscape changes in buffering capacity against shocks due to climate- and market-related factors, exposures and impacts of shocks on communities and farmers, responses to reduce impacts and gaps in capacity to reduce immediate and long-term impacts and increase resilience (local knowledge assessment disaggregated by gender) .
2. Disseminate the results of the vulnerability assessment to communities; conduct a participatory analysis of strengths, weaknesses, opportunities and threats for conservation and livelihoods issues; and conduct interviews with local government agencies to identify resources and government programs that potentially bring opportunities to increase the resilience of farmers.
3. Build consensus among multiple stakeholders (including farmers, government officers, the private sector and researchers) on common, specific objectives for conservation and livelihoods to increase farmers' resilience.
4. Develop a participatory strategy to reach specific objectives for conservation and livelihoods using outcome mapping through identification of outcome challenges and progress markers.
5. Conduct participatory action planning to implement the strategies through a joint process to identify resources, working groups, institutions and policies that can support the plan.

There are two main methods used to assess vulnerability.

» Scientific assessment of land-use and land-cover changes (ALUCT) and the impact on the buffering capacity of the watershed (GenRiver and FlowPer), carbon-stock dynamics (RaCSA) and biodiversity (QBSur).

» Local knowledge assessment at the household and community levels.

  - Roles of the five capitals (assets) in livelihoods' strategies under shock and hazard conditions: availability of water quality and quantity; direct use and market value of local biodiversity; aligning expenditures and income.
  - The resilience of tree and farming systems to shocks (Treesilience)
  - Immediate responses (coping) and long-term responses (adapting) to the impacts of shocks and capacity deficits in coping and adapting (Treesilience).
  - Selecting farming systems and tree species (G-TreeFarm).

Steps 2–5 largely use a facilitation process through workshops, training and discussions. Ideally, a formalized working group is developed after or during Step 3. CaSAVA combines the outcome mapping method and logical framework analysis in participatory strategy development with boundary partners mainly due to the complex nature of the problems. Behavioral changes of boundary partners defined as outcome challenges are developed into progress markers and, together with other indicators of successes, are included in the monitoring and evaluation system. Toward Step 5, champions within the working group or other boundary partners should be more dominant than CaSAVA facilitators.

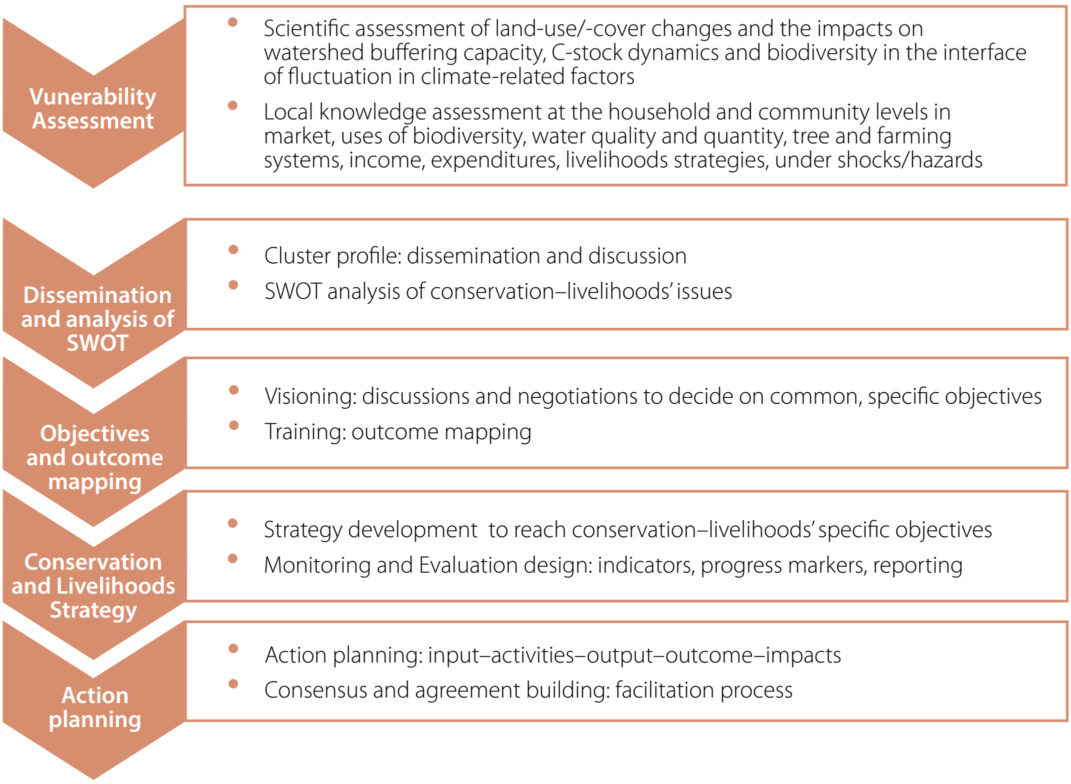
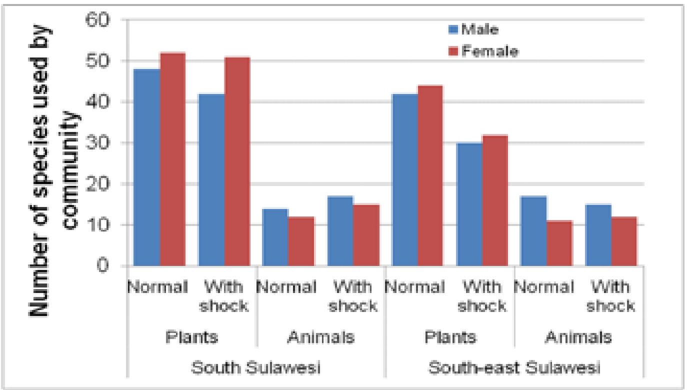


Figure 44.2. The five steps of CaSAVA to develop capacities of farmers to increase their resilience to shocks and hazards

Case study: CaSAVA in Indonesia

At the time of writing, CaSAVA is being developed in South and Southeast Sulawesi provinces, Indonesia. Steps 1 (vulnerability assessment) and 2 (dissemination of results to communities) have been successfully implemented but the results are yet to be published. Application is approaching Step 3.

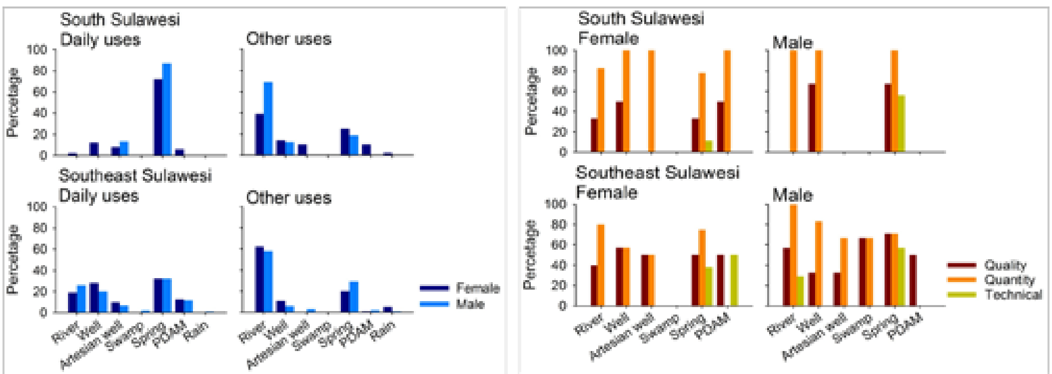
Figure 44.3 shows results from Step 1's focus-group discussions on biodiversity uses, which were conducted at several sites in Sulawesi. Figure 44.4 shows results from Step 1's focus-group discussions on water sources, quality and quantity. Other results from Step 1 are presented as examples with the Treesilience and G-TreeFarm tools.



- Females tend to use more plant species and lee animal species than male
- Increased animal use occurred during shock conditions in South Sulawesi
- Number of tree species used during normal years tends to be higher than those during years with shocks

Figure 44.3. Results from focus-group discussions on the uses of biodiversity under normal year and year of shocks for male and female gender groups in South and Southeast Sulawesi.

Source: Khasanah et al 2013



Daily uses: cooking, washing, drinking, bathing
Others uses: agriculture, livestock, micro hydro, transportation, others.

Quality: muddy, contaminated
Quantity: less amount of water in dry season, more amount of water in wet season, flooding
Technical: broken/clogged pipe

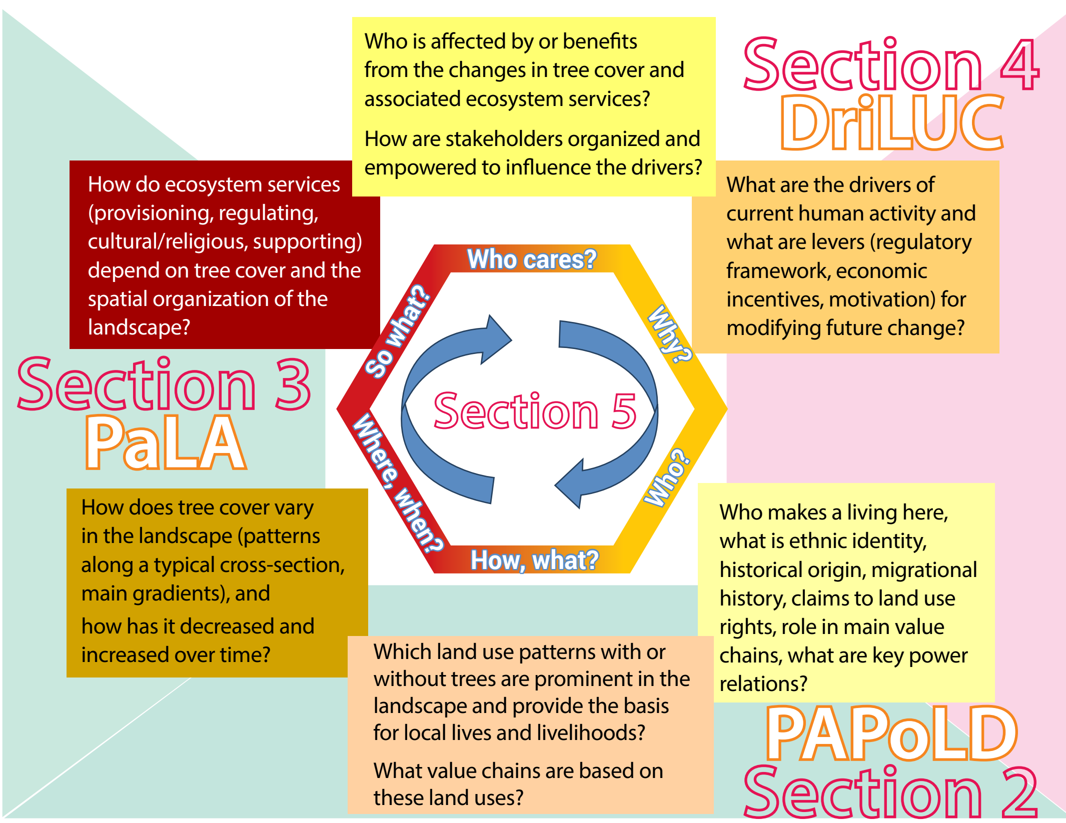
- The main sources of water for daily uses in Southeast Sulawesi vary, while that in South Sulawesi is mainly spring
- For other uses main sources of water are river and well, both in South and Southeast Sulawesi
- Quality and quantity are the two main problems encountered in almost all sources of water, with quantity is the main problem across different sources of water, provinces and gender groups

Figure 44.3. Results from focus-group discussions on water sources, water quality and quantity for female and male gender groups in South and Southeast Sulawesi.

Source: Khasanah et al 2013

SECTION 05

Negotiation support as process



45 | Assessing and adopting social safeguards in all planned programs (AASSAPP)

Sébastien de Royer, Gamma Galudra and Ujjwal Pradhan

'Social safeguards' are procedures that ensure that projects take into consideration people's rights, aspirations and the 'do no harm' principle. The concept of 'safeguards' encompasses free, prior and informed consent; participation; resolution of land conflict; clarifying land and natural resource use-rights; livelihoods and food security; and poverty alleviation. Free, prior and informed consent as part of social safeguards is defined as protecting the right of local and indigenous communities to negotiate the terms of externally imposed policies and projects. This applies to 'development' as well as to 'conservation' projects.

Introduction

In the last few decades, countries such as Indonesia have experienced increasing pressure on community lands from commercial entrepreneurs and investors, which has lead to marginalization and dispossession of local and indigenous communities. The land-use planning process has often prioritized powerful interest groups who benefit financially from land and resource. The role of provincial and district governments is crucial because their land-use policies can favour these interest groups or local communities. Applying social safeguards to the process of land-use planning includes transparency and accountability at district and provincial government levels.

The effective use of social safeguards in a land-use planning process represents a fair approach beyond compliance, which aims to reconcile the different perspectives. Safeguards help to change the paradigm from top–down, state-driven planning to a more participative, bottom–up, grass-roots, rights-based approach that takes into account the aspirations of multiple stakeholders. Incorporating safeguards is a practical way of minimizing social exclusion and maximizing social equity in planning for low-carbon development. This requires new ways of thinking about land use and how to plan.

Much of the work around social safeguards is about land tenure since a lack of clarity over the right to land is often the source of conflicts between local communities, indigenous people, governments and businesses. Another issue is 'indigeneity and indigenous rights', that is, identifying who is and who is not 'indigenous' and, therefore, entitled to articulate traditional rights over land.

The acknowledgement of self-identification as contained in the United Nations declarations of the Rights of Indigenous Peoples and Human Rights can lead to conflicts and competing claims among stakeholders.

Both issues of indigeneity and land tenure are the main challenges to be addressed during the assessment and adoption of social safeguards. Even at the level of the United Nations Framework

Convention on Climate Change, negotiations to add safeguards as an obligation slow and complicate implementation on the ground, especially in the context of REDD+. These are complex situations in which various people are developing different sets of principles and criteria in line with their political agendas and own interests. A more comprehensive approach to land use is needed.

Objectives

The Assessing and Adopting Social Safeguards in All Planned Programs (AASSAPP) tool is meant to help local governments and communities go beyond compliance mechanisms and integrate social safeguards into the broader architecture of landscape management. The primary objective is to assess land-use planning and implementation based on the principles, criteria and indicators appropriate for social safeguards. The second objective is to adopt the appropriate principles, criteria and indicators in the mechanisms and regulations.

Steps

AASSAPP uses a participative approach, which includes all groups of people involved with a landscape. In order to safeguard social attributes in land-use plans, a 'principles, criteria and indicator' approach is used that covers all major social concerns that might be undermined during the process.

This approach helps achieve high social standards during land-use planning. 'Principles' provide the main objectives that define performance to meet social standards; 'criteria' define the delivery of the principles; and 'indicators' are quantitative and qualitative information that show progress in achieving the criteria. There are five major principles, 18 criteria and 60 indicators.

1. Participation of rights holders and stakeholders
2. Respect and strengthening of rights to land, territories and natural resources
3. Respect and strengthening of rights to traditional knowledge, culture and local practices
4. Promotion of poverty alleviation and security of livelihoods
5. Promotion of reconciliation of various conflicting interests over land and resources

The AASSAPP method consists of five steps

1. The participative identification of specific principles, criteria and indicators of social safeguards by the stakeholder groups through a series of workshops. In these workshops, the principles are encouraged to be respected by local governments who commit to adopt social safeguards in their land-use planning. Criteria and indicators are used as guidelines that are adapted to local circumstances.
2. Identification of enabling conditions based on rules and regulations; and institutions and mechanism to adopt the safeguards. These identifications are used for formulating protocols to integrate safeguards into land-use planning, implementation, monitoring and evaluation. They are also used to assess hindrances to adoption.
3. Determine implementing stakeholders for adopting safeguards, based on Step 2. The governance structure to support the implementation and monitoring of the safeguards should be defined before implementation.
4. Organize a series of workshops to formulate a work plan.
5. Gathering information to evaluate and assess performance.

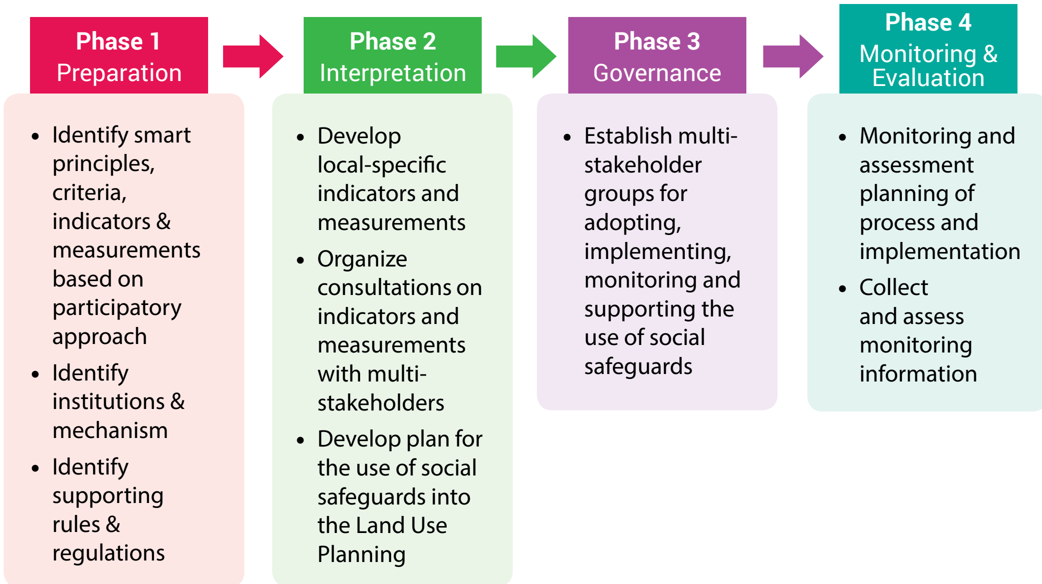


Figure 40.1. Steps involved in assessing and adopting social safeguards in all planned programs

Example of application

At the time of writing, the use of social safeguards in land-use planning is being tested in the province of Papua in Indonesia, with assistance from the European Union. The governor of the province has recognized that land-use planning can support the government's commitment to conserve biological and cultural diversity. Including local communities in planning has been acknowledged as central to a more just approach to resources management.

We used AASSAPP to assess the application of social safeguards in land-use planning in Jayapura district in the province of Papua. A one-day workshop was conducted, to which we invited various stakeholders, such as representatives of central and local government authorities, business enterprises, local communities and indigenous people. The objective of the workshop was to raise awareness of social safeguards and the importance of integrating them into land-use planning. During the workshop, we were able to develop participative, locally appropriate principles, criteria and indicators; identify the enabling conditions based on rules and regulations; and examined the implementation mechanisms and the changes needed to support adoption of the safeguards (see Table 40.1). The process is still underway and results so far are restricted to Step 2.

Table 45.1. Mechanism for adopting social safeguards in land-use planning in Jayapura district, Papua province, Indonesia

Principles	Enabling conditions	Implementation mechanism	Changes
Participation of rights holders and stakeholders	Participation of community in land-use planning	Discussion of planning and development at village level	Transparency Capacity building
Respect and strengthening of rights to land, territories and natural resources	Recognition and security of communities' rights over land, including conflict resolution	Mapping of customary rights and territories through a decree of the district head	
Transparency and right to information	Information dissemination about land-use planning	Raising awareness of the district land-use plan	Mechanism of dispute resolution for reaching agreement on development plans
Promotion of reconciliation of various conflicting interests over land and resources	Reconciliation of various conflicting interests	Customary reconciliation mechanism	

Box 45.1. List of existing guidelines

Asian Development Bank. 2009. *Safeguards policy statement.* Manila: Asian Development Bank.

Bonfante TM, Voivodic M, Meneses Filho L. 2010. *Developing social and environmental safeguards for REDD+: a guide for a bottom–up approach.* Piracicaba, Brazil: Institute for Forest and Agriculture Management and Certification.

Convention on Biological Diversity. 1992. *Convention on Biological Diversity.* New York, USA: United Nations.

Climate, Community and Biodiversity Alliance; CARE International. 2012. *REDD+ social and environmental standards.* Version 2. Arlington, VA: Climate, Community & Biodiversity Alliance; London: CARE International.

Climate, Community and Biodiversity Alliance. 2008. *Climate, community and biodiversity project design standards.* Second Edition. Arlington, VA: Climate, Community and Biodiversity Alliance.

Food and Agriculture Organization of the United Nations; United Nations Environment Programme. 1999. *The future of our land. Facing the challenge: guidelines for integrated planning for sustainable management of land resources.* Rome: Food and Agriculture Organization of the United Nations.

Forest Stewardship Council. 1996. *Principles and criteria for forest stewardship.* Version 4. Bonn, Germany: Forest Stewardship Council.

Global Environmental Facility. 2011. *Policies on environmental and social safeguards and gender mainstreaming.* Washington, DC: Global Environmental Facility.

Deutsche Gesellschaft für Internationale Zusammenarbeit. 2011. *Land-use planning: concept, tools and application.* Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit.

Deutsche Gesellschaft für Technische Zusammenarbeit. 1999. *Land-use planning: methods, strategies and tools.* Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit.

Perkumpulan untuk Pembahruan Hukum Berbasis Masyarakat dan Ekologis. 2010. *Beyond carbon: rights-based safeguards principles in law*. Jakarta: Perkumpulan untuk Pembahruan Hukum Berbasis Masyarakat dan Ekologis.

International Finance Corporation. 2012. *IFC performance standards on environmental and social sustainability*. Washington, DC: International Finance Corporation.

Roundtable on Sustainable Biofuels. 2010. *RSB principles & criteria for sustainable biofuel production*. Version 2. Geneva, Switzerland: Roundtable on Sustainable Biofuels.

United Nations Framework Convention on Climate Change. 2011. *Decision 1/CP.16. The Cancun Agreements: outcome of the work of the Ad Hoc Working Group on Long-term Cooperation Action under the Convention*. Bonn, Germany: United Nations Framework Convention on Climate Change.

United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. 2012. *UN-REDD programme social and environmental principles and criteria*. UN-REDD Programme Eight Policy Board Meeting, 25–26 March 2012, Asuncion, Paraguay. Geneva, Switzerland: United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries.

World Bank. 2011. *Common approach to environmental and social safeguards for multiple delivery partners*. Washington, DC: Forest Carbon Partnership Facility Readiness Fund, World Bank.

World Bank. 2010. *Terms of reference: strategic environmental and social assessment, Indonesia*. Washington, DC: Forest Carbon Partnership Facility Readiness Fund, World Bank.

World Bank; United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. 2012. *Guidelines on stakeholder engagement in REDD+*. Washington, DC: Forest Carbon Partnership Facility, World Bank; Geneva, Switzerland: United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries.

46 | RUPES role-play game (RPG)

Grace B. Villamor, Beria Leimona and Meine van Noordwijk

The Rewarding Upland Poor for Environmental Services (RUPES) project developed a role-play game (RPG) that simulated the options for land-use changes for villages in a tropical forest margin. The game resembles the decision-making process gone through by villagers interacting with external agents. The agents offer opportunities for further logging and conversion of forests to monoculture tree plantations or incentives to protect environmental services. The game shows the complexity of negotiations under time pressure, with limited information about what the 'rules of the game' imply. Primarily meant as a learning tool for those playing, observing and analyzing the game, the results can also be compared between the results achieved in multiple replications of the game.

Introduction

Financial incentives can both support and undermine social norms compatible with enhancement of environmental services. External co-investments—for example, through incentives from mechanisms for reducing deforestation and forest degradation (REDD)—need to synergize with local efforts by understanding their dynamics and the conditions for free, prior, informed consent. The RPG can help assess the perceptions and behaviours of local dynamics, which feeds into planning institutionalized rewards' schemes. Such schemes deploy incentives to conserve or enhance environmental services in the landscape but are in competion with mainstream economic development that degrades natural capital. The RPG helps to highlight the issues.

Objectives

The RPG aims at providing a schematized but recognizable representation of the decisions that villagers can make about land use, with consequences for food security and income. It is a learning process for those who play, observe and analyze. It also allows data capture for comparison between situations.

Steps

1. Study the initial game design as reported in Villamor and van Noordwijk (2011) and make adjustments that fit the local conditions of land use and change agents.
2. Prepare land-use game boards that represent each village. In application to date, game boards consisted of a village, rice fields (rain-fed rice), monoculture rubber plantations, rubber agroforests and forests.
3. Prepare role descriptions for the external agents that reflect the performance standards they have to work against (number of contracts they need to secure).

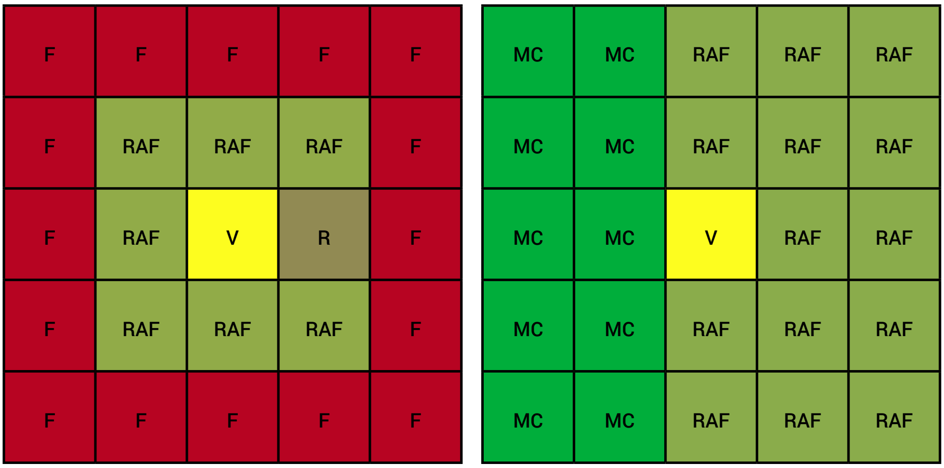


Figure 46.1. Example of gameboards

Note: The stickers with different colours represent different land uses: V = village, R = ricefield, MC = monoculture tree crops, RAF = rubber agroforest, F = forest

1. Assign a game master who will be in charge of the game and one or more assistants who interact with the agents with special roles and/or help villagers with the bookkeeping part of the game. Lack of clarity of the rules of negotiation is an essential part of the game and this learning process must take its due course. Observer roles can be added.
2. Bring participants (25–30) to a setting that is conducive to free exchange and give a short account of the purpose, learning opportunities and game procedure. Invite volunteers to leave the room and be instructed on their terms of reference and receive their initial supply of money (tokens). Meanwhile, the other participants are divided into multiple villages (4–6 participants per village board, multiple villages in the space).
3. Based on negotiations with other agents, income from either maintaining or changing the land use is accounted for in annual time steps. Negotiations with the external agent are constrained by the time step (15 minutes, 5–10 minutes per year to update the targets and keep the records for the year; total length of the game is announced to be 10 years but the game may stop after seven or eight years). At the end of each simulated year, external agents leave the room (may require gentle persuasion...) and the villagers as well as agents take stock of their performance so far.
4. Once the basic routine has been settled, the game master can announce ad hoc changes such as a forest fire, population growth or a sudden change in commodity prices. If external agents do not meet their performance goal they get a warning and may subsequently be taken out of the game owing to bankruptcy.
5. Once the game is ended, villagers and external agents are asked to reflect on their roles, explaining why they did what they did, while the game master offers simple observations to further probe what took place. When this stage of learning is reaching saturation, the assumption that this was purely fictitious is brought to the group, allowing participants to express which aspects may actually have some similarity with real life. From the factual land-use representation this can be taken towards the inter-agent dynamics (lack of clarity, trust, misunderstanding, cheating), and the lack of clarity of the 'rules of the game'.

Further description is provided in Villamor and van Noordwijk (2011).

Figure 46.2. Different ways of playing the game: sitting on the floor in a community house or at tables in a school

Case study: RPG: testing for gender differences in response to options to change land uses

The role-play game was used by Villamor et al (2013) to explore the role of gender as a factor in decision making about alternative land-use options and in responses to new investment opportunities in a forest margin landscape in Jambi, Sumatra, Indonesia.

The RPG was used to assess participants' responses in a simulated social setting of women-only and men-only groups.

When women from either upland or lowland villages played the RPG, external investors proposing logging or conversion of forests to oil palm were approached very positively and the resulting land-use change was more dynamic and extensive than in the equivalent men-only groups. Consequently, women outperformed men in achieving income targets. In lowland areas, gender was strongly associated with land-use change while in the uplands the level of conservation awareness played a more crucial role in the maintenance of rubber agroforests. Based on the data, and contrary to expectations and gender stereotypes, it is expected that the greater involvement of women in landscape-level decision making will increase emissions from deforestation and forest degradation in the area, posing further challenges to efforts to reduce such emissions.

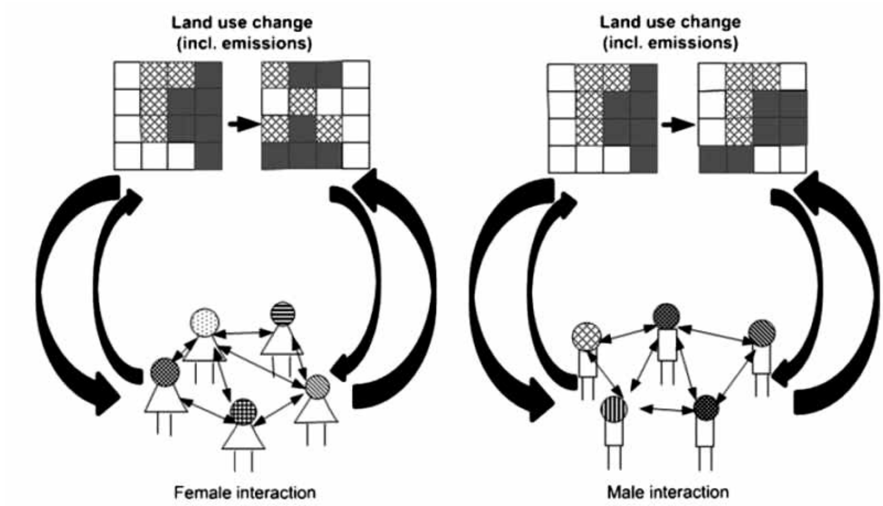


Figure 46.3. Schematic diagram of the use of an RPG to explore the different responses of men and women to proposed changes in their landscape

Source: Villamor et al 2013

Key references

Villamor GB, van Noordwijk M. 2011. Social role-play games vs individual perceptions of conservation and PES agreements for maintaining rubber agroforests in Jambi (Sumatra), Indonesia. *Ecology and Society* 16(3):27.

Villamor GB, Desrianti F, Akiefnawati R, Amaruzaman S, van Noordwijk M. 2013. Gender influences decisions to change land-use practices in the tropical forest margins of Jambi, Indonesia. *Mitigation and Adaptation Strategies for Global Change* 2013:1–23.

47 Conservation auction and environmental services enhancement (Con$erv)

Beria Leimona

Procurement auctions have been designed to efficiently allocate conservation contracts and reveal hidden information on the opportunity costs of supplying environmental services. The Conservation Auction and Environmental Services Enhancement (Con$erv) uses a step-by-step approach to go beyond an economic interpretation focussed on prices and efficiency to encompass the social dimensions of learning, perceptions and fairness, which also require attention and, in so doing, offers an opportunity for deeper analysis of the motivations of stakeholders.

Introduction

Payments for ecosystem services (PES) have become part of the portfolio of policy options to retain, recover or enhance environmental services, including the provision of watershed functions. It assumes voluntary participation by farmers and rural communities in performance-based contracts, with clear conditionality.

An important aspect of implementing a PES scheme is transparency regarding the conditions under which incentives or rewards can be granted. Balanced information and shared power of transaction are the basis for any ecosystem services' agreements, with risks and benefits understood by all parties.

Procurement auctions on conservation contracts have been widely implemented in the USA, Australia and Europe (Stoneham et al 2003). The award of contracts on the basis of competitive bidding is a method frequently used in procuring commodities for which there are no well-established markets (Latacz-Lohmann and van der Hamsvoort 1997, Ferraro 2008), such as in markets for environmental services.

Contract procurement auctions have emerged as an alternative mechanism for deriving information from providers of environmental services on the level of payments or incentives that will cover their expected costs minus co-benefits when joining a conservation program. From experience so far, other perspectives on the interactions before, during and after the auction can add to the understanding of actors' behaviours as well.

Objectives

The primary objective of a conservation auction is the efficient allocation of limited funds (for example, those planned for watershed rehabilitation) among prospective PES participants and exposure of hidden information on the opportunity and implementation costs of supplying environmental services. A secondary objective is to be aware of the learning dimensions of the auction process and its relation to the motivation of actors and the perceived communication between them.

Steps

The steps presented here use watershed services as the focus; with some modifications, they can be applied to biodiversity conservation or enhancement of landscape carbon stocks.

1. Identify the sample population and potential auction participants at the watershed level, starting from a prior analysis of the issues that need to be tackled and after securing a budgetary envelope for contracts.
2. Design the conservation contract to be offered in the auction. For this, basic information is needed.
   a. What problems would be solved by the conservation project?
   b. Do local farmers have a shared understanding of the issue and potentially untapped knowledge that can help to solve the key watershed problems in innovative ways? (build on RHA tool)
   c. What are proven conservation techniques that can serve as a benchmark for performance-based contracts and/or activity-based contracts?
   d. What are the farmers' preferences for terms of payment, as emerges from a conjoint analysis?
   e. When should the contract begin? What contract duration is desirable?
3. Test and select some elements of the auctions through two types of experiments: a laboratory auction experiment with students and field-framed experiments with farmers.
4. Conduct a natural field experiment and monitor the success and completion rate of the contract by farmers who won the auction in the period of the contractual agreement.

   Include social scientists and techniques in the process to obtain a broader perspective on motivational aspects and learning curves.

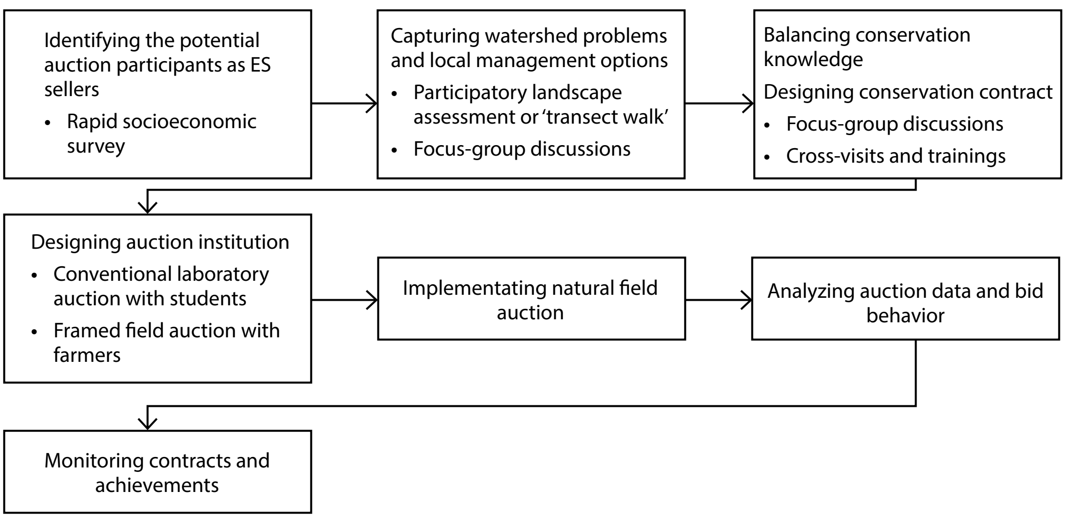


Figure 47.1. Con$erv research steps

Case study: Con$erv in Indonesia

The setting of this case study was the Sumberjaya watershed in Lampung, Indonesia, where soil erosion had broad implications for on-site and off-site damage. The most direct on-site effect was the loss of top soil from the coffee farmlands that dominated the watershed, resulting in low agricultural productivity. Off-site effects included siltation, water-flow irregularities, a reduction in irrigation, water pollution and agrochemical runoff. The soil sediment reduced the capacity of a reservoir located downstream of the watershed, adversely affecting irrigated agriculture and hydro-electricity generation.

Most of the farmers in the research sites were Sundanese, originating from West Java, and Javanese, originating from Central and East Java. Each farmer owned an average of 1 hectare or less. The farmers' livelihoods depended on coffee farming, either as owners of coffee gardens or as labourers to other farmers.

Based on the hydrological survey of the sub-watershed, we selected two sites, Way Ringkih (Site 1) and Way Lirikan (Site 2), with high sedimentation rates. In addition to this biophysical consideration, we set qualifications for selecting eligible participants for the auction project. The farmers had to own their land and be actively managing it themselves. These stipulations were made in order to avoid conflicts on signature of contract and regarding payment and to ensure that the farmers did not neglect the land after signing the contract. Farmers on private land need incentives to manage their land sustainably.

There were 44 and 45 households eligible in the sub-watersheds respectively. The Way Ringkih sub-watershed consisted of two *talang* (hamlets in the local language): Talang Harapan and Talang Kuningan (Site 1). The Way Lirikan sub-watershed consisted of one talang: Talang Anyar (Site 2). As part of a wider project, World Agroforestry Centre scientists had previously facilitated participatory water-monitoring activities in Way Ringkih and Way Lirikan. These activities gave additional benefits that contributed to the measurement of the study's environmental impact.

Our study resulted in a set of auction rules for determining how limited watershed rehabilitation funds could be allocated. We examined the applicability of such an auction design in an Indonesian rural setting by testing: 1) auction design factors, such as participants' understanding of auction rules, the ease-of-use of these rules, the appropriateness of the participants' bid offered during the auction, and the fairness of the auction process; 2) social factors, such as impact on the relationship between contracted and non-contracted farmers, general interpersonal relationships between communities, and information exchange amongst farmers; and 3) environmental factors, such as awareness of soil and water conservation and the rate of contract completion.

Our results show that a sealed-bid, multiple round, second-price Vickrey auction with a uniform price can be applied in a situation where most of the auction participants have a low education level, low asset endowment, small plot size, and where market-based competitiveness is not common. The auctioneer set a limited budget of USD 2000 (approximately IDR 20 000 000) per auction for a total of USD 4000, which is the average budget provided by the potential buyer, a neighbouring hydropower company, for its annual corporate social responsibility fund. In total, 82 farmers participated in two auctions. Of these, farmers were awarded contracts that provided for soil conservation activities on 25 hectares. The contract price per hectare was USD 172; the mean bid was USD 263.

Our finding was that farmers' bids to be involved in conservation contracts are more dependent on their learning process during the auction than on observable factors such as their socioeconomic background, their awareness of conservation or their status in local social capital. We also found that introducing a procurement auction as a market-based approach to rural communities did not harm their social relationships and was an applicable method in a rural setting such as the one tested here (with ample experience in market interactions in commodity production and without a long history of local rule development, as is common for indigenous groups). Nevertheless, this learning process did not guarantee the successful accomplishment of a conservation contract. The rate of contract accomplishment was moderate and this may be influenced by many other factors, such as the leadership of the farmers' groups and their institutional arrangements for conducting conservation activities.

The implication of the findings is that designing a proper conservation auction method and estimating the 'right' value for contracts form only minimal requirements for the success of any conservation contract.

A further indication that the auctions are not only about establishing a 'right' price was obtained where contracts similar to the ones that emerged from the auction were tested in other locations with similar conditions. High acceptance of such contracts suggested that the price was higher than necessary and lower implementation rates suggested that the process of bidding had shaped motivation.

■ Key references

Leimona B, Jack BK, Lusiana B, Pasha R. 2010. *Designing a procurement auction for reducing sedimentation: a field experiment in Indonesia*. Singapore: Economy and Environment Program for Southeast Asia.

Leimona B, Jack BK. 2010. *Indonesia: a pilot PES auction in the Sumberjaya watershed: paying for biodiversity: enhancing the cost-effectiveness of payments for ecosystem services.* Paris: Organisation for Economic Co-operation and Development. p. 161–178.

Ajayi OC, Jack BK, Leimona B. 2012. Auction design for the private provision of public goods in developing countries: lessons from payments for environmental services in Malawi and Indonesia. *World Development* 40:1213–1223.

48 | Multi-scale payments-for-environmental services' paradigms (MuScaPES)

Beria Leimona, Sara Namirembe, Meine van Noordwijk and Peter A. Minang

Beyond the umbrella term of 'payments for environmental services', a range of paradigms and associated mechanisms have emerged that differ in articulation and in economic, social and political assumptions. This tool helps clarify the range of possibilities.

Introduction

As discussed in volume 1 (van Noordwijk et al 2011), rewards for the continued or enhanced provision of environmental services are an attempt to close the loop and link the concerns of stakeholders who are external to decision making about land use in a certain landscape to those that make the decisions.

'Payments for ecosystem (or environmental) services' (PES) (Swallow et al 2010, Namirembe et al 2014) have been broadly defined as a conditional instrument where environmental stewards are given incentives to maintain or improve the flow of environmental services by those who benefit from these flows. We have identified three main paradigms within this concept: 1) commoditization (also termed commodification); 2) compensation; and 3) co-investment, which use the acronyms CES, COS and CIS (van Noordwijk and Leimona 2010).

Table 48.1. Reward mechanisms under the three paradigms of commodification, compensation and co-investment

Reward mechanism	Sub-category	Performance indicator	Example of source of reward
Commoditisation	Commoditisation of environmental services as such	Delivery of specified services above agreed baseline level	Global regulated or voluntary carbon markets
	'Environmental service' branding of established commodities	Audited compliance with certification standards, with clarified force majeure clauses	Eco-certified coffee, cocoa or tea; Forest Stewardship Council certification of timber
Compensation	Compensation	Adherence to restrictions or proxies for generation of specified services beyond legal requirements	International conservation organisations, wildlife tourism or niche market commodity consumers

Reward mechanism	Sub-category	Performance indicator	Example of source of reward
Co-investment	Payment for effort proven or trusted to generate specified services	Proof of actions known for generation of specified services	Conservation organisations, conservation funds, carbon brokers
	Incentive for a set of efforts for ecosystem management without specifying which services	Achievement of mutually negotiated actions for maintaining or enhancing baseline condition of an ecosystem	International conservation organisations, conservation funds, national governments
	Incentives for private businesses that generate positive ecosystem services' externalities	Maintaining or enhancing baseline condition of ecosystem	National governments

Source: modified from Namirembe et al 2014

PES has often been described as 'internalizing externalities' because it tries to make the micro-economic incentives for farm-level decision making aligned with meso- and macro-economic interests and to reduce the negative impacts of decisions on other stakeholders. Beyond micro- and macro-economies, however, we now recognize the giga-economics of planetary boundaries and also the pico-economic scale of brain-level decision making (van Noordwijk et al 2012). The real internalization can now be seen as touching on the underlying layer of emotions that guides human decisions before they are 'rationalized' as a way of communicating with others. That raises the question where environmental issues sit in a hierarchy of emotions.

Van Noordwijk et al (2013) proposed a 'motivational pyramid' that can be used to discuss the priorities of a local or national government and its concerns for the health and well-being of its citizens, as well as relations to global environmental quality, global commodity trade and development.

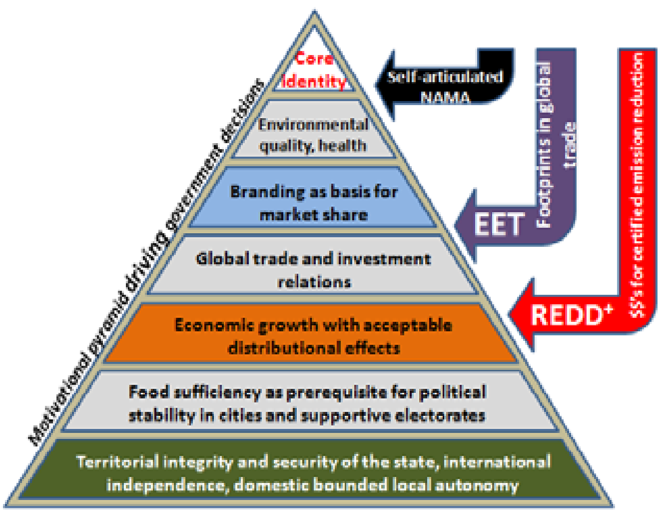


Figure 48.1. Motivational pyramid of the concerns of a typical government and its interactions with possible mechanisms to reduce greenhouse gas emissions

Note: NAMA = nationally appropriate mitigation actions; EET = emissions embodied in trade; REDD+ = reducing emissions from deforestation and forest degradation plus conservation

Source: van Noordwijk et al 2013

Objectives

Assist local, national and international proponents of PES and PES-like arrangements in choosing a locally appropriate paradigm and understand its relation with underlying motivation.

Steps

1. Conduct focus-group discussions with proponents of PES and PES-like arrangements (local communities, government officials, NGOs and private entities) to understand the paradigms, similarity in goals and differences in ways of achieving them, as well as the positive and negative connotations of the terms used (buyer/seller/intermediary/market versus compensator/compensee versus co-investors/shared risks and benefits). Make a list of local examples and discuss their clarification according to Table 48.2.
2. Explore the preconditions, appropriateness of underlying principles and strictness of conditionality (Table 48.2) in the local context in separate discussions and in-depth interviews with key stakeholders.

Table 48.2. Decision table to identify suitable sub-categories of PES instruments

Preconditions	Type of reward	Principle for establishing reward	Strictness of conditionality	Sub-category
Clarity of property rights over land and trees; compliance with legal requirements for generation of environmental services	Cash or in-kind rewards to individuals or groups. Sometimes with co-benefits	Willingness of buyers to pay for environmental services additional to a baseline status	Payment proportional to quantity of specified, verified and certified environmental services additional to a baseline.	Commoditisation of environmental services as such
Existing commodity markets with interest in enhancement of environmental services	Maintenance of market share (traded volumes) and/or price	Willingness of consumers to pay premium price for quality of production process rather than the product as such	Certification standards and auditing practice are under public scrutiny	'Environmental service' branding of established commodities
Legality of environmental-services reducing practices that are foregone and now compensated	Cash or in-kind rewards to individuals or groups. Sometimes with revenue or benefit sharing	Willingness of sellers to accept compensation for opportunity costs for maintaining or enhancing existing baseline environmental services' status	Payment proportional to opportunity cost of land and/or of adherence to specified restrictions or conservation actions	Compensation

Preconditions	Type of reward	Principle for establishing reward	Strictness of conditionality	Sub-category
	In-kind to groups. Inputs, for example, seedlings, labour. Sometimes with capacity building and advisory support	Mutual sharing of roles to achieve livelihood and environmental services' outcomes. Ownership of environmental services sometimes distinct from ownership of livelihoods.	Payment proportional to effort (for example, number of trees planted) for achieving environmental services' outcome	Payment for effort proven or trusted to generate specified environmental services
Applicable where preconditions for other reward mechanisms are not yet achieved	In-kind: access to or (co-) ownership of resources or land, tree seedlings, support of conservation friendly enterprise, for example, bee keeping. Benefit sharing	Precautionary investment in management plans for meaningful participation of local stakeholders as insurance banking for environmental services without market demand.	Negotiated rewards provided fully and good relations maintained, with continuous negotiation and encouragement of good performance. Rewards can be completely withdrawn but this is rare	Incentive for a set of efforts for ecosystem management without specifying environmental services
	License permits, rights or (co-) ownership of resource to businesses or community organizations	Willingness of buyers to pay for high value commodities or services that may maintain or enhance or unspecified environmental services	Permits upheld provided there are no negative environmental impacts	Incentives for private businesses that generate positive environmental services externalities

3. Focus-group discussion: is the motivational pyramid of Figure 47.1 applicable and/or does it need modification to understand local conditions?
4. Building on the approach and results of FERVA, consider the opportunities to balance fairness and efficiency at three scale transitions: 1) the international border of a country; 2) the interactions between national government and sub-national/local governments and private sector actors; and 3) the interactions between a local government and/or private sector agent mandated (through a concession) by government and local community members and agencies. Is it feasible (and if so under what conditions) to combine paradigms across scales without compromising on transparency and clarity? Identify examples where such combinations operate.
5. Bring the conclusions of preceding steps into local discussions of options for locally appropriate PES arrangements. Identify opportunities and bottlenecks for improvement of existing PES approaches and options to address these. Contribute to the debate on which designs are appropriate at international, national and local scales, bringing in the local experience and evidence.

Case study: CES, COS and CIS in Africa

Namirembe et al (2014) classified 50 existing PES applications in Africa according to the CES, COS and CIS framework and found 15, 6 and 29 projects that (predominantly) use the paradigms, respectively. Within CES, which applies exclusively to carbon at this stage, the prices used were subsidized ('compensated for co-benefits') above market levels.

As an example of Step 5, Minang and van Noordwijk (2013) discussed the emerging lessons of the REDD+ discussion (Figure 47.2) and concluded that a multiple paradigm construction is feasible. While it adds complexity at the interfaces, it allows a balance between fairness and efficiency (see FERVA) to be struck at each level, beyond what a single paradigm approach might achieve.

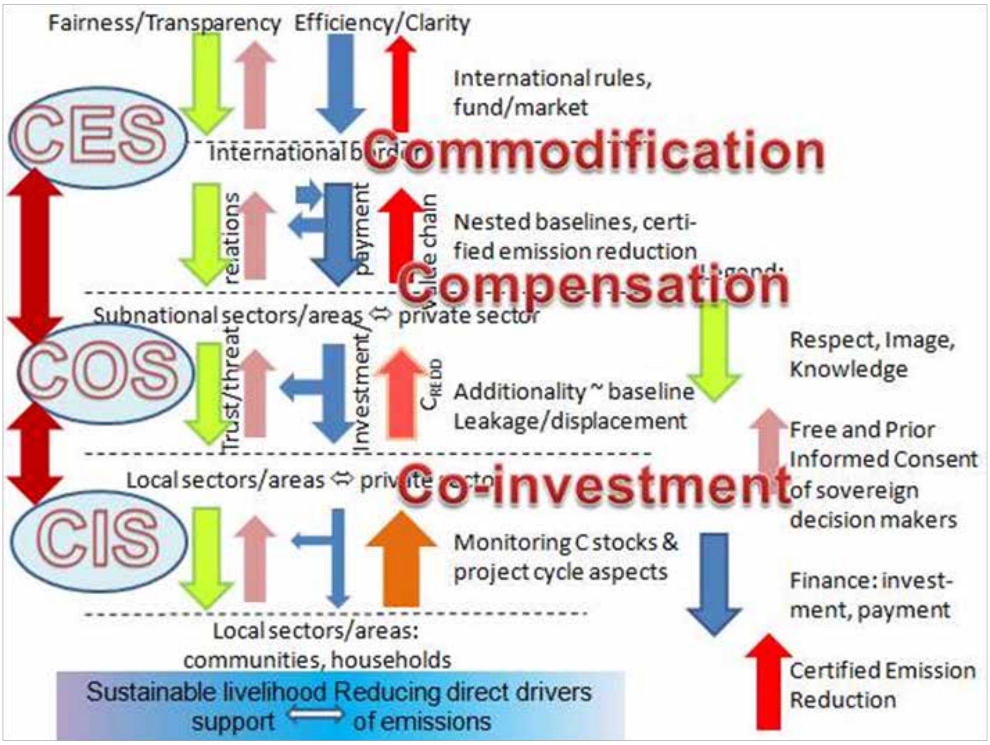


Figure 48.2. Cross-scale relations of the fairness exchange (respect versus commitment) and the efficiency transactions (environmental service enhancement per unit funds invested)

Source: modified from Minang and van Noordwijk 2013

■ Key references

Namirembe S, Leimona B, van Noordwijk M, Bernard F, Bacwayo KE. 2013. Co-investment paradigms as alternatives to payments for tree-based ecosystem services in Africa. *Current Opinion in Environmental Sustainability*. http://dx.doi.org/10.1016/j.cosust.2013.10.016.

van Noordwijk M, Agus F, Dewi S, Purnomo H, Lusiana B, Villamor GB. 2013. *Reducing emissions from all land uses in Indonesia: motivation, expected funding streams and multi-scale policy instruments.* ASB Policybrief 34. Nairobi, Kenya: ASB Partnership for the Tropical Forest Margins.

49 | Integration

Meine van Noordwijk, Beria Leimona, Sonya Dewi, Ujjwal Pradhan, Sara Namirembe, Delia Catacutan, James M. Roshetko and Peter A. Minang

Some guidance is given on how the support of negotiations between stakeholders over crucial landscape issues can be organized in a multidisciplinary, multi-skilled team with awareness of the need for, and challenges of, communication across multiple knowledge systems, attitudes, skills and aspirations.

Introduction

In the end, it is all about communication, relationships and fairness. Clark et al (2011) provided the overarching framework of boundary work and boundary objects as the way science, policy and action can be linked in negotiation support systems. Aristotle[1] already knew that it was the combinations of *pathos*, *ethos* and *logos* that conveyed the salience, legitimacy and credibility of a speaker. We can now link that to the public/policy, local and science-based dimensions of the knowledge systems we explored throughout the tools presented here. The default assumption has to be that we deal with the most complex of situations, multiple stakes and multiple knowledge systems (or claims to knowledge), where all 'evidence' is contested as representing a political bias, until proven otherwise. Fairness perceptions and the relevance of relationships, beyond what standard economics deals with, remain hard to grasp (Pagiola et al 2005, Ariely 2008, van Noordwijk et al 2012). Learning can shift knowledge, attitudes, skills and aspirations but generally requires a safe space, shielded from the daily routine and not confined by the trenches that all institutions tend to form around them.

Given the tools that are available, effectively supporting negotiations in learning landscapes requires that the team involved is aware of the complexities and through its own composition crosses the boundaries between disciplines, culture, gender, age and experience. Affinity of team members with the different stakeholders can bring the complexity of the real world into the team itself but can also help in communicating results. If we value diversity for the strength, buffering and filtering it provides in ecological systems, we need to embrace it ourselves.

As stated in the introduction, this volume aims to provide guidance and learning points for the integration and process aspects of negotiation support. A number of steps have been identified but need not necessarily be followed in order. In negotiation systems, the steps become part of an iterative process that is flexible and reflexive, allowing learning to take place at each step.

For a class of problems where the primary stakeholders can see eye to eye, the concept of outcome mapping (Earl et al 2001) within the negotiation process can be used. For each boundary partner, outcome challenges, that is, changes in behaviours that will contribute to the common objectives, are identified. Progress markers are defined to monitor whether the process is getting closer to reaching the outcome, which is mostly non-linear in many ways.

[1] http://en.wikipedia.org/wiki/Rhetoric

Objectives

Provide guidance and learning points for the integration and process aspects of negotiation support.

Points to consider

- Form multidisciplinary teams with members who represent a variety of institutional associations, disciplinary backgrounds, cultural roots, gender and experience, language and non-linguistic communication skills but who share a sense of commitment to learning, individually and as team.
- Engage with the various boundary partners at an early stage, while identifying further the strategic partners and nuances within what appeared to be homogenous groups in the process. Listen to concerns, try to unpack the way knowledge, attitudes, skills and aspirations are intertwined with claims to rights and where insecurity blocks change.
- Start with the three exploratory tools of Section 1 and use early results to select which other tools can be used to understand the complexity and priority issues of the area (Figure 49.1).

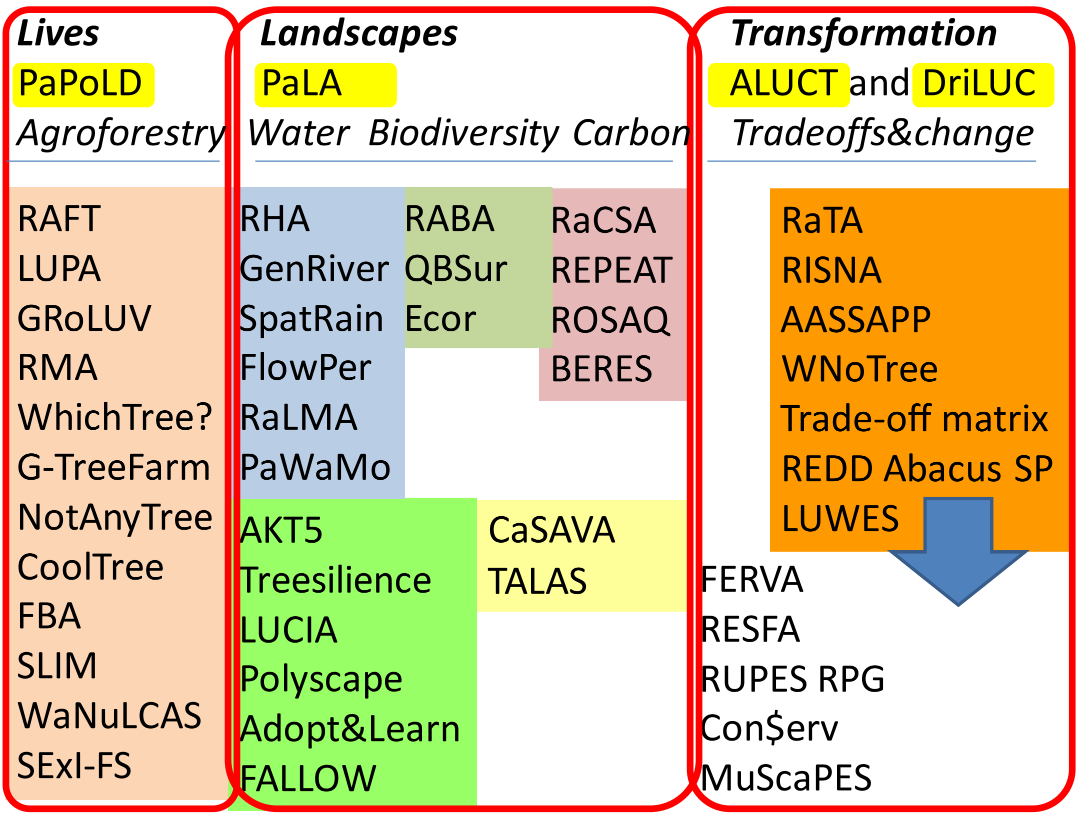


Figure 49.1. Grouping of the tools as a stepped approach to the complexity of the socio-ecological system

- Identify opportunities for some 'early wins' to create confidence and trust before facing the bigger challenges. Remain honest and humble about what these wins can achieve in the face of the bigger issues.
- Create a safe space where emerging knowledge can be criticized, dissected, enriched without undermining confidence and self esteem, celebrating success in relation to the external relations and ensuring that due credit is given for all roles and contributions.
- Have team members immersed in the field, without overly tight deadlines on deliverables, to facilitate the identification of new issues and solutions while engaging with the landscape, the people, its history and the multiple visions, risks, peceptions and aspirations. There always are multiple timescales involved and the typical project operates at only one of these, while real change is a much slower process.
- Protect the team from the tendency of management systems to become more than the support system for internal fairness and efficiency plus external accountability that they are supposed to be.
- Build in quality time points for reflection and internal learning, with key stakeholders of the landscapes and issues of focus, as well as internally. Share emerging lessons widely to get feedback and create new alliances. Don't be shy to challenge existing theories of change in the research or development realm, even those that underpin current funding, when the evidence and experience does not appear to align existing theory and established wisdom.
- Be ready for harsh criticisms and strong blocks generated by competing stakeholders; consider resource limitations that create protracted knowledge and communication that can harm the negotiation process

Example of application

None of the above steps are particularly new or innovative. Experience with the ASB Partnership for Tropical Forest Margins was described by Tomich et al (2007). Subsequent experience in projects such as REALU (Bernard et al 2013) have reconfirmed the possibility of working in a nesting of national teams within an international effort to jointly learn and explore new avenues. Many of the steps are also closely linked to outcome mapping, which has been widely applied (http://www.outcomemapping.ca/).

Referring to the six leading questions of Figures 0.3 and 0.13, we recently experimented with a new boundary object: a hexagon of six posters which on each side gives highlights of emerging understanding of one of the aspects while allowing team members and others to walk around and notice new connections between what might have been seen as separate issues. Examples of the sets of six posters for ten learning landscapes can be found at http://worldagroforestry.org/apps/slideshow.

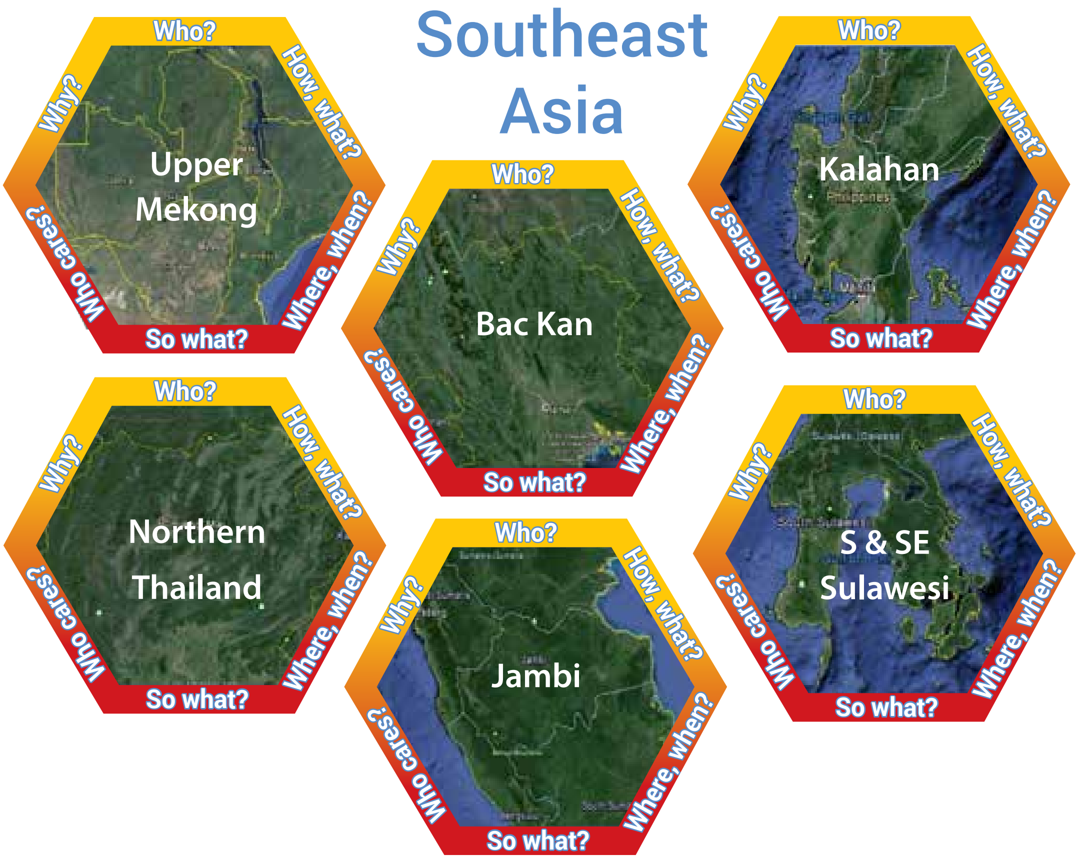


Figure 49.2. Learning landscapes as question-filled hexagons

Concluding remarks

Our overarching hypothesis from volume I (van Noordwijk et al 2011) for this tool collection has been:

> Investment in institutionalising rewards for the environmental services that are provided in multifunctional landscapes with trees is a cost-effective and fair way to reduce vulnerability of rural livelihoods to climate change and to avoid larger costs of specific 'adaptation' while enhancing carbon stocks in the landscape.

Through the various tools and discussions herein, the concepts of multifunctionality, environmental services, livelihoods and climate change will hopefully become concrete for any specific context and discussions can progress towards institutional support for work on the ground that reduces human and ecosystem vulnerability. The negotiation support tools presented in this volume offer tremendous opportunities for deriving what is legitimate, credible and salient solutions to complex landscape issues but the tools are only as good as the users' ability to apply them. A well-trained and committed team is needed. Our toolbox is constantly growing and we welcome contact with all who want to make this a joint effort.

References

Agus F, Farida, van Noordwijk M, eds. 2004. Hydrological impacts of forest, agroforestry and upland cropping as a basis for rewarding environmental service providers in Indonesia. *Proceedings of a workshop in Padang/Singkarak, West Sumatra, Indonesia, 25–28 February 2004*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Alkabbashi AN, Alam MdZ, Mirghani MES, Al-Fusaiel AMA. 2009. Biodiesel production from crude palm oil by transesterification process. *Journal of Applied Science* 9(17).

Ash N, Blanco H, Brown C, Vira B, Garcia K, Tomich T. 2010. *Ecosystems and human well-being: a manual for assessment practitioners*. Washington, DC: Island Press.

Bagstad KJ, Semmens DJ, Waage S, Winthrop R. 2013. A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services* 5:27–39.

Bayas JL, Marohn C, Dercon G, Dewi S, Piepho H, Joshi L, van Noordwijk M, Cadisch G. 2011. Influence of coastal vegetation on the 2004 tsunami wave impact in West Aceh. *Proceedings of the National Academies of Science*. http://www.pnas.org/content/early/2011/11/02/1013516108.

Bernard F, Minang PA, van Noordwijk M, Freeman OE, Duguma LA, eds. 2013. *Towards a landscape approach for reducing emissions: substantive report of Reducing Emissions from All Land Uses (REALU) project*. Nairobi: World Agroforestry Centre (ICRAF).

Bernard F, van Noordwijk M, Luedeling E, Villamor GB, Gudeta S, Namirembe S. 2014. Measuring and monitoring sustainability in agriculture: engaging relevant audiences in developing countries. *Current Opinion in Environmental Sustainability*.

Betser L, Degrande A. 2001. Marketing surveys. In: *Tree domestication in agroforestry*. Module 2, Session 5. Nairobi: World Agroforestry Centre (ICRAF).

Bian L. 1997. Multiscale nature of spatial data in scaling up environmental models. In: DA Quattrochi, MF Goodchild, eds. *Scale in remote sensing and GIS*. Boca Raton, FL: CRC Lewis.

Bourne M, Makui P, Muller A, Gassner A. In press. Social network analysis for determining gender-differentiated sources of information and tree seedlings. In: D Catacutan, MA Llanza, E Mcgaw, eds. *In equal measure: a user-guide to gender analysis in agroforestry*. Los, Baños, Philippines: World Agroforestry Centre (ICRAF) Philippines.

Bruijnzeel S, van Noordwijk M. 2008. *Deforestation and the multiple functions of tropical watersheds: are tropical forests indispensable for regulating rainfall and ensuring clean and reliable water supplies?* ASB Policybrief 08. Nairobi: ASB Partnership for the Tropical Forest Margins. http://intranet/downloads/publications/PDFs/BR08133.PDF.

Buttoud G, Place F, Gauthier M, Gallopin K, Gauthier M, Detlefsen G, Torquebiau E, Ajayi O. 2013. *Advancing agroforestry on the policy agenda: a guide for decision-makers.* Agroforestry Working Paper no. 1. Rome: Food and Agriculture Organization of the United Nations.

Carsan S, Karanja E, Bourne M, Muchugi A, Franzel S, Jamnadass R. In press. Mapping gender preferences for tree and shrub forages. In: D Catacutan, MA Llanza, E Mcgaw, eds. *In equal measure: a user-guide to gender analysis in agroforestry*. Los, Baños, Philippines: World Agroforestry Centre (ICRAF) Philippines.

Catacutan D, Llanza MA, Mcgaw E, eds. 2014. *In equal measure: a user-guide to gender analysis in agroforestry*. Los Baños, Philippines: World Agroforestry Centre (ICRAF) Philippines.

Chokkalingam U, Suyanto S, Permana RP, Kurniawan I, Mannes J, Darmawan A, Khususiyah N, Susanto RH. 2006. Community fire use, resource change, and livelihood impacts: the downward spiral in the wetlands of southern Sumatra. *Mitigation and Adaptation Strategies for Global Change* 12. DOI 10.1007/s11027-006-9038-5: P. 75-100 http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1501

Clark WC, Tomich TP, van Noordwijk M, Guston D, Catacutan D, Dickson NM, McNie E. 2011. Boundary work for sustainable development: natural resource management at the Consultative Group on International Agricultural Research (CGIAR). *Proceedings of the National Academies of Science*. DOI:10.1073/pnas.0900231108

Corley RHV, Tinker B. 2003. *The oil palm*. 4th edition. Hoboken, NJ: Blackwell Publishing.

Cronin M, Bourne M. In press. Participatory resource mapping for gender analysis. In: D Catacutan, MA Llanza, E Mcgaw, eds. *In equal measure: a user-guide to gender analysis in agroforestry*. Los, Baños, Philippines: World Agroforestry Centre (ICRAF) Philippines.

Crutzen PJ, Mosier AR, Smith KA, Winiwarter W. 2008. N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. *Atmospheric Chemistry and Physics* 8:389–395.

Danielsen F, Adrian T, Brofeldt S, van Noordwijk M, Poulsen MK, Rahayu S, Rutishauser E, Theilade I, Widayati A, The An N, Nguyen Bang T, Budiman A, Enghoff M, Jensen AE, Kurniawan Y, Li Q,. Mingxu Z, Schmidt-Vogt D, Prixa S, Thoumtone V, Warta Z, Burgess N. 2013. Community monitoring for REDD+: international promises and field realities. *Ecology and Society* 18(3):41. http://dx.doi.org/10.5751/ES-05464-180341.

Demirbas A. 2007. Importance of biodiesel as transportation fuel. *Energy Policy* 35.

Dewi S, Ekadinata A, Galudra G, Agung P, Johana F. 2011. *LUWES: Land use planning for low emission development strategy*. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Dewi S, Johana F, Agung P, Zulkarnain MT, Harja D, Galudra G, Suyanto S, Ekadinata A. 2013a. *Perencanaan penggunaan lahan untuk mendukung pembangunan rendah emisi*. Land use planning to support low emission development strategies. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Dewi S, van Noordwijk M, Ekadinata A, Pfund JL. 2013b. Protected areas in relation to landscape multifunctionality: squeezing out intermediate land use intensities in the tropics? *Land Use Policy* 30:38–56.

Ekadinata A, Agung P. 2011. *Planning for low-emissions development in Tanjung Jabung Barat district, Jambi province, Indonesia*. Brief 20. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Ekadinata A, Widayati A, Vincent G. 2004. Rubber agroforest identification using object-based classification in Bungo District, Jambi, Indonesia. *Asian Conference on Remote Sensing* (2004):551–556.

Ekadinata A, Rahmanulloh A, Pambudhi F, Ibrahim I, van Noordwijk M, Sofiyuddin M, Sardjono MA, Rahayu S, Dewi S, Budidarsono S, Said Z. 2010. *Carbon emissions from land use, land use change and forestry (LULUCF) in Berau District, East Kalimantan, Indonesia*. Project Report. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Evans K, Velarde SJ, Prieto R, Rao S, Sertzen S, Dávila K, Cronkleton P, de Jong W. 2006. *Field guide to the future: four ways for communities to think ahead*. Nairobi: Center for International Forestry Research; ASB Partnership for the Tropical Forest Margins; World Agroforestry Centre (ICRAF). http://www.asb.cgiar.org/ma/scenarios.

European Union. 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. *Official Journal of the European Union* 5.6.2009:16-62.

Galudra G, Sirait MT, Pasya G, Fay CC, Suyanto S, van Noordwijk M, Pradhan U. 2010. *RaTA: a rapid land tenure assessment manual for identifying the nature of land tenure conflicts*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Galudra G, van Noordwijk M, Suyanto, Sardi I, Pradhan U, Catacutan D. 2011. Hot spots of confusion: contested policies and competing carbon claims in the peatlands of Central Kalimantan (Indonesia). *International Forestry Review* 13:431–441.

Galudra G, van Noordwijk M, Agung P, Suyanto S, Pradhan U. 2013. Migrants, land markets and carbon emissions in Jambi, Indonesia: land tenure change and the prospect of emission reduction. *Mitigation and Adaptation Strategies for Global Change*. http://link.springer.com/article/10.1007/s11027-013-9512

Gittinger JP. 1982. *Economic analysis of agricultural projects.* 2nd edition. Baltimore, USA: John Hopkins University Press.

Hairiah K, Rahayu S. 2007. *Pengukuran karbon tersimpan di berbagai macam penggunaan lahan*. Measuring carbon stocks across land-use systems. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestry.org/sea/publication?do=view_pub_detail&pub_no=MN0035-07.

Hairiah K, Sitompul SM, van Noordwijk M, Palm CA. 2001. *Methods for sampling carbon stocks above and below ground*. ASB Lecture Note 4B. Bogor, Indonesia: International Centre for Research in Agroforestry Southeast Asia Regional Research Programme.

Hairiah K, Dewi S, Agus F, Velarde SJ, Ekadinata A, Rahayu S, van Noordwijk M. 2011. *Measuring carbon stocks across land use systems: a manual.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Harja D, Vincent G, Purnomosidhi P, Rahayu S, Joshi L. 2005. Impact of rubber tree planting patterns on Imperata cylindrica dynamics: exploring weed control through shading using SExI-FS, a forest stand simulator. *Proceedings of the International Workshop on Smallholder Agroforestry Options on Degraded Soils*. Batu, East Java, Indonesia, 18–21 August 2005. (np, np).Harja D, Dewi S, van Noordwijk M, Ekadinata A, Rahmanulloh A, Johana F. 2012a. *REDD Abacus SP: buku panduan pengguna dan software*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Harja D, Vincent G, Mulia R, van Noordwijk M. 2012b. Tree shape plasticity in relation to crown exposure. *Trees: Structure and Function* 26(4):1275–1285. doi 10.1007/s00468-012-0703-x.

He J. 2010. Globalised forest products: commodification of the matsutake mushroom in Tibetan villages, Yunnan, Southwest China. *International Forestry Review* 12(1).

Hörhold S, Marohn C. 2012. *User manual for the land use change impact assessment tool LUCIA*. Hohenheim, Germany: Hohenheim University. https://lucia.uni-hohenheim.de/fileadmin/einrichtungen/lucia/lucia_user_manual.pdf.

[IPCC] Intergovernmental Panel on Climate Change. 1996. *Revised 1996 IPCC guidelines for national greenhouse gas inventories*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

[ILO] International Labour Organization. 2000. *Rapid market appraisal: a manual for entrepreneurs*. FIT Manual Series. Geneva: International Labour Organization.

Jackson LE, Pulleman MM, Brussaard L, Bawa KS, Brown G, Cardoso IM, de Ruiter P, García-Barrios L, Hollander AD, Lavelle P, Ouédraogo E, Pascual U, Setty S, Smukler SM, Tscharntke T, van Noordwijk M. 2012. Social-ecological and regional adaptation of agrobiodiversity management across a global set of research regions. *Global Environmental Change* 22:623–639.

Johana F, Agung P. 2011. *Planning for low-emissions development in Merangin district, Jambi province, Indonesia*. Brief 19. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Johana F, Agung P, Widayati A, Suyanto. 2013a. Low emission development (LED) initiatives as part of maintaining local ecosystem services in Tanjung Jabung Barat District, Province of Jambi, Indonesia. *6th Annual International Ecosystem Services Partnership Conference.* 26–30 August 2013, Bali, Indonesia. Wageningen, The Netherlands: Ecosystem Services Partnership.

Johana F, Suyanto S, Widayati A, Zulkarnain MT, Muller D, Budiman A. 2013b. *Local mitigation actions supporting the low emission development plan in Kutai Barat District, Indonesia: initial process*. Brief 35: Kutai Barat series. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Joshi L, Wibawa G, Beukema HJ, Williams SE, van Noordwijk M. 2003. Technological change and biodiversity in the rubber agroecosystems. In: JH Vandermeer, ed. *Tropical agroecosystems: new directions for research*. Boca Raton, FL: CRC Press. p. 133–157.

Joshi L, Shrestha P, Moss C, Sinclair FL. 2004a. Locally derived knowledge of soil fertility and its emerging role in integrated natural resource management. In: M van Noordwijk, G Cadisch, CK Ong, eds. *Belowground interactions in tropical agroecosystems: concepts and models with multiple plant components*. Wallingford, UK: CABI.

Joshi L, Schalenbourg W, Johansson L, Khasanah N, Stefanus E, Fagerström M, van Noordwijk M. 2004b. Soil and water movement: combining local and modellers' ecological knowledge in scaling up from plot to landscape. In: M van Noordwijk, G Cadisch, CK Ong, eds. *Belowground interactions in tropical agroecosystems: concepts and models with multiple plant components*. Wallingford, UK: CABI.

Kamahara H, Widiyanto A, Tachibana R, Atsuta Y, Goto N, Daimon H, Fujie K. 2008. *Greenhouse gas balance on life cycle of biodiesel: a case of palm biodiesel production in Indonesia*. Paper presented at 8th International Conference on EcoBalance, Tokyo, 10–12 December 2008. Tokyo: Institute of Life Cycle Assessment.

Kuncoro SA, van Noordwijk M, Martini E, Saipothong P, Areskoug V, Ekadinata A, O'Connor T. 2006. Rapid agro-biodiversity appraisal (RABA) in the context of environmental service rewards. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1496.

Le Quéré C, Peters G, Andres R, Andrew R, Boden T, Ciais P, Friedlingstein P, Houghton RA, Marland G, Moriarty R, Sitch S, Tans P, Arneth A, Arvanitis A, Bakker DCE, Bopp L, Canadell JG, Chini LP, Doney SC, Harper A, Harris I, House JI, Jain AK, Jones SD, Kato E, Keeling RF, Klein Goldewijk K, K**ö**rtzinger A, Koven C, Lef**è**vre N, Omar A, Ono T, Park G-H, Pfeil B, Poulter B, Raupach MR, Regnier P, R**ö**denbeck C, Saito S, Schwinger J, Segschneider J, Stocker BD, Tilbrook B, van Heuven S, Viovy N, Wanninkhof R, Wiltshire A, Zaehle S, Yue C. Under review. Global Carbon Budget 2013. *Earth System Science Data Discussions.* http://www.earth-syst-sci-data-discuss.net/6/689/2013. DOI:10.5194/essdd-6-689-2013.

Leimona B, Joshi L, van Noordwijk M. 2009. Can rewards for environmental services benefit the poor? Lessons from Asia. *International Journal of the Commons* 3(1). http://www.thecommonsjournal.org/index.php/ijc/article/viewArticle/121

Lillesand TM, Kiefer RW, Chipman JW. 2004. *Remote sensing and image interpretation*. 5th Edition. Hoboken, NJ: John Wiley and Sons.

Lippe M, Thai Minh T, Neef A, Hilger T, Hoffmann V, Lam NT, Cadisch G. 2011. Building on qualitative datasets and participatory processes to simulate land use change in a mountain watershed of Northwest Vietnam. *Environmental Modelling & Software* 26:1454–1466.

Lusiana B, van Noordwijk M, Rahayu S. 2005. *Carbon stocks in Nunukan, East Kalimantan: a spatial monitoring and modelling approach*. Report from the carbon monitoring team of the Forest Resources Management for Carbon Sequestration project. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Lusiana B, Widodo R, Mulyoutami E, Adi DK, van Noordwijk M. 2008a. *Assessing the hydrological situation of Talau Watershed, Belu Regency, East Nusa Tenggara*. Working Paper 57. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Lusiana B, Widodo R, Mulyoutami E, Adi DK, van Noordwijk M. 2008b. *Kajian kondisi hidrologis DAS Kapuas Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat*. Hydrological study of the Kapuas Hulu watershed, Kapuas Hulu district, West Kalimantan. Working Paper 60. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Mackinnon J, Phillips K. 1993. *Field guide to the birds of Sumatra, Borneo, Java and Bali (the Greater Sunda Islands)*. Oxford, UK: Oxford University Press.

Marohn C, Cadisch G. 2013: Linking natural resource use and environmental functions in the uplands and lowlands: the land use change impact assessment (LUCIA) tool. In: H Fröhlich, P Schreinemachers, G Clemens, K Stahr, eds. *Sustainable land use and rural development in Southeast Asia: innovations and policies for mountainous areas.* Heidelberg, Germany: Springer.

Marohn C, Schreinemachers P, Quang DV, Berger T, Siripalangkanont P, Nguyen TT, Cadisch G. 2013. A software coupling approach to assess low-cost soil conservation strategies for highland agriculture in Vietnam. *Environmental Modelling and Software* 45:116–128.

Martini E, Roshetko JM, van Noordwijk M, Rahmanulloh A, Mulyoutami E, Joshi L, Budidarsono S. 2011. Sugar palm (Arenga pinnata (Wurmb) Merr) for livelihoods and biodiversity conservation in the orangutan habitat of Batang Toru, North Sumatra, Indonesia: mixed prospects for domestication. *Agroforestry Systems* 86:401–417.

Martini E, Roshetko JM, Purnomosidhi P, Tarigan J, Idris N, Zulfadhli T. 2013. Fruit germplasm' resources and demands for smallscale farmers post-tsunami and conflicts in Aceh, Indonesia. *Acta Horticulturae* (ISHS) 975:657–664.

Martini E, Tarigan J, Roshetko JM, Manurung G, Kurniawan I, Tukan J, Budidarsono S, Abdo M, van Noordwijk M. 2008. *Capacity building activities to strengthen agroforestry as a sustainable economic alternative in the orangutan habitat conservation program of Batang Toru, North Sumatra*. Working Paper 61. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1860

Maswar. 2011. *Kajian cadangan karbon pada lahan gambut tropika yang didrainase untuk tanaman tahunan*. Carbon stock assessment of tropical peatlands drained for annual crops. Bogor, Indonesia: Sekolah Pascasarjana, Institut Pertanian Bogor.

Meadows D. 1999. Leverage points: places to intervene in a system. *Solutions for a Sustainable and Desirable Future* 1:41–49.

Mbow C, Neufeldt H, van Noordwijk M, Minang P, Kowero G, Luedeling E. 2014. Agroforestry solutions to address climate change and food security challenges in Africa. *Current Opinion in Environmental Sustainability* 6:61–67.

Michon G, de Foresta H, Levang P, Verdeaux F. 2007. Domestic forests: a new paradigm for integrating local communities' forestry into tropical forest science. *Ecology and Society* 12(2):1. http://www.ecologyandsociety.org/vol12/iss2/art1/.

Minang PA, van Noordwijk M. 2013. Design challenges for achieving reduced emissions from deforestation and forest degradation through conservation: leveraging multiple paradigms at the tropical forest margins. *Land Use Policy* 31:61–70.

Minang PA, Duguma LA, Bernard, F, Metz O, van Noordwijk M. In press. Prospects for agroforestry in REDD+ landscapes in Africa. *Current Opinion in Environmental Sustainability*.

Monke E, Pearson SR. 1989. *The policy analysis matrix for agricultural development*. Ithaca, NY: Cornell University Press.

Muriuki J, Roshetko J, Nyoka I. 2012 Tree nursery practices. In: I Dawson, C Harwood, R Jamnadass, J Beniest, eds. *Agroforestry tree domestication: a primer*. Nairobi: World Agroforestry Centre (ICRAF). p. 70–79.

Namirembe S, Leimona B, van Noordwijk M, Bernard F, Bacwayo KE. 2014. Co-investment paradigms as alternatives to payments for tree-based ecosystem services in Africa. *Current Opinion in Environmental Sustainability* 6, 89–97.

Nang'ole EM, Mithöfer D, Franzel S. 2011. *Review of guidelines and manuals for value chain analysis for agricultural and forest products*. ICRAF Occasional Paper No. 17. Nairobi: World Agroforestry Centre (ICRAF).

Norman JM, Kucharik CJ, Gower ST, Baldocchi DD, Crill PM, Rayment M, Savage K, Striegl RG. 1997. A comparison of six methods for measuring soil-surface carbon dioxide fluxes. *Journal of Geophysical Research* 102(D24):28,771–28,777.

Ordonez JC, Luedeling E, Kindt R, Tata HL, Harja D, Jamnadass R, van Noordwijk M. 2014. Tree diversity along the forest transition curve: drivers, consequences and entry points for multifunctional agriculture. *Current Opinion in Environmental Sustainability* 6:54–60.

Parker C, Mitchell A, Trivedi M, Mardas N. 2008. *The Little REDD Book: a guide to governmental and non-governmental proposals for reducing emissions from deforestation and degradation*. Oxford: Global Canopy Programme.

Parton WJ, Schimel DS, Cole CV, Ojima DS. 1987. Analysis of factors controlling soil organic levels of grasslands in the Great Plains. *Soil Science Society of America Journal* 51:1173–1179.

Perdana A, Roshetko JM, Kurniawan I. 2012. Forces of competition: smallholding teak producers in Indonesia. *International Forestry Review* 14 (2):238–248.

Predo C. 2002. *Bioeconomic modeling of alternatives land uses for grasslands areas and farmers' tree-growing decisions in Misamis Oriental, Philippines*. PhD thesis. Los Baños, Philippines: University of the Philippines.

Quang DV. 2010. *Innovations and sustainability strategies in the upland agriculture of Northern Vietnam: an agent-based modeling approach*. Project report No. 2010-RR4. Singapore: Economy and Environment Program for Southeast Asia.

Rahmanulloh A, Sofiyudin M, Suyanto. 2012. *Agroforestry and Forestry in Sulawesi series: Profitability and land-use systems in South and Southeast Sulawesi*. Working paper 157. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. DOI: 10.5716/WP12056.PDF.

Rathjen L. 2010. *Characterization of current cassava-based cropping systems in the Chieng Khoi Watershed, NW Vietnam*. BSc Thesis. Hohenheim, Germany: Institute of Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim. https://sfb564.uni-hohenheim.de/84888.

Roshetko JM. 2007. *Agroforestry on the interface of orangutan conservation and sustainable livelihoods in Batang Toru (North Sumatra)*. Working Paper 56. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1794

Roshetko JM, Idris N, Purnomosidhi P, Zulfadhli T, Tarigan J. 2013. Farmer extension approach to rehabilitate smallholder fruit agroforestry systems: the Nurseries of excellence (NOEL) program in Aceh, Indonesia. *Acta Horticulturae* (ISHS) 975:649–656.

Roshetko JM, Mulawarman, Suharisno, Iriantono D, Harum F. 2003. *Direktori penyedia benih pohon di Indonesia, edisi kedua*. Directory of tree seed suppliers in Indonesia, second edition. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Little Rock, AR: Winrock International.

Roshetko JM, Nugraha E, Tukan JCM, Manurung G, Fay C, van Noordwijk M. 2002. Agroforestry for livelihood enhancement and enterprise development. Manuscript. Bogor, Indonesia: International Centre for Research in Agroforestry; Little Rock, AR: Winrock International.

Roshetko JM, Purnomosidhi P. 2013. Smallholder agroforestry fruit production in Lampung, Indonesia: horticultural strategies for smallholder livelihood enhancement. *Acta Horticulturae* (ISHS) 975:671–679.

Roshetko JM, Purnomosidhi P, Mulawarman. 2005. Farmer demonstration trials: promoting tree planting and farmer innovation in Indonesia. In: J Gonsalves, T Becker, A Braun, D Campilan, H de Chavez, E Fajber, M Kapiriri, J Rivaca-Caminade, R Vernooy, eds. *Participatory research and development for sustainable agriculture and natural resource management: a sourcebook*. Volume 3. Lima: International Potato Center. p. 1–8. http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=1214.

Ruthenberg H. 1976. *Farming systems in the tropics*. Oxford, UK: Oxford University Press.

Santos-Martin F. 2008. *Using native timber trees for recovering degraded landscapes in the Philippines: social, biophysical and economic assessment of agroforestry systems practiced by smallholder farmers*. PhD Thesis. Madrid: Cordoba University.

Santos-Martin F, van Noordwijk M. 2011. Is native timber tree intercropping an economically feasible alternative for smallholder farmers in the Philippines? *Australian Journal of Agricultural and Resource Economics* 55:257–272.

Santos-Martin F, Lusiana B, van Noordwijk M. 2010. Tree growth prediction in relation to simple set of site quality indicators for six native tree species in the Philippines. *International Journal of Forestry Research*. DOI: 10.1155/2010/507392. http://www.hindawi.com/journals/ijfr/2010/507392.html.

Saxton KE, Rawls WJ. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Science Society of America Journal* 70:1569–1578.

Schmitter P, Dercon G, Hilger T, Ha LTT, Thanh HN, Lam N, Vien TD. 2010. Sediment induced soil spatial variation in paddy fields of Northwest Vietnam. *Geoderma* 155:298–307.

Selvarajah R. 2013. *A NOEL approach to rehabilitating Aceh's smallholder agroforestry systems*. http://blog.worldagroforestry.org/index.php/2013/09/06/a-noel-approach-to-rehabilitating-acehs-smallholder-agroforestry-systems/.

Simelton E, Bac VD, Finlayson R. 2013. *The talking toolkit: how smallholders and local government can together adapt to climate change*. Hanoi: World Agroforestry Centre Viet Nam. http://worldagroforestrycentre.org/regions/southeast_asia/vietnam/products/tools/talking-toolkit.

Sinclair FL. 1999. A general classification of agroforestry practice. *Journal of Agroforestry Systems* 46:161–180.

Sitompul SM, Hairiah K, van Noordwijk M, Palm CA. 2001. *Carbon stocks of tropical land use systems as part of the global C balance: effects of forest conversion and options for clean development activities.* ASB Lecture Note 4A. Bogor, Indonesia: International Centre for Research in Agroforestry Southeast Asia Regional Research Programme.

Sofiyuddin M, Rahmanulloh A, Suyanto S. 2012. Assessment of profitability of land use systems in Tanjung Jabung Barat District, Jambi Province, Indonesia. *Open Journal of Forestry* 2(4):252–256.

Supit I. 2003. *Updated system description of the WOFOST crop growth simulation model as implemented in the crop growth monitoring system applied by the European Commission*. Heelsum, The Netherlands: Treemail Publishers. http://www.treemail.nl/download/treebook7/start.htm.

Suyamto DA, Mulia R. 2008. *Forest, agroforest, low-value landscape or wasteland (FALLOW) model: a simple tool to help you illuminate future options on development strategies to transform your rural agroforested landscapes into places worth living in and worth fighting for*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Suyamto DA, van Noordwijk M. 2005. Scenario studies of land use in Nunukan, East Kalimantan (Indonesia): drivers, local livelihoods and globally relevant carbon stocks. In: Lusiana B, van Noordwijk M, Rahayu S, eds. *Carbon stocks monitoring in Nunukan, East Kalimantan: a spatial and modelling approach*. Report from the Carbon Monitoring Team of the Forest Resources Management for Carbon Sequestration project. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Suyamto DA, van Noordwijk M, Lusiana B, Ekadinata A, Khasanah N. 2006. *Prospects of adoption of tree-based systems in a rural landscape and its likely impacts on carbon stocks and farmers' welfare: the FALLOW model application in Muara Sungkai, Lampung, Sumatra, in a ´Clean Development Mechanism' context*. ICRAF working paper 14. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Suyanto S. 2006. Underlying cause of fire: Different form of land tenure conflicts in Sumatra. *Mitigation and Adaptation Strategies for Global Change* 12:67–74. DOI 10.1007/s11027-006-9039-4. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1500

Suyanto S, Permana RP, Khususiyah N, Joshi L. 2004. Land tenure agroforestry adoption and reduction of fire hazard in a forest: a case study from Lampung, Sumatra, Indonesia. *Agroforestry Systems* 65(1):1–11.
http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=286

Swallow BM, van Noordwijk M, Dewi S, Murdiyarso D, White D, Gockowski J, Hyman G, Budidarsono S, Robiglio V, Meadu V, Ekadinata A, Agus F, Hairiah K, Mbile PN, Sonwa DJ, Weise S. 2007. *Opportunities for avoided deforestation with sustainable benefits: an interim report by the ASB Partnership for the Tropical Forest Margins.* Nairobi: ASB Partnership for the Tropical Forest Margins.

Swallow BM, Kallesoe MF, Iftikhar UA, van Noordwijk M, Bracer C, Scherr SJ, Raju KV, Poats SV, Kumar A, Duraiappah B, Ochieng O, Mallee H, Rumley R. 2009. Compensation and rewards for environmental services in the developing world: framing pan-tropical analysis and comparison. *Ecology and Society* 14(2):26. http://www.ecologyandsociety.org/vol14/iss2/art26/.

Tata HL, van Noordwijk M, Harja D, Joshi L. 2009. Dipterocarp trees in rubber agroforestry: interplanting strategies for high-value timber production in Sumatra. *World Congress on Agroforestry 2009*. Nairobi: World Agroforestry Centre.

Tata HL, Mulyoutami E, Janudianto, Sid Z, Ekadinata A, Widayati A, NIngsih H, Rahayu S, Ayat A, Nugroho P, Noerfahmy S, Taufik I. 2011. Recognizing biodiversity in rubber plantations. In: HL Tata, ed. *Toward a biodiverse rubber estate: quick biodiversity survey of Bridgestone Sumatra Rubber Estate, North Sumatra*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Program; Tokyo: Bridgestone Japan.

Tomich TP, Fagi AM, Michon G, Murdiyarso D, Stolle F, van Noordwijk M. 1998a. Indonesia's fires: smoke as a problem, smoke as a symptom. *Agroforestry Today*. http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=691

Tomich T, van Noordwijk M, Budidarsono S, Gillison A, Kusumanto T, Murdiyarso D, Stolle F, Fagi A. 1998b. *Alternatives to slash-and-burn in Indonesia: summary report and synthesis of phase II*. Bogor, Indonesia: ASB Indonesia; Central Research Institute for Food Crops.

Tomich TP, van Noordwijk M, Vosti S, Whitcover J. 1998c. Agricultural development with rainforest conservation: methods for seeking best bet alternatives to slash-and-burn, with applications to Brazil and Indonesia. *Agricultural Economics* 19:159–174.

Tomich TP, Timmer DW, Velarde SJ, Alegre J, Areskoug V, Cash DW, Cattaneo A, Cornelius J, Ericksen P, Joshi L, Kasyoki J, Legg C, Locatelli M, Murdiyarso D, Palm C, Porro R, Perazzo AR, Salazar-Vega A, van Noordwijk M, Weise S, and White D. 2007. Integrative science in practice: process perspectives from ASB, the Partnership for the Tropical Forest Margins. *Agriculture Ecosystems and Environment* 9: 269-286

Tukan CMJ, Roshetko JM, Budidarsono S, Manurung GS. 2006. Market chain improvement: linking farmers to markets in Nanggung, West Java, Indonesia. *Acta Horticulturae* 699: I.

Vandermeer J, van Noordwijk M, Ong C, Anderson J, Perfecto Y. 1998. Global change and multi-species agroecosystems: concepts and issues. *Agriculture, Ecosystems and Environment* 67:1–22.

Van Dijk AIJM, van Noordwijk, Calder IR, Bruijnzeel SLA, Schellekens JAAP, Chappell NA. 2009. Forest-flood relation still tenuous: comment on 'Global evidence that deforestation amplifies flood risk and severity in the developing world' by CJA Bradshaw, NS Sodi, KS-H Peh, BW Brook. *Global Change Biology* 15:110–115. http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2008.01708.x/abstract.

Van Noordwijk M, Leimona B. 2010. Principles for fairness and efficiency in enhancing environmental services in Asia: payments, compensation, or co-investment? *Ecology and Society* 15(4):17. http://www.ecologyandsociety.org/vol15/iss4/art17/

Van Noordwijk M, Lusiana B. 1999. WaNuLCAS: a model of water, nutrient and light capture in agroforestry systems. *Agroforestry Systems* 43:217–242.

Van Noordwijk M, Mulia R. 2002. Functional branch analysis as tool for fractal scaling above- and belowground trees for their additive and non-additive properties. *Ecological Modeling* 149:4151.

Van Noordwijk M, Purnomosidhi P. 1995. Root architecture in relation to tree-soil-crop interactions and shoot pruning in agroforestry. *Agroforestry Systems* 30:161173.

Van Noordwijk M, Spek LY, de Willigen P. 1994. Proximal root diameter as predictor of total root size for fractal branching models I. Theory. *Plant Soil* 164:107117.

Van Noordwijk M, Tomich TP, Verbist B. 2001. Negotiation support models for integrated natural resource management in tropical forest margins. *Conservation Ecology* 5(2):21. http://www.consecol.org/vol5/iss2/art21.

Van Noordwijk M, Williams SE, Verbist B, eds. 2001. *Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns.* ASB Lecture Notes 1–13. Bogor, Indonesia: International Centre for Research in Agroforestry Southeast Asia Regional Research Programme.

Van Noordwijk M, Lusiana B, Khasanah M. 2004a. *WaNuLCAS version 3.1. Background on a model of water, nutrient, and light capture in agroforestry systems*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Cadisch G, Ong CK, eds. 2004b. *Belowground interactions in tropical agroecosystems.* Wallingford, UK: CABI.

Van Noordwijk M, Verbist B, Hairiah K. 2006. *Muddy rivers: lack of trees? Synthesis: the difference a tree can make*. Nairobi: World Agroforestry Centre.

Van Noordwijk M, Agus F, Verbist B, Hairiah K, Tomich TP. 2007. Managing watershed services in eco-agriculture landscapes. In: SJ Scherr, JA McNeely, eds. *Farming with nature: the science and practice of ecoagriculture.* Washington, DC: Island Press. p. 191–212.

Van Noordwijk M, Suyamto DA, Lusiana B, Ekadinata A, Hairiah K. 2008a. Facilitating agroforestation of landscapes for sustainable benefits: tradeoffs between carbon stocks and local development benefits in Indonesia according to the FALLOW model. *Agriculture Ecosystems and Environment* 126:98–112.

Van Noordwijk M, Purnomo H, Peskett L, Setiono B. 2008b. *Reducing emissions from deforestation and forest degradation (REDD) in Indonesia: options and challenges for fair and efficient payment distribution mechanisms*. Working Paper 81. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestrycentre.org/sea/publications/searchpub.asp?publishid=2120.

Van Noordwijk M, Hoang MH, Neufeldt H, Öborn I, Yatich T, eds. 2011a. *How trees and people can co-adapt to climate change: reducing vulnerability through multifunctional agroforestry landscapes.* Nairobi: World Agroforestry Centre (ICRAF).

Van Noordwijk M, Dewi S, Suyanto S, Minang PA, White D, Robiglio V, Hoang MH, Ekadinata A, Mulia R, Harja D. 2011b. *Abatement cost curves relating past greenhouse gas emissions to the economic gains they allowed.* Project Report. Bogor, Indonesia. World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Lusiana B, Khasanah N, Mulia R. 2011c. *WaNuLCAS version 4.0: background on a model of water nutrient and light capture in agroforestry systems.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Program.

Van Noordwijk M, Leimona B, Jindal R, Villamor G B, Vardhan M, Namirembe S, Catacutan D, Kerr J, Minang PA, Tomich TP. 2012a. Payments for environmental services: evolution towards efficient and fair incentives for multifunctional landscapes. *Annual Review of Environmental Resources* 37:389–420.

Van Noordwijk M, Dewi S, Lusiana B, Harja D, Agus F, Rahayu S, Hairiah K, Maswar M, Robiglio V, Hyman G, White D, Minang PA, Verchot L, Phuong VT. 2012b. *Recommendations on the design of national monitoring systems relating the costs of monitoring to the expected benefits of higher quality of data.* Project Report. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Agus F, Dewi S, Purnomo H. 2013a. Reducing emissions from land use in Indonesia: motivation, policy instruments and expected funding streams. *Mitigation and Adaptation Strategies for Global Change*. DOI: 10.1007/s11027-013-9502-y.

Van Noordwijk M, Agus F, Dewi S, Purnomo H, Lusiana B, Villamor GB. 2013b. *Reducing emissions from all land uses in Indonesia: motivation, expected funding streams and multi-scale policy instruments*. ASB Policybrief 34. Nairobi: ASB Partnership for the Tropical Forest Margins.

Villamor GB, van Noordwijk M. 2011. Social role play games versus individual perceptions of conservation and PES agreements for maintaining rubber agroforests in Jambi (Sumatra), Indonesia. *Ecology and Society*. http://www.ecologyandsociety.org/vol16/iss3/art27/.

Villamor GB, van Noordwijk M, Le QB, Lusiana B, Mathews R. 2011. Diversity deficits in modelled landscape mosaics. *Ecological Informatics* 6:73–82.

Villamor GB, Desrianti F, Akiefnawati R, Amaruzaman S, van Noordwijk M. 2013a. Gender influences decisions to change land use practices in the tropical forest margins of Jambi, Indonesia. *Mitigation and Adaptation Strategies for Global Change*. DOI: 10.1007/s11027-013-9478-7.

Villamor GB, Pontius RG, van Noordwijk M. 2013b. Agroforestry's growing role in reducing carbon losses from Jambi (Sumatra), Indonesia. *Regional Environmental Change.* DOI: 10.1007/s10113-013-0525-4.

Villamor GB, Chiong-Javier E, Djanibekov U, Catacutan DC, van Noordwijk M. 2014. Gender differences in land-use decisions: shaping multifunctional landscapes? *Current Opinion in Sustainability in press*.

Vincent G, Harja D. 2007. Exploring ecological significance of tree crown plasticity through three-dimensional modelling. *Annals of Botany* 101(8):1221–1231.

Vosti SA, Witcover J, Gockowski J, Tomich TP, Carpentier CL, Faminow M, Oliviera S, Diaw C. 2000. *Working group on economic and social indicators: report on methods for the ASB best-bet matrix.* Nairobi: International Centre for Research in Agroforestry.

Walker DH, Sinclair FL. 1998. Acquiring qualitative knowledge about complex agroecosystems. Part 2: Formal representation. *Agricultural Systems* 56(3):365–386.

Wicke B, Dornburg V, Junginger M, Faaij A, 2008. Different palm oil production systems for energy purposes and their greenhouse gas implications. *Biomass and Bioenergy* 32:1322–1337.

Wiersum KF. 1997. Indigenous exploitation and management of tropical forest resources: an evolutionary continuum in forest–people interactions. *Agriculture, Ecosystems and Environment* 63:1–16.

Woolhiser DA, Smith RE, Goodrich DC. 1990. *KINEROS: a kinematic runoff and erosion model: documentation and user manual.* Washington, DC: Agricultural Research Service, US Department of Agriculture.

Young S. 1994. *Rapid market appraisal (RMA): a tool for market systems research in agricultural development*. Malakand Fruit and Vegetable Development Project. Bern, Switzerland: Helvetas Intercooperation.

Further reading

Focus-group discussions

A focus group is a form of qualitative research in which a group of people are asked about their perceptions, opinions, beliefs and attitudes towards a product, service, concept, advertisement, idea or packaging. Questions are asked in an interactive group setting where participants are free to talk with other group members.

http://en.wikipedia.org/wiki/Focus_group

A focus-group discussion (FGD) is a good way to gather together people from similar backgrounds or experiences to discuss a specific topic of interest. The group of participants is guided by a moderator (or group facilitator) who introduces topics for discussion and helps the group to participate in a lively and natural discussion amongst themselves. The strength of FGD relies on allowing the participants to agree or disagree with each other so that it provides an insight into how a group thinks about an issue, about the range of opinion and ideas, and the inconsistencies and variation that exists in a particular community in terms of beliefs and their experiences and practices.

FGDs can be used to explore the meanings of survey findings that cannot be explained statistically, the range of opinions/views on a topic of interest and to collect a wide variety of local terms. In bridging research and policy, FGD can be useful in providing an insight into different opinions among different parties involved in the change process, thus enabling the process to be managed more smoothly. It is also a good method to employ prior to designing questionnaires.

http://www.odi.org.uk/publications/5695-focus-group-discussion

Surveys assume that people know how they feel. But sometimes they really don't. Sometimes it takes listening to the opinions of others in a small and safe group setting before they form thoughts and opinions. Focus groups are well suited for those situations. Focus groups can reveal a wealth of detailed information and deep insight. When well executed, a focus group creates an accepting environment that puts participants at ease allowing then to thoughtfully answer questions in their own words and add meaning to their answers. Surveys are good for collecting information about people's attributes and attitudes but if you need to understand things at a deeper level then use a focus group.

If you've ever participated in a well-run focus group you'd probably say it felt very natural and comfortable to be talking with a group of strangers. What you didn't know perhaps were the many hidden structures behind it all. A good focus group requires planning: a lot more planning than merely inviting a few key people to casually share their opinions about a topic.

http://assessment.aas.duke.edu/documents/How_to_Conduct_a_Focus_Group.pdf

A related set of tools to explore the relations between people and forest

Angelsen A, Wunder S. 2003. *Exploring the forest—poverty link: key concepts, issues and research implications*. CIFOR Occasional Paper no. 40. Bogor, Indonesia: Center for International Forestry Research. http://www.cifor.org/publications/pdf_files/occpapers/op-40.pdf.

Pierce Colfer CJ, Minarchek RD. 2012. *Women, men and forest research: a review of approaches, resources and methods for addressing gender*. CIFOR Occasional Paper no. 80. Bogor, Indonesia: Center for International Forestry Research. http://www.cifor.org/publications/pdf_files/OccPapers/OP-80.pdf.

Locatelli B, Herawati H, Brockhaus M, Idinoba M, Kanninen M. 2008. *Methods and tools for assessing the vulnerability of forests and people to climate change: an introduction*. Working Paper no. 43. Bogor, Indonesia: Center for International Forestry Research. http://www.cifor.org/publications/pdf_files/WPapers/WP43Locatelli.pdf.

MLA tool descriptions: http://www.cifor.org/mla/_ref/method/index.htm

Set of methods for the MLA approach

Field based methods

The field survey was a combination of relatively standard scientific descriptions of terrain, soil and vegetation, and of equivalent observations from a local people's perspective. Typically the team would be 7-10 people: 2-4 local informants, the soil specialist, the botanist, the ethnobotanist, a recorder and 1 or 2 assistants.

- **Site description**
  complete physical description of the terrain, as well as local people's description of its use history, the location's importance for different use categories, accessibility, local names for the location, the land unit and the vegetation, etc. **Download datasheet**

- **Herbs transect**: a 40x5 meter transect line was subdivided into 10 subunits. In each of these, herbs, climbers and other smaller plants were recorded. A botanist would name the species or collect the specimen while the ethnobotanist would ask informants for local names and uses. **Download datasheet**
- **Tree sample unit**: a new and versatile sample unit was developed, suitable for rapid assessments of tropical forest in heterogeneous areas. Species, height and girth of a maximum of 40 trees was assessed for each forested site, which allow **calculations of density and basal area**. Apart from that, local informants gave information about the use(s) of each tree. **Download datasheet**
- **Soil assessments**: two holes were drilled with a Belgi augur and one profile of 60cm depth was dug to make a complete physical description of the soil. A local informant, selected by the community itself for his knowledge of soil and cultivation, was asked for local assessment and descriptions of the soil's qualities, its name and its potential use. **Download datasheet**

4. Rapid appraisal of agroforestry practices, systems and technology (RAFT)

Michon G, de Foresta H, Levang P, Verdeaux F. 2007. Domestic forests: a new paradigm for integrating local communities' forestry into tropical forest science. *Ecology and Society* 12(2):1. http://www.ecologyandsociety.org/vol12/iss2/art1/.

Roshetko JM, Purnomosidhi P, Mulawarman. 2005. Farmer demonstration trials: promoting tree planting and farmer innovation in Indonesia. In: J Gonsalves, T Becker, A Braun, D Campilan, H de Chavez, E Fajber, M Kapiriri, J Rivaca-Caminade, R Vernooy, eds. *Participatory research and development for sustainable agriculture and natural resource management: a sourcebook*. Volume III. Lima: International Potato Center. p. 1–8. http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=1214

Ruthenberg H. 1976. *Farming systems in the tropics.* Oxford: Oxford University Press.

Sinclair FL. 1999. A general classification of agroforestry practice. *Journal Agroforestry Systems* 46:161–180.

Vandermeer J, van Noordwijk M, Ong C, Anderson J, Perfecto Y. 1998. Global change and multi-species agroecosystems: concepts and issues. *Agriculture, Ecosystems and Environment* 67:1–22.

Van Noordwijk M, Williams S, Verbist B. 2001. *Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns*. ASB Lecture Notes 1–13 (Full Package). Bogor, Indonesia: International Centre for Research in Agroforestry Southeast Asia Regional Research Programme.

Wiersum KF. 1997. Indigenous exploitation and management of tropical forest resources: an evolutionary continuum in forest-people interactions. *Agriculture, Ecosystems and Environment* 63:1–16.

7. Rapid market appraisal (RMA)

He J. 2010. Globalised forest products: commodification of the matsutake mushroom in Tibetan villages, Yunnan, Southwest China. *International Forestry Review* 12(1).

Tukan CMJ, Roshetko JM, Budidarsono S, Manurung GS. 2006. Market chain improvement: linking farmers to markets in Nanggung, West Java, Indonesia. *Acta Horticulturae* 699:429–438.

Betser L, Degrande A. 2001. Marketing surveys. In: *Tree domestication in agroforestry*. Module 2, Session 5. Nairobi: World Agroforestry Centre (ICRAF).

[ILO] International Labour Organization. 2000. *Rapid market appraisal: a manual for entrepreneurs*. FIT Manual Series. Geneva: International Labour Organization.

Young S. 1994. *Rapid market appraisal (RMA): a tool for market systems research in agricultural development.* Malakand Fruit and Vegetable Development Project. Bern, Switzerland: Helvetas Intercooperation.

12. Functional branch analysis (FBA)

Martin FS. 2008. *Using native timber trees for recovering degraded landscapes in the Philippines: social, biophysical and economic assessment of agroforestry systems practiced by smallholder farmers*. PhD Thesis. Madrid: Cordoba University.

Van Noordwijk M, Lusiana B, Khasanah M. 2004. *WaNuLCAS version 3.1. Background on a model of water, nutrient, and light capture in agroforestry systems*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Mulia R. 2002. Functional branch analysis as tool for fractal scaling above- and belowground trees for their additive and non-additive properties. *Ecological Modeling* 149:4151.

Van Noordwijk M, Purnomosidhi P. 1995. Root architecture in relation to tree-soil-crop interactions and shoot pruning in agroforestry. *Agroforestry Systems* 30:161173.

Van Noordwijk M, Spek LY, de Willigen P. 1994. Proximal root diameter as predictor of total root size for fractal branching models I. Theory. *Plant Soil* 164:107117.

15. Spatially explicit individual-based forest simulator (SExI-FS)

Harja D, Vincent G, Mulia R, van Noordwijk M. 2012. Tree shape plasticity in relation to crown exposure. *Trees: Structure and Function* 26(4):1275–1285. doi 10.1007/s00468-012-0703-x.

Tata HL, van Noordwijk M, Harja D, Joshi L. 2009. Dipterocarp trees in rubber agroforestry: interplanting strategies for high-value timber production in Sumatra. *World Congress on Agroforestry 2009*: Nairobi: World Agroforestry Centre.

Van Noordwijk M, Verbist B, Hairiah K. 2006. *Muddy rivers: lack of trees? Synthesis: the difference a tree can make*. Nairobi: World Agroforestry Centre.

Vincent G, Harja D. 2007. Exploring ecological significance of tree crown plasticity through three-dimensional modelling. *Annals of Botany* 101(8):1221–1231.

17. Analysis of land-use and -cover trajectory (ALUCT)

Ekadinata A, Widayati A, Vincent G. 2004. Rubber agroforest identification using object-based classification in Bungo District, Jambi, Indonesia. *Asian Conference on Remote Sensing* (2004):551–556.

Lillesand TM, Kiefer RW, Chipman JW. 2004. *Remote sensing and image interpretation.* 5th edition. Hoboken, NJ: John Wiley and Sons.

19. Rapid hydrological appraisal (RHA)

Agus F, Farida, van Noordwijk M, eds. 2004. Hydrological impacts of forest, agroforestry and upland cropping as a basis for rewarding environmental service providers in Indonesia. *Proceedings of a workshop in Padang/Singkarak, West Sumatra, Indonesia, 25–28 February 2004.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Bruijnzeel S, van Noordwijk M. 2008. *Deforestation and the multiple functions of tropical watersheds: are tropical forests indispensable for regulating rainfall and ensuring clean and reliable water supplies?* ASB Policybrief 08. Nairobi: ASB Partnership for the Tropical Forest Margins. http://intranet/downloads/publications/PDFs/BR08133.PDF.

Lusiana B, Widodo R, Mulyoutami E, Adi DK, van Noordwijk M. 2008. *Kajian kondisi hidrologis DAS Kapuas Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat*. Hydrological study of the Kapuas Hulu watershed, Kapuas Hulu district, West Kalimantan. Working Paper 60. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Agus F, Verbist B, Hairiah K, Tomich TP. 2007. Managing watershed services in ecoagriculture landscapes. In: SJ Scherr, JA McNeely, eds. *Farming with nature: the science and practice of ecoagriculture*. Washington, DC: Island Press. p. 191–212.

25. Rapid carbon stock appraisal (RaCSA)

Sitompul SM, Hairiah K, van Noordwijk M, Palm CA. 2001. *Carbon stocks of tropical land use systems as part of the global C balance: effects of forest conversion and options for clean development activities.* ASB Lecture Note 4A. Bogor, Indonesia: International Centre for Research in Agroforestry Southeast Asia Regional Research Programme.

26. Reducing emissions from peatlands (REPEAT)

Norman JM, Kucharik CJ, Gower ST, Baldocchi DD, Crill PM, Rayment M, Savage K, Striegl RG. 1997. A comparison of six methods for measuring soil-surface carbon dioxide fluxes. *Journal of Geophysical Research* 102(D24):28,771–28,777.

28. Biofuel emission reduction estimator scheme (BERES)

Alkabbashi AN, Alam MdZ, Mirghani MES, Al-Fusaiel AMA. 2009. Biodiesel production from crude palm oil by transesterification process. *Journal of Applied Science* 9(17).

Corley RHV, Tinker B. 2003. *The oil palm*. 4th edition. Hoboken, NJ: Blackwell Publishing.

Crutzen PJ, Mosier AR, Smith KA, Winiwarter W. 2008. N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. *Atmospheric Chemistry and Physics* 8:389–395.

Demirbas A. 2007. Importance of biodiesel as transportation fuel. *Energy Policy* 35.

European Union. 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. *Official Journal of the European Union* 5.6.2009:16-62.

Hairiah K, Rahayu S. 2007. *Pengukuran karbon tersimpan di berbagai macam penggunaan lahan*. Measuring carbon stocks across land-use systems. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestry.org/sea/publication?do=view_pub_detail&pub_no=MN0035-07.

Intergovernmental Panel on Climate Change. 1996. *Revised 1996 IPCC guidelines for national greenhouse gas inventories*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Kamahara H, Widiyanto A, Tachibana R, Atsuta Y, Goto N, Daimon H, Fujie K. 2008. *Greenhouse gas balance on life cycle of biodiesel: a case of palm biodiesel production in Indonesia*. Paper presented at 8th International Conference on EcoBalance, Tokyo, 10–12 December 2008. Tokyo: Institute of Life Cycle Assessment.

Maswar. 2011. *Kajian cadangan karbon pada lahan gambut tropika yang didrainase untuk tanaman tahunan*. Carbon stock assessment of tropical peatlands drained for annual crops. Bogor, Indonesia: Sekolah Pascasarjana, Institut Pertanian Bogor.

Wicke B, Dornburg V, Junginger M, Faaij A, 2008. Different palm oil production systems for energy purposes and their greenhouse gas implications. *Biomass and Bioenergy* 32:1322–1337.

34. Forest, agroforest, low-value landscape or wasteland (FALLOW)

Suyamto DA, van Noordwijk M. 2005. Scenario studies of land use in Nunukan, East Kalimantan (Indonesia): drivers, local livelihoods and globally relevant carbon stocks. In: Lusiana B, van Noordwijk M, Rahayu S, eds. *Carbon stocks monitoring in Nunukan, East Kalimantan: a spatial and modelling approach*. Report from the Carbon Monitoring Team of the Forest Resources Management for Carbon Sequestration project. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Suyamto DA, van Noordwijk M, Lusiana B, Ekadinata A, Khasanah N. 2006. *Prospects of adoption of tree-based systems in a rural landscape and its likely impacts on carbon stocks and farmers' welfare: the FALLOW model application in Muara Sungkai, Lampung, Sumatra, in a ´Clean Development Mechanism' context*. ICRAF working paper 14. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Van Noordwijk M, Suyamto DA, Lusiana B, Ekadinata A, Hairiah K. 2008. Facilitating agroforestation of landscapes for sustainable benefits: tradeoffs between carbon stocks and local development benefits in Indonesia according to the FALLOW model. *Agriculture Ecosystems and Environment* 126:98–112.

36. REDD abacus SP

Dewi S, Ekadinata A, Galudra G, Agung P, Johana F. 2011. *LUWES: Land use planning for low emission development strategy*. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Dewi S, Johana F, Agung P, Zulkarnain MT, Harja D, Galudra G, Suyanto S, Ekadinata A. 2013. *Perencanaan penggunaan lahan untuk mendukung pembangunan rendah emisi.* Land use planning to support low emission development strategies. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

Harja D, Dewi S, van Noordwijk M, Ekadinata A, Rahmanulloh A, Johana F. 2012. *REDD Abacus SP: buku panduan pengguna dan software*. REDD Abacus SP: user's manual and software. Bogor, Indonesia. World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Dewi S, Suyanto S, Minang PA, White D, Robiglio V, Hoang MH, Ekadinata A, Mulia R, Harja D. 2011. *Abatement cost curves relating past greenhouse gas emissions to the economic gains they allowed*. Project Report. Bogor, Indonesia. World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Van Noordwijk M, Dewi S, Lusiana B, Harja D, Agus F, Rahayu S, Hairiah K, Maswar M, Robiglio V, Hyman G, White D, Minang PA, Verchot L, Phuong VT. 2012. *Recommendations on the design of national monitoring systems relating the costs of monitoring to the expected benefits of higher quality of data*. Project Report. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

38. Why No Tree (WNoTree)?

Chokkalingam U, Suyanto S, Permana RP, Kurniawan I, Mannes J, Darmawan A, Khususiyah N, Susanto RH. 2006. Community fire use, resource change, and livelihood impacts: the downward spiral in the wetlands of southern Sumatra. *Mitigation and Adaptation Strategies for Global Change* 12. DOI 10.1007/s11027-006-9038-5: P. 75-100 http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1501

Suyanto S. 2006. Underlying cause of fire: Different form of land tenure conflicts in Sumatra. *Mitigation and Adaptation Strategies for Global Change* 12:67–74. DOI 10.1007/s11027-006-9039-4. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1500

Suyanto S, Permana RP, Khususiyah N, Joshi L. 2004. Land tenure agroforestry adoption and reduction of fire hazard in a forest: a case study from Lampung, Sumatra, Indonesia. *Agroforestry Systems* 65(1):1–11. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=286

Tomich TP, Fagi AM, Michon G, Murdiyarso D, Stolle F, van Noordwijk M. 1998. Indonesia's fires: smoke as a problem, smoke as a symptom. *Agroforestry Today*. http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=691

Martini E, Tarigan J, Roshetko JM, Manurung G, Kurniawan I, Tukan J, Budidarsono S, Abdo M, van Noordwijk M. 2008. *Capacity building activities to strengthen agroforestry as a sustainable economic alternative in the orangutan habitat conservation program of Batang Toru, North Sumatra*. Working Paper 61. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast

Asia Regional Program. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1860

Roshetko JM. 2007. *Agroforestry on the interface of orangutan conservation and sustainable livelihoods in Batang Toru (North Sumatra)*. Working Paper 56. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp?publishid=1794

41. REDD/REALU site-level feasibility appraisal (RESFA)

Parker C, Mitchell A, Trivedi M, Mardas N. 2008. *The Little REDD Book: a guide to governmental and non-governmental proposals for reducing emissions from deforestation and degradation*. Oxford: Global Canopy Programme.

Van Noordwijk M, Purnomo H, Peskett L, Setiono B. 2008. *Reducing emissions from deforestation and forest degradation (REDD) in Indonesia: options and challenges for fair and efficient payment distribution mechanisms*. Working Paper 81. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://www.worldagroforestrycentre.org/sea/publications/searchpub.asp?publishid=2120.

Van Noordwijk M, Suyamto DA, Lusiana B, Ekadinata A, Hairiah K. 2008. Facilitating agroforestation of landscapes for sustainable benefits: tradeoffs between carbon stocks and local development benefits in Indonesia according to the FALLOW model. *Agriculture, Ecosystems and Environment* 126:98-112. http://www.worldagroforestrycentre.org/sea/publications/searchpub.asp?publishid=1937.

List of contributors and their institutional affiliation

Ai Farida
STKIP PGRI Sumbar
Indonesia
aifarida@yahoo.com

Andree Ekadinata
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
a.ekadinata@cgiar.org

Arif Rahmanulloh
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
a.rahmanulloh@cgiar.org

Atiek Widayati
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
a.widayati@cgiar.org

Aulia Perdana
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
a.perdana@cgiar.org

Avniar N. Karlan
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
a.karlan@cgiar.org

Beria Leimona
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
L.Beria@cgiar.org

Betha Lusiana
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
b.lusiana@cgiar.org

Bruno Verbist
Division Forest, Nature and Landscape
Department of Earth and Environmental
Sciences, KU Leuven, Leuven
bruno.verbist@ees.kuleuven.be

Carsten Marohn
Institute of Plant Production and Agroecology
in the Tropics and Subtropics,
University of Hohenheim, Germany
carsten.marohn@uni-hohenheim.de

Dam Viet Bac
World Agroforestry Centre (ICRAF)
Hanoi, Viet Nam
Dvietbac@cgiar.org

Degi Harja
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
d.harja@cgiar.org

Delia Catacutan
World Agroforestry Centre (ICRAF)
Hanoi, Viet Nam
d.catacutan@cgiar.org

Desi Ariyadhi Suyamto
Indonesia
sumtoday@gmail.com; twitter: @sumtoday

Diah Wulandari
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
d.wulandari@cgiar.org

Elisabeth Simelton
World Agroforestry Centre (ICRAF)
Hanoi, Viet Nam
e.s.simelton@leeds.ac.uk

Elok Mulyoutami
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
e.mulyoutami@cgiar.org

Endri Martini
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
e.martini@cgiar.org

Fahmuddin Agus
Indonesian Soil Research Institute
Indonesia
f_agus@litbang.deptan.go.id

Fergus Sinclair
World Agroforestry Centre (ICRAF)
Nairobi, Kenya
f.sinclair@cgiar.org

Feri Johana
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
f.johana@cgiar.org

Gamma Galudra
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
g.galudra@cgiar.org

Georg Cadisch
Institute of Plant Production and Agroecology in the Tropics and Subtropics,
University of Hohenheim, Germany
georg.cadisch@uni-hohenheim.de

Grace B. Villamor
World Agroforestry Centre (ICRAF) and Department of Ecology and Natural Resources Management, Center for Development Research (ZEF), University of Bonn, Germany
g.villamor@cgiar.org; gracev@uni-bonn.de

Gregoire Vincent
Institut de Recherche pour le Développement (IRD), Unité Mixte de Recherche AMAP, France
gregoire.vincent@ird.fr

Hesti Lestari Tata
Forestry Research and Development Agency (FORDA), Ministry of Forestry, Indonesia and World Agroforestry Centre (ICRAF)
Bogor, Indonesia
h.tata@cgiar.org

Hoang Minh Ha
World Agroforestry Centre (ICRAF)
Hanoi, Viet Nam
hoangminhha58@gmail.com

Iwan Kurniawan
Consultant
Indonesia
i.kurniawan@yahoo.com

James M. Roshetko
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
j.roshetko@cgiar.org

Janudianto
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
janudianto@cgiar.org

Jenny C. Ordonez
World Agroforestry Centre (ICRAF)
Cartago, Costa Rica
j.ordonez@cgiar.org

Jihad
Burung Indonesia
Indonesia
biji.bio@gmail.com

Jules Bayala
World Agroforestry Centre (ICRAF)
Bamako, Mali
j.bayala@cgiar.org

Kurniatun Hairiah
Soil Science Department, Faculty of Agriculture, Brawijaya University, Indonesia
k.hairiah@cgiar.org and kurniatunhairiah@gmail.com or kurniatun.fp@ub.ac.id

Laxman Joshi
Nepal
lxjoshi@gmail.com

Lisa Tanika
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
l.tanika@cgiar.org

Martua Sirait
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
m.sirait@cgiar.org

Maswar Bahri
Indonesian Soil Research Institute
Indonesia
maswar_bhr@yahoo.com

Meine van Noordwijk
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
m.vannoordwijk@cgiar.org

Muhammad Sofiyuddin
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
m.sofiyuddin@cgiar.org

Ni'matul Khasanah
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
n.khasanah@cgiar.org

Noviana Khususiyah
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
n.khususiyah@cgiar.org

Nurhariyanto
Borneo Orangutan Survival Foundation (BOSF)
Indonesia
noer_39@yahoo.com

Pandam Nugroho Prasetyo
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
p.prasetyo@cgiar.org

Peter Akong Minang
World Agroforestry Centre (ICRAF)
Nairobi, Kenya
a.minang@cgiar.org

Pham Thu Thuy
World Agroforestry Centre (ICRAF)
Hanoi, Vietnam
brissiesugar@gmail.com

Pratiknyo Purnomosidhi
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
p.purnomosidhi@cgiar.org

Rachmat Mulia
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
r.mulia@cgiar.org

Reny Juita
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
r.juita@cgiar.org

Retno Maryani
Forestry Research and Development Agency
(FORDA), Ministry of Forestry, Indonesia
Indonesia
retnomaryani@hotmail.com

Robert Finlayson
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
r.finlayson@cgiar.org

Rodel Lasco
World Agroforestry Centre (ICRAF)
Los Baños, The Philippines
r.lasco@cgiar.org

Roeland Kindt
World Agroforestry Centre (ICRAF)
Nairobi, Kenya
r.kindt@cgiar.org

Rudy Harto Widodo
Indonesia
widodo_rudy@yahoo.com

Sandra Velarde
Crawford School of Public Policy, Australian National University
Australia

Sara Namirembe
World Agroforestry Centre (ICRAF)
Nairobi, Kenya
s.namirembe@cgiar.org

Sébastien de Royer
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
s.royer@cgiar.org

Sonya Dewi
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
s.dewi@cgiar.org

Subekti Rahayu
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
s.rahayu@cgiar.org

Suseno Budidarsono
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
s.budidarsono@cgiar.org

Suyanto
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
suyanto@cgiar.org

Thomas P. Tomich
Agricultural Sustainability Institute
University of California, Davis
California, USA
tptomich@ucdavis.edu

Timothy Pagella
Bangor University
United Kingdom
t.pagella@bangor.ac.uk

Ujjwal P. Pradhan
World Agroforestry Centre (ICRAF)
Bogor, Indonesia
u.pradhan@cgiar.org

Glosary of terms and acronyms

ABACUS	Abatement cost curve calculator
ABM	Agent-based model
AFOLU	Agriculture, Forestry and Other Land Uses
Agroforestry	1) An umbrella term covering a wide range of practices in which trees are grown on farms and in (agricultural) landscapes; 2) The integration of agriculture and forestry at landscape scale and in policy circles
ASB-matrix	A trade-off table with land -se systems as rows and their key attributes as columns
CES	Commodification of environmental (or ecosystem) services
CIS	Co-Investment in Landscape Stewardship
CO_2	Carbon Dioxide
COP	Conference of Parties
COS	Compensation for Opportunity Skipped
ΔLU	Land use change
ECor	Ecological Corridors model
FALLOW	Forest, Agriculture, Low-value Lands or Waster model
FERVA	Fair and Efficient REDD Value-chain Analysis
FlowPer	Flow Persistence model
FPIC	Free and Prior Informed Consent
GHG	Greenhouse Gas
GIS	Geographic Information System
IPR	Intellectual Property Rights
IPG	International Public Good
LAAMA	Locally Appropriate Adaptation and Mitigation Actions
LEK	Local ecological knowledge
LUWES	Land-Use Planning for Low Emission Development Strategy
MEK	Modellers' ecological knowledge
MRV	Monitoring, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
OpCost	Opportunity Cost analysis scheme
NPV	Net Present Value (sum of discounted future costs and benefits)
NSS	Negotiation Support System

NTFP	Non-Timber Forest Products
PEK	Public/policy ecological knowledge
PES or P/RES	Payments or rewards for environmental services
PRA	Participatory Rural Appraisal
RaCSA	Rapid Carbon stock appraisal
RATA	Rapid Tenure Claim Appraisal
REALU	Reducing Emissions from All Land Uses
REDD+	Reducing Emissions from Deforestation and Degradation
REL/RL	Reference (emission) level
RPG	Role play game
RUPES	Rewarding Upland Poor for the Environmental Services they provide
TALaS	Trade-off Analysis for Land-use Scenarios

The landscape scale is a meeting point for bottom–up local initiatives to secure and improve livelihoods from agriculture, agroforestry and forest management, and top–down concerns and incentives related to planetary boundaries to human resource use.

Sustainable development goals require a substantial change of direction from the past when economic growth was usually accompanied by environmental degradation, with the increase of atmospheric greenhouse gasses as a symptom, but also as an issue that needs to be managed as such.

In landscapes around the world, active learning takes place with experiments that involve changes in technology, farming systems, value chains, livelihoodS' strategies and institutions. An overarching hypothesis that is being tested is:

> Investment in institutionalising rewards for the environmental services that are provided by multifunctional landscapes with trees is a cost-effective and fair way to reduce vulnerability of rural livelihoods to climate change and to avoid larger costs of specific 'adaptation' while enhancing carbon stocks in the landscape.

Such changes can't come overnight. A complex process of negotiations among stakeholders is usually needed. The divergence of knowledge and claims to knowledge is a major hurdle in the negotiation process.

The collection of tools—methods, approaches and computer models—presented here was shaped by over a decade of involvement in supporting such negotiations in landscapes where a lot is at stake. The tools are meant to support further learning and effectively sharing experience towards smarter landscape management.

World Agroforestry Centre

ASB Partnership for the Tropical Forest Margins

AARD

Universitas Brawijaya Malang

Universität Hohenheim 1818

Federal Ministry for Economic Cooperation and Development

Norad

IFAD Enabling poor rural people to overcome poverty

CGIAR Research Program on Forests, Trees, and Agroforestry