Negotiation-support toolkit for learning landscapes

Editors
MEINE VAN NOORDWIJK
BETHA LUSIANA
BERIA LEIMONA
SONYA DEWI
DIAH WULANDARI

WORLD AGROFORESTRY CENTRE
Southeast Asia Regional Program

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Editors
Meine van Noordwijk, Betha Lusiana, Beria Leimona, Sonya Dewi, Diah Wulandari

Authors
Ai Farida, Andree Ekadinata, Arif Rahmanulloh, Atiek Widayati, Aulia Perdana, Beria Leimona, Betha Lusiana, Bruno Verbist, Carsten Marohn, Dam Viet Bac, Degi Harja, Delia Catacutan, Desi A. Suyamto, Elisabeth Simelton, Elok Mulyoutami, Endri Martini, Fahmuddin Agus, Fergus Sinclair, Feri Johana, Gamma Galudra, Georg Cadisch, Grace B. Villamor, Gregoire Vincent, Hesti Lestari Tata, Hoang Minh Ha, Iwan Kurniawan, James M. Roshetko, Janudianto, Jenny C. Ordonez, Jihad, Jules Bayala, Kurniatun Hairiah, Laxman Joshi, Lisa Tanika, Martua Sirait, Maswar Bahri, Meine van Noordwijk, Muhammad Sofiyuddin, Ni'matul Khasanah, Noviana Khususiyah, Nurhariyanto, Pandam N. Prasetyo, Peter A. Minang, Pham Thu Thuy, Rachmat Mulia, Reny Juita, Retno Maryani, Robert Finlayson, Rodel Lasco, Rudy H. Widodo, Sandra Velarde, Sara Namirembe, Sébastien de Royer, Sonya Dewi, Subekti Rahayu, Suseno Budidarsono, Suyanto, Thomas P. Tomich, Timothy Pagella, Ujjwal Pradhan

Language editors
Robert Finlayson and Ruth Raymond

WORLD AGROFORESTRY CENTRE
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Citation

Van Noordwijk M, Lusiana B, Leimona B, Dewi S, Wulandari D, eds. 2013. *Negotiation-support toolkit for learning landscapes*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

This is volume 2 of a series. Volume 1 is:

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

ISBN 978-979-3198-74-3

World Agroforestry Centre

Southeast Asia Regional Program
Jl. CIFOR, Situ Gede, Sindang Barang, Bogor 16115
[PO Box 161 Bogor 16001] Indonesia
Tel: +(62) 251 8625 415
Fax: +(62) 251 8625416
Email: icraf-indonesia@cgiar.org
www.worldagroforestry.org/regions/southeast_asia

Cover images

The front and back page photographs were taken in Sumberjaya, Lampung province, Indonesia, where the negotiation-support terminology originated: in a landscape with settlers' coffee farms (front cover), a major conflict with forest authorities emerged that lead to evictions, in the context of a hydropower scheme. Reconsideration of how watershed functions could be maintained led to negotiated agreements (back cover) with local communities, providing them with tenure security. Photos: Meine van Noordwijk.

Design and layout

Riky Mulya Hilmansyah and Tikah Atikah

2013

Preface

At the time of writing, the world's attention is turning to the Sustainable Development Goals as a follow on from the uneven success achieved through the Millennium Development Goals. We need to go beyond the jargon and find out what the many manifestations of unsustainable development are and how the landscapes where these occur can be managed on a path towards recovery, if possible without the loss of local livelihoods.

Integrated natural resource management requires site-specific understanding of the various trade-offs between the goods and services that agro ecosystems can provide. In the past 15 years, we have learned that a landscape approach is needed owing to the many interactions that occur at this scale, both in ecological and in social policy terms.

Resource managers in national and sub-national institutions that interact with the private sector, local communities and migrants need access to cost-effective, replicable tools, methods and approaches to appraise the likely impacts of new technologies and changes in market access and to support evidence-based negotiations over contentious issues. Such issues are likely to arise along with land conversion and intensification and need to be understood in management terms because although the problems would probably not exist if there were no people, excluding people is only an option under very specific conditions. Most of the issues have to be resolved in negotiation with local communities and other stakeholders. We have therefore left the 'decision support' language for use in a restricted set of single-decision-maker situations and focus instead on negotiation support.

The World Agroforestry Centre in Southeast Asia has pioneered negotiation-support approaches in high-conflict landscapes in Indonesia. For wider application, however, a need was identified for tools (used in the widest sense to include methods, approaches and computer models) that allow rapid appraisals of landscapes, conflict over land tenure, markets, hydrology, agrobiodiversity and carbon stocks. Simulation models at various scales (for example, tree and crop interaction at the plot level, water flows in landscapes, land-use-change dynamics) can be used to combine generic insights with the specific properties of any new location. The toolkit that emerged from this effort has been tested in settings throughout Southeast Asia with staff of various national institutions. New situations brought new demands for additional tools or combinations of tools and thus the toolkit became bigger. While we have more detailed manuals and descriptions for many of the tools and examples of their application, the overview that you'll find in this volume is meant to show the interconnectedness of the tools and their underlying conceptualization of the constantly evolving set of issues.

We acknowledge the feedback from many participants in training courses, colleagues who started to use (or at least try out) the methods, discussants in workshops who helped sharpen the tools' articulation and descriptions. We appreciate the funding sources that include, but are not restricted to, Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ/Federal Ministry for Economic Cooperation and Development) for the Trees in Multi-Use Landscapes in Southeast Asia project), International Fund for Agricultural Development (for the Rewarding Upland Poor for Environmental Services project), Norwegian Agency for Development Cooperation (for the Reducing Emissions from All Land Uses project) and the CGIAR Research Program on Forests, trees and Agroforestry.

We appreciate the language editing by Robert Finlayson and Ruth Raymond and the design by Tikah Atikah and Riky Mulya Hilmansyah. We look forward to further comments and suggestions for improvement and refinement and apologize for any shortcomings.

On behalf of the editors

Meine van Noordwijk
Chief Science Advisor
World Agroforestry Centre

Contents

Introduction

The Editors

In Volume 1 of this series (van Noordwijk et al 2011), we looked at the opportunities for people and trees to co-adapt to changing climates and all the other changes that occur in landscapes, whether they are at the tropical forest margins, in the urban fringe or anywhere in between. Specifically, we formulated the hypothesis that

> 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.

The book unpacked this rather rich and concept-laden sentence and looked at available evidence. The overall conclusion was that context matters so much that generic statements about forests, trees and agroforestry have little more than indicative value: assessment tools are needed to drill down to the specifics of any landscape where action is deemed desirable. Yet, we don't need long-term and expensive studies to rediscover the wheel in any new place: as we present here in this volume, we now have a fairly elaborate toolkit of methods that can be used to support negotiations between local stakeholders on issues that address livelihoods, landscapes and the ecosystem services they provide. The methods were designed with reasonable cost (~USD 10 000) and time-span (< 6 months) in mind.

Multifunctional landscapes

We are using the term 'landscape' here as an important scale in the nested socio-ecological systems that encompass global issues such as the number of people on the planet, the lifestyles to which they aspire and the limitations of current patterns of resource use (Figure 0.1). The landscape scale is a meeting point for bottom–up approaches that start from local aspirations and top–down restrictions on local resource use, in view of (negative) external effects of local land-use change, such as loss of watershed functions, biodiversity and contributions to climate change.

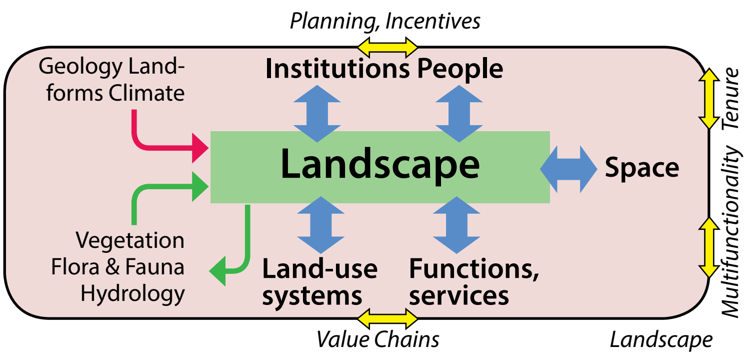


Figure 0.1. A landscape as the interaction between human actions, ecosystems and the abiotic factors that shape the physical environment

Three key elements of a multifunctional landscape are farming, natural vegetation and tree-based value chains. They can be spatially segregated ('agro' versus 'forest' versus 'trees') or more finely integrated in landscape mosaics that are described as 'agroforestry' (Figure 0.2).

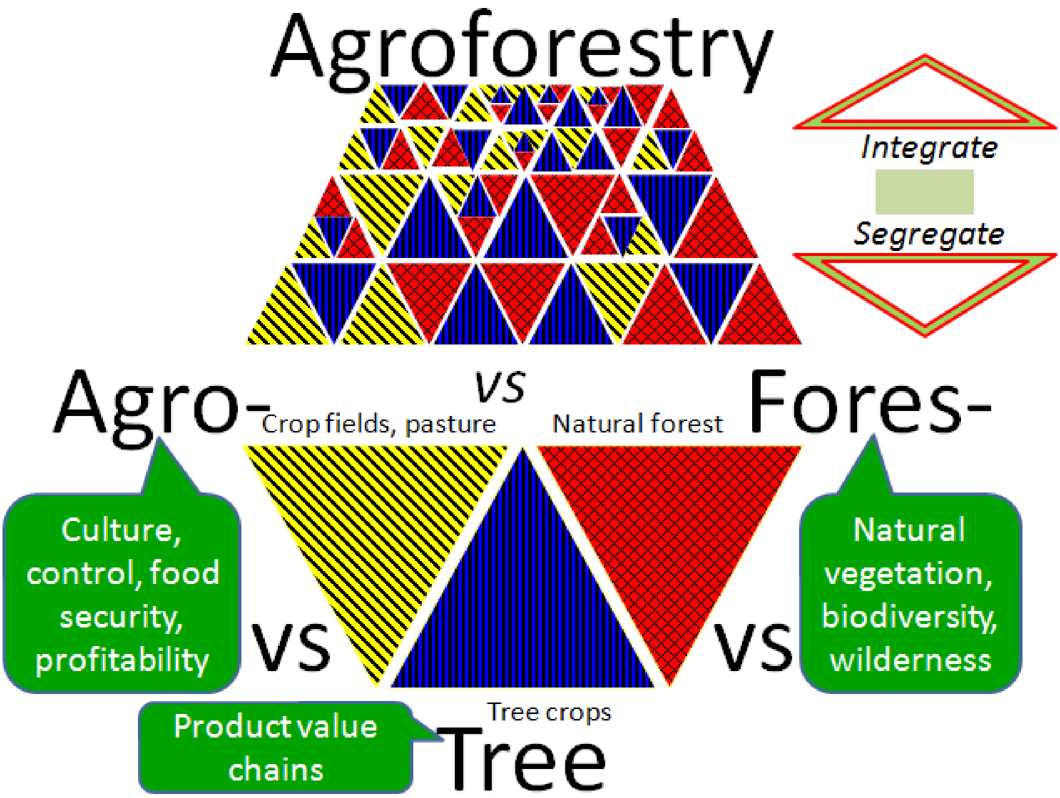


Figure 0.2. Different options for spatial arrangements and patterns of three key elements of multifunctional landscapes that can be seen as a gradient from 'integrated' to 'segregated' solutions

Perceptions of the desirability of more segregated or more integrated solutions for a landscape differ between stakeholders. These preferences involve knowledge, attitude, skills and aspirations. We cannot expect that knowledge as such, even if it was supported by strong evidence, can shift attitudes, skills and aspirations. To be effective, the advance of scientific knowledge cannot be separated from what stakeholders in a landscape know, feel, can do and aspire to. We need to understand landscapes as dynamic socio-ecological systems driven by feedback loops. One such feedback loop (Figure 0.3) is of specific interest here, as it relates to the options for landscapes to retain multifunctionality and buffer capacity, which are needed to deal with future uncertainties and change.

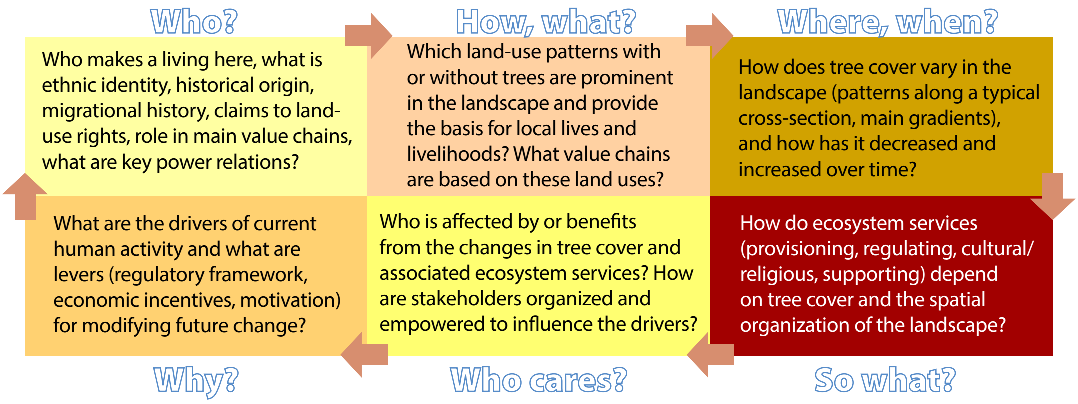


Figure 0.3. Six groups of landscape questions

Note: The question groups are logically related and jointly lead to a deeper understanding of the landscape as a feedback system in which the consequences of decisions and actions are themselves influencing future actions and decisions, even if the consequences were borne by other than the primary decision makers

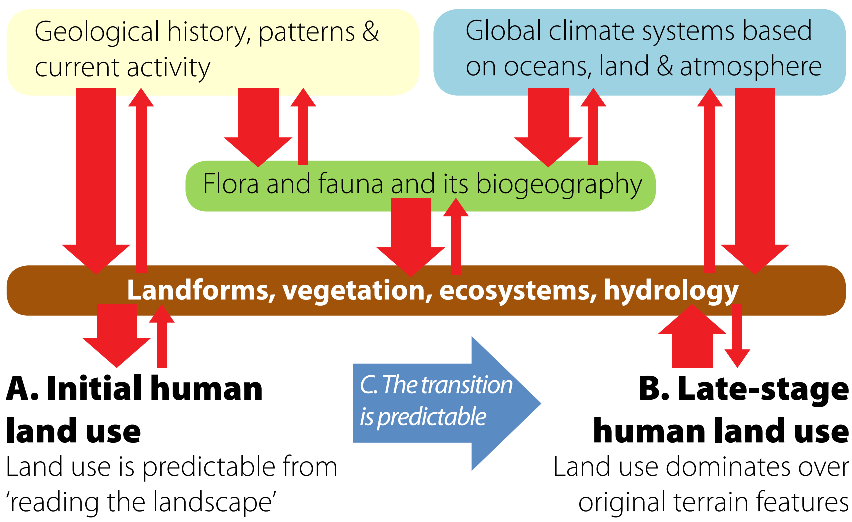


Figure 0.4. Stages in the interaction between the landscape and human land use

Note: Land use interacts with land form and land cover, which are themselves related to geology , soil formation, flora, fauna and climate. Early stage (A) dependence of land use on the landscape at its niches is transformed to a a stage (B) where land use dominates

Negotiation support

We explicitly use the term 'negotiation support' rather than 'decision support' (Figure 0.5) because in all landscapes we know there are multiple stakeholders with multiple interests and multiple claims to knowledge and understanding, with multiple types of empirical experience on which such knowledge is based. Discussions about 'who has the right to do what where' tend to be difficult because of all these layers of complexity.

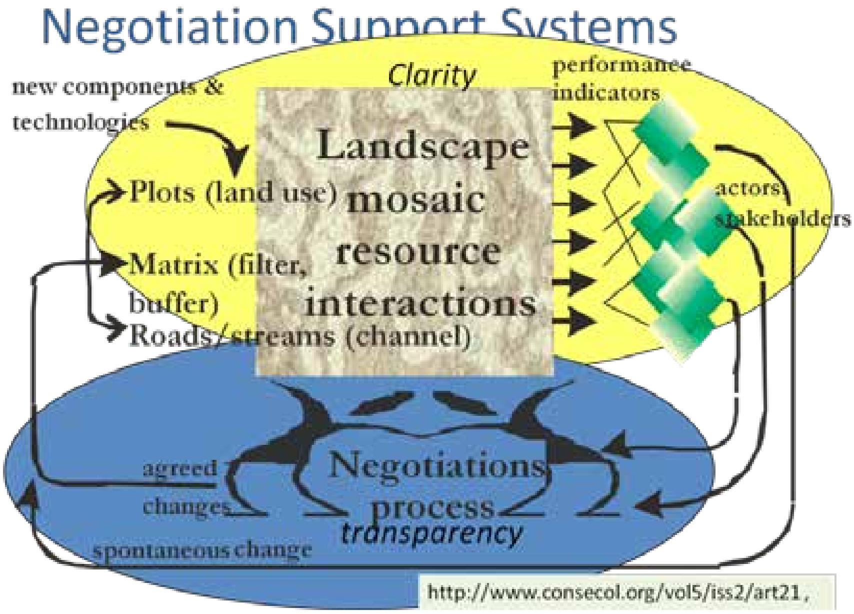


Figure 0.5. Negotiation-support systems as the combination of a scenario tool and negotation process

Note: The scenario tool allows users to think through, or preview, the consequences of certain actions in the landscape, using the performance indicators they care about, in combination with a process of negotiations that can lead to changes in rules, incentives and perceptions

In some of the places where we worked, it proved possible, however, by carefully mapping and comparing the multiple knowledge systems, to find actions and options that could break existing deadlocks and improve the situation for all, relative to current conflicts. The starting point for progress was a shared understanding of the landscape mosaic and its resource interactions. The tools presented in this book are meant to bring such shared understanding within reach, when used in a context-specific way. This is not a cookbook with recipes for success; it is a description of ingredients with their strengths and weaknesses as we currently know them. Please join our learning community.

Map, territory and knowledge system

For the methods that follow, it is important to be clear about distinctions between 'map' and 'territory'. A map is a communication tool and knowledge product that is distilled from, but supposedly retains relevant features of, an area of real-world territory. It is virtually impossible to communicate about a territory without using maps because the concept is broadened to include descriptions in text, diagrams, drawings, paintings and photography. It is quite likely, however, that there are multiple maps of any given territory. Different actors and stakeholders by reading different maps have a different mental image of the territory and act upon that in their decisions, negotiations, dreams and scenarios. If the maps are different, it is likely that conflicts emerge.

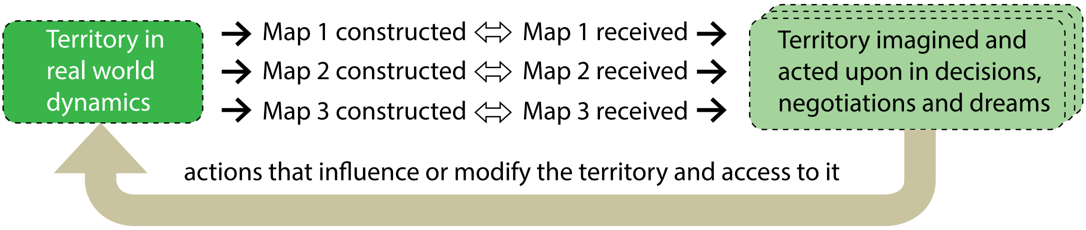


Figure 0.6. Maps and a territory in their relation with decision making

Note: Multiple stakeholders tend to use different maps and perceive them to be the reality of the territory

In the above, we can replace the word 'map' by 'knowledge system'. Three broad categories of knowledge systems are 1) the local ecological knowledge derived by people with a long-term track record of survival in the territory; 2) public opinion and the policies it supports; and 3) science and its multiple disciplines (including physics, chemistry, biology, ecology, geography, economics, and social and political science) and multiple maps and models. If all stakeholders used the same map, it would be difficult enough to reconcile their various interests and negotiate a course of action that optimized damage and gains for all, within the political reality of the broader system context. By maintaining different maps, and by assuming that one's own map conforms to the territory in the real world, the conflicts can become intractable. Negotiation-support systems, therefore, invest considerable effort in creating a 'map of maps'. An inventory of the various maps being used can lead to a clarification of contrasts and similarity, identify the position and size of 'white spots' and straighten contradictions.

Each of the three knowledge systems tends to see its own map as superior to others, even if it may acknowledge that its map is not the territory. That's true for science, for public knowledge and for local knowledge systems. Each may have very good reasons to think that their map is better than others, as it was modified over time to serve its prime functions, which differ between the stakeholders. Although it is hard for any but the most dogmatic to maintain that learning isn't possible, contrasts between theory and practise tend to persist in each of the knowledge systems. As science is one of the three knowledge systems identified here, it is attractive for science to put its knowledge system on a pedestal and claim that scientists know more and have better ways of adjusting maps than any of the others. This may be true, it might not be. It doesn't help, however, to maintain such a claim of superiority if we want to help to resolve conflicts between local stakeholders and the public and private sector maps of the territory and associated claims on access rights and restrictions on what can be done. A more humble starting position, which first of all aims for a 'we-agree-to-disagree' stage in the negotiations, can lead to learning by all and the emergence of new solutions.

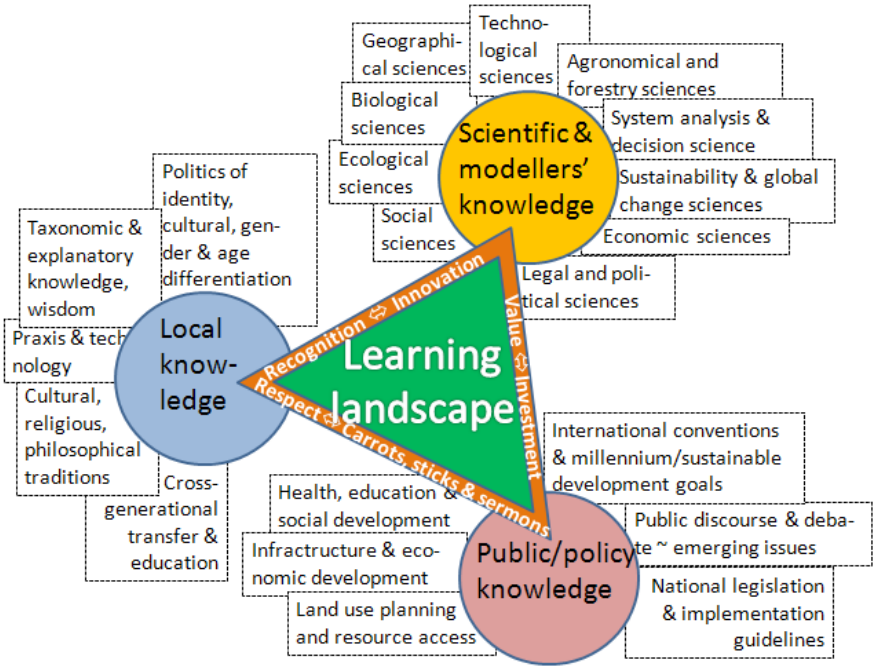


Figure 0.7. Triangular relations between three broad groups of knowledge systems

Note: Shows the internal distinctions and divisions as they relate to the reality of a learning landscape

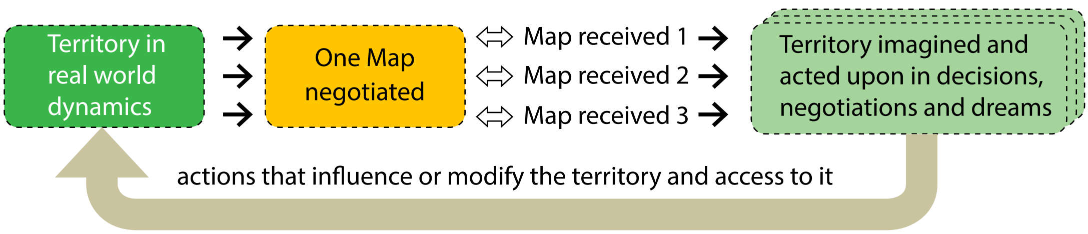


Figure 0.8. Modified form of Figure 0.5 with a unified single knowledge map

Note: Retains the multiple interpretations that are linked to stakeholders' goals and interests

Learning landscapes

Learning landscapes are characterized by a commitment to learning by doing, by experimenting and by shared reflection on what has and what hasn't been achieved. Our toolkit for negotiation support in learning landscapes emphasizes the exploration of three main knowledge systems in the way they relate to various aspects of the landscapes that shape the lives and livelihoods of the people who live in them. Beyond the current state of the knowledge system, our interest is in how each of the knowledge systems can change in response to 'new facts'.

After mapping the knowledge systems together with the stakeholders as much as possible, we identify where there is sufficient agreement to act—even though there may be different explanations and rationalizations of why this might work—and where differences in perceived evidence and system properties will make it hard to come to any type of joint action unless these are addressed head-on. Of course, it may be concluded that no specific action is needed but usually the process started at some early stage of an issue cycle (Figure 0.9; Tomich et al 2004) where at least some stakeholders perceive that there is an issue that needs attention.

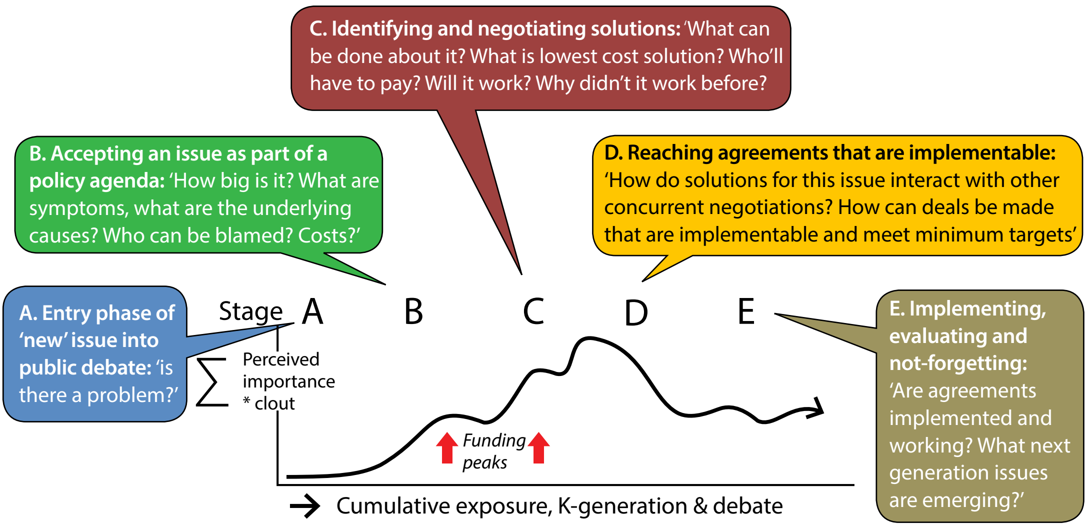


Figure 0.9. Depiction of an issue cycle

Note: Shows the multiple stages of a process in which issues can gain importance in public policy debates and might lead to negotiated solutions. Knowledge (K), specifically, scientific knowledge, can assist the process in different ways in the various stages

The term 'learning landscape' indicates that it is the landscape and its inhabitants that is learning, while it allows others (for example, scientists and managers of policy processes at national and sub-national levels) to engage with the process and learn as well, adding a layer at which trial and error occurs. It can be contrasted with the term 'sentinel landscape', where the primary emphasis is on a 'watchdog' function: identifying issues and providing early-warning signs for problems that affect countries, continents or the planet. Indeed, the terminology differs, as do the primary tools used. In sentinel landscapes it is important to be consistent with the issues addressed and to use standardized methods for cross-site comparisons. There is space for studies of the different knowledge systems and the local dynamics of negotiation but from the perspective of long-term monitoring we want to minimize the effect that observers have on the observed. Otherwise, change recorded in a return visit might be due to a complex interaction between what the dynamics would have been at this location without research and what it became with the presence of the researchers.

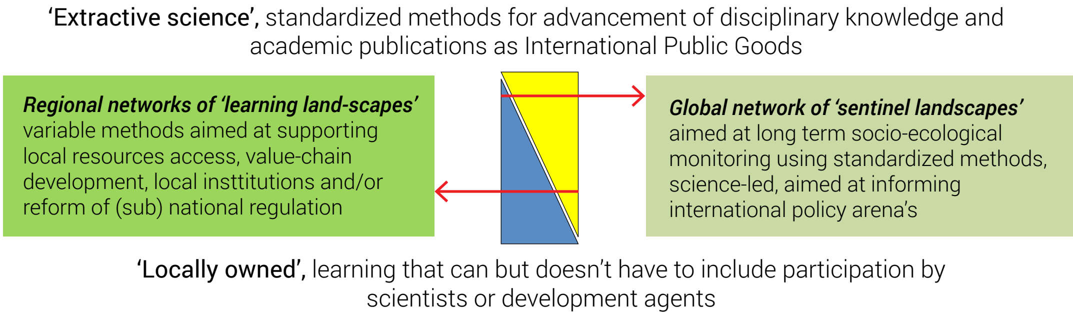


Figure 0.10. Gradient between two primary approaches to improving natural resource management

Note: One is based on objective, globally standardized methods that can be perceived, however, to be extractive from a local perspective; and the other is based on local learning with a diversity of methods that can be perceived to be biased and unreliable. The networks of sentinel and learning landscapes position themselves differently in this gradient, but can be mutually supportive if the interaction is managed well

The dual goals of local and external learning (Figure 0.10) may suggest a choice of methods that is focussed on the diagonal of synergy. However, the balance may be achieved across a portfolio of methods rather than in every method as such (Figure 0.11).

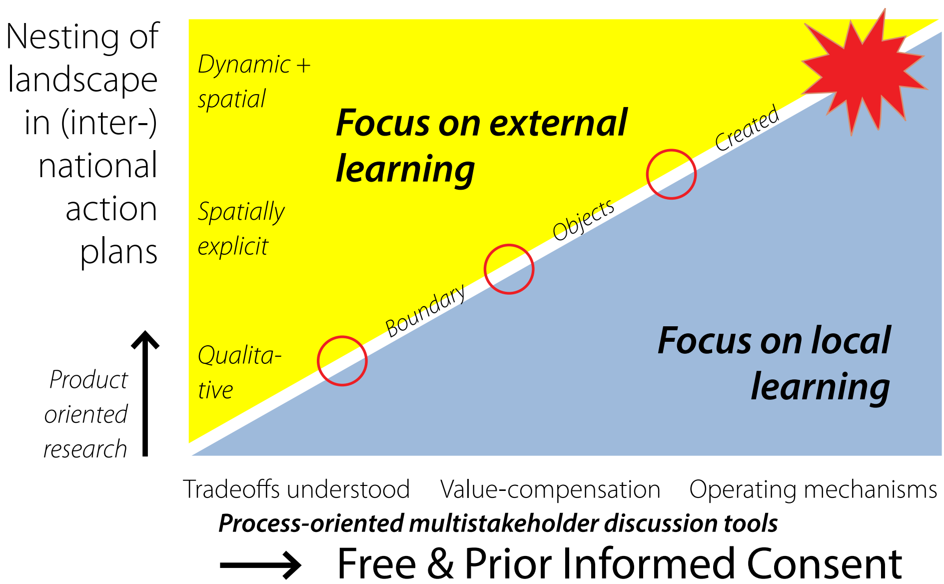


Figure 0.11. Dual objectives of local and external learning

Note: The dual objectives need to be synergized before working mechanisms can be nested in national and international action plans. The methods discussed in this book can contribute to the emergence of free and prior informed consent through the phases of the issue cycle with external learning progressing through a sequence of qualitative, spatially explicit and dynamic boundary objects

Leading towards co-investment in environmental services

In line with the central hypothesis of Volume I, which was quoted at the start of this introduction, negotiation support may lead to investment in institutionalising rewards for environmental services. From the experience in developing countries, as summarized by van Noordwijk et al (2012) and Namirembe et al (2014), we learned that such co-investment must meet three important criteria.

1. **Realistic:** Interventions need to be based on knowledge of the area's ecosystem functions and natural capital (including vegetation, flora and fauna, watershed functions), of processes of degradation and regeneration and the way such processes depend on the landscape, land use and a changing climate. They also need to take into account the trade-offs between economic benefits from land-use change and the consequences for measurable environmental services.
2. **Voluntary:** The mechanisms need to respect existing property and land-use rights and follow principles of free and prior informed consent. Any agreements with local communities require a shared understanding of the issues and options for fulfilling them.
3. **Conditional:** Any economic incentives must be performance-based and thus require systems for monitoring changes in biodiversity, agrobiodiversity, watershed functions and/or carbon stocks in the landscape that can be implemented locally and that relate to the real interests of local stakeholders.

In many cases, the co-investment will also have to address existing poverty and at a minimum do no harm but explicit targets of being pro-poor, beyond moral considerations, will generally increase the acceptability of any program and the chances that it will become a success. Similarly, explicit attention to the gender dimension is relevant and may give opportunity to jointly achieve sustainable development goals that relate to gender and those that relate to environmental quality.

Leverage points in complex social-ecological systems

Negotiation support is meant to facilitate change that contributes towards solutions of, often complex, problems at the poverty and environment nexus. Although the emphasis here is on 'knowledge' in its multiple forms, it is clear that knowledge is only one of several aspects that contribute to action: power and aspirations of stakeholders are at least as important. However, power and knowledge interact, as do aspirations and knowledge (Figure 0.12).

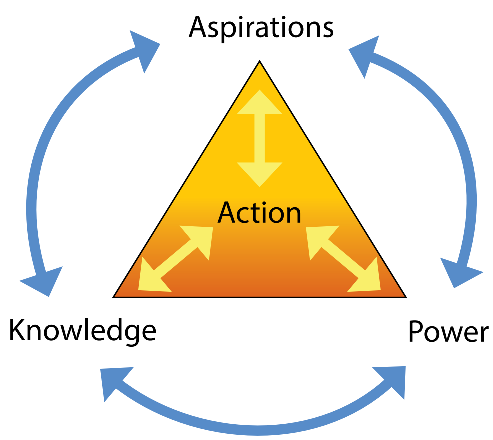


Figure 0.12. Action and changes on the ground will depend on knowledge, aspirations and power

If we see the landscape in its interaction with local and external people as a complex socio-ecological system, it may help to envision how such a system can change: through the numbers of its various parameters, through the degrees of buffering and lag times of the feedback loops, through the rules that govern the various interactions, through the structure of the model, its goals or its underlying paradigm. Meadows (1999) provided a 12-point scale of the degree of leverage she expected, on the basis of experience with many types of models, from the various types of changes to have on a system's behaviour (Figur 0.13).

Twelve places to intervene in a system (in increasing order of effectiveness in changing its dynamic properties):

12. Constants, parameters, numbers (such as subsidies, taxes, standards, data)
11. Sizes of buffers and stabilizing stocks relative to associated flows
10. Structure of material stocks and flows (such as transport networks, population age structure)
9. Lag times and time of delays, relative to the rate of system change
8. Strength of negative feedback loops, relative to the impacts they are trying to correct against
7. The gain around driving positive feedback loops
6. The structure of information flows (who does and does not have access to what kinds of information)
5. The rules of the system (such as incentives, punishments, constraints)
4. The power to add, change, evolve, or self-organize system structure
3. The goals of the system
2. The mindset or paradigm out of which the system (with its goals, structure, rules, delays, feedbacks and parameters) arises
1. The power to transcend paradigms

Figure 0.13. Ranking of leverage points on dynamic system behaviour
Source: Meadows 1999

In many situations a *change of theory* or paradigm shift from those in power will be needed to find effective solutions. Our *theory of change* must thus target the most powerful part of the leverage points and can expect substantial resistance to change. For the paradigm shifts to happen, the knowledge systems that are used to rationalize and justify the status quo may need to be tackled head-on. Our tools allow a gradual approach but focus, indeed, on the mindsets, paradigms and knowledge systems.

Tools

A tool is any physical item that can be used to achieve a goal, especially if the item is not consumed in the process. Informally, the word is also used to describe a procedure or process with a specific purpose (http://en.wikipedia.org/wiki/Tool). Tool use by humans dates back millions of years and other animals are also known to employ simple tools, especially where cultural transmission by intergenerational learning has emerged. Tools that are used in particular fields or activities may have different designations, such as 'instrument', 'utensil', 'implement', 'machine' or 'apparatus'. The set of tools needed to achieve a goal is called 'equipment' or a 'toolkit'. Like a physical toolkit with hammers, screwdrivers, spanners and saws, the toolkit we discuss here is full of instruments that can be used well but also misused to cause more harm than good.

In this book, we describe the tools according to the following format.

- Title (ACRONYM)
- Names of the authors of the description of the tool (see list of current addresses of authors at the end of the book)
- A short explanation of what the tool does (in a box)
- Introduction of the issues that the tool is meant to address
- The objectives of the tool
- The steps involved in using the tool
- An example of the tool in action
- Key references that provide more details (for example, a manual or report). Other references are compiled at the end of the book

Box: Ethics of interacting with indigenous or traditional knowledge

The World Agroforestry Centre's policy acknowledges the complexity of the evolving legal frameworks that protect indigenous and traditional knowledge and requires researchers to comply with national standards as well as act in the spirit of international treaties. See

http://www.worldagroforestrycentre.org/sites/default/files/ICRAF_policy_indig%26tradknowl.pdf

The basic reference in this field is

> Hansen SA, van Fleet JW. 2003. Traditional knowledge and intellectual property: a handbook on issues and options for traditional knowledge holders in protecting their intellectual property and maintaining biological diversity. Washington, DC: American Association for the Advancement of Science.

Recent analysis has focussed on the need to strike a balance between legal protection of intellectual property rights and the need to ensure cultural preservation and access to knowledge (Andanda 2012). Engaging with traditional knowledge systems in ways that enhance understanding, respect and recognition, while protecting them from 'grabs' by private sector entities, is to be encouraged.

> Andanda P. 2012. Striking a balance between intellectual property protection of traditional knowledge, cultural preservation and access to knowledge. Journal of Intellectual Property Rights 17:547–558. http://nopr.niscair.res.in/bitstream/123456789/15023/1/JIPR%2017(6)%20547-558.pdf.

For guidance on broader issues of research ethics, see http://www.worldagroforestry.org/downloads/policies%20and%20guidelines/ICRAF_policy_research_ethics.pdf.

The basic ethical principles

1. **Respect for persons:** incorporates at least two ethical convictions: 1) that individuals should be treated as autonomous agents; and 2) that persons with diminished autonomy are entitled to protection.
2. **Beneficence:** Researchers have an obligation to strive to ensure benefits to both individuals and society while minimising the risk of harm.
3. **Justice:** Researchers have an obligation to do all within their power to ensure a fair distribution of the benefits and burdens of research.

Many of the tools make use of common methods of qualitative research.

- Focus-group discussions (see box)
- Transect walk (See http://siteresources.worldbank.org/EXTTOPPSISOU/Resources/1424002-1185304794278/4026035-1185375653056/4028835-1185375678936/1_Transect_walk.pdf)
- Community resource map
- Social mapping(See http://www.forestpeoples.org/topics/environmental-governance/participatory-resource-mapping)
- Timeline, seasonal calendar and other participatory rural appraisal tools (See http://www.agraria.unipd.it/agraria/master/02-03/PARTICIPATORY%20RURAL%20APPRAISAL.pdf)
- Visioning and scenarios (Evans et al 2006. See http://www.asb.cgiar.org/ma/scenarios)
- Ecosystem services' analysis (Ash et al 2010)

We will not repeat the basic guidance that already exists in well-illustrated form in the literature but rather focus on the use of the tools for specific lines of enquiry.

A forthcoming compilation of research methods that include an explicit gender focus, see Catacutan et al. (2014).

Structure of the book

The methods described here build on the rich experience of participatory rural appraisals as these emerged and became popular in the 1980s and 1990s. In repackaging the methods, we retained their flexibility and respect for bottom–up processes but added greater specificity to unpack the rather complex concepts of ecosystem (also referred to as environmental) services.

We first describe methods that allow an initial approximation of answering the six questions in Figure 0.3, assessing the local context (Figure 0.14).

Three methods in the initial appraisal (Section I) jointly provide a first approximation of the answers to the six questions of Figure 0.3: 1) a participatory landscape appraisal (PALA); 2) an analysis of poverty and its local determinants (PaPoLD); 3) and an analysis of local drivers of land-use change (DriLUC) (Figure 0.14).

An initial diagnostic derived from these leads to a choice of methods for the next steps (Fig. 0.15) , zooming in on further details of lives, land use and livelihoods (methods described in Section II), on landscape functions and ecosystem services (Section III) and/or on the process of change, rights and transformations (Section IV).

In the final Section V, we share experience and provide some guidance on the process of negotiation support. Volume 3 of this series (in preparation) will provide a synthesis of the many lessons learnt in developing and applying these methods in Southeast Asia. Experience so far has suggested that several of the methods can be translated to African contexts with local adjustments. We hope that that experience will be described in a future sequel.

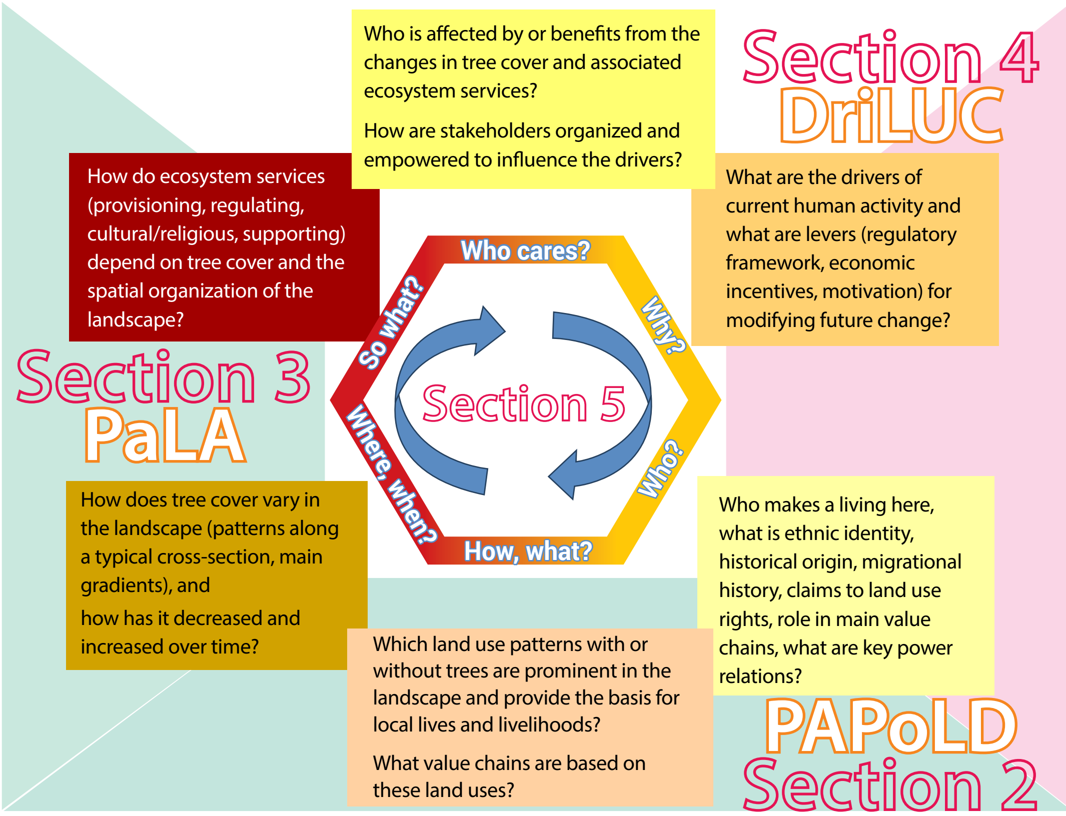


Figure 0.14. Initial appraisal methods

Note: From different starting points, the methods address the questions framed in Figure 0.3. The different types of disciplinary expertise needed include social, economic, policy, agronomic/forestry, ecological and geographical sciences (Descriptions of PALA, PaPoLD and DriLUC are in Section I)

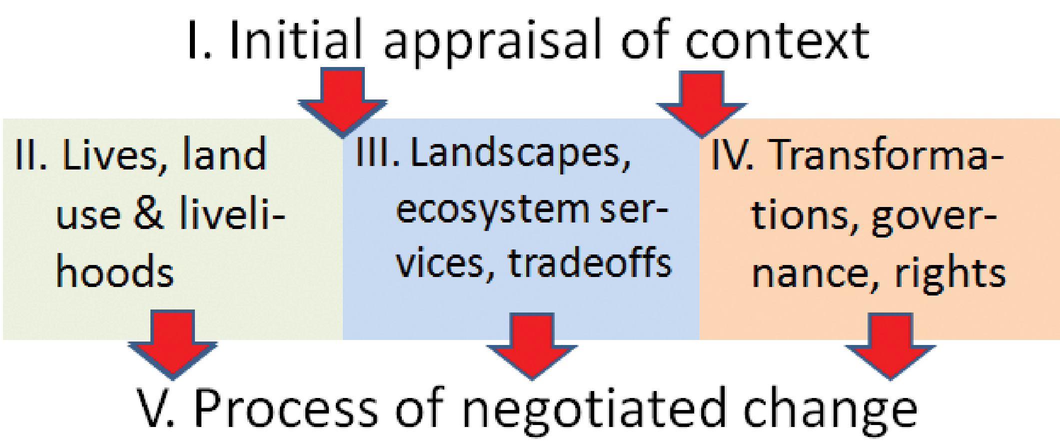
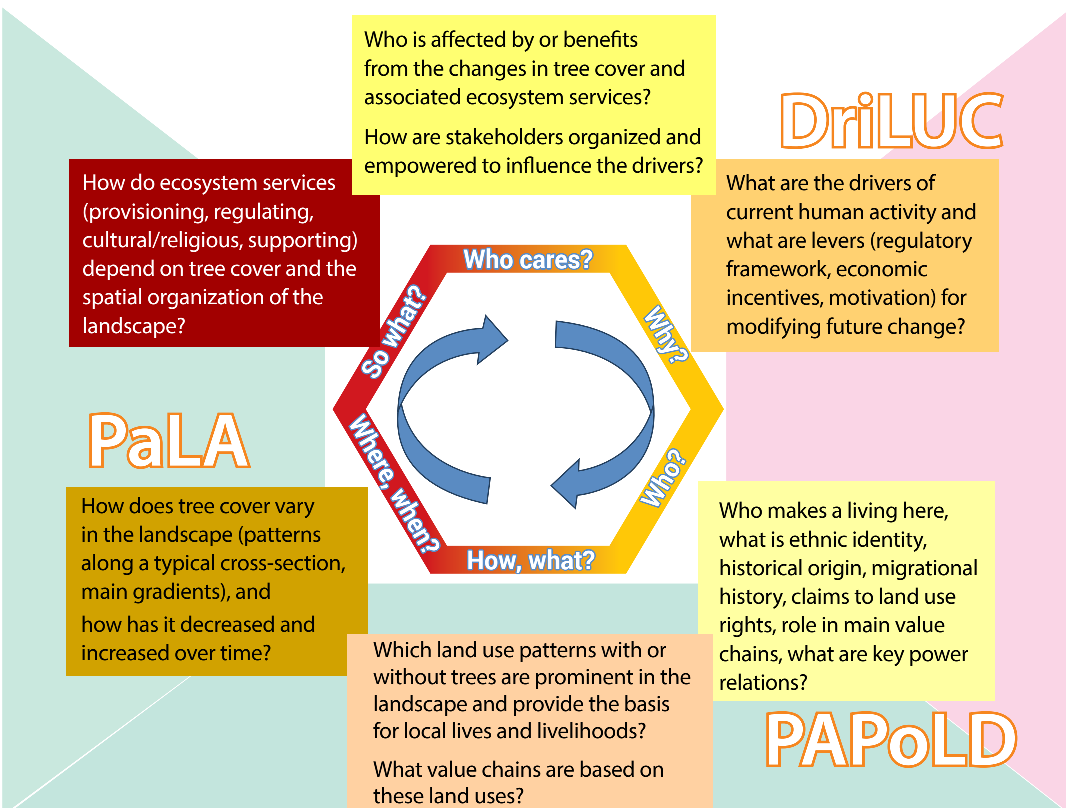


Figure 0.15. Outline of the book and its sections

SECTION 01

Understanding context: multifunctional landscape mosaics



1 Participatory landscape appraisal (PaLA)

Hoang Minh Ha, Laxman Joshi and Meine van Noordwijk

Participatory Landscape Appraisal (PaLA) can be used as an early diagnostic tool of the issues in a landscape. It can help document a process of participatory appraisals of issues of local concern, such as changes in water flows, soil erosion, slope stability or agrobiodiversity. It combines Rapid Rural Appraisal and Participatory Rural Appraisal (RRA/PRA) tools and methods with agroecological analysis to capture local knowledge at relevant temporal and spatial scales. PaLA can be used in scoping studies that can inform more detailed, subsequent analysis of specific functions and issues.

Introduction: multifunctional landscapes and their stakeholders

When people first settle in a landscape, they tend to select the most suitable places, generally where water availability and soil fertility are most favourable (Figure 1.1.A). Landscapes change in response to how the people inhabiting them earn their living and lead their lives.

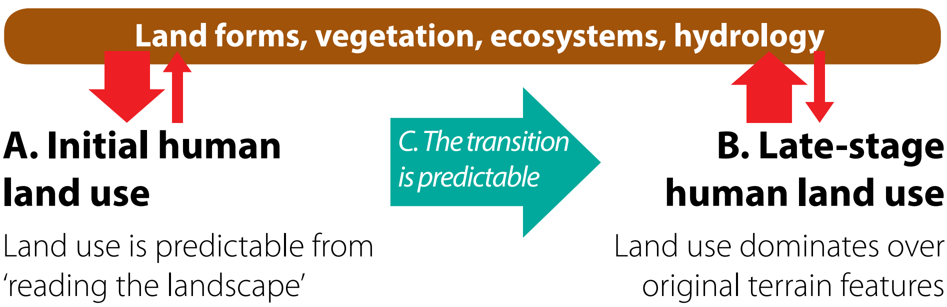


Figure 1.1. Land use is both dependent on the landscape (stage A) and influences it (stage B)

Drastic change tends to come from outside, such as logging or mining concessions and the associated migrants, who may stay behind when the extraction frontier moves on. Change also derives from the step-by-step process of intensification if the sum of local population growth and migrants exceeds the number of people leaving to seek their fortune elsewhere. Roads bring opportunities to participate in external markets and their demand for products that can be produced at competitive prices. Specialization of a few commodities is a logical consequence, often stimulated by development agencies and governments. The result is that parts of the landscape that are sensitive to degradation get used and indeed start to degrade. In a later stage of human land-use, the underlying structure of the landscape may be masked and land use dominates the vegetation, ecosystems and hydrology (Figure 1.1B).

Farmers' knowledge of landscape relationships and their perceptions of an underlying logic to these relationships play an important role in their management decisions. The way farmers understand the landscape and interact with it may differ from the way government land allocation and land-use policies classify land and understand interactions with water flows and other landscape functions. Government land-use planning may only partially match local regulations, determining who is allowed to do what and where. It is safe to assume that development of sustainable land-use practices at farm and landscape levels depends on bridging the gaps between the perceptions and concerns of the multiple stakeholders of landscape functions. This is an important step towards involving them in the analysis of trade-offs between the short- and long-term benefits of sustainable land use, drawing on their knowledge and perspectives.

Two concepts that are important in the way landscapes are more than the sum of plots are buffering and filtering (see van Noordwijk et al 2011). What happens in one plot has an impact elsewhere, influencing flows of water, moisture in the air, sediment, organisms (beneficial, detrimental and neutral), fires and ensuing smoke or haze. The pattern of land use and its relation to the underlying structure of the landscape determine the overall availability of goods and services.

Box 1.1 Buffers and filters

The concepts of 'buffers' and 'filters', as used here, are related. Buffers reduce variability, filters (selectively) reduce transmission. The technical definitions of 'buffer' are indeed based on variance reduction: rainfall is highly variable (being zero much of the time and having high values a couple of hours per year); stream flow is buffered, although still variable: if it would be the same amount every day buffering would be 100%. The concept of buffering applies to anything that varies and where variation matters: prices, rainfall, temperature, politics, human health in the face of diseases, crop health in the face of pests, soil water content etc. Buffering cannot, however, shift the means over a longer time period. Filters can. Filters separate particles from their carrier, as a coffee filter does. Landscape filters can intercept part of the soil particles in the overland flow of water by allowing them to settle. Filters intercept monetary (or budget) flows, preventing funds from reaching downstream stakeholders. Filters lead to selective transmission of information. The concepts are further discussed in van Noordwijk et al 2011a. In the context of PALA, the buffers and filters relate mostly to water flows and erosion/sedimentation processes. The strips of land along rivers, or in other strategic positions in a landscape, that have a filter function can be called 'filters' themselves. The term 'buffer' is often used as shortening for 'buffer zone', an area in between intensive agriculture and conservation of natural habitat and associated biodiversity. The buffer zone buffers human influence on wildlife and wildlife influence on humans.

Objectives

The objectives of PaLa are to:

- articulate and study farmers' perceptions of the relationship between land use and landscape functioning;
- understand farmers' management options and the choices they make, interacting with the buffering of externally imposed variability;

- understand the flows of water, sediment, nutrients and organisms and the internal filter functions that determine landscape functioning, on the basis of land-use practices and the interactions between landscape units; and
- raise awareness among community members and government officials of issues connected to ecological and administrative boundaries.

Steps

The methods are derived from several decades of experience with RRA/PRA. PaLA consists of eight steps, which are evenly distributed between indoor sessions and fieldwork.

1. Identification of ecological and administrative domains with clear boundaries (indoor sessions and observation). This includes reviewing existing maps and reports (biophysical, ecological socioeconomic and policy). Relevant documents include topographical, land-use, soil and administrative maps. An Internet search can uncover hidden gems of information that are relevant for understanding the landscape.
2. Sampling the stakeholders to be interviewed, using questionnaires and/or ranking methods (indoor sessions and observation). The selected set of stakeholders should be broadly representative of the study area and the selection should be based on criteria including the locations of their fields (for example, in the upper, middle or down slope areas), income, gender, social status, age, experience and education. The criteria should be based on the goals of the project. It will be important to discuss them at the start of the PaLA process, and report them along with the results. Representativeness is easily claimed but hard to prove.
3. Forming an interdisciplinary survey group and planning and designing PRA tools (indoor sessions and observation). The concepts behind PaLA and the steps that need to be taken to implement it should be agreed on by the team.
4. Making a village sketch or model that identifies the land-use patterns and the landscape focus points (fieldwork). The methodology consists of semi-structured interviews with male and female groups. The expected model should show the local names of different areas, the distribution of land-use plots, and the main features of the landscape, such as rivers, streams, mountains and roads.
5. Going on a transect walk in order to gain an understanding of the soil–plant–water interactions in a landscape (fieldwork). The selected transect/s should cover most of the land-use types found in the study area/s. The methods used for this activity are simultaneous transect walks and semi-structured interviews. The expected outputs are representative transects and sketches of the areas, with the locations of transects entered on a map. During the transect walk buffers and filters are specifically noted and discussed as to their function, management and limitations.
6. Drawing up a timeline for each land-use type along transects and/or for the fields situated in the representative areas of the study catchment or village (fieldwork). The timeline can be used to study land-use changes over time. This activity will involve semi-structured interviews and timeline drawing.
7. Gathering feedback in order to report findings to the farmers and other stakeholders and to get their input (indoor sessions). The methods used for this activity are posters and other communications tools and group meetings.
8. Data analysis using teamwork (indoor sessions). Qualitative data resulting from the PRA tools, such as sketch transects, timelines and secondary data, is analysed by different team members. All findings are then compared and cross-checked in order to get a complete picture of landscape patterns and issues.

PaLA case study: Dong Cao catchment, Hoa Binh province, Viet Nam

Figure 1.2. Location of Dong Cao catchment, Hoa Binh province, Viet Nam; numbers mark places of specific interest. Photo: Tran Duct Toan

Dong Cao catchment (20° 58' N, 105° 29' E) is located in the Tien Xuan commune, Luong Son district, Hoa Binh province, 60 km south of Hanoi. The area receives a mean annual rainfall of 1500 mm, which falls mainly between April and September. Ferralsols and Acrisols soils consisting of clay loam and clay dominate the area. Most of the area has been converted to agricultural uses. Patches of secondary forest exist, mainly at higher altitudes. Cassava, corn, arrowroot and soybean are the major annual crops grown in the uplands and rice cultivation dominates the lowlands. The slope gradient in the area is between 15 and 60%. Situated at an elevation of 200–600 m, the low mountain zone of Viet Nam's northern mountain region is home to 39% of ethnic minorities. Two ethnic groups—the Muong and the Kinh—live in the study area.

PaLA was used as a scoping study for the Dong Cao catchment. During the PaLA survey, farmers' perceptions about current land use and their visions of how land use would change in the future were investigated using a 3D village model, a village sketch, transects and timelines. The results were used to develop hypotheses for the local ecological knowledge (LEK) survey and simulation work.

We started at the plot level with current land use (village sketch/model) and continued at the landscape level (transect). For each plot, we looked at the history of the land and at its future, to uncover farmers' ideas of how land use would change. We started with simple questions covering what, why, when and how, and followed these with open-ended, in-depth interviews.

The research team consisted of three Vietnamese and three Swedish researchers and students working in parallel for nine days. Five of those days were spent in the field together with 14 selected local farmers, while the remaining four days were used for indoor work (see figures 1.2 and 1.3). Brainstorming was the main tool used for team interactions. All concepts, definitions and methods were discussed and agreed to by the team members. Rapid reports—in which all of the information obtained during the day is written in a structured form—were completed at the end of each day of fieldwork to ensure that the information was properly documented. The method and the checklist to be used the next day were also agreed upon. The open-ended interviews aimed to establish an equal partnership between the farmers involved in the study and the team members. Farmers were asked for their feedback throughout the research process.

Figure 1.3. Team dynamics during the indoor session (Photo: Dan Olsson); the outdoor transect walk (Photo: La Nguyen) and village model (Photo: Johan Iwald)

The focus points in the landscape, including the points where buffering is weak and sensitivity to erosion high and the filters that intercept overland flows of water and sediment were identified both in the field and on maps. The characteristics of the filters and the points with weak buffering were described in a simple Geographic Information System (GIS) map (Figure 1.3) and on a timeline.

Farmers' knowledge expressed during the PaLA process indicated that the presence and abundance of trees in the upper sub-catchment was associated with higher stream flow, especially in the dry season. A more in-depth study as part of the LEK survey helped to formulate hypotheses and explanations for the outputs of the modelling work. The modelling, along with discussions with farmers, helped in identifying tree-based, land-use options for low-cost soil and water conservation.

For the weakly buffered points in the catchment the tentative conclusions were that:

- bamboo hedgerows prevent erosion better than *Acacia mangium* and *Tephrosia candida hedgerows*; and
- improved fallow of *T. candida* (two years) in rotation with cassava (two years) prevents erosion better than bamboo hedgerows intercropped with cassava.

For enhancing buffering and filtering functions in the catchment, it was clear that

- trees conserve water for the whole catchment; and
- *Acacia* and bamboo species are better for water conservation than are weeds/short natural fallow and monocropping.

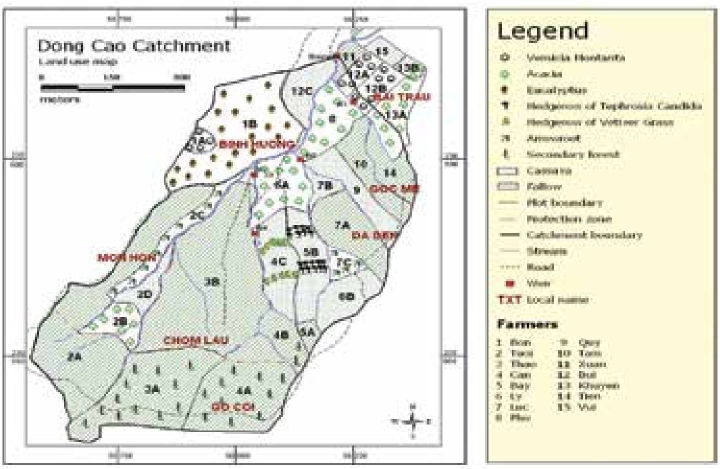


Figure 1.4. Simple GIS map of the Dong Cao catchment with local names of the fields and list of owners

Further reading

Hoang Fagerström MH, van Noordwijk M, Nyberg Y, eds. 2005. *Development of sustainable land-use practices in the uplands for food security: an array of field methods developed in Viet Nam*. Hanoi: Science and Techniques Publishing House.

Box 1.2: Land Use Fertility Effect Predictor

Researchers who want to know the impact of land use practices on soil conditions, often sample the land use systems as they are found in the landscape (what else could they do?) and infer from differences between soil measurements what impacts the land use systems have on the soil. That's where it can go wrong badly.

The LUFEP (Land Use Fertility Effect Predictor) worksheet explores the bias in such a procedure that is caused by a combination of:

1) farmer knowledge of fertility conditions of soils in the landscape,
2) farmer preferences to allocate specific sites for specific uses,
3) farmers' ability to implement such preferences,
4) the proportions of different land uses in the landscape.

As a result we may find that land uses with the strongest negative effect on soil fertility are still found on the most fertile sites, and soils under land use systems without negative effects occur on infertile soils. Such reversals mean that estimated effects of land use on soil fertility have a strong bias, unless there is a way to estimate the effects of farmer site selection.

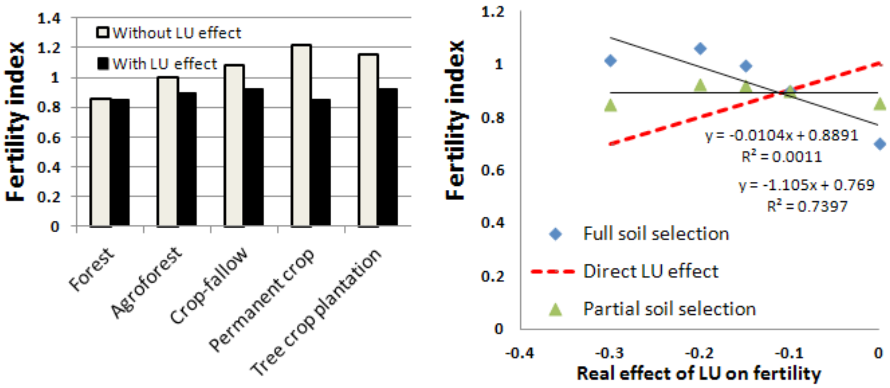


Figure LUFEP.1. A. Soil fertility index of soils used for five different land use systems with and without the effects of land use on soil fertility being expressed; B. Measurements in various land use systems in relation to the direct land use effect, showing the effect of soil selection on effect estimates

Figure LUFEP.1 shows an example for the default version of the model. In the "active model" sheet you can change the names of the land use systems and provide a number of numerical estimates of properties of the LU systems, the landscape's soil, farmer knowledge, implementation of LU preferences, and LU fractions in the landscape, to explore the discrepancy between what the innocent researcher observes and the real effect of LU systems on the soil.

The spreadsheet can be found at http://www.worldagroforestry.org/downloads/wanulcas/lufep.xlsx

2 Participatory analysis of poverty, livelihoods and environment dynamics (PAPoLD)

Hoang Minh Ha and Pham Thu Thuy

The Participatory Analysis of Poverty, Livelihoods and Environment Dynamics method (PAPoLD) provides insights in the local ranking and classification of wealth versus poverty, the indicators that can be used as proxies and the challenges at the bottom of the local pyramid to move out of poverty.

Introduction

Poverty, livelihoods' strategies and the environment are linked in numerous ways. Some of these links are distinctly spatial: they can be measured using household surveys and remote-sensing technologies and be mapped using geographic information systems. Other links are more context-specific and, therefore, more difficult to observe. PAPoLD was developed to capture specific issues of local importance. The method is dynamic and comparable (Hoang et al 2007a) and a refinement of the Stages of Progress method developed by Dr Krishna of Duke University in the USA[1]. The method was modified to become PAPoLD by the World Agroforestry Centre in Viet Nam in 2007, in collaboration with the Ministry of Labour, Invalids and Social Affairs and the Viet Nam Institute of Economics, to better address the links between poverty and the environment. By integrating PAPoLD with a sustainable livelihoods approach, the links between poverty and the environment can be understood in a more comprehensive way.

Objectives and steps

Table 2.1. PAPoLD objectives and associated questions and tasks

Step	Objective	Specific questions/tasks
1	To understand stakeholders, including local people's, viewpoints on poverty and the environment	1. What is poverty, what are the causes of poverty and who are the poor? 2. How do people perceive their environment and what are their environmental concerns?

[1] Dr Krishna and colleagues have produced a training manual for the method, as well as a number of journal articles summarizing the results (see http://www.pubpol.duke.edu/krishna/). The website includes a training manual and results from case studies in India, Kenya, Uganda and Peru.

Step	Objective	Specific questions/tasks
2	To understand the Stages of Progress and livelihoods' activities in the area	1. What are the local livelihoods' assets and what is the capital that people use to pursue their livelihoods? 2. What are the natural and environment-related livelihoods' assets and the dynamics/changes associated with those assets? 3. What are the communal livelihoods' activities? 4. Life changes (escape from poverty, falling back into poverty etc) in relation to key livelihoods' activities. 5. Rank the importance of the community's livelihood activities.
3	To identify the impact of natural resources and of the environment on livelihoods' activities and strategies and vice versa	1. How do people use natural resources to support their livelihoods? 2. How do livelihoods' activities affect the environment? (use Rapid Market Appraisal to analyse the value chain).
4	To identify shocks, risks and vulnerabilities relating to the environment and natural resources	What are the sources of natural and environment-related shocks and what risks do they pose to livelihoods?
5	To understand institutional and policy-related issues	To what extent are livelihoods' activities influenced by policies and institutional arrangements related to the management of natural resources?

PAPoLD case study: land-use strategies and the impacts of market and resource access on poor tea growers in Hoang Nong, Viet Nam

The commune of Hoang Nong in the Dai Tu district of Thai Nguyen province in Viet Nam belongs to the buffer zone of the Tam Dao National Park (Figure 2.1). The population of the study village consisted of six ethnic groups. Most of the households relied mainly on agricultural activities for their incomes, including paddy farming, rearing cattle and tea cultivation. Among these activities, cattle rearing gave farmers the highest economic return. Local farmers, especially the poorer households, also earned a living from forestry-related activities, such as hunting and wildlife trading.

PAPOLD was used together with other participatory rural appraisal tools to study the land-use strategies used by upland rural households for dealing with changes in commercialization processes (Hoang et al 2007b). Two villages were selected for the study as representative of two of the most dominant ethnic groups in the area: the Kinh in Doan Thang; and the Dao group in Dinh Cuong. Selected groups from the two villages (representing about 30% of the total households in each village) were asked to define local notions of poverty, identify 'stages of progress' that households in the villages might go through as they obtained more and more investment funds and characterize each household in the village according to its current and past stage in the stages of progress. Focus groups were also asked to describe their livelihoods' strategies. Two focus groups of tea growers were selected per village using representative criteria relating to wealth, age, and gender.

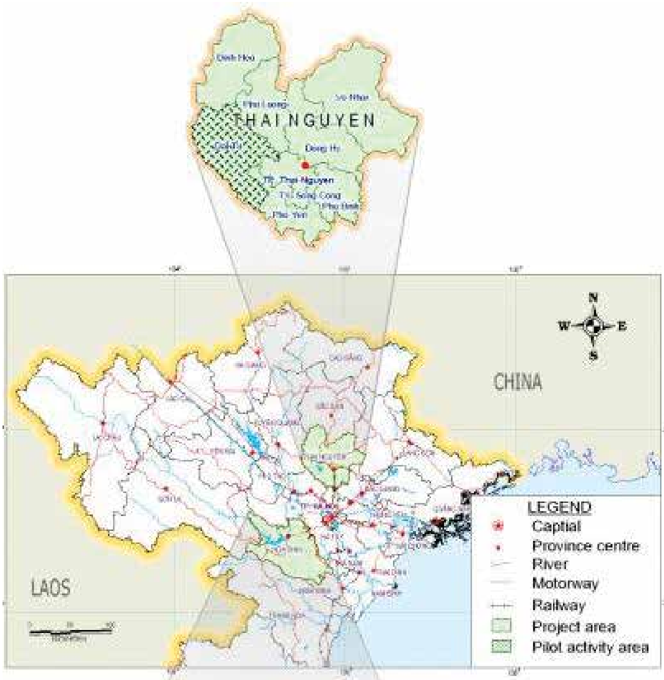


Figure 2.1. Map of Thai Nguyen, Viet Nam

Summary of findings

1. Links between poverty and policy: the Hoang Nong study showed that land-use changes over time were related to land and cooperative reforms. This was particularly the case in the early 1990s, when the establishment of the Tam Dao National Park, together with land privatization, left little land for young families to build on and to cultivate. This was the main cause of poverty among younger households.
2. Poverty indicators: the most common indicators of poverty were housing, land areas, labour, income, selling price of tea, the need to repay loans and buy furniture (Table 2.2).
3. Self-rated poverty level: most of the villagers rated themselves as being in stage 1 of progress (Table 2.2). This was defined as lacking land, suffering from bad health and unemployed. The farmers who described themselves as being in the medium stages of progress (stages 3 to 7) seemed to have more diverse crop and animal patterns, which gave them higher security and sometimes enough money to expand their farms or to invest. The better-off households (described as being in stage 5 and above) either had a large amount of land to begin with or had managed their investments well and were able to buy additional land.
4. Poverty changes over time for each household: changes in wealth over time showed that better access to land, credit and labour were the main factors that helped local farmers make their way out of poverty (Table 2.3).
5. Strategies for getting out of poverty: owning tea plantations, being able to afford fertilisers, waged employment, smaller families, reduced expenditure and collecting and consuming wild foods were the main strategies that were listed for getting out of poverty.

Table 2.2. Stages of progress and their definitions for the village of Doan Thang, Viet Nam

Stage number	Indicator
	Wealthy
10	Expanding business; able to use the brand name of Hoang Nong
9	Applying technology; investment; marketing; learning about the product market
8	Owning advanced multimedia (radio and television)
7	Accruing savings; taking care of health
	From average to wealthy
6	Buying a motorbike
5	Building house; improving and upgrading kitchen and house furniture; owning a bathroom
	Poverty line
4	Buying cows and buffalo
3	Buying fertilizers and basic machines
2	Buying additional land
1	Having little land and/or poor land; having many dependants; do not have basic houses; often sick

Table 2.3. Examples of changes in household poverty over time in Doan Thang village, Viet Nam

Examples	1982–1986	1991–1992	1994	1997	2001	2005	2007	Reasons for changes
		Land allocation and 'red book' (land title) issued		Selling young labour to the south	Electricity becomes available	The German Organisation for International Cooperation project starts and a 'safe tea' cooperative is established		
A				1	→	→	3	Children grow up, health improves, hard working (14 hours/day)
B				4	→	→	3	Old parents, able to pay for small children to go to school
C				4	→	→	3	Old parents, able to pay for small children to go to school
D						2 →	3	Purchase more land for tea, children get bigger
E					2	→	3	Children get bigger
F				2	→	→	3	Parents are less sick
G				1 →	2	→	4	Business service, selling equipment for tea, and drying and processing tea
H	2	→	→	→	3	→	4	Working with tea, children grow up, more labour
I	3 →	4	→	→	→	→	4	More labour, creativity, pension

Note: Refers to stages of poverty identified in Table 2.2

The PAPoLD method helped researchers to understand the livelihoods' strategies that people use to get out of poverty and the positive or negative impacts that these strategies have on the environment. The poverty lines, the wealth line and the poverty indicators show that there are ways to improve livelihoods in the area, primarily by promoting livestock production and by cultivating 'environmentally safe' tea.

Further reading

Hoang MH, Pham TT, Swallow B, Nguyen TLH, Thai PT, Nguyen VH, Dao NN. 2007a. *Understanding the voice of the poor: participatory poverty analysis with environment focus*. Hanoi: United Nations Development Programme; Ministry of Natural Resources and Environment of Viet Nam.

Hoang MH, Nguyen LH, Pham TT, Mai HY, Be QN. 2007b. *Comparative analysis of market and resource access of the poor in upland zones of the Greater Mekong Region (MMSEA project)*. Viet Nam case study. Hanoi: World Agroforestry Centre Viet Nam.

3 Rapid appraisal of drivers of land-use change (DriLUC)

Meine van Noordwijk

Rapid Appraisal of Drivers of Land-use Change (DriLUC) provides an initial overview of the dynamics of land-use change in the local context and the way this is related to processes acting at larger scales. The method combines desk study of available documents and maps with interviews with key informants and focus-group discussions. A specific topic is the trade-off between economic development and environmental quality, as locally perceived.

Introduction: drivers and responses of land-use change

Land use is dynamic. It is the result of the decisions and choices made by many different people. The consequences of any changes that take place as a result have an impact on many other people. Consequently, the key features of a landscape need to be mapped and understood at an early stage of developing an integrated natural resource approach to managing a particular landscape. Treating a dynamic landscape as a system includes the notions of 'internal' (endogenous) and 'external' (exogenous) drivers of change, even though the system boundary may be fluid. A system is subject to pressure, has response options, time lags and feedback mechanisms that allow for learning and internal adjustment. Yet, we shouldn't lose sight of the problems that may arise from a lack of communication, differing interests and, sometimes, open conflicts between the various people involved. Viewing the multiple interests in a landscape from a political-ecology perspective can help to create a platform for negotiations among stakeholders.

Objectives

The primary objective of DriLUC is to provide a system-level understanding of the way local drivers of land-use change relate to external conditions and the types of local, regional and national feedback that influence livelihoods and the provision of goods and services.

Steps

1. Document changes in land cover, demographics, economic indicators, road or river access, and analyze conditions and trends

There are many definitions of 'forest' and, subsequently, statistics of deforestation rates can refer to changes in woody biomass, changes in institutional control or a combination of the two (Figure 3.1).

Similarly, there are several ways to define poverty. Data gathered in different studies may not be comparable. Demographics data tend to be weak on issues of migration and the temporary movement of people. GIS can combine data based on administrative boundaries with data from remote sensing, Google Earth, and other similar sources.

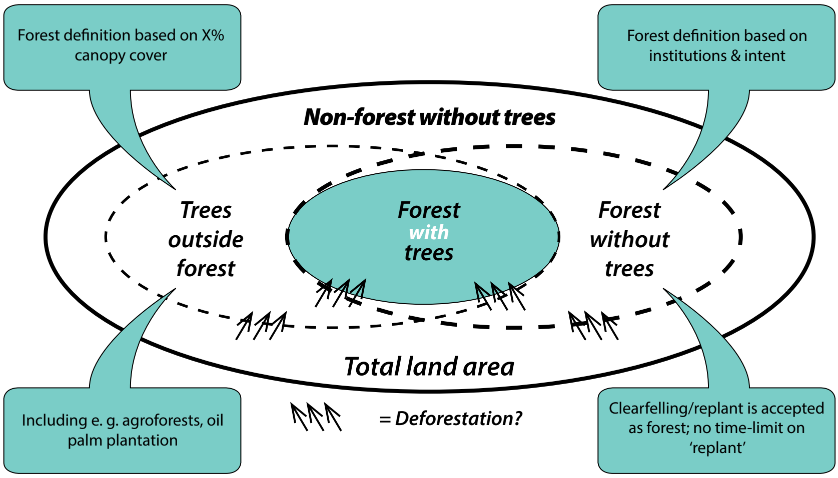


Figure 3.1. Institution and vegetation-based interpretation of the term 'forest' and the resultant four classes of forest/non-forest lands with or without trees

2. Discuss with key stakeholders how choices are made about changing land uses

This includes learning within and between the groups and local representations of external changes, which may respond to conditioning factors that originate at the national scale (Figure 3.2).

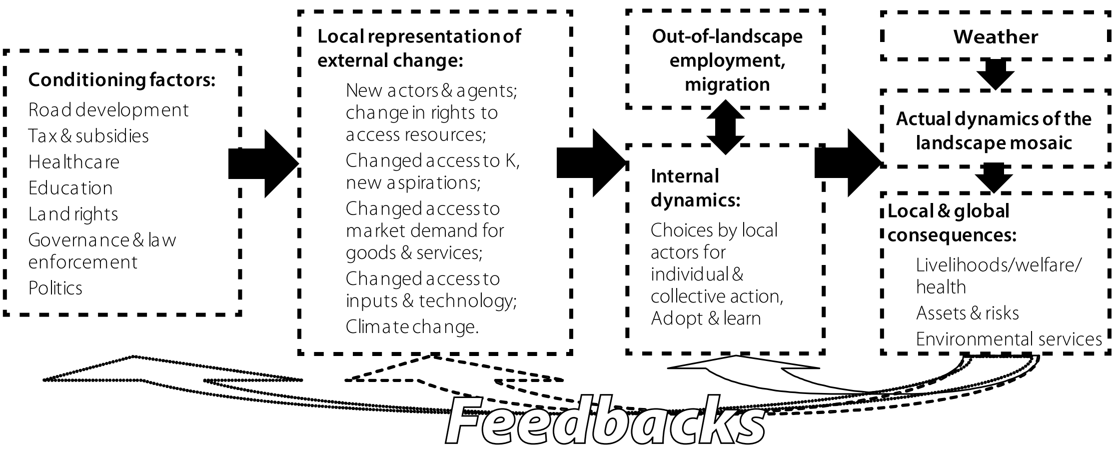


Figure 3.2. Interrelationships between groups in a landscape

As indicated in Figure 3.2, a main driver of land-use change might be the 'new' people involved in the landscape as a result of changes in access rights or owing to temporary employment outside of the landscape (which may lead to permanent out-migration). In the short term, such out-of-landscape jobs lead to remittances to family members who have stayed behind. They also create social safety nets that reduce risk for all family network members and stimulate change in terms of knowledge and aspirations.

3. Identify the local and national links between the five capitals of the sustainable livelihoods approach

The livelihoods approach introduced and supported by the UK Department for International Development recognizes five interacting types of capital: natural, human, social (including political), physical and financial.

The approach moves beyond a purely financial definition of livelihoods towards a more inclusive one. Asymmetric changes apply, in particular, to natural and social capitals, which can be rapidly destroyed but which take a long time to rebuild.

In this context, we identified five dominant dimensions of rural poverty related to the five capitals:

1. lack of access to, and use of, land rights (social and natural capital);
2. lack of access to clean water and local agrobiodiversity, resulting, for example, in poor health (natural and human capital, modified by physical and social capital);
3. lack of investment funds for clean development (financial and natural capital, interacting with social and human capital);
4. lack of income opportunities (human and financial capital); and
5. lack of (political) voice; receiving blame for environmental destruction (social and natural capital).

Analysis of the local versions of these five capitals and their interactions must also be considered in a broader context and take into account the capitals at the national level as well (Figure 3.3).

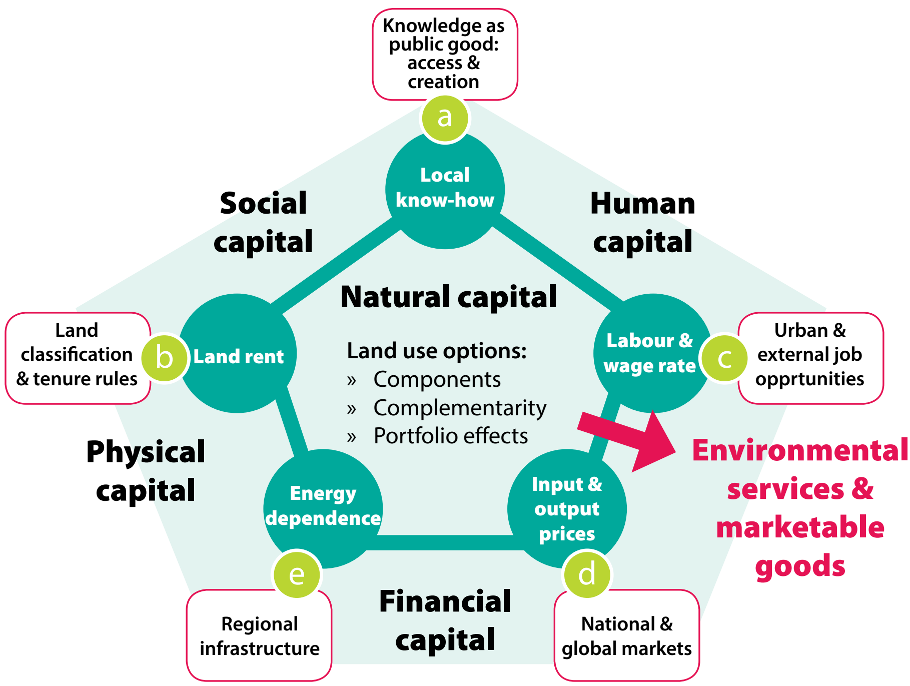


Figure 3.3. Cross-scale interrelationships of the five capitals (asset types) of the livelihoods' analysis

Five major policy domains link local constraints to land use to their equivalent at the national level:

1. creation of, and access to, knowledge through responsive research and extension systems;
2. policies on forestland classification and land-access rules;
3. overall economic development and creation of (urban or rural) jobs in the primary agricultural production sectors;
4. price policies, subsidies and regulation of market access; and
5. development of regional infrastructure for transport, water flows, energy supply and the provision of health and education services.

These five policy domains are part of the overall context in which governance and poverty reduction strategies are developed.

4. Determine the position on the tree-cover transition curve

Many landscapes experience phases of degradation where initial opportunities for resource extraction lead to non-sustainable use. The transition to a resource-recovery phase usually requires tenurial control. This will provide investment returns along with increased physical, economic and political access to markets. The resulting agroforest transition curves can have multiple forms. The X-axis can refer to time, population density or overall economic indicators. The Y-axis can refer to forest cover or to the provision of environmental services (see Figure 3.4 for an initial hypothesis).

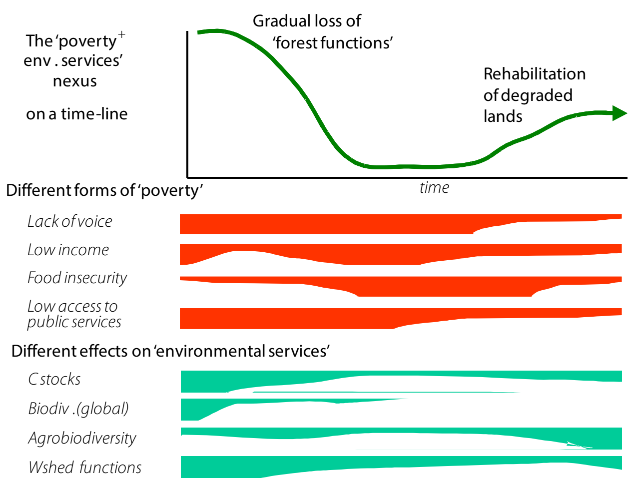


Figure 3.4. Tree-cover (forest) transition curve (above) and hypothetical relationship to poverty (centre) and environmental services (below) to be tested in focus-group discussions

5. Understand the dynamics along the segregate–integrate axis

Land-cover change is usually described in terms of tree cover (the vertical axis on the graph). However, an equally important characteristic, especially when it comes to intermediate forest cover, is the spatial pattern of the various types of land cover (Figure 3.5). We should distinguish between fully segregated or zoned systems and those that are more integrated and multifunctional. The driving forces for increasing or decreasing functional integration are as important as changes in tree cover (deforestation/reforestation).

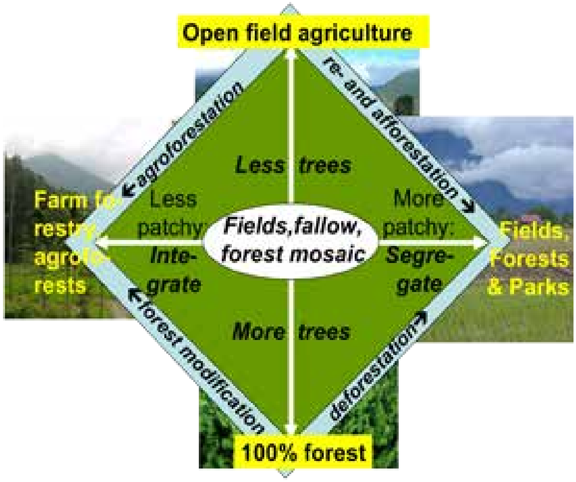


Figure 3.5. Segregated–integrated landscape dynamics

Source: Thomas et al 2008

6. Recognize stages of conflict and collective action

There are two types of social capital: 'bonding' capital or trust within a local community and 'bridging' capital or trust with outside agencies. Some level of bonding capital is usually needed before bridging capital can be established. Strengthening local institutions can also help by bringing tensions with the outside world into the open. By reconstructing local experiences of engagement with the outside world and combining this with an analysis of the degree of internal structures within a community, an assessment can be made of relative strengths and opportunities (Figure 3.6).

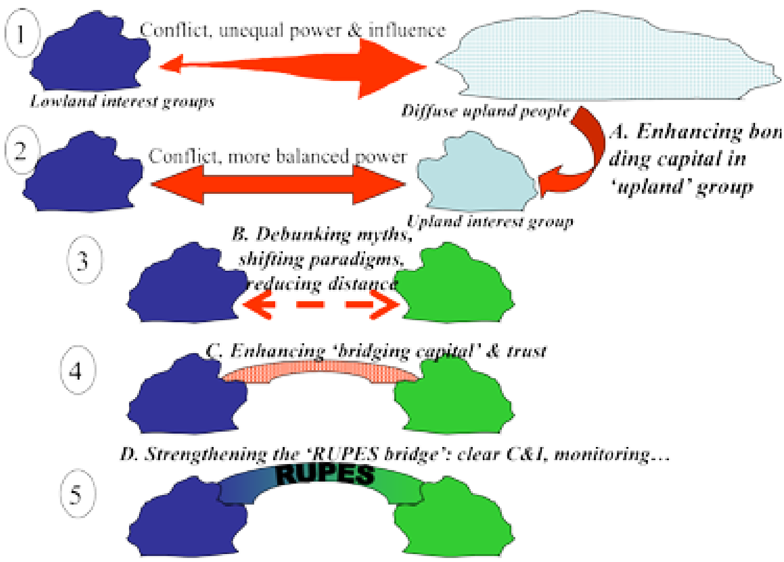


Figure 3.6. Stages of conflict and collective action

Note: for a detailed explanation, see van Noordwijk et al (2011), Figure G.3, page 84.

Source: van Noordwijk et al 2001

7. Understand agents of land-use change and stakeholders' views on the trade-offs between goods and services

Elements of land-use change and their associated drivers involve shifts in the trade-offs between goods (profitability) and services (conservation). The potential relevance of rewards for providing environmental services needs to be understood in relation to the position of the landscape to the protected areas (for example, rotating the field so that more of the 'services' project on the utility vector, compatible with the commoditized goods) (Figure 3.7).

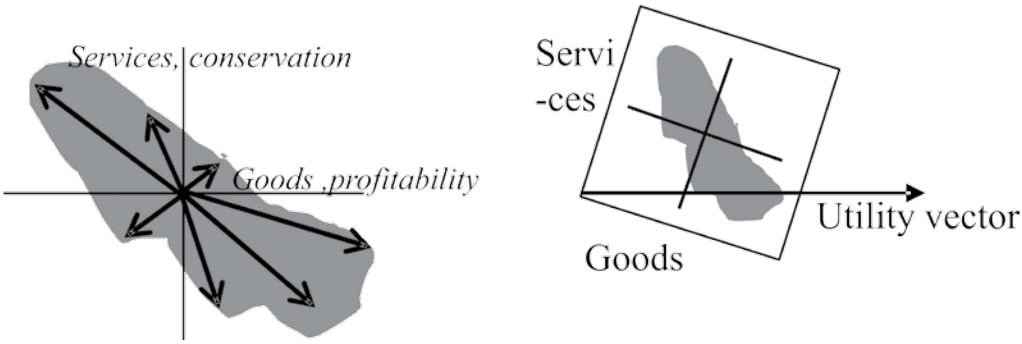


Figure 3.7. Changing the perspective of environmental goods and services

Next steps

Details of the methodology will have to be adjusted to suit local circumstances and the capacity of DriLUC partners. The analysis can go hand in hand with PaLA and PAPoLD. DriLUC can identify the main issues surrounding agroforestry technology and/or environmental services that merit further study, for example, through the use of the Rapid Agroforestry Systems and Technology (RAFT) tool, Rapid Hydrological Appraisal (RHA), Rapid Agrobiodiversity Appraisal (RABA) and Rapid Carbon Stock Appraisal (RaCSA). DriLUC will also help to define the framework for any land-use scenario analysis and the use of simulation models, such as Forest, Agroforest, Low-value Landscape or Wasteland (FALLOW).

Example of trade-off analysis in Jambi province, Indonesia

Steps 1–6 of DriLUC were part of the initial characterization of the ASB Partnership for the Tropical Forest Margins in Jambi (Tomich et al 1998). Step 7 was tested in a focus-group discussion with local stakeholders in Jambi, involving NGO staff, local government officials and farmers. It proved to be intuitive to define the two axes and to have group members identify the various land-use activities, reaching agreement on where to place them on the axes (sometimes after considerable discussion and clarification between participants). In a second pass of the graph the main people involved in the land-use activities were identified (Figure 3.8).

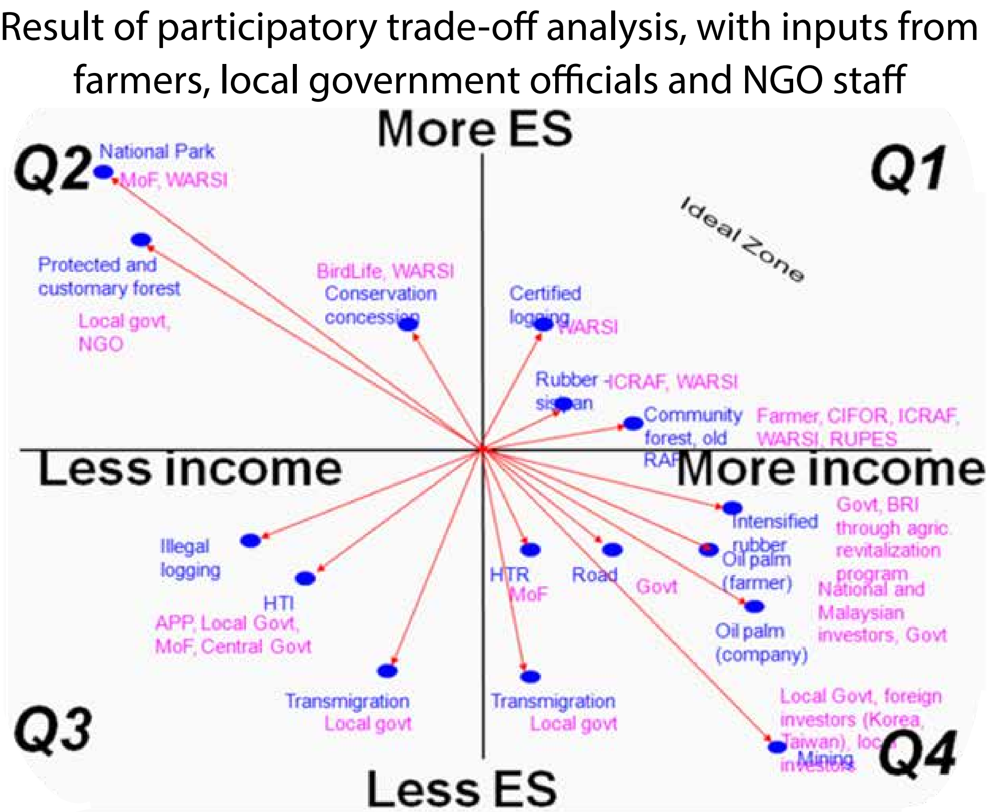


Figure 3.8. Example of trade-off analysis between land uses as emerged from a focus-group discussion in Jambi province, Indonesia

Note: ES = environmental services; MoF = Ministry of Forestry; WARSI = local environmental NGO; BirdLife = international wildlife NGO; ICRAF = International Centre for Research in Agroforestry/World Agroforestry Centre; CIFOR = Center for International Forestry Research; APP = Asia Pulp and Paper; HTI = Hutan Tanaman Industri (Industrial Plantation Forest) HTR = Hutan Tanaman Rakyat (People's Plantation Forest)

■ Further reading

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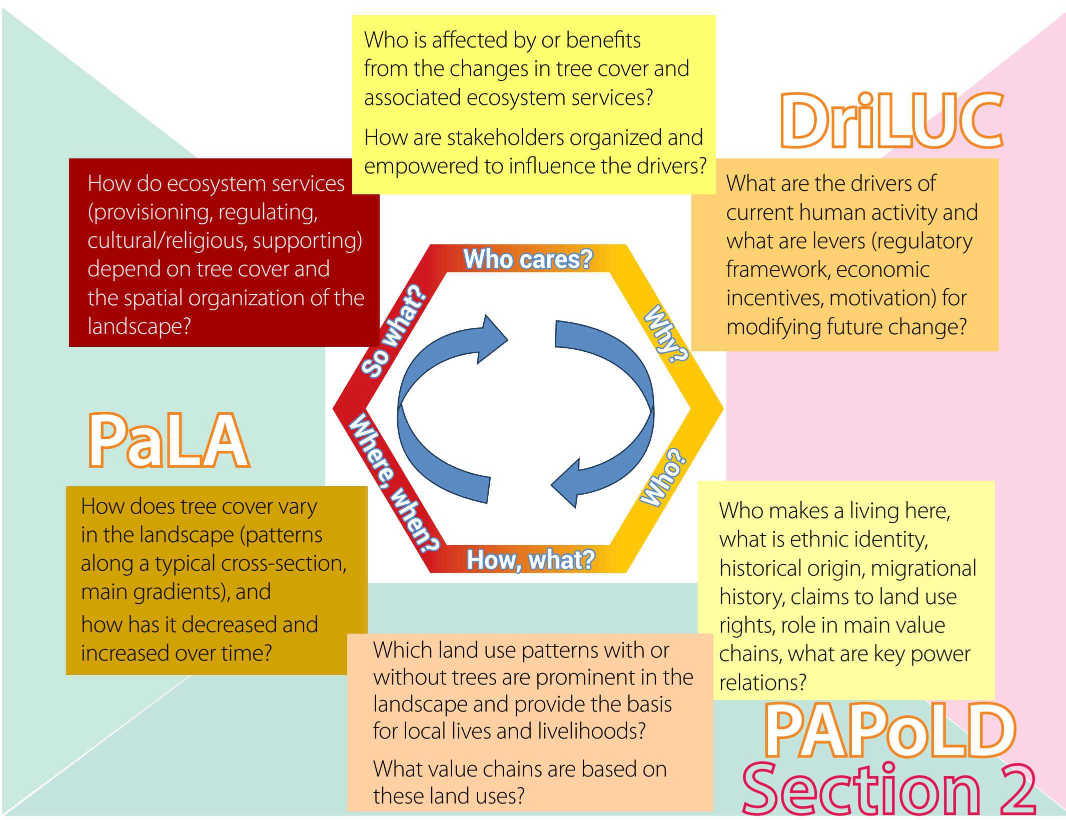
SECTION 02

Lives, land use and livelihoods: trees, agroforestry technology and markets



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

Laxman Joshi, Meine van Noordwijk, Endri Martini and Janudianto

Agroforestry practices, systems and technology exist in many forms but are often 'invisible' in official documents and statistics that see agriculture, commodities and forestry as separate sectors. The Rapid Appraisal of Agroforestry Practices, Systems and Technology (RAFT) tool helps assess what exists in the landscape as seen through the eyes of farmers and land managers and to relate that to emerging classifications of land use to become more inclusive.

Introduction

'Agroforestry' is an umbrella term covering a wide range of practices in which trees are grown on farms and in agricultural landscapes. The RAFT framework provides guidelines for the description and analysis of the different ways trees are used to improve rural livelihoods, on farms and in landscapes. A distinction between agroforestry technologies (for example, focussed on the way tree–soil–crop–animal interactions are managed) and agroforestry systems (the farming systems that include the deliberate use of trees, using multiple discrete technologies in different parts of the farm) follows the analysis by Sinclair (1999).

Objectives

1. Clarify terminology of agroforestry practices, systems and technologies appropriate for local use and global adaptation.
2. Understand the relationship between 'domestication' from the perspectives of trees as biological resources, control over access to resources and knowledge and belief systems.
3. Appraise strengths, weaknesses, opportunities and threats with the main agroforestry stakeholders to plan applied research and development support.
4. Initiate more detailed data collection on input and output streams at various phases of the lifecycle of an agroforestry system.

Steps

1. Clarify local terminology for the various uses of trees in space and time, in relation to existing generic schemes, building on the initial exploration in the PaLA tool.
2. Participatory appraisal of current tree management and domestication.
3. Explore the depth of local ecological knowledge and awareness of intellectual property rights.
4. Appraise component interactions at technology and system levels.

5. Quantify input/output relations and initiate a profitability assessment (for follow up with LUPA).
6. Assess tree and land-tenure arrangements and associated policy issues.
7. Jointly with farmers, analyze strengths, weaknesses, opportunities and threats of the agroforestry technologies and systems.

Step 1a. Terminology

LOCAL MEANINGS AND SENSITIVITIES AROUND TERMINOLOGY

In different languages, similar agroforestry terms may be used to refer to a dominant commodity, the way it is managed or to a form of semi-managed, woody vegetation. Understanding the true meaning of similar terms used in different languages is not easy, as the values embedded in the word may be lost or changed. 'Community-based forest management' or even 'forest' and 'agroforest' can refer to the same vegetation but imply different political control. Sensitivities around specific terms need to be carefully explored with local stakeholders, including men and women, farmers, landless peasants and government officials.

NATIONAL-LEVEL INSTITUTIONAL TERMINOLOGY FOR FORESTS AND TREES OUTSIDE OF FORESTS

An 'objective' descriptor, such as the degree of crown cover of woody perennials, may allow monitoring by remote sensing but might not match national policies or categories used to track deforestation and forest degradation. There is growing recognition that trees outside of forests provide goods and services but such trees may still fall through the cracks of a 'forestry versus agriculture' dichotomy.

INTERNATIONAL COMPARISON IN META-LAND-USE SYSTEMS

To ease global comparisons, the ASB Partnership for the Tropical Forest Margins introduced the term 'meta-land uses' (van Noordwijk et al 2001).

Table 4.1. Main products and 'meta-land-use' system

Primary focus	Land-use system
Forest products	Natural forest (F_n), without extraction beyond the occasional harvest of non-timber forest products and/or hunting of wildlife
	Managed forests (F_m), with various degrees of harvest of timber and non-timber forest products and grazing but no commercial logging
	Logged forests (F_l), with various intensities and degrees of management to enhance the regrowth of valuable trees; can include 'enrichment planting' up to one-third of total tree basal area
Tree crops and timber plantations	Extensive agroforests (T_e) are complex, multistrata agroforestry systems with at least one-third of tree basal area derived from spontaneously established trees and more than five recognized harvestable commodities
	Intensive agroforests (T_m) with at least two recognized harvestable commodities and less than one-third of tree basal area derived from spontaneously established trees
	Simple, intensive tree-crop systems (T_s) or timber plantations, with one or two harvested commodities

Primary focus	Land-use system
Annual crops	Extensive crop/long fallow system (C_e), with the cropping period of less than one-third of the length of the intervening fallow (for the 'shifting cultivation' subset this may be less than one-sixth)
	Medium intensity, crop/short fallow systems (C_m), with the cropping period up to twice the length of the intervening fallow
Primary Focus	Land-use system
	Intensive, crop/short fallow system (C_i), with fallow periods less than half of the cropping period
	Continuous annual cropping system (C_p), which occasionally may skip a growing season as 'fallow'
Animal products	Pasture/grasslands /rangeland (A_e) based on spontaneously established vegetation but subject to various degrees of management
	Intensive pasture (Ai), with farmers' control over the composition and growth of the vegetation and various levels of drainage, fertiliser use and seeding of desired species

INTERNATIONAL AGROFORESTRY TERMINOLOGY

Present classification schemes confuse agroforestry practices, where trees are intimately associated with agricultural components at a field scale, with the whole farm and forest systems of which they form a part. In fact, it is common for farming systems to involve the integration of several reasonably discrete agroforestry practices on different types of land. The purpose of a general classification is to identify different types of agroforestry practices and to group the ones that are similar, thereby facilitating communication and the organized storage of information (Sinclair 1999).

Step 1b. Use of trees in space and time

There are several topics to explore as a follow up to PaLA, jointly with local informants and stakeholders.

1. Rotational systems and those with internal tree regeneration.
2. Spatial configuration of trees.
3. Landscape niches and their different uses.
4. Responses to climate variation, seasonality, fire and drought years.
5. Ethnobotany and ethnozoology: how much do local people know about plants and animals?

By combining steps 1a and 1b, a locally relevant classification systems and terminology can be defined that can be used in all subsequent studies and tools.

Step 2. Participatory appraisal of current tree management and domestication

There are several questions to consider when surveying trees in an agroforestry system.

1. Origin: Were the trees spontaneously grown in situ, transplanted from the wild, grown in a nursery from local or external seed a or grafted with local or external budwood?
2. Ownership: What are the use seeds for fruits, fallen branches and other non-destructive plant parts? What are the rights for timber, bark or other products requiring destructive harvest?
3. Use: How are trees and their products included in local consumption and use, in marketed products, and as providers of environmental services, such as for slope stabilization, mulch, nitrogen fixation?

The results of the survey should be compared with thresholds in tree domestication (open access use, regulated use, managed regeneration, planted, selective propagation, breeding), changes in technology, resource control and knowledge and beliefs.

Wiersum (1997) identified three thresholds in the process of domestication: 1) 'controlled utilization' (the separation of open access from a controlled harvesting regime); 2) 'purposeful regeneration' (the separation of dependence on natural regeneration from interventions that generally require control over subsequent utilization); and 3) 'domestication' (a movement toward a horticultural or plantation style of production system).

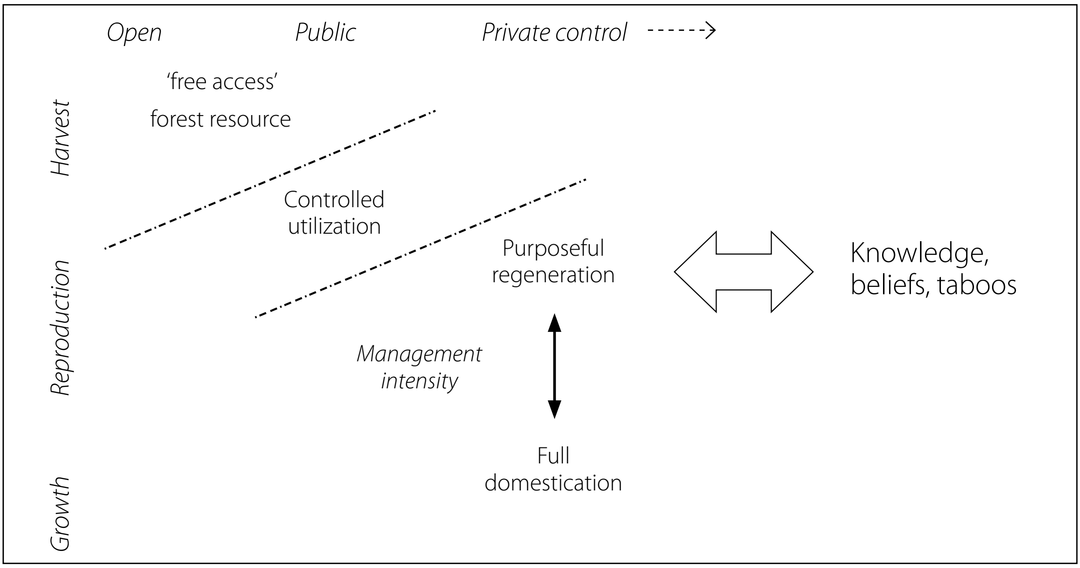


Figure 4.1. Stages in the domestication of forest resources

Note: Based on the various types of control (tenure) exerted over the land and on the type of control exerted over the reproduction and growth of the plants involved. Modified from Wiersum 1997.

Step 4. Appraising the depth of local ecological knowledge and awareness of intellectual property rights

There are several topics to explore to assess local ecological knowledge and awareness of intellectual property rights.

1. Ethnobotany: the components of the local agroforestry system, their properties and potential uses
2. Ecological knowledge of relationships
   - i Management practices
   - ii Skills and technology
3. Socio-cultural value of trees and tree products
4. Restrictions on access to knowledge within the community (for example, medicinal plants)
5. Issues regarding intellectual property rights with outsiders, neighbouring communities and/or the wider community of similar ethnic origin

Step 5. Component interactions

The main topic to explore in Step 5 is the interactions between target trees and other system components, such as other trees, weeds, crops, domestic animals, pests, diseases, pollinators and seed dispersal agents.

Step 6. Input/output relations and profitability assessment

In setting up a framework for quantifying input/output relationships and profitability (see LUPA), distinctions need to be made between system phases (for example, year $T_0 - T_1$ 'establishment', $T_1 - T_2$, 'early production) and for each phase a list is needed of the inputs (type, volume, current price, labour use and possible land rents) and outputs (harvested products, volume, current price). This will inform the subsequent, more detailed LUPA data collection that explores variation in all quantities involved before characterizing a 'typical' system input/output table as the basis for profitability analysis.

Land	Open access (de facto)	L1
	Community-controlled land and resources	L2
	Community-controlled land, private resources	L3
	Private control	L4
Plant resources	Propagule source: 'natural'	P1
	Propagule source: locally selected	P2
	Propagule source: externally obtained	P3
	Propagule source: externally 'improved'	P4
	Growth: reducing competitors	G1
	Growth: securing symbionts	G2
	Growth: fertiliser	G3
	Growth: irrigation	G4
	Growth: drainage	G5
	Flowering induced	R1
	Pollination & fruit set stimulated	R2
	Protection from frugivores	R3
	Advanced harvest techniques	H1
	Post-harvest processing	H2
Animal resources	Harvest from wild, managed wild populations, domesticated stock with uncontrolled/ controlled mating, specific selection of parentage ; roaming free, controlled range, stall -fed	A
Market	Local use within village Use (buyers) within district/province Use (buyers) at national scale Regional markets International markets	M1 M2 M3 M4 M5

Figure 4.2. Classification system for land, animals, plants and markets

Step 7. Tree and land tenure and policy issues

Rights to land can follow different dynamics than rights to trees, both in the local traditions and under national law. Often, the rights to future benefits of a tree are passed on to the heirs of the planter. Trees derived from natural regeneration, even if they grow alongside privately owned planted trees, may still be seen as public goods, as the example of durian trees in rubber agroforests in Sumatra shows (Joshi et al 2003). In some systems, trees can often be pawned.

Step 8. SWOT of the agroforestry technology

At the end of a RAFT, an analysis of strengths, weaknesses, opportunities and threats is carried out with local stakeholders to help synthesize all of the information.

Case study: RAFT applied in Sulawesi, Indonesia

RAFT was applied to compile information about the different types of cocoa agroforestry systems in the provinces of South and Southeast Sulawesi, Indonesia. A survey was conducted in 2013 in 25 plots in the two provinces. Based on tree inventory data in the survey, we defined three groups of cocoa farming systems.

1. Cocoa monoculture, which has on average two species (range 1–4 species), that is, cocoa and shade trees (*Gliricidia* or banana).
2. Simple cocoa agroforestry, which has on average four species (range 2–5 species), that is, cocoa, fruit trees (durian, *Lansium*, coconut, rambutan, *Parkia*, banana), timber trees (teak and *Toona*) and/or commodity species (clove and pepper).
3. Multistrata cocoa agroforestry, with on average 10 species (range 6–13 species), that is, cocoa, timber trees (*Toona, Gmelina, Paraserianthes, Antidesma, Pterocarpus, Dalbergia, Shorea*), fruit trees (mango, durian, *Parkia*, banana, avocado, coconut), and/or commodity species (clove, candlenut, arenga, cashew, areca and coffee)

Out of 25 plots observed, 48% were simple cocoa agroforestry, 36% cocoa monoculture and only 16% were multistrata cocoa agroforestry. For each of the cocoa farming systems, a SWOT analysis was performed with farmers. In the SWOT analysis, information was collected on cocoa domestication, tree management, production, profitability and government support. The result of the SWOT analysis is shown in Table 4.3.

Table 4.3. Analsysis of strengths, weaknesses, opportunities and threats for three cocoa cropping systems in South and Southeast Sulawesi, Indonesia

	Monoculture	Simple cocoa agroforest	Complex cocoa agroforest
Strengths	High cocoa yields Potential high price and market support for cocoa	Moderate cocoa yields Diverse sources of income from other species Potential high price and market support for cocoa	Low agricultural input Diverse sources of income from other species Potential high price and market support for cocoa

	Monoculture	Simple cocoa agroforest	Complex cocoa agroforest
Weaknesses	High input High cocoa pest and disease problems Only one source of income	Moderate agricultural input Moderate cocoa pest and disease problems	Low cocoa yields High cocoa pest and disease problems Other
Opportunities	Species' enrichment in the gardens will create diverse sources of income for farmers to buffer potential low prices for cocoa Pruning and fertilizing key to lowering cocoa pest and disease problems	Spacing between species needs to be arranged to ensure enough light intensity for cocoa (that is, not less than 50%) Pruning and fertilizing key to lowering cocoa pest and disease problems	Spacing between species needs to be arranged to ensure enough light intensity for cocoa (that is, not less than 50%) Pruning and fertilizing key to lowering cocoa pest and disease problems
Threats	High cocoa pest and disease problems may result in farmers converting their cocoa gardens Low tree maintenance will cause high cocoa pest and disease problems	Low tree maintenance will cause high cocoa pest and disease problems	High cocoa pest and disease problems may result iin farmers ignoring cocoa production or abandoning the cocoa garden Low tree maintenance will cause high cocoa pest and disease problems

■ Key references

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5 | Local ecological knowledge: agroecological knowledge toolkit (AKT5)

Laxman Joshi, Fergus Sinclair and Elok Mulyoutami

The Agroecological Knowledge Toolkit (AKT5) provides a systematic framework for documenting and subsequently analyzing local agroecological knowledge. Within the frame of a relational database, local knowledge is teased apart into unitary statements that can subsequently be viewed with all their interconnections.

Introduction

Local ecological knowledge (LEK) refers to what people know about their natural environment, based primarily on their own experience and observation. LEK is widely seen as important and of potential use in research and development programs related to natural resource management. However, there is a need for effective methods for exploring, accessing and evaluating LEK if it is to be integrated into the planning process in an explicit manner. One method that has been developed to enable representation of local knowledge is a knowledge-based systems approach. In this method, qualitative LEK are articulated by local people and represented using computer software. This is based on earlier studies (reviewed in Walker and Sinclair 1998) that show the majority of articulated knowledge can be broken down into unitary statements of knowledge that can then be represented through computer software using a formal grammar and a local taxonomy of terms. Such represented knowledge can then be subjected to synthesis and evaluation in an objective and unbiased manner.

The AKT5 software was developed at the University of Wales, Bangor, UK, with contributions from many national and international research and development institutions (Walker and Sinclair 1998, Joshi et al 2004a, b). It was designed to create knowledge bases from a range of sources. It allows representation of knowledge elicited from farmers and scientists or knowledge abstracted from written material. The methodology involves the creation of knowledge bases that comprise formal records of local knowledge that then can be flexibly accessed and used by research and extension staff.

Research using the AKT5 system has shown that local people often have sophisticated knowledge about ecological processes underpinning natural resource management.

Objectives

1. Document local agroecological knowledge in a form that allows the representation of an interconnected knowledge system, built up from unitary statements.
2. Select statements that can be used to analyze how widespread are specific forms of knowledge.
3. Compare knowledge systems beyond locations and/or stakeholders.

Steps

1. Download most recent version of the AKT5 software

The latest version of the AKT5 software can be downloaded free for non-commercial purposes from the AKT website: http://akt.bangor.ac.uk.

2. Read the manual

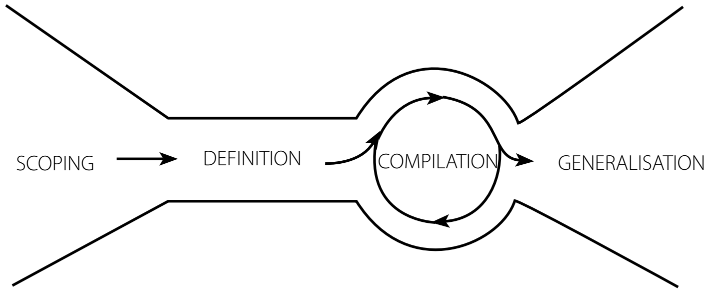
The process of acquiring and representing knowledge using this system is described in the AKT5 manual (Dixon et al 2001). Essentially, during knowledge-base creation, knowledge is elicited through a process of semi-structured interviews with a stratified sample of carefully selected informants. This knowledge is then broken down into short statements, comprising single items of knowledge that we refer to as unitary statements. These are then represented with a computer using a formal grammar. In practice, the process of representation requires evaluation of the knowledge as it is entered and provides the basis for further questioning. This iterative process of elicitation and representation continues until no new knowledge is revealed by further questioning. Robust knowledge bases on specified topics from well-defined sources are created. The knowledge is stored in a form that is comprehensive, accessible and easily updated. Automated reasoning tools assist comparative analysis of knowledge held by different groups of people and can be customised to explore the implications of combining local and scientific knowledge.

3. Knowledge elicitation

The framework is divided into four stages (Figure 5.1).

1. Scoping
2. Definition of the domain
3. Compilation
4. Generalisation

The important feature of this four-stage strategy for knowledge acquisition, in terms of sampling, is the separation of knowledge-base development (the first three stages), where a small purposive sample of people are intensively involved, and the generalisation stage, where a large randomised sample of people is drawn from the target community to explore how representative the knowledge base is.



Objective	To refine knowledge acquisition objectives	To generate a broad understanding of domain and define boundaries and terms	To create coherent and comprehensive knowledge base	To test how representive the knowledge base is of farmers generally
Informants and activities	A broad range of activities a cross the community	One or two intensive interactions with a small number of purposively selected informants	Iterative cycle: repeated interaction with statified sample of key informants, knowledge representation and evaluation of emerging knowledge base	A variety of questionnaire-based survey approaches on a sufficiently large and randomly selected sample of informants from the community

Figure 5.1. Four stages in elicitation of local ecological knowledge

Source: Dixon et al 2001

Sets of unitary statements as captured in the knowledge base should be evaluated in terms of

- repetition,
- contradiction,
- completeness and
- consistency in use of terms,

as elaborated in Dixon et al (2001).

4. Analytical steps

For use in negotiation support we are particularly interested in a comparison of the LEK, PEK and MEK mental maps of the world. If all three are similarly mapped in AKT5 we can now start to overlay them and explore consequences (Table 5.1).

Table 5.1. Analysis of differences and overlaps between knowledge systems, with consequences for negotiations

	Examples	Consequences for negotiation	Suggested next steps
Areas of agreement	Although details may differ, all knowledge systems recognize effects of trees on microclimate	Actions that directly align with this shared knowledge have good chance of being accepted by all	This common ground can form the basis of agreements, needs to be in the preamble
Areas of contradiction	While foresters (PEK) claim their tree planting increased water availability, farmers (LEK) perceived the opposite effect; MEK mostly agrees with LEK	Negotiations will move in circles around such hot issues until a common cognitive base is found	This contrast needs to be analyzed and where feasible to be resolved by joint fact-finding on agreed criteria and case definitions
Differences in detail of articulation	Science (MEK) will usually have more detail but also more recognized uncertainty than either LEK or PEK	Differences in detail (or in degree) of explanations are okay as long as they don't affect expected response to actions	Optimal fuzziness may require multiple iterations of further clarification and compromise
Topics absent from one or more	Local knowledge (LEK) may invoke spiritual links absent from (if not contradicted by) science (MEK); MEK relates to fundamental laws not understood locally; PEK tends to deny or ignore negative consequences of current economy	Discussions between 'believers' and 'non-believers' have little chance of progress as neither side will leave their trenches	Seek optimal fuzziness as before, while creating safe space outside negotiations to explore complementarity of 'wisdom' behind the 'knowledge'

Examples of application

The AKT methodology has been used successfully in a number of projects in Asia, Africa and Latin America and has been adopted globally by the World Agroforestry Centre. This has included use with the development of multistrata cocoa and non-timber forest products in Ghana and Cameroon; jungle rubber, soil erosion and conservation and Javanese home garden systems in Indonesia; participatory plant breeding for cassava in Colombia and hill maize in Nepal; forest gardens and smallholding rubber in Sri Lanka; range management in South Africa and Lesotho; and trees in crop fields and rangelands in Kenya and Tanzania. A Spanish language version is used in Latin America by the Tropical Agricultural Research and Higher Education Centre and a Thai version has been developed in conjunction with the Department of National Parks, Wildlife and Plant Conservation in Thailand. New applications include peri-urban vegetable production and waste recycling in Viet Nam and China, alternative animal health care in Wales and a group of users have created an email network to support a range of activities in the Philippines.

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6 | Land-use profitability analysis (LUPA)

Arif Rahmanulloh, Muhammad Sofiyuddin, Suyanto and Suseno Budidarsono

Land-Use Profitability Assessment (LUPA) is an analysis framework for economic assessment of land-use systems, conducted at landscape level. LUPA estimates monetary surplus (profitability) for each land area as result of investment allocated by the operator, both smallholders or large-scale.

Introduction

The most important source of livelihoods for most people living surrounding forests comes from land use. Understanding the characteristics of existing land-use systems is important to develop interventions to improve people's livelihoods. LUPA can be used to identify which one of the land-use systems generates the most economic benefit. This tool also analyzes labour engagement in land-use systems.

Within the context of low-carbon development strategies it is important to identify the economic performance of each land-use system and to analyze the trade-off between reducing greenhouse gas emissions and increasing economic benefits. LUPA generates a figure of economic performance of land-use systems, allowing the creation of a set of low-carbon development intervention options with estimated economic benefits.

Objectives

LUPA is designed to provide key characteristics of economic performance for each land-use system in a landscape.

Steps

1. Identification

This step is done by analyzing land-cover information from spatial imagery combined with secondary data on land uses as well as commodity production figures. This step generates early information on major land-use systems and indicative locations where the system exists. It can build on the RAFT appraisals and be aligned with ALUCT.

2. Field verification

The verification confirms land-use systems 'on the ground' and the typology or variation of each system. Using the land-use system list from Step 1, the researchers directly observe in the field before collecting data.

3. Data collection

This step involves interviews with key informant (include focus-group discussions) and gathering secondary literature. Data is categorized as follows: 1) macro-economic data; 2) input and output quantities; 3) prices. The macro-economic data set consists of real interest and exchange rates. Input data means all items used in the production process that consist of tradable purchased inputs (planting materials, chemicals, tools etc) and labour use. All input items are quantified using a common unit. Labour use is estimated both for family and hired labour. The output data consist of all products generated by the systems during the period of estimation. Agroforestry systems usually produce several products, from the beginning to the end of the period. Prices attributed to all items of input and output should be 'farmgate'.

4. Analysis

In this step, the researchers develop two important tables: input-output table and farm budget. The first table shows quantity allocations of purchased inputs, non-tradable inputs, capital and also labour into a range of time (usually 30 years for timber-based systems). The input-output table also provides the annual quantity of production. Each item of input and output has a unit compatible with the market price.

Farm budgets are developed by valuing the input-output table using gathered price data. All item units, both for input and output, use the same currency. All input items for a farm budget are attributed as 'cost' while the output items are 'revenue'. The profitability is found by summing all revenue then subtracting all costs.

Depending on the aim of the study, the analysis can be done at different levels of depth. Two common profitability indicators used are 'return to land' and 'return to labour'.

Profitability indicators

Net present value (NPV) is the most common indicator used for comparing the profit of different types of investment. The NPV of an investment is defined as the sum of the present values of the annual cash flows minus the initial investment. The annual cash flows are the net benefits generated from the investment during its lifetime. These cash flows are discounted or adjusted by incorporating the uncertainty and time value of money (Gittinger 1982). NPV is one of the most robust financial evaluation tools to estimate the value of an investment. The investment for one specific land use is labelled profitable if the NPV is higher than 0. The formula to calculate the NPV is:

$$NPV = \sum_{t=0}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

where B_t is benefit at year t, C_t is cost at year t, t is time denoting year and i is discount rate.

The measure of return to labour is reached by adjusting the wage rate until the NPV reaches zero. This proxy can be used since the calculation converts the surplus to a wage rate. The value of return to labour indicates the attractiveness of the system: if the return to labour is higher than the average wage rate then it is attractive for people to work in the system (Tomich et al 1998, Vosti et al 2000).

Policy analysis matrix (PAM)

The Policy Analysis Matrix (PAM) is a matrix of information about agricultural and natural resources policies and factors of market imperfections that is created by comparing multiple years of a land-use system's budget calculated at financial prices (reflecting actual markets) and economic prices (reflecting efficiency). The matrix is designed to analyze the pattern of incentives at the microeconomic level and to provide quantitative estimates of the impact of polices on those incentives.

PAM's structure is composed of two set of identities. One set defines profitability and the other defines the difference between private price and social values, measuring the effect of divergence; as the difference between observed parameters and parameters that would exist if the divergence were removed (Monke and Pearson 1995).

Profitability as the first identity of the accounting matrix is measured horizontally, across the columns of the matrix. Profits, shown in the right-hand column, are found by subtraction of cost, given in two middle columns, from revenue, indicated in the left-hand column. This column constitutes profitability identities. There are two profitability calculations: private profitability and social profitability.

Private profitability calculation is provided in the first row. The term 'private' refers to observed revenues and costs reflecting market prices received, or paid, by farmers, merchants or processors in the agricultural system. Private profitability calculations show the competitiveness of agricultural systems at given current technologies, output values, import cost and policy transfer. Social profitability calculation is the accounting matrix utilizing social prices. These valuations measure comparative advantages or efficiencies in the agricultural commodity system.

Table 6.1. Policy Analysis Matrix (PAM)

	Revenues	Cost		Profits
		Tradable inputs	Domestic Factor	
Private prices	A	B	C	D1
Social prices	E	F	G	H2
Effect of divergences	I3	J4	K5	L6

Note: 1) Private profit, D, equals A minus B minus C; 2) Social profit, H, equals E minus F minus G; 3) Output transfer, I, equals A minus E; 4) Input transfer, J, equals B minus F; 5) Factor transfer, K, equals C minus G; 6) Net transfer, L, equals D minus H (they also equal I minus J minus K). Source: Monke and Pearson (1995, p.19)

Case study: Tanjung Jabung Barat

Existing land-use systems in Tanjung Jabung Barat district, Jambi province, Indonesia, were analyzed from available land-cover maps. Based on the spatial classification, eight types of land uses in the district were identified: natural forests, timber plantations, oil palm, coconut, rubber, coffee, betelnut and annual food crops. The verification step found that there were two types of land: mineral and peat. The land-use systems were further classified into large- and small-scale operations.

Table 6.2. Land cover of Tanjung Jabung Barat district and the main land-use systems

Land-cover type	Selected land-use system: On mineral soil	Selected land-use system: On peat soil	Scale of operation
Forest	Forest extraction. Logging (low density)	n/a	Large-scale enterprises
Acacia mangium	Industrial timber plantation (*Acacia mangium*) (and similar species)	n/a	
Oil palm	Oil palm (3000 ha)	n/a	
Oil palm (1–2 ha)	Nucleus estate and smallholdings (NES)	Independent smallholding	Smallholdings
	Oil palm		
Coconut (1–2 ha)	Coconut monoculture	Coconut-based mixed garden (with coffee and betel nut)	
Rubber (1–2 ha)	Rubber monoculture	Rubber monoculture rubber agroforest	
Coffee (1–2 ha)	n/a	Coffee-based mixed garden (with betel nut)	

Figure 6.1. shows profitability estimates for each land use.

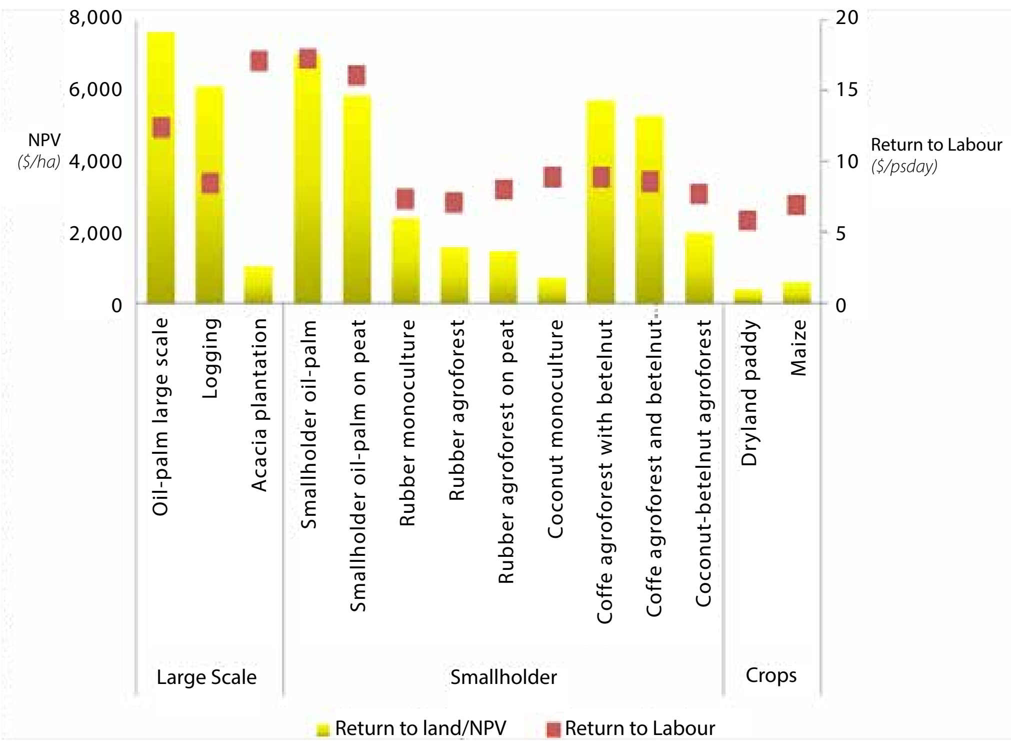

Figure 6.1. Net present value and return to labour for major land-use systems in Tanjung Jabung Barat

Note: i= 8%, exchange rate= IDR 9084/USD 1

Interpretation

Oil palm is the most profitable land-use system in Tanjung Jabung Barat district for both large- and small-scale operations. Oil palm on peat has lower profitability compared to that on mineral soil because of the additional costs of development and maintenance of drainage.

With high return to labour, oil palm is the most attractive for people compared to working in another land-use system.

The competitiveness of agroforestry systems is high, with the profitability rate almost as high as oil palm. The threat of conversion of these systems to oil palm is higher on mineral than on peat soil.

References to other recent case studies include Ekadinata et al. (2010), Rahmanulloh et al. (2012) and Sofiyuddin et al. (2012).

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7 | Rapid market appraisal (RMA)

Aulia Perdana, Suseno Budidarsono, Iwan Kurniawan and James M. Roshetko

The Rapid Market Appraisal (RMA) has been designed to analyze value chains from farmgate to consumers, the role of various people involved in adding value, and their bargaining power used to capture part of the end-user value. This information can subsequently be used to 1) raise awareness with farmers about the importance of market information; and 2) guide interventions aimed at improving the efficiency of marketing systems and generating benefits for participants.

Introduction: market opportunities for enhancing local livelihoods

The development of market economies and rural infrastructure has expanded commercial opportunities to many farm communities. However, traditional tree management often leaves communities unprepared to produce reliable quantities of high-quality products that meet market specifications. For example, Predo (2002) found in the Philippines that tree farming was more profitable than crop production but uncertain marketing conditions were a deterrent to planting trees. Smallholders generally have weak market links and poor access to market information. They typically sell products through traders and are unaware of the final customer and the quality requirements in the value chain. Farmers tend to produce and sell agricultural products according to local norms, competing with neighbours for a small part of the market. Market agents spend considerable time and other resources searching for, collecting and sorting smallholders' products of small quantity and various qualities. The status quo of this farmer–market agent interaction tends to be entrenched and it is not easy to shift towards more informed producers with greater bargaining power along the value chain but examples abound that it can be done. The starting point has to be awareness of the current system, collective action forchange and a policy environment that is conducive.

The Rapid Market Appraisal (RMA) strengthens awareness regarding the importance of market information (Young 1994). It is a tool to understand how products (commodities) flow to end users and to understand how commodity systems are organized, operate and perform. Through an RMA, farmers will begin to see the importance of customers' views and market information and specifications. It can inspire farmers to develop new understanding regarding the commodities they produce; and to evaluate commodity marketability by seeking input directly from customers and market agents. Farmers will become aware of the advantages they have, the barriers they face, and in what state of competition they are in (Perdana et al 2012). The information can also inform higher-level policy in supporting fair and efficient value chains.

RMA is a quick, flexible and effective way of collecting, processing and analyzing information and data about markets. RMA is also an efficient method for acquiring knowledge about marketing systems to inform production and marketing strategies, policy (He 2010) and the design and implementation of relevant interventions. It is a process for discovering market opportunities and how to capture them through focus on an entire value chain (Nang'ole et al 2011).

Objectives of RMA

1. To analyze the existing value chain from farmgate to consumers and the current roles in adding value and the bargaining power to capture part of the end-user value.
2. Raise awareness with farmers about the importance of market information.
3. Help producers to understand how commodities flow to end users and how markets are organized, operate and perform.
4. Guide interventions aimed at improving the efficiency of marketing systems and generating benefits for participants.

Steps

RMA comprises a range of simple methods and tools for collecting quantitative as well as qualitative information. Such methods avoid the costs and delays of formal questionnaire surveys, which have often failed to provide timely and sufficiently detailed information.

Flexibility is one of the main attributes of an RMA. There are no fixed rules regarding the size and composition of the team involved, which will depend on the resources available, the characteristics of the location, and the objectives of the survey. Likewise, the number and type of markets visited, and the number and type of 'key informants' selected, will vary according to the purpose of the RMA and the resources available. Similar comments can be made regarding the time required to collect and analyze information.

The method follows the steps below.

1. Define objectives
   a. Determine what products will be assessed, identify and clarify information needs, specify objectives jointly with farmers and community representatives
2. Appraisal planning
   a. Design the survey, sampling method and questionnaire
3. Collection of available information
   a. Select enumerators
   b. Conduct in-depth interview, market observations, focus-group discussions, secondary data collection, data cross-checking
4. Data analysis (product-based)
   a. Identify market structures and characteristics in relation to the production system, harvesting, post-harvest processing and marketing practices
   b. Characterize the product flow along the value chain, identifying added values, chain actors and their roles, price structures and margins for each of the chain's actors
   c. Analyze constraints and opportunities for change
5. Share initial results and prioritize 'action research' by farmers' groups who want to try and change the status quo
6. Share results at higher policy levels to discuss options to remove bottlenecks and facilitate the value chain to further develop

An example of RMA in agroforestry

The example is taken from an RMA activity (Tukan et al 2006) focusing on improving the market chain of bananas grown in farm gardens by linking farmers to markets in West Java. The RMA started with informal visits to make observations in the study area and hold discussions with key farmers and other stakeholders. The information derived from these visits and knowledge gained from secondary information was used to design the market survey. After selecting enumerators and producing a reliable questionnaire, the survey was then conducted applying snowball sampling, which can take the enumerators from farmers all the way to the trading companies, and even consumers. The information sought was key market actors and their roles, values added at each node, prices of sales and profit margins at each node, and obstacles and opportunities faced by each market actor. The information was then cross-checked by direct observation and focus-group discussions with relevant stakeholders in the project area. The cross-checking process continued until the findings were clear, consistent and complete. The output was a thorough value chain of banana. A draft summary of the output was then shared with stakeholders in a formal workshop. This provided an opportunity for additional cross-checking with larger groups. Any inconsistencies or gaps in the information were identified and addressed through further field investigation. A summary of farmers' marketing practices was finalized. It included detailed priority species, marketing channels and agents, farmers' market roles, marketing problems and opportunities. Subsequent to the RMA, work plans were developed consisting of intervention recommendations of what farmers, market agents and other stakeholders could do to improve the production and marketing of smallholders' bananas.

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8 | Gender roles in land use and value chains (GRoLUV)

Elok Mulyoutami, Delia Catacutan, Endri Martini, Noviana Khususiyah, Janudianto, Grace B. Villamor and Meine van Noordwijk

Gender specificity of land use (decisions, labour, remuneration) and participation in value chains needs to be understood. While preceding methods are supposed to represent the diversity among the farming community, intra-household relations and the position of female-headed households deserve specific attention. Analysis and reliable data can be used by local 'agents of change' to step over the shadow of cultural norms of the status quo and create conditions for greater gender equity. Gender Roles in Land Use and Value Chains (GRoLUV) guides analysis of gender differentiation.

Introduction

In most cultures, livelihoods' options differ between men and women. Gender-specific norms usually restrict the freedom of new generations of individuals to realize their potential for self-realization. Educational and social systems influence aspirations and reproduce the norms as desirable and appropriate, so the system conserves itself. Yet, at the level of the Millennium Development Goals, equal access to education for girls has been accepted as an important element of development strategies. Quisumbing and Pandolfelli (2010) estimated that production in agricultural and agroforestry sectors can be expected to increase by 10–20% if women's roles in use of farm inputs and labour were appreciated through proper access to education and other resources. Women and men have different strategies in managing natural resources that lead to different problems and also different types of solutions; they also generate knowledge about environmental changes in different ways. Therefore, taking into account the differences between women and men is necessary in the course of designing and implementing a development program with attention to environmental issues.

Tools such as PALA, PAPoLD, RAFT and RMA will have already provided indications of the gender-specific dimensions of land-use and poverty patterns, livelihoods' strategies, use and knowledge of the landscape and engagement with post-harvest processing and marketing. The GroLUV tool can be used to further elicit gender-specific information and understand the conditions underpinning differences.

In many cultures it is the norm that men are taking the lead in activities in the landscape far from the homestead, except for collection of drinking water from rivers or firewood, which is usually a woman's task, while women focus on activities closer to the homestead. In many situations, harvesting and management of forest products (timber and non-timber) is dominated by men, while processing and marketing may be more of women's task. For example, Martini et al (2012) described for sugar palm the role of women in marketing differed between palm sugar and palm wine as marketed products (Figure 8.1).

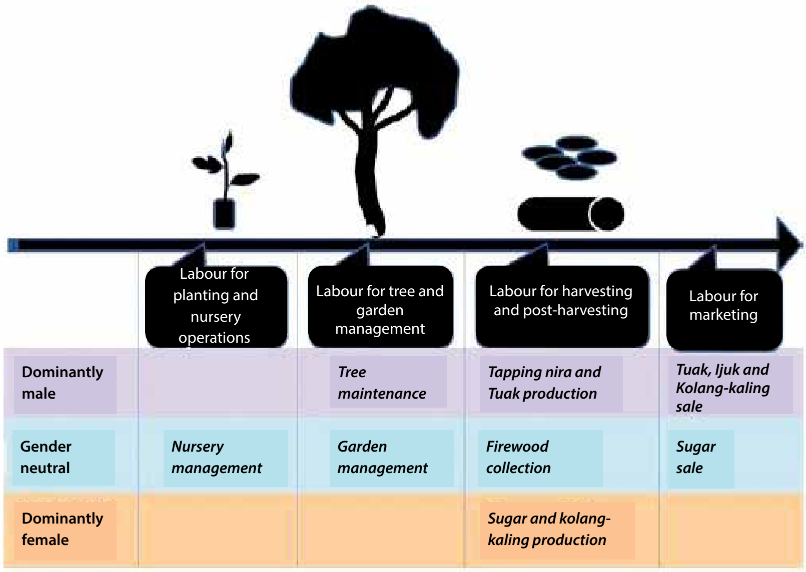

Figure 8.1. Gender differentiation of tasks and responsibilities along the stages of a sugar-palm production cycle in Batang Toru, North Sumatra

Note: As analyzed by Martini et al 2012

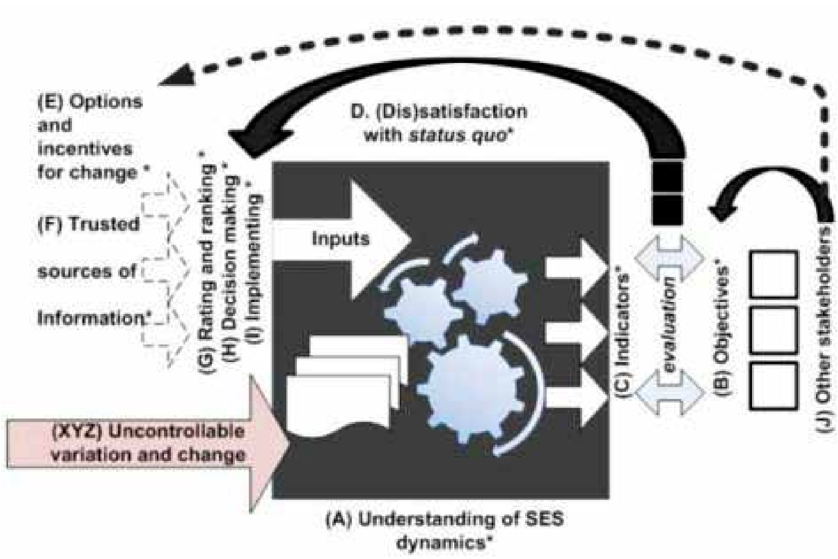

Figure 8.2. Conceptualization of management decision cycles that involve satisfaction with status quo and/or active search for new options; potentially all steps are gender-differentiated

Source: Villamor et al 2014

Not only the portfolio of practices and preferences but also the style of learning can be gender specific (Figure 8.2). As stated before, learning landscapes need two types of learning: 1) local actors and stakeholders will learn by experience if there is political space for innovation; while 2) external stakeholders want to understand the types of change that occur in comparison with a properly documented baseline. These dual aspects of learning can be mutually supportive through appropriate combination of approaches but their differences (reminiscent of sentinel versus learning landscapes in Fig. 0.10) need to be respected.

Objectives

1. Appreciate gender specificity, in the local cultural context, of production factors: labour; access to, and control of, land; access to credit; knowledge and access to innovation; and product value chains.
2. Understand gender specificity within the local cultural context and of the different stages along a management cycle and participation in market-based value chains of major agroforestry components.
3. Understand gender specificity of preferences for trees (or absence thereof) in the farmed landscape.
4. Assess the degree to which gender specificity of preferences gets expressed on farms and in the landscape.

Steps

1. A baseline survey prior to project implementation aimed at portrayal of the real condition, using the Harvard Analytical Framework and the Moser Gender Planning Framework. The Harvard framework makes women's roles and work visible (Overholt et al 1985, Rao et al 1991). The Moser framework (Moser 1993) provides clear guidance for identifying strategic gender needs. Descriptive statistical analysis quantifies the captured information regarding gender access and control.
2. Focus-group discussions on access to land, daily and seasonal time schedules, input requirements and output prospects of the main agroforestry products and services.
3. Focus-group discussions on gender specificity related to
   a. the stages of a tree's lifecycle and associated value chain;
   b. access to (and perceived security in) areas of increasing distance to the village or homestead;
   c. access to, and control of, agroforestry benefits.
4. Descriptive statistical analysis to quantify captured information regarding gender access and control over resources and benefits.
5. Landscape walks, with informants from both genders, to identify the major trees, discussing their utility for domestic use and/or marketing, triangulating possible differences between men and women with information obtained in steps 1 and 2.
6. Focus-group discussions similar to the WNoTree method that clarify any gaps between desirable tree cover, tree diversity and species portfolio, and what is present.
7. More detailed analysis of gender differences in decision making and access to new information from trusted sources that can lead to identification of communication priorities.

8. Ensure that gender specificity of current and potential future agroforestry practices is appreciated and that appropriate steps are taken to reduce or remove inequities in access to external resources and opportunities as part of broader action plans and based on local initiative.

Case study: GRoLUV in Indonesia

As suggested by Step 1, at the start of the Agroforestry and Forestry in Sulawesi (AgFor) project in Indonesia, considerable effort by the researchers and partners was put into detailed description of the baseline, both to assist in prioritization of subsequent project activities, and to have a proper reference for future impact studies, aimed at structured learning of what worked well and what not or less so.

Data collection employed both qualitative and quantitative approaches closely related to the research question. The range of data collected was implemented based on consideration of the methods best able to address detailed questioning. The detailed research questions and methods are described in Mulyoutami et al (2012). The primary data collection methods employed were full-day mini-workshops or group discussions with village representatives (Box 8.1). Separate discussions were held with female and male groups, using the same set of questions to compare the different points of view. Household surveys were conducted using descriptive statistics to capture current situations. Some individual interviews were undertaken to gain general views of village and community conditions. Data from the bureau of statistics and reports on the Human Development Index, Gender Development Index and Gender Empowerment Index were used to illustrate how gender issues at district and provincial levels were situated in the national context.

Box 8.1. Focus-group discussions in practice

A full day mini-workshop or focus-group discussion was held in each village with participants comprised of invited villagers and key people indicated by leaders of the village prior to the discussions. The aim was to gain basic information about land use and sources of livelihoods, demography and migration patterns, land-management practices, poverty, information related to training, extension and village organization, marketing practices, sources of, and access to, planting materials, communication and gender roles within natural resource management. They were implemented utilizing participatory principles and applied triangulation processes from multiple sources of information. This information was consolidated within the discussions. Mini-workshops or group-based interviews usually started at 9 am and ended at 4 pm. In each village, the participants were divided into three different groups consisting of 4–8 farmers. The first group consisted of mostly male participants and discussed issues of land use, history of livelihoods' sources, land-management practices, demography and migration. The second group consisted of only male participants and discussed gender roles in land management, communication, village institutions, gender perceptions of land use, values and poverty and basic information about their needs for extension. The third group used the same set of questions as the second group but consisted of only female participants. Discussions were held in village offices or in houses belonging to local leaders.

The results clearly demonstrated that women and men had different roles in managing households, faming activities and natural resources. In the areas of household, farm production, land-use management and marketing, women were mostly responsible for domestic tasks and maintaining the land located close to the settlement. Men were mostly responsible for earning income from working in the public domain and were fully responsible for maintaining the land that was located far from the settlement and for physically heavy work. The close proximity of the area of work to the house was favourable for women so that they could still undertake other productive work while doing household chores.

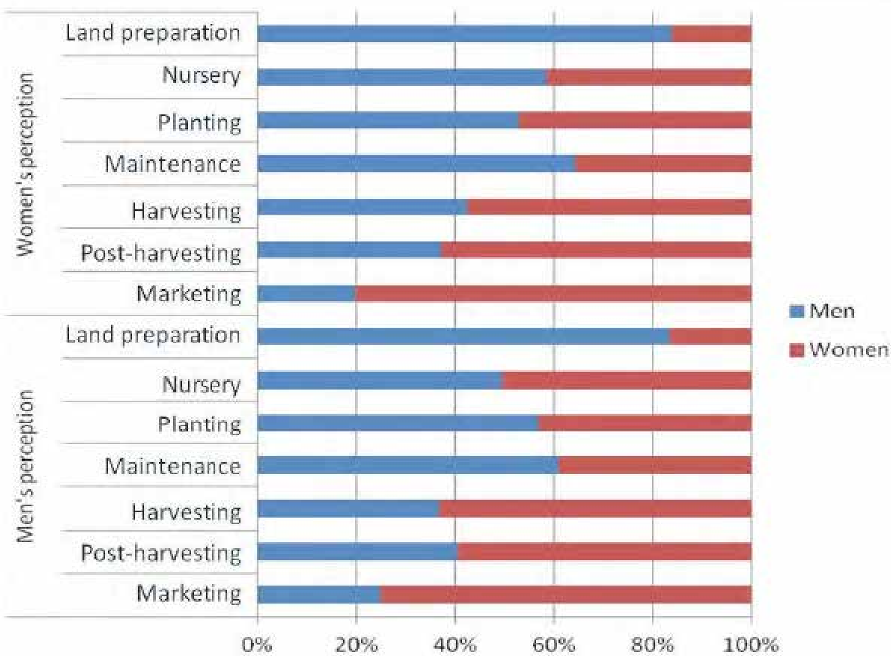

Figure 8.3. Gender roles in selected farming activities in the AgFor Sulawesi case study

Source: Mulyoutami et al 2012

The relationship between gender and land, particularly in terms of land rights and ownership, as well as how gender influences perceptions of land use and function was clearly observed. Women were not acknowledged as legal landholders since most of the land certificates were under the name of men. Clearly, providing a more conducive condition for women to become land owners, legalized in land certificates, would increase equity in terms of land rights and ownership. This is specifically an issue for female-headed households. Gender was also found to influence men and women's perceptions of land-use values, their importance and function.

Furthermore, the data showed that women were more knowledgeable about land-use values with regards to environmental issues related to the use value of biodiversity, especially medicinal plants, while men were more aware of conservation or protecting the environment. The market chain in

Sulawesi, in particular in South and Southeast Sulawesi, had already taken women into account. Women had equal positions in marketing, with responsibility for cocoa, clove and coffee. However, the producer or villager is at the end of the market chain and without access to knowledge of markets and related product (quality, price) information so they have little room to expand their income.

The study led to a number of recommended criteria and indicators for gender empowerment in the local context that informed further project-level discussions.

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9a | Tree diversity and tree–site matching (WhichTreeWhere?)

Degi Harja, Roeland Kindt, Jenny C. Ordonez, Hesti Lestari Tata, Subekti Rahayu, Avniar N. Karlan and Meine van Noordwijk

The slogan, 'The right tree in the right place for a clear function', points to the need to be specific about which trees grow where and how they can be managed to meet expectations of functions. The method described here starts with an inventory of tree presence in the landscape and local knowledge and perceptions of identity and function compared with taxonomic identity and recorded uses in existing databases. A second level of analysis in tree and site matching is understanding how tree growth and productivity depends on site conditions, which is closely linked to the question of which aspects of site conditions actually matter. A third level takes a critical look at functions in relation to landscape niches.

Introduction

Trees have both positive and negative attributes from a human perspective and the right-tree-at-the-right-place slogan suggests that specific choices out of the global spectrum of tree diversity should be combined with an appropriate concept of niches or locations where such trees are allowed to grow (if they survived and were retained from previous vegetation), allowed to settle (for spontaneously established trees) or are planted (based on availability of planting material). To further operationalize the concept we need to know 1) which trees currently grow where; 2) how well they grow at the locations where they grow; 3) what direct and indirect functions they have associated with their properties; and 4) how important tree diversity is at multiple scales of management.

Tree diversity depends on the scale of consideration. At global scale there are approximately 100 000 species of trees, which is one quarter of all plants, spread over about 250 plant families[1]. Woody perennials occur in six of 11 divisions of plants: *Angiospermae* (including monocots, eudicots), *Magnoliophyta*, *Gnetophyta*, *Pinophyta* (=Coniferae), *Cycadophyta*, *Pteridophyta*). In many genera there are trees and non-trees. This implies that either the genetic base of being a woody perennial has been reinvented many times or that such genes can be easily switched off and on during evolutionary change.

On the other end of the scale, we can consider a single tree species with its intraspecific genetic diversity and an often complex network of relationships with relatives that can be teased apart with genetic markers. At scales in between, we consider the tree diversity of a plot, a farm, a landscape transsect, watershed or ecoregional zone. With respect to human use, some value chains demand specific properties, defined below the species level as in tree crops with distinct cultivars, others use broad 'trade names' that can refer to multiple species. The simplest distinction of timber (floaters

[1] In the discussions around the definition of 'forest', the concept of 'tree' is important because forests tend to be defined relative to the presence of trees; and if an oil palm is a tree, conversion of forests to oil-palm plantations is not 'deforestation'.

versus sinkers) not only indicates consequences for the mode of downstream transport but also the wood density and correlates of strength and durability.

At plot level, (alpha) tree diversity comes in four shades of grey: no trees; monoculture of a single species; simple mixed system with limited (usually 2–5) species diversity; and complex mixed systems with higher diversity. The beta diversity describes the diversity across a category of plots: even for systems that are 'simple mixed' systems at plot level, the total diversity can be high if the companion trees of the dominant component are varied from plot to plot. On the high end of diversity, where the pre-human diversity of the natural landscape is the point of reference, we can quantify and understand the characteristics of the 'diversity deficit' [2]. At the gamma diversity scale of a landscape we can consider which groups of species from the original flora are underrepresented in the human-dominated landscape and which ones are overrepresented. Research so far suggests that the dispersal mode of tree seeds, as well as the direct use value for humans, are both involved, interacting with human management styles and local ecological knowledge (Joshi et al 2003, Tata et al 2008). Databases with such tree properties need to be combined with survey data.

In the background of the 'forest transition curve', a 'tree diversity transition' is taking place (Ordonez et al 2014, Figure 9a.1): depending on the part of the tree life cycle considered (seedbank, seedlings, saplings, poles or reproductive trees), we can now expect multiple lines for the loss of tree diversity during forest conversion, while the recovery phase of agroforestation or reforestation involves a gradual increase of the diversity of planted trees. Agroforestry systems differ in tree origin, although systematic data on this aspect are not yet available.

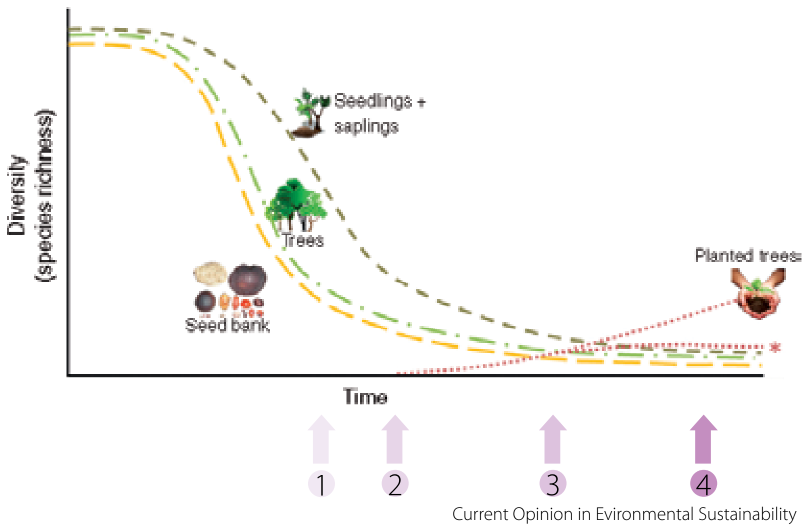

Figure 9a.1. Tree diversity transition curve

Source: Ordonnez et al 2014

[2] Villamor et al (2011) considered diversity deficits in three domains: 1) in the real world where actual diversity is less than a potential state that is deemed desirable (hence we worry about loss of biodiversity and cultural diversity); 2) in representation and modelling of the real world (where 'residual variance' may represent a diversity deficit of the model); and 3) in our recognition of the driving forces that are used to construct a model (a diversity deficit due to oversimplification). Diversity in the real world is lost when it disappears from the knowledge that is being shared.

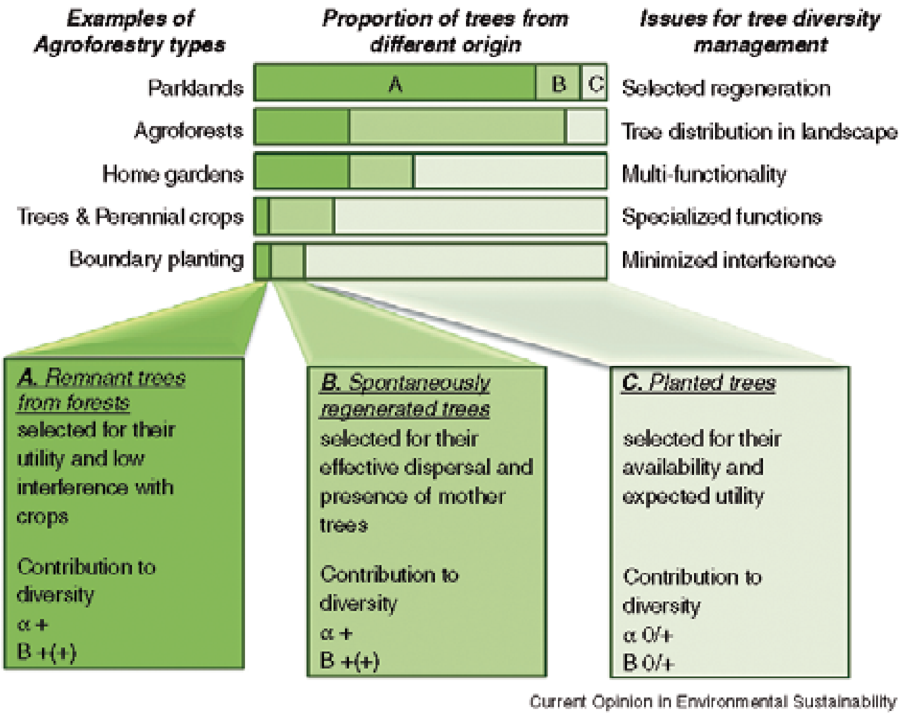

Figure 9a.2. Tree portfolios of agroforestry systems by origin of the trees

Source: Ordonnez et al 2014

Objectives

The WhichTreeWhere? tool systematically collects data of trees found on farms and in the landscape, allowing an analysis of tree portfolios with respect to functional properties as well as tree–site matching with respect to expected tree growth rates under current and future climate conditions.

Steps

1. Data collection of field occurrence of trees at plot, farm or landscape transect scale
   a. The choice of sampling scale (plot, farm or landscape transect) will often depend on the opportunities for synergy with other research, for example, economics (for which plot and farm are relevant), carbon stocks (plot or landscape scale) or watershed functions (specific landscape niches, such as riparian zones, slopes sensitive to landslides)
   b. Measurement protocols normally use tree stem diameter at breast height (1.3 m above the ground; for special cases see Hairiah et al 2011) as the basis for allometrics, accompanied by tree height for trees in more open landscape conditions (in closed stands it is difficult to measure and adds little information to allometrics); this is to be linked to tree identity in local taxonomy (linked to use value) and botanical taxonomy; the latter may require collection of specimens for herbarium comparisons

c. Assistance of local informants may be needed to record the origin of the tree as 1) retained from preceding vegetation; 2) spontaneously established; or 3) planted. An intermediate category is 'farmer-managed natural regeneration', which is mostly in category 2. Finer distinctions in 'planted' (3) can be: 3a) directly seeded; 3b) transplanted wildings; 3c) transplanted from nursery; 3d) grafted in nursery; 3e) grafted in situ on planted rootstock; 3f) grafted on spontaneously established trees. And further categories as locally appropriate

2. Linking local and botanical tree taxonomy to use values and other knowledge
   a. Local tree taxonomy tends to differ substantially from the botanical, as it is generally linked to use value. For fruit trees this may, for example, mean that varieties within a single species are differentiated by name; for timber species, terms such as 'medang' or 'meranti' can cover a wide range of botanical species
   b. Methods to explore local knowledge of trees and their properties are provided with AKT5
3. Linking tree data to functional attributes in dedicated databases

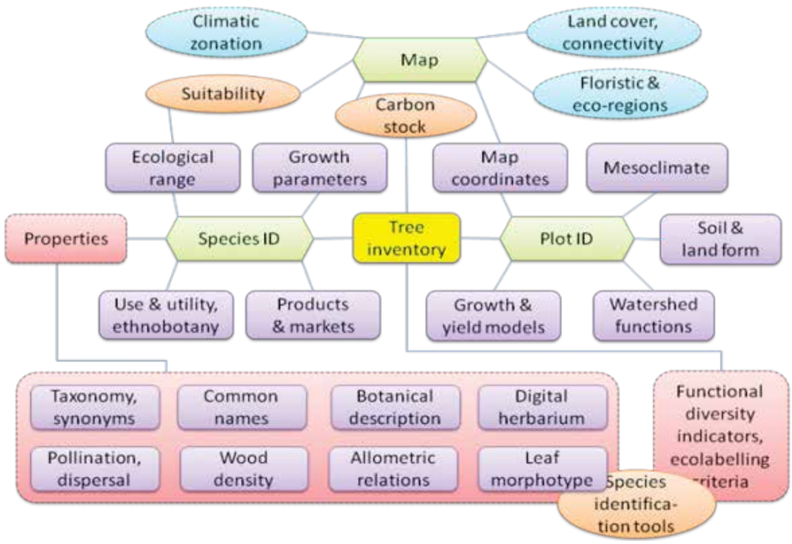

Figure 9a.3. Module diagram of Tree FUNATIC database

4. Analyzing tree growth in relation to site properties and climate
   a. If tree or site-level properties of soil, climate and management are recorded, as well as age of the tree, the predictive power of such variables[3] in accounting for tree growth rates can be tested (Santos-Martin et al 2010)
   b. Using existing spatial databases, the climatic conditions where the trees occur and basic soil and site properties can be used to map 'climatic suitability' for trees, especially for those with high use value. In combination with climate-change predictions, this may assist anticipating the growth conditions under which a tree will mature in the choice of what is currently planted.

[3] For example, landscape position, soil texture, organic matter, soil chemical and soil biological properties in order of increasing data cost; interacting with farmers' characteristics and management styles

A number of databases are now available that can assist with such analyses. The Agroforestry Species Switchboard (www.worldagroforestry.org/products/switchboard/index.php) provides easy access. It includes an option of searching for a genus or species by directly typing the name of the URL (hyperlink) in the web browser: http://www.worldagroforestry.org/products/switchboard/index.php/name_like/ .

Agroforestree database

The Agroforestree database is a species' reference and selection guide for agroforestry trees. In the context of the database, agroforestry trees are those that are deliberately grown or kept in integrated land-use systems and are often managed for more than one output. They are expected to make a significant economic or ecological impact, or both.

The main objective of the database is to provide detailed information on a number of species to field workers and researchers who are engaged in activities involving trees suitable for agroforestry systems and technologies. It is designed to help them make rational decisions regarding the choice of candidate species for defined purposes. Information for each species covers identity, ecology and distribution, propagation and management, functional uses, pests and diseases and a bibliography. To date, more than 500 species have been included. The specific aims of the database are to

1. enable quick and efficient access to a consolidated pool of information on tree species that can assume useful production or service functions, or both;
2. provide a tool that will assist with the selection of species for use in agroforestry and related research, using factors that are relevant to the chosen agroforestry technologies;
3. help researchers assess potential agroforestry trees for uses other than those commonly known, such as timber; and
4. provide indicators for the economic assessment of species through yield information on tree products.

Download from http://www.worldagroforestry.org/sea/Products/AFDbases/AF/index.asp.

Wood density database

The wood density database records the dry weight per unit volume of wood for particular species. It can be used in allometric equations that estimate tree biomass and carbon stocks from stem diameter values (for example, W = 0.11 r D2+c , Ketterings et al 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management* 146:199–209) and indicate the use value (higher density wood tends to burn slower and is thus more useful as firewood or as source of charcoal, it also correlates with strength, although there are better parameters for strength per se).

Wood density varies with tree species, growth conditions and part of the tree measured. The main stem generally has a higher wood density than the branches, while fast growth is generally related to relatively low wood density. For most species, the literature thus gives a range with low, medium and high values. In this database we have collected quantitative information from a number of publicly available sources. As you will note, there is no standardization of the moisture content of the ('air dry') wood in the densities reported and some conversions may be needed. For questions and comments please contact s.rahayu@cgiar.org.

Download from http://worldagroforestrycentre.org/regions/southeast_asia/resources/wood-density-database.

Tree diversity analysis

A manual and software for common statistical methods for ecological and biodiversity studies

Effective data analysis requires familiarity with basic concepts and an ability to use a set of standard tools, as well as creativity and imagination. Tree diversity analysis provides a solid practical foundation for training in statistical methods for ecological and biodiversity studies.

This manual arose from training researchers to analyse tree diversity data collected on African farms, yet the statistical methods can be used for a wider range of organisms, for different hierarchical levels of biodiversity and for a variety of environments, making it an invaluable tool for scientists and students alike.

Focusing on the analysis of species survey data, *Tree diversity analysis* provides a comprehensive review of the methods that are most often used in recent diversity and community ecology literature including:

- species accumulation curves for site-based and individual-based species accumulation, including a new technique for exact calculation of site-based species accumulation;
- description of appropriate methods for investigating differences in diversity and evenness, such as Rényi diversity profiles, including methods of rarefaction to the same sample size for different subsets of the data;
- modern regression methods of generalized linear models and generalized additive models that are often appropriate for investigating patterns of species occurrence and species counts; and
- methods of ordination for investigating community structure and the influence of environmental characteristics, including recent methods such as distance-based redundancy analysis and constrained analysis of principal coordinates.

The BiodiversityR software was initially developed for the R 2.1.1 statistical environment. Please check for changes in installation procedures and some new options for data preparation in the document provided below.

Download from http://worldagroforestrycentre.org/resources/databases/tree-diversity-analysis.

Molecular markers for tropical trees: statistical analysis of dominant data

In the last decade, there has been an enormous increase worldwide in the use of molecular marker methods to assess genetic variation in trees. These approaches can provide significant insights into the defining features of different taxa and this information may be used to define appropriate management strategies for species.

However, a survey of the literature indicates that the implementation of practical, more optimal management strategies based on results from molecular marker research is very limited to date for tropical trees. In order to explore why this is the case, the World Agroforestry Centre undertook a survey of molecular laboratories in low-income countries in the tropics. The survey looked at the kinds of molecular marker studies that were being carried out on tree species and the problems faced by scientists in this research.

One of the constraints that the survey identified for the proper application of molecular markers is the effective handling and analysis of data sets once they have been generated. This guide has been designed to address this need for data obtained using dominant marker techniques. It has been created especially for students (MSc, PhD) and other researchers in developing countries who find themselves isolated from their peers and—when faced with an apparently bewildering array of options—find it difficult to settle on appropriate methods for analysis.

Most benefit will be obtained from this guide if it is used together with the companion volume on practical protocols for molecular methods (ICRAF Technical Manual no. 9) and so we recommend that scientists read both.

Download from http://worldagroforestrycentre.org/resources/databases/molecular-markers-for-tropical-trees.

Tree functional attributes and ecological database (Tree FUNATIC)

Tree FUNATIC is a web-based database that both stores and gives information about the attributes and ecological information of a variety of tree species, including taxonomy, geographic distribution, ecological range, functions and wood density. The database also stores tree entity information from observations, such as stem diameter, height and crown dimensions, as well as habitat information, including that geographic information on soils and climate.
Tree FUNATIC is a web application that can be accessed anywhere and anytime within internet coverage. The Tree FUNATIC application is made with a simple interface using the latest technology to enable easy access for users to get the information they need. Most of the database can be accessed by the public; some information can be accessed only through membership.

The Tree FUNATIC Database is accessible at http://db.worldagroforestry.org/.

- Tree site distribution based on climate, soil and elevation range of each species.
- Uses and function of each species.
- Wood-density information extracted from species, genus, family, common name.
- Carbon-stock information at plot level in various locations, especially Indonesia.
- Species allometry to estimate tree biomass.
- Tree market, supplier and location information.
- Tree-species identification based on morphotype and herbarium database.
- Watershed along with its climate information.

Tree FUNATIC Database is a relational database using MySQL as its server. Members can access the MySQL to do direct queries using the SQL language code. Currently, Tree FUNATIC has 452 allometry data per species to estimate biomass in various locations gathered from various literature sources. The database is still under active development.

9b | Gender perspectives in selecting tree species (G-TreeFarm)[1]

Sonya Dewi, Janudianto and Endri Martini

Gender Perspectives in Selecting Tree Species and Farming Systems using an Analytic Hierarchy Process (G-TreeFarm) reveals two layers of decision-making processes in selecting tree species and farming systems between different gender or other diversified groups, such as migrant and native groups. The tool produces 1) lists of tree species and farming systems based on the order of preferences (what); and 2) lists of selections and the order of perceived importance (why). The first list has direct uses for development programs to identify tree species that people want and the second list can guide to a broader search of tree species and farming systems that match the important criteria that people have, which are not in the first list.

Introduction

An important factor that affects the failure or success of development programs with tree planting and agricultural development is the buy-in and adoption rates of farmers. Understanding the perspectives and aspirations of farmers is crucial, since self-motivation will lead to high adoption rates of any introduced farming or land-use management system. In the past, many landscape rehabilitation or reforestation programs have failed owing to top–down approaches in selecting and introducing types of tree species and farming systems that were imposed on the farmers. On the other hand, there are success stories from development programs that supported and provided technology and good seedling material of tree species that people wanted.

Gender, social and cultural inclusions in a community should be captured to understand the diverse perspectives and preferences in selecting tree species and farming systems. Development programs should respect social diversity by not ignoring minor community groups; often these groups are the stakeholders in need of aid.

Introduction of new tree species and farming systems is often tricky since adoption rates are influenced by many unpredictable factors. However, criteria used for selecting tree species and farming systems can guide the task of searching for suitable new species and systems, along with success stories from other places. Addressing the criteria can also help to reconcile diverse preferences, if necessary, as well as stimulate discussion and negotiation among farmers. In addition, the criteria can be indications of constraints or barriers met in specific local areas that may burden intervention processes in development programs.

[1] This method will also be discussed in Janudianto et al. (2014). A related ranking technique is described by Kiptot and Franzel (2014); specifically for fodder shrubs Carsan et al. (2014) discusses options and preferences.

Analytic hierarchy process (AHP) is a decision-making framework used for large-scale, multiparty, multi-criteria decision analysis developed by Thomas L. Saaty in the 1970s. This framework was adopted and used in the TreeFarm[2] module to elucidate the gender differences in selecting tree species and farming systems in Sulawesi, Indonesia. Decision making in AHP is undertaken by:

- identifying criteria and assigning relative importance to each in selecting tree species and farming systems; and
- identifying potential tree species and farming systems in the area and the relative preferences of each with regard to each criterion.

Objectives

The objective of G-TreeFarm is to first clarify, for different stakeholder groups, the primary functions needed and then focus on which trees, crops and farming systems can fulfil these functions. Subsequent analysis can clarify gender and social differentiation in criteria and knowledge of options to provide the desired functions.

Steps

1. Prepare separate group discussions for men and women. The discussions can be held in parallel in the same area but at different places. The participants may represent certain villages, clusters or landscapes within the study areas, with 8–10 participants in each group.
2. Explain the discussion objective, the background of the study, and the general consensus at the beginning of the discussion. Encourage participants to relate the actual field or landscape conditions based on their perceptions and observations.
3. Ask the participants to develop a list of existing and potential farming systems (annual cropland, monoculture perennials, mixed perennials, mixed annual–perennials) based on their perceptions.
4. Rank the farming system according to their importance to farmers (for example, cash benefits, subsistence) (Table 9b.1).

Table 9b.1. List of existing farming systems in the community (the example is taken from a women-only group)

Farming system	Source of cash? (Yes/No)	Rank (1 as the highest source of cash)	Source of non-cash?[a]	Rank (1 as the highest source of food)
Annual cropland				
• Paddy	Y	3	1	1
• Patchouli	Y	2	2	
• Maize	Y	1	1	2
Monoculture perennials				
• Rubber	Y	1	3	
• Coconut	Y	2	3, 5	1

[2] The TreeFarm module is part of the Capacity-Strengthening Approach to Vulnerability Assessment (CaSAVA) tool developed to analyze decision making in selecting tree species and farming systems that incorporates gender specificities.

Farming system	Source of cash? (Yes/No)	Rank (1 as the highest source of cash)	Source of non-cash?[a]	Rank (1 as the highest source of food)
Mixed perennials	-	-	-	-
Mixed annual–perennials	-	-	-	-
Shrublands	-	-	-	-
Forests	-	-	-	-

Note: [a] Food=1; Medicinal=2; Timber=3; Energy=4; Handicraft=5; Cultural and aesthetics=6; Livestock=7; Bush meat=8; Other=9

5. Ask the participants to identify a list of criteria in selecting the farming system based on their perceptions (Table 9b.2). The criteria comprise the background used by participants when selecting the most profitable farming systems in the community (for example, price, market access, available technology).

Table 9b.2. List of criteria on selecting farming systems (or tree species) in the community

No.	Criterion	Notes
1	Easy to market	
2	High price	
3	Available good planting materials	
4	Low labour input	
5	Can be mixed in a plot	
6	Easy to harvest	
7	Quick to produce	

6. Assess the relative weight of the criteria by comparing each pair of criteria using a score of 1 to 5 based on importance to livelihoods (Table 9b.3). Note that the shaded cells should be left empty because the matrix is symmetric and the diagonal cells are left blank since they are self-comparison. Put 1/1 if each pair of criterion has the same weighting; otherwise 1/5 if one criterion has extremely strong weighting compared to another. The first number represents the row cell, the second one the column. For example, the weighting 5/1 of the red shaded cell in the second row, fourth column of Table 9b.3 means that the first criterion (easy to market) was extremely important compared to the second criterion (available good planting materials). Give attention to the weightings that are given, such that there are no conflicts or inconsistencies across the weighting schemes. Ideally, the scores should be entered and tested in the AHP software for consistencies but it is often not possible to be run during a group discussion without disturbing the flow of the discussion. Take notes if there are consistent disagreement among particular sub-groups: it is an indication that there are marked diversity within a group. Explore further what characterize sub-groupings, for example, size of land owned.

Table 9b.3. Criteria weighting (the example is taken from a men-only group in Southeast Sulawesi)

Criterion	Easy to market	High output price	Available good planting materials	Low labour input	Can be mixed in a plot	Easy to harvest	Quick to produce
Easy to market		1/1	5/1	5/1	5/1	5/1	1/1
High output price			1/1	1/1	3/1	1/1	1/1
Available good planting materials				1/1	1/1	1/1	1/1
Low labour input					3/1	1/1	1/1
Can be mixed in a plot						1/3	1/3
Easy to harvest							1/5
Quick to produce							

Note: Criteria weighting is done by comparing each pair of criteria (1=same, 5=extremely strong). In this example, only five criteria are given

7. Assess the farming system weighting in each of the criterion by comparing each pair of farming systems with a similar procedure. In the example in Table 9b.4, we seem to have a tree species list but in this area farmers manage their farm mostly in mixed systems: fruit farming system means various fruit tree species dominate the plot, which has several other species as well. Put 1/1 if each pair of farming systems has similar importance to the criterion and 1/5 if one of the farming systems is extremely important compared to the others. The weighting 1/5 in the red shaded cell of Table 9b.4 means that in terms of marketing, pepper was deemed far easier to market than patchouli. Similarly to Step 6, pay attention to inconsistencies.

Table 9b.4. Farming system weighting using criterion 'easy to market' identified by a male group

Tree-Farming	Patchouli	Cocoa	Pepper	Fruit	Timber	Coconut	Sago
Patchouli		1/5	1/5	1/5	5/1	5/1	1/5
Cocoa			1/1	5/1	5/1	5/1	1/1
Pepper				5/1	5/1	5/1	1/1
Fruit					5/1	5/1	1/5
Timber						1/5	1/5
Coconut							1/5
Sago							

Note: For each criterion, do comparisons between farming system options for couples as in the previous step

8. Conduct similar steps for tree species selection using a similar table. Create a list of existing and potential tree species (Table 9b.1), identify a list of criteria in selecting the tree species (Table 9b.2) and conduct the criteria weighting and tree species weighting (tables 9b.3 and 9b.4).
9. Enter the data in spreadsheet format and run the AHP software to get the results. Table 9b.5a shows an example of results: low labour input is being perceived as by far the most important criterion, which perhaps indicates other livelihoods' options and/or available labour market. Introducing a farming system that is labor intensive to this group will have a low probability of success. Table 9b.5b shows the weighting results of farming systems based on each criterion. For example, in terms of low labour input, patchouli and pepper systems are the two most-preferred systems. Cocoa and pepper are perceived as the most preferred as far as easy to market is concerned. Table 9b.5c shows the combined weights between criteria and preferences based on each criterion. Patchouli comes first, mostly because it is being perceived as having low demand for labour compared to other farming systems, while low labour input is the criterion most important within the list of criteria.

Table 9b.5a. Ranking of importance of criteria

Criterion	Weight	Rank
Low labour input	0.4454	1
Easy to market	0.1804	2
Easy to harvest	0.0990	3
Quick to start producing	0.0934	4
Planting material is easily available	0.0685	5
High output price	0.0618	6
Can be mixed	0.0515	7

Table 9b.5b. Weightings of farming systems based on each criterion

	Easy to market	High price	Available good planting materials	Low labour input	Can be mixed in a plot	Easy to harvest	Quick to produce
Patchouli	0.0663	0.1262	0.1328	0.2850	0.0513	0.0807	0.4519
Cocoa	0.2464	0.0614	0.1805	0.1148	0.1146	0.0807	0.1420
Pepper	0.2464	0.1378	0.1805	0.2467	0.0449	0.0807	0.1420
Fruit	0.0827	0.0417	0.1805	0.1319	0.2609	0.3278	0.0796
Timber	0.0396	0.2082	0.1647	0.0719	0.2245	0.0511	0.0523
Coconut	0.0880	0.2582	0.1328	0.1148	0.2609	0.3278	0.0680
Sago	0.2306	0.1665	0.0282	0.0350	0.0430	0.0511	0.0643

Table 9b.5c. Rank of preferences of farming system across all criteria

Farming systems	Weights	Rank
Patchouli	0.2086	1
Pepper	0.1988	2
Coconut	0.1443	3
Fruit	0.1419	4
Cocoa	0.1389	5
Timber	0.0848	6
Sago	0.0827	7

Example of application

The method has been applied in 40 villages in Sulawesi, across gender groups, and showed some interesting findings regarding the perceptions of male and female groups on an existing farming system, variations of preferences in tree species and farming system, and criteria perceived as most important in selecting tree species and farming system.

- Across the 20 group discussions held in different places, the variations in lists of criteria and the orders of importance were marked. In addition to low labour input and easy to market criteria, land and climate suitability, food self-sufficiency, customary and cultural values, acquired cultivating skills, long productive lifespan and multiple benefits of the farming system were perceived as being important. The local context, such as cultural factors, market access, infrastructure, land access etc, shaped the criteria and their importance in selecting tree species and farming systems. This finding can be used to guide broader research of potential tree species and farming systems than what appeared in the list during the discussion.
- The Sulawesi exercise showed that segregation data was possible to collect through the separate-but-parallel discussion sessions with male and female groups. The gender differences were clearly shown in the process of tree and farming system selection within the community. As an example, the results of the women-only group of the same study area as the example given above show more even weightings across criteria but nevertheless low labour input is the lowest while land and climate suitability is the highest. The two gender groups agree that the criterion 'easy to market' is the second-most important criterion.

Key references

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10 Access to trees of choice (NotJustAnyTree)

James M. Roshetko, Pratiknyo Purnomosidhi and Endri Martini

The choice of trees that are planted is unfortunately often dominated by supply (what is available) rather than by what is prioritized by planters. The NotJustAnyTree tool provides an evaluation approach of the planting material that can be obtained from existing local nurseries, and its quality. The tool also includes evaluation criteria for outcome and impact studies of efforts to support nurseries of excellence.

Introduction

Preceding tools help in defining which trees might be suitable where, and what level of tree diversity (between and within species) is desired or prioritized. Unfortunately, tree-planting programs are mostly evaluated by the numbers of trees planted rather than by the number of trees that actually survive and grow and even less in the quality of products and services that they provide. A major shift is needed from supplying what is easily available to what is prioritized. Past evaluations of tree-planting programs have focussed on the number of seedlings supplied and program funding rather than on the appropriateness of what was supplied and planted.

It is possible for farmers to obtain tree seed, sow it directly or use it to produce seedlings in a small-scale family nursery. Larger-scale tree nurseries, oriented towards local needs, offer economies of scale and other advantages. These can be managed by a farmers' group or as part of a broader community training and education program; they may also evolve into private enterprises focused on serving market demand. Often such enterprises grow out of external or community efforts to develop the technical skills and experience, access to tree seed and information, and awareness of market mechanisms necessary for individuals or groups to effectively operate a tree nursery.

An important step for any nursery that wants to supply the markets is the production of reliable quality seedlings through informal or formal quality control; in government-monitored markets this may include certification programs. The actual quality of a tree can only be assessed many years after it has been planted, but molecular markers that allow early identification of cultivars or strains are becoming more widely available.

Objectives

The aim of the NotJustAnyTree tool is to assess the supply and demand of quality tree germplasm, the capacity of local nurseries, and the effectiveness of support to local nursery development.

Steps

1. Survey of existing tree nurseries in a geographic area to assess the species and types of species produced, seedling quality (origin of seed, budwood, other material; type of seedling propagation; size and age of seedlings etc), the quantity of seedlings produced, average number of seedlings per sale, business capacity of the nursery, relation to other components of the tree seed sector (other nurseries, germplasm suppliers, government agencies, the private sector,

customers etc) (Roshetko and Purnomosidhi 2013). Gap analysis that starts with potential demand can identify opportunities for new species to enter into the nurseries (Narendra et al 2013).

2. Similar surveys of germplasm suppliers (government and private) that operate at local, national or international levels; and assessment of government support to facilitate local access to these suppliers (Roshetko et al 2003).
3. Needs assessment of nurseries' human resources and infrastructure to identify any training and equipments inputs required to enhance nursery operations[1].
4. Evaluation of the technical and cost effectiveness of the inputs required to enhance nursery operations.
5. Forecast of future seedling demand (government, project, private sector) and evaluation of local nurseries potential to meet that demand (Martini et al 2013).

Case study: nurseries of excellence in Indonesia

Aceh, the northern- and western-most province of Indonesia, covers an area of 57 000 km^2 and has a population of just over 4 million. Household economies were based on rice production for household consumption, fisheries for income generation and tree crops for both income generation and household needs. In Aceh Barat, tree crops provided 60% of household incomes. Across the province, smallholders cultivated mixed tree and crop systems under non-intensive management. Key species were rubber, cocoa, coconut, betel nut and fruits.

Figure 10.1. Participants in a NOEL nursery establishment and management training course

The tsunami of 2004 had catastrophic effects in Aceh. Approximately 200 000 people were killed and 500 000 displaced. Local economies were devastated and many Acehnese communities lost vital capacity and experience in tree-garden management. A generation of young farmers was not mentored by skilled elders. As a result, tree management practices were non-intensive and farmers'

[1] An appropriate assessment could be testing various types of nursery containers. A comparison of seedlings grown in biodegradable containers with those grown in normal polythene bags showed that although physical appearance was less appealing, seedling success after planting on farm was higher (Muriuki et al 2013).

access to quality tree germplasm, professional technical assistance and market links was limited. Efforts towards livelihoods' enhancement and land rehabilitation began in 2007 but many of the aid agencies in Aceh lacked staff, experience and information related to tree-garden management. Most nurseries in Aceh did not produce seedlings. They purchased them from outside the province for resale in Aceh, which meant resources used to buy and transport seedlings were not available for local investment. The quality of the purchased seedlings was often poor and damage occurred during transportation. Poor seedling quality lead to poor post-planting survival and performance.

It was important to help farmers produce high-quality germplasm, improve tree-garden management skills and enhance their market awareness. The Rehabilitation of Agricultural Systems in Aceh: Developing Nurseries of Excellence (NOEL) project, implemented by the World Agroforestry Centre and Winrock International aspired to do exactly that. The program aimed to improve agroforestry-based livelihoods and tree gardens through the use of productive tree crops produced in community-based 'nurseries of excellence'.

Implemented in Aceh Barat, Aceh Jaya and Pidie districts, NOEL facilitated the access of smallholders—both men and women—to high-quality planting materials and trained them to establish and operate tree nurseries and tree gardens. Initiated in April 2007, NOEL operated until March 2009. Program activities included introductory nursery training, bi-weekly follow-ups, intensive vegetative propagation training, technical consultations, cross-visits, market studies, nursery development and demonstration plot establishment.

NOEL partners included farmer groups, 'dayah' (community Islamic organizations), NGOs, international development organizations, universities and local technical agencies.

What did the NOEL program achieve? In just 18 months, 178 capacity-building events were conducted, training 3582 people. Across all NOEL activities, the involvement of women exceeded 30%. Fifty 'nurseries of excellence' were established, 32 by program partners and 18 'susulan' (spontaneous) nurseries by neighbouring farmers who were inspired by the success of NOEL. Over 400 000 seedlings were produced. There was a 92% success rate in nursery establishment, which is in huge contrast to many post-tsunami, pre-NOEL community nurseries where farmers were provided with only a small amount of nursery training and no follow-up technical support, as a result of which the nurseries ceased to function or operated at very low levels.

The NOEL farmers' extension approach demonstrated that a program of training, intensive follow-up and material support could facilitate the successful development of farmers' technical capacity, community tree nurseries and related infrastructure, even with partners previously unfamiliar with tree nursery operations. Supporting susulan further expanded the program's impact. The NOEL approach can effectively be replicated in other sites in Indonesia and Southeast Asia, where land rehabilitation and community livelihoods' enhancement are key objectives. (Roshetko et al 2013, Selvarajah 2013.)

■ Key references

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Tree seeds for farmers: a toolkit and reference source

This toolkit has been developed to provide information on sustainable production of seeds and seedlings of agroforestry species.

The prime objective of the toolkit is to provide information and examples of how the quality of seeds and seedlings can be maintained from collection to field planting for the great diversity of agroforestry species that are useful to small-scale farmers. The toolkit was developed recognizing the wide range of actors and stakeholders that are involved in expanding agroforestry systems. Its format is designed to answer the questions that various actors may have in relation to seed production. The toolkit is based on a review of existing documentation and extension materials on seed production. Useful references to augment the toolkit information are also provided.

The toolkit complements existing materials on seed production in two fundamental ways. Firstly, it provides information on how joint strategies can be made by the various actors and stakeholders in expanding tree planting in defined regions. Secondly, it explores in further detail the option of developing sustainable systems that provide quality material by involving the private sector in seed production. The final section of the toolkit primarily focuses on tree nursery management.

The toolkit contains three sections: 1) strategies for expanding seed production; 2) technical guidelines in seed production; and 3) the private sector and seed production.

Download the *Tree Seeds for Farmers* toolkit: http://worldagroforestrycentre.org/research/tree_diversity_domestication/genetic-resources-unit/articles-documents/tree-seeds-for-farmers.

Indonesian local tree nursery directories

Individuals and organizations often do not know what nursery resources are available to meet their tree seedling needs. The development and publication of local tree nurseries helps publicize the existence of nurseries and availability of seedling resources. The directories also increase business opportunities for nurseries. The publishing of a local tree nurseries directory in an inexpensive and practical output, which can expand the impact of a project or program.

Below are listed four examples of local tree nursery directories from Indonesia.

Purnomosidhi P, Roshetko JM, Prahmono A, Moestrup S. 2012. *Direktori usaha pembibitan tanaman buah, kayu dan perkebunan di Propinsi Jambi*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Little Rock, AR: Winrock International; Copenhagen: Faculty of Life Science, University of Copenhagen.

Purnomosidhi P, Roshetko JM, Prahmono A, Moestrup S. 2012. *Direktori usaha pembibitan tanaman buah, kayu dan perkebunan di Propinsi Lampung (edisi II)*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Little Rock, AR: Winrock International; Copenhagen: Faculty of Life Science, University of Copenhagen.

Purnomosidhi P, Roshetko JM, Prahmono A, Moestrup S. 2012. *Direktori usaha pembibitan tanaman buah dan perkebunan di Kabupaten Aceh Barat, Aceh Jaya, Pidie/Pidie Jaya dan Nagan Raya*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Little Rock, AR: Winrock International; Copenhagen: Faculty of Life Science, University of Copenhagen.

Purnomosidhi P, Roshetko JM, Prastowo NH, Moestrup S. 2012. *Direktori usaha pembibitan tanaman buah, perkebunan, kayu dan hias di Kabupaten Bogor dan sekitarnya (edisi II)*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Little Rock, AR: Winrock International; Copenhagen: Faculty of Life Science, University of Copenhagen.

International tree seed suppliers directory

This directory is intended to contribute to the informed use of tree germplasm, which is an essential component of sustainable forestry and agroforestry practices, and promote wider use of quality germplasm.

Quality has both a genetic and a physiological component, and both are described in the directory. Quality descriptors can be used as criteria to select suppliers, and this will ensure that both the users and the suppliers recognize seed quality requirements. The directory also highlights the importance of biosafety issues, and it presents biosafety information that suppliers have provided

Although the directory focuses on tree taxa of importance in the tropics, it lists temperate taxa as well. It does not discriminate between taxa used for agroforestry and forestry. The purpose is to ensure that the information is useful to a wide range of users.

The directory lists suppliers by country. Download from http://www.worldagroforestry.org/our_products/databases/tssd.

Indonesian seed suppliers directory

Seed is the most important input of any tree-planting or reforestation program. Adequate quantities of seed assure planting targets can be achieved. The use of quality seed, combined with good planning and management, leads to high survival rates, fast growth and program success.

Unfortunately, the availability of tree seed is often limited. Surveys indicate that nearly all Indonesia-based NGOs and farmers' groups active in tree-planting activities lack access to tree seed of adequate quantity and quality. Many projects and government agencies face similar shortages. This problem is exasperated by a paucity of information concerning tree seed suppliers. At the national and provincial levels some lists of tree seed suppliers exist but they are not widely circulated or frequently updated. This directory supplements the international directory, above.

The majority of tree seed used in Indonesia is collected, exchanged and traded through the informal sector. The seed collectors and traders involved in this sector generally have little formal training in seed technology. They record and report little information concerning the source and quality of the seed they collect. This lack of information makes it difficult for consumers to evaluate the seed available from these suppliers. The informal seed sector operates on personal links of past contacts and word of mouth. Some suppliers are able to sell large quantities of seed because of strong customer links. Based on past experience, these suppliers collect seed to fill specific orders and meet anticipated last-minute orders. However, the potential of most suppliers is limited because they lack strong consumer links. Likewise, most consumers (seed users) have little idea where to secure seed and consistently suffer seed shortages. Projects and NGOs may contract local farmers to collect small volumes of seed but for large volumes they contact big seed suppliers in Central and East Java. Some of the seed sold by these big suppliers is collected on outer islands, shipped to Java and then re-sold to consumers on outer islands; sometimes to the same islands from which the seed was originally collected. The information and links gap between consumers and suppliers in Indonesia causes the national tree seed collection and distribution pathways to be inefficient, resulting in higher prices and seed of sub-optimal quality.

The directory was developed to address the tree seed information and links gaps prevalent in Indonesia. It provides reliable information to seed consumers—farmers, NGOs, projects, government institutions and others—and promotes the services and products of seed suppliers*. Most importantly, the directory provides a channel for consumers and suppliers to build links. The information in the directory was collected through a survey of 140 seed suppliers operating throughout Indonesia. The seed suppliers were identified by compiling the experience of five forest tree seed centres: Balai Perbenihan Tanaman Hutan in Palembang, Bandung, Denpasar, Banjar Baru, and Ujung Pandang; Directorate of Forest Tree Seeds, Ministry of Forestry; and the World Agroforestry Centre and Winrock's network of NGOs, farmers' groups and development organizations. In addition to the survey, more information was gathered through interviews with key seed suppliers in Wonogiri, Central Java, and Ponorogo, East Java, which are the primary sources of tree seeds in Indonesia (Roshetko et al 2003).

Available at http://worldagroforestry.org/regions/southeast_asia/resources/db/seedsuppliers

11 | Climate: using local tree influences (CooLTree)

Meine van Noordwijk, Jules Bayala and Kurniatun Hairiah

Trees have a substantial influence on windspeed, maximum temperature during the day (especially on the hottest days of the year), humidity, minimum temperature and possibly play a role in modification of rainfall. Where the actual climate for crops, livestock and people is involved, one of the most effective things that people can do is manage trees, including tree planting. However, the official climate data that form the basis for climate policy exclude such effects and scientists are only slowly coming to grips with this issue. The CooLTree method contrasts the local, public/policy and science-based knowledge.

Introduction

People associate climate issues with trees. Tree planting as a ceremonial activity has intuitive appeal in the context of climate change and is popular among politicians who want to show that they're not just talking about climate but are willing to act. At the micro-scale, this is a logical association as we seek the shade of trees on a hot day, seek shelter under trees if surprised by a rainstorm (but some know that deep-rooted trees attract lightning), select tree-covered roads to cycle against the wind (if living in a bicycle culture) and prefer trees around our houses to buffer both the heat of summer (or the day) and the cold of winter (or the night). Yet, trees have mostly been discussed in the climate-change debate in terms of their carbon storage and the contributions they make to the global carbon balance. Their more direct effect on micro- and mesoclimate is largely absent from the debates, including that involving agriculture.

Recent discussions about 'climate-smart' landscapes are changing the paradigm that adaptation to climate change will have to primarily consist of a change of crops and crop cultivars. Active management of 'cool' and cooling trees may offer opportunities that farmers are generally aware of but that have not yet been part of climate-adaptation planning in the formal and public knowledge domains. Van Noordwijk et al (2014) posed the hypothesis, and reviewed available evidence for it, that the presence of trees increases the degree of buffering of climate variability from the perspective of an annual food crop and that retention and increases of trees in agricultural landscapes can be a relevant part of climate-change adaptation strategies.

Objectives

1. Explore the differences and synergy between the understanding of microclimatic effects of trees in local (LEK), modellers' and hydrologists (MEK) and policy makers' (PEK) ecological and climatic knowledge.
2. Contribute to the evaluation of 'climate smartness' of current landscapes and the options to modify the quantity, quality and spatial pattern of tree cover to obtain greater buffering.

Steps

- **LEK:** Landscape transect walk during the hottest part of the day, with focus on microclimatic differences between parts of the landscape, discussing any advantages or disadvantages associated with the tree-cover effect on climatic variables of local concern.
- **MEK1:** Instrument typical transects in the landscape with various levels of tree cover with data-loggers that record temperature, windspeed and/or humidity and relate the neighbourhood effects of trees to the annual cycle of seasons and daily variability within seasons.
- **MEK2:** Discuss with local climate experts how information on microclimatic effects of trees in the local context can be used in existing downscaling routines for climate models to explore both the effects of macroclimatic change that are beyond local control and the tree effects that can be managed and optimized locally.
- **PEK:** Discuss with development agencies, local NGOs and government agencies interested in adaptation to climate change and reduction of human vulnerability to climate extremes the options trees offer to buffer climatic variation and provide a suitable microclimate.
- **LEK * PEK * MEK interaction:** Describe discrepancies between the three knowledge systems in an effort to get PEK and MEK closer aligned to LEK, for greater chance of success of any action plan.

Example of application

1. In a case study in the Kali Konto landscape in East Java, Indonesia, farmers expressed a strong preference to have an intermediate level of shade trees in their coffee gardens. Measurements by students from a local university quantified the daily cycle of air temperature (measured inside the standard boxes of weather stations, thus avoiding direct radiation on the thermometer, and inside the soil at different depths), as summarized in Figure 9.1. This type of MEK confirmed the farmers' opinion and preferences and could be brought into discussions of climate-change vulnerability and adaptation.

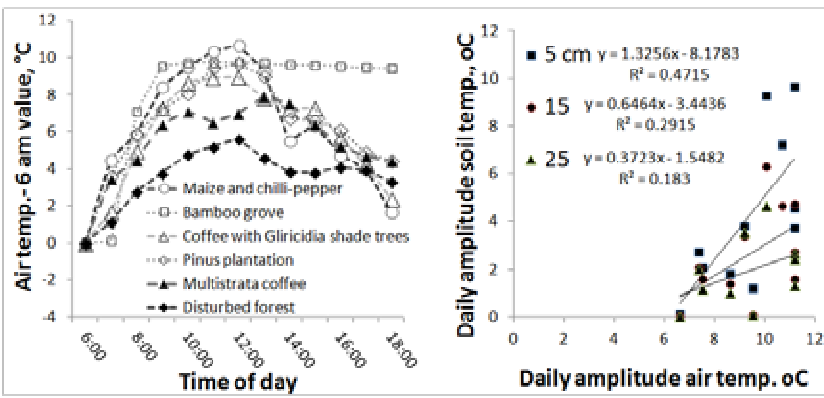


Figure 9.1. Daily temperature, air amplitude and soil temperature profiles for an East Java mountain location (Ngantang, Indonesia)

Note: A. Daily temperature profile for different land-cover types, including simple shade and multistrata coffee agroforestry systems, compared to (degraded) forest and open field agriculture (data were averaged for dry season and rainy season measurements); B. Relationship, across seasons and land-use systems, between daily amplitude of air temperature and temperature at 5, 15 or 25 cm depth of soil.

2 In the parkland agroforestry systems of West Africa, temperatures tend to be above the optimum for crop growth, at least during part of the growing season. Farmers have long since retained tree species with useful fruit in the landscape where they grow crops. The trees also provide welcome shade for domestic animals and people during the hottest part of the day. A network of microclimatic measurement with automatic data-loggers gives a quantitative idea of the effects (Figure 9.2). Temperature in the cropped zone under the tree canopy was found to be 2 ^{0}C cooler but in the next circle beyond the canopy it was still 1 ^{0}C cooler than in-between the trees. Further analysis will have to clarify to what extent this 'control' was influenced by the presence of trees in the wider landscape.

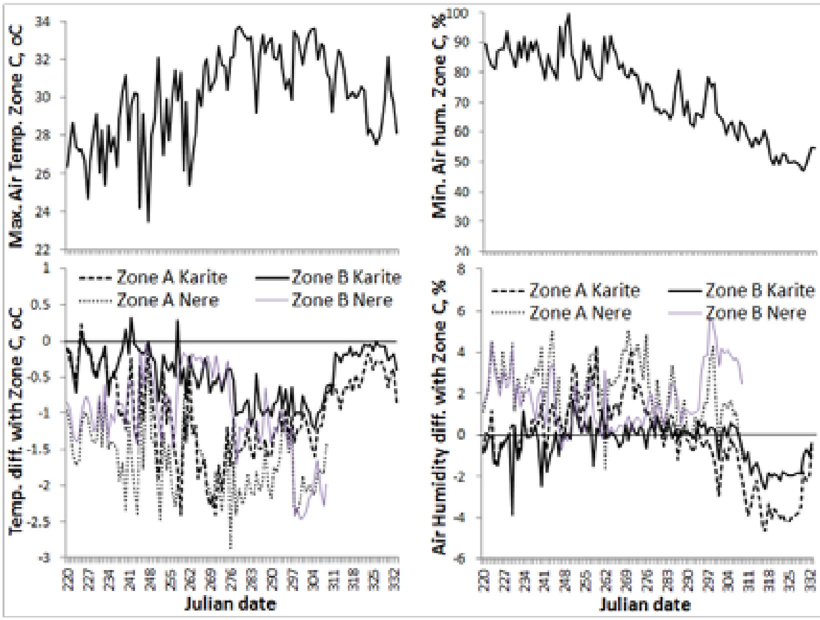


Figure 9.2. Effect of tree position

Note: Effect of position relative to a 'karité' (Vitellaria paradoxa) or 'néré' (Parkia biglobosa) tree on maximum daily temperature at crop level (left panels) or minimum air humidity (right panels) for zones A (under the tree) and B (edge of tree canopy) compared to zone C (in-between trees) in the parkland landscape of Sapone, Burkina Faso.

Data source: Bayala et al 2013

As in the first case study, the immediate effects of trees on maximum temperature were found to be of a magnitude that is relevant for buffering macroclimatic change.

■ Key references

Bayala J, Sanou J, Bazié P, van Noordwijk M. 2013. *Empirical data collection of tree effects on temperature and humidity at crop level.* Nairobi: World Agroforestry Centre.

Van Noordwijk M, Bayala J, Hairiah K, Lusiana B, Muthuri C, Khasanah N, Mulia R. 2014. Agroforestry solutions for buffering climate variability and adapting to change. In: J Fuhrer, PJ Gregory, eds. *Climate change impact and adaptation in agricultural systems*. Wallingford, UK: CABI.

12 | Tree and farming system resilience to climate change and market fluctuations (Treesilience)

Sonya Dewi, Endri Martini and Janudianto

Two of the biggest external sources of uncertainties in farmers' livelihoods are 1) impacts of changes in the mean and fluctuations of annual rainfall and shifts in seasons; and 2) market fluctuations of agricultural products. Tree and Farming System Resilience to Climate Change and Market Fluctuations (Treesilience)[1] uses focus-group discussions to encourage farmers to 1) identify the fluctuations that cause shocks to their livelihoods in a guided process thinking though the shocks-exposure-responses-capacity chain; 2) reveal the impacts of the shocks to their farming systems; 3) characterize the impacts of the shocks on dominant tree species; and 4) semi-quantitatively assess the price fluctuations of dominant tree products.

Introduction

Global warming does not only alter the mean annual rainfall but also the fluctuations and seasons, which have major impact on ecological processes; hazards such as floods, landslides, fire, erosion and sedimentation; and the productivity of trees and annual crops. Apart from low and fluctuating productivity per unit areas of land managed by farmers in developing countries and fluctuations owing to climate-related uncertainties, market uncertainties are huge in developing countries for tree and agricultural products. A basic pattern of boom followed by bust is repeated, with sudden increases in process owing to disasters (drought, civil war, frost) elsewhere.

These two issues have a huge influence on farmers' incomes but since conceptually they are not easily grasped, addressing the problems is not easy. Most farmers are unaware of the roots of the problems, what impacts the shocks can bring, how to respond, what capacities are needed and which are available.

A preventive, long-term strategy—rather than a survival strategy after a shock—is most cost effective. The majority of aid, however, addresses the latter, while strengthening capacity to increase resilience and the adaptive capacity of farmers in shock-prone, poor areas is crucial. Such aid is effective in helping in emergencies immediately after incidence of a big shock but accumulative impacts of smaller shocks become a latent problem that is left unaddressed. Further, the sustainability of such aid usually is not considered.

[1] The term Treesilience was first coined by Mary Njenga, Jan de Leeuw, Miyuki Iiyama, Jeremias Mowo and, Ramni Jamnadass: http://worldagroforestry.org/sites/default/files/Need%20to%20Build%20Resilience%20ICRAF%20Seminar%2015%20November%202013.pdf

Awareness of shocks-exposure-responses-capacities are necessary as part of local knowledge to address uncertainties. Further, it is imperative for the farmers to have strengthened capacities in 1) identifying resilience of tree and farming systems to climate-related factors; 2) resilience of tree products to market fluctuations.

Objectives

- Identify fluctuations in 1) climate-related factors that have an impact on tree and agricultural products; 2) price and other factors that have an impact on the production system and marketing
- Reveal the impacts of shocks to farming systems
- Characterize the impacts of shocks on dominant tree species
- Semi-quantitatively assess price fluctuations of dominant tree products
- Guide the thinking process through the shocks-exposure-responses-capacities chain to identify gaps in capacities in order to increase farmers' resilience

Steps

Before the focus-group discussion, facilitators are recommended to:

- collect rainfall data for the past 10 years and identify any anomalies, for example, droughts, extreme humidity, high fluctuations;
- discuss with key informants in the village the climate- and market-related factors and others that create shocks to tree and agricultural products and to farmers' livelihoods;
- identify any unusual events stimulated by external factors that might have an impact on the majority of farmers in the village; and
- discuss with key informants the distinct characteristics of farmers in the village that possibly causes different levels of vulnerabilities, different responses to shocks etc and use this to decide ways to organize the focus-group discussions, for example, by gender or place of origin.

The focus-group discussion is divided into six steps. Steps 3 and 6 have been modified from Quan et al (2012).

1. List and rank, based on the perceived importance, the dominant farming systems and the most common tree species that are managed by farmers in the area.
2. Identify the years of shocks during the past 15 years, describe the causes and the impact, ranked from the most severe to the least. Choose the first three highest ranked and label those years with the type of shocks, for example, '2002: extremely wet year; 2007: long drought'. Choose the most recent year that is considered to be a normal year and use this as the base year.
3. For each of the three years of shocks, guide the causal thinking process of shocks-exposure-responses-capacity and the identification of necessary capacities to act in response to the shocks and the impacts of shocks, in real time and for the long term (Figure 12.1). Starting with identified shocks, invite participants to nominate the causes, followed by what they are exposed to as impact. List the immediate responses that they had during that year of shock, and the long-term responses to reduce exposure in the future (increased resilience), both those that have been done already or are perceived to be important to do. Lastly, list perceptions of the necessary actions. The findings can help government and aid agencies develop an adaptation program.

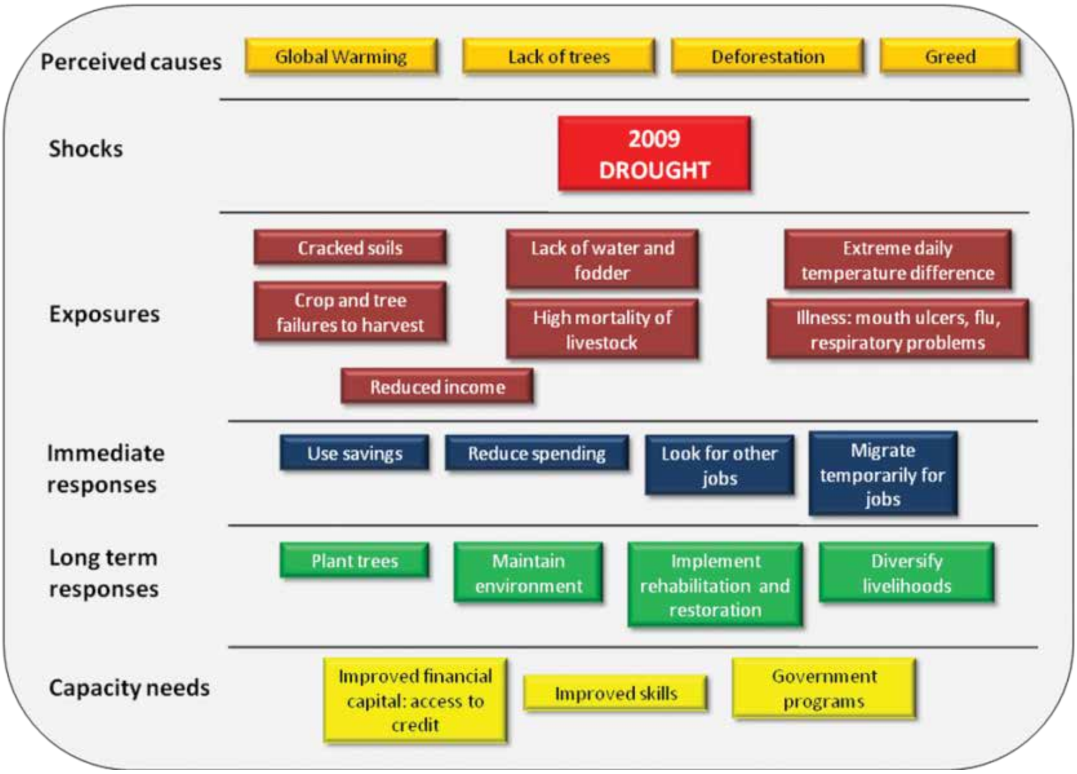


Figure 12.1. Example of a result from a guided thinking process for identifying shock-exposure-responses-capacities in one village in Sulawesi

4. Establish relative monthly rainfall calendar for the base year and the activities for each dominant farming and tree management system. Develop similar calendars for the three years of shocks (Table 12.1). Compare the activity calendars across the multiple years to identify farming systems and commodities affected by each shock and how farmers alter their labour allocation accordingly.

Table 12.1. Example of results from an activity calendar during the base year in a male group in a village in Sulawesi

Farming system	Com-modity		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual productiv-ity per ha
Annual crop	Maize	Planting													2–2.5 tons
		Managing													
		Harvesting													
	Ground nuts	Planting													1 ton
		Managing													
		Harvesting													
Agro-forestry	Fruit–maize–yam	Planting													30 trees (approxi-mately 1 ton)
		Managing													
		Harvesting													
Mono-culture tree crop	Cashew	Planting													50 trees (approxi-mately 0.3 ton)
		Managing													
		Harvesting													
	Teak	Planting													Harvest only in 20–30 years
		Managing													
		Harvesting													
Other activities															
Max. rainfall															
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	

5. Based on the list produced in Step 1, select 5–10 dominant tree species. Record the prices, price fluctuation within certain period of time, and within certain radius of areas, for example, the minimum and maximum price per unit during the past two years within the surrounding villages.
6. Copy the list of the 5–10 dominant tree species from Step 5. Discuss and fill for each tree species, the impact of droughts, extreme rainfall, pests and diseases, shift in seasons, fires, strong wind, lack of fertilizer, lack of management such as pruning, and other climate-related factors that frequently occur, and have an impact on trees and tree products in the area. The impacts are further differentiated between young trees and mature, producing trees, in terms of mortality rate, growth and productivity.

Table 12.2. Example from subset of results of Step 6 from Sulawesi

Tree species	Annual production per ha during base year	Extreme rainfall					Drought				
		Effects on young plants	Score	Effect on mature plants	Score	Effect on productivity (% from base year)	Effects on young plants	Score	Effect on mature plants	Score	Effect on productivity (% from base year)
Cashew	100 kg/tree	Good	3	Fruits are damaged	3	10	Do not grow well	3	Fruits are of bad quality	3	85
Clove	100–200 litres	Good	3	Flowers fall	3	60	Mortality is high	5	Leave fall	3	70
Cocoa	500 kg	Good	2	Fruits are damaged due to pests and diseases	5	60	Leaf disease, mortality is high	5	Leaf fall	5	50
Langsat	150 kg/tree	Good	1	Some do not produce fruit	3	50	Mortality is high	3	Do not produce fruit	3	60
Candle nut	100 kg/tree	Good	1	Flowers fall	2	70	Good	1	Low productivity	3	25
Durian	100/tree	Died		Productivity decrease		60	Leaves fall	1	Low productivity	1	75
Rambutan	4200 kg/tree	Good		Fruits fall	3	50			Flowers fall	3	75

Example of application

The full range application of the tool has just been successfully conducted in 10 clusters of 40 villages in South and Southeast Sulawesi provinces, Indonesia. Figure 12.2 shows one result, drawn from the information collected in steps 5 and 6. Resilience of tree species to fluctuations in climate-related factors are calculated from the effect of extreme rainfall (either low or high) on productivity. The less productivity of one particular tree species is affected by extreme weather, the more resilient that tree species is. This applies similarly for resilience to fluctuations in price. Four main types of tree species were identified. In Sulawesi, Type 1 tree species (low resilience to climate-related factors, high resilience to price fluctuations) are dominated by export commodities such as cloves and cocoa. The results can further be used to help identifying the intervention or support that can be provided in increasing the resilience of particular tree species to fluctuations in climate-related factors and/or in price and therefore increasing farmers' resilience to both types of fluctuations that are specific to tree species.

Application of steps 3 and 6 in Viet Nam, which were adapted for Treesilence, can be found in Quan et al (2012).

Figure 12.2. Example of findings derived from information collected in steps 5 and 6

Key references

Hoang MH, Namirembe S, van Noordwijk M, Catacutan D, Öborn I, Perez-Teran AS, Nguyen HQ, Dumas-Johansen MK [in press] Farmer portfolios, strategic diversity management and climate change adaptation : implications for policy in Viet Nam and Kenya. *Climate and Development*. DOI: 10.1080/17565529.2013.857588.

Nguyen Q, Hoang MH, Öborn I, van Noordwijk M, 2013. Multipurpose agroforestry as a climate change adaptation option for farmers: an example of local adaptation in Vietnam. *Climatic Change* 117:241–257.

The talking toolkit: how smallholding farmers and local governments can together adapt to climate change

Elisabeth Simelton, Dam Viet Bac, Rodel Lasco and Robert Finlayson

Download: http://worldagroforestrycentre.org/regions/southeast_asia/vietnam/products/tools/talking-toolkit.

13 | Functional branch analysis (FBA): Tree architecture and allometric scaling

Meine van Noordwijk, Rachmat Mulia and Degi Harja

Functional Branch Analysis (FBA) is a tool to generate tree architecture and allometric scaling. It can be used as a non-destructive approach to develop allometric equations that are often used to estimate plot-level carbon stocks.

Introduction

Trees come in various shapes and sizes, grow at different rates, and interact with their neighbours during development. However, many of the properties of an individual tree can be predicted by the diameter of its stem. The relationship between this diameter and properties such as tree height, tree biomass, leaf area and harvestable timber are called 'scaling rules' or allometrics.

Empirical allometric scaling equations for tree biomass—Y on the basis of stem diameter D—are often used in forest inventories and for assessments of carbon and nutrient stocks in vegetation. The most common form is $Y = aD^b$. The equations are based on cutting selected trees and obtaining destructive measurements that can then be related to the stem diameter. However, a non-destructive approach is sometimes used. In addition to reducing cost and time, it is particularly desirable when shifting from homogenous plantation forestry to mixed forestry or to multispecies agroforestry systems.

Certain regularities in the development of tree form are captured in 'fractal branching' models. Such models can provide a transparent scheme for deriving tree-specific scaling rules on the basis of easily observable, non-destructive methods. Apart from total tree biomass, the models can provide rules for total leaf area and the relative allocation of current growth to leaves, branches, stem or litter, or the ratio of green to brown projection area that modulates tree-crop interactions in a savannah.

Objectives

The FBA protocol and program are designed to efficiently describe the architecture and key properties of a tree and to use the derived parameters to reconstruct trees with simple, repetitive ('fractal') rules. They are also used to derive scaling rules that relate stem and/or proximal root diameter to total biomass and to other properties. The allometric scaling relations derived with the FBA module can be directly used in the Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) model of tree–soil–crop interactions

Steps

The model needs information about link diameter and length (that is, shoot or root segment) and about final structure (that is, leaves or fine roots). Not all, but at least 50 and preferably 100, successive links need to be measured to get a precise estimate of branch parameters. The elements of the model governing the branching pattern can be calculated using the FBA Help File. The independency of p (proportionality factor) and q (equity factor) to link diameter should be checked since independency is a requisite for the self-repetition rule.

Fractal branching models repeatedly apply the same equations to derive subsequent orders of the branching process ('self-repetition rule'). For practical applications, a rule is added for stopping when a certain minimum size is reached. The rules can refer to the diameter, length and/or orientation of the next order of branches. Figure 13.1 describes the elements of a functional branch analysis scheme, which can be applied to above- as well as belowground parts of trees. The combinations of the various parameters can be used to predict total size—weight, surface area, length, height, lateral extent—and the allometric scaling equations between these.

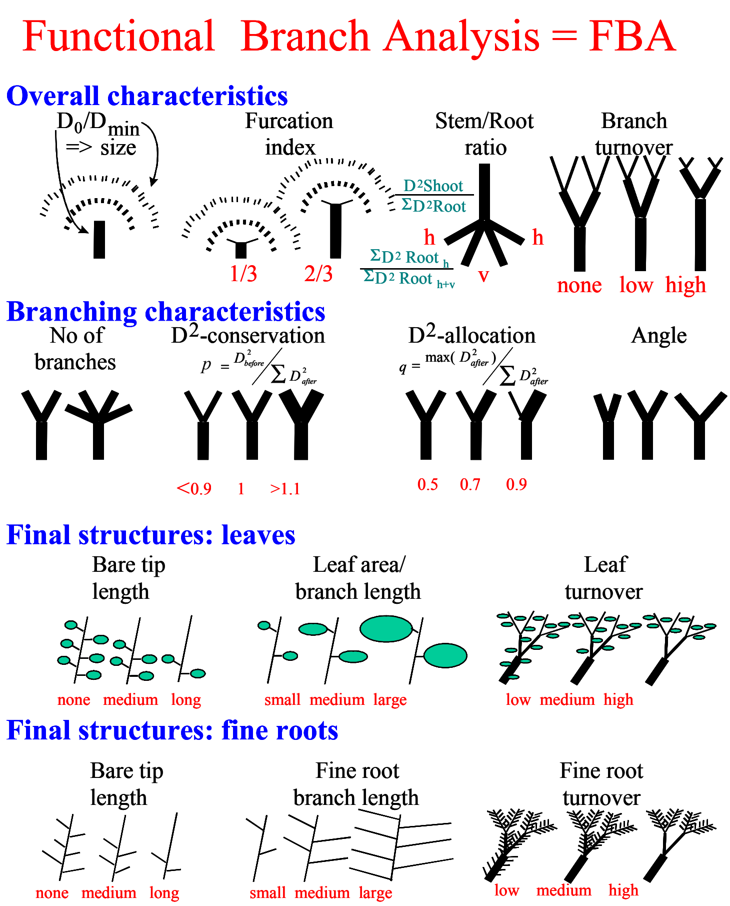


Figure 13.1. Elements of the functional branch analysis model for deriving allometric scaling equations between above- or belowground tree parts

Example of application

A comparison between model estimation and real observation of tree biomass aboveground and its components was carried out for four tropical tree species in the Philippines: *Shorea contorta*, *Vitex parviflora*, *Pterocarpus indicus* and *Artocarpus heterphyllus* (Figure 13.2). Total aboveground tree biomass, as calculated with the allometric equations from the FBA model, fit well with the biomass measurements obtained from destructive methods (Figure 13.2A). Slight differences were found for the tree components: wood (Figure 13.2B) and leaf biomass (Figure 13.2C) for all four tree species.

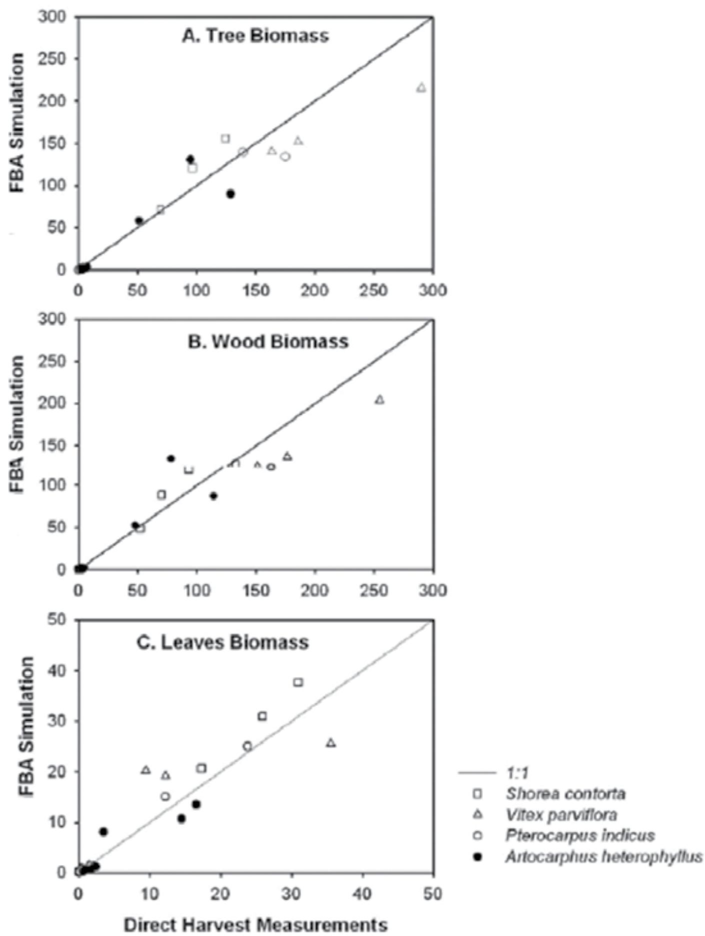


Figure 13.2. Comparison between FBA estimation and direct harvest biomass values of tree biomass

Note: (A) wood biomass; (B) and leaves biomass; (C) for four tropical tree species in the Philippines: *Shorea contorta*, *Vitsex parviflora*, *Pterocarpus indicus* and *Artocarpus heterphyllus*. Points along the 1:1 line means that values simulated by the FBA exactly match the actual measured values. Source: Martin 2008

FBA is also equipped with visualization tools that can be used if the angles between branches are also measured (figures 13. 3 and 13.4).

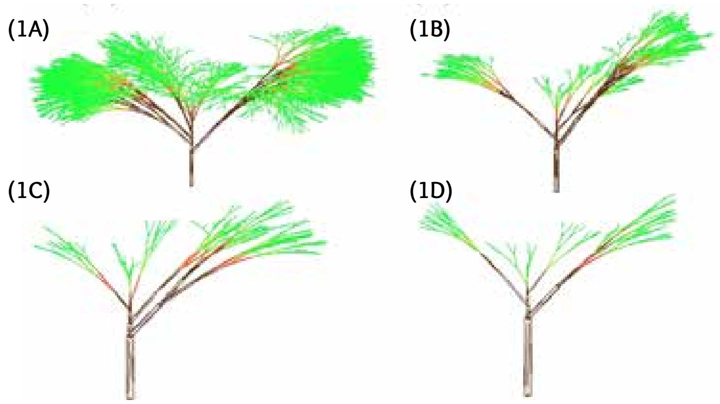


Figure 13.3. Example of tree shapes by varying just one parameter in the fractal branching routine

Note: In the example above, variation of the proportionality factor, p, for change of stem diameter at a branching point, has the values 0.8, 1.0, 1.2, and 1.4 respectively, in figures A–D. Trees with low p value are endowed with more branches and leaves; those with high p value have fewer branches and leaves owing to more significant branch tapering

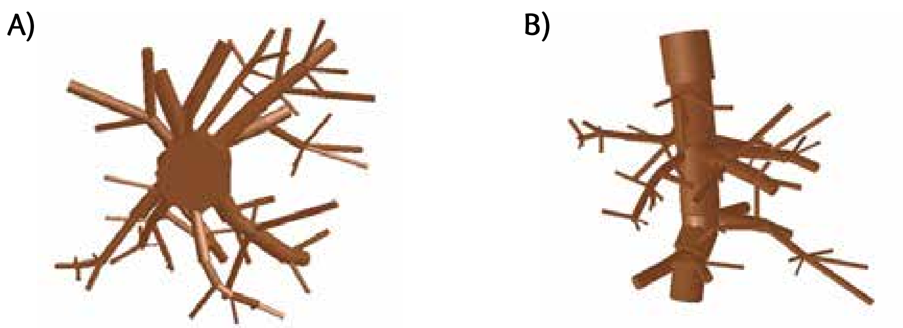


Figure 13.4. An example of tree root architecture produced by the FBA model as seen from the top (A) and from the side (B).

How to get the FBA model

The FBA model, embedded in an Excel worksheet, can be downloaded from the World Agroforestry Centre website: http://www.worldagroforestry.org/sea/Products/AFModels/WaNulCAS/downloadc.htm.

The model allows users to derive results for new parameter combinations and/or to seek new applications.

Key references

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 Modelling* 149:41–51.

Smiley G, Kroschel J. 2008. Temporal change in carbon stocks of cocoa–gliricidia agroforests in Central Sulawesi, Indonesia. *Agroforestry Systems* 73:219–231.

14 | Simple light interception model (SLIM)

Degi Harja and Gregoire Vincent

The purpose of the Simple Light Interception Model (SLIM) is to compute canopy closure (an index of long-term light levels) at any height above the ground within a forest canopy. The forest canopy in SLIM is a 3D geometrical object modelled from measured tree properties. SLIM can be used for stand profile visualization.

Introduction

Measurement of canopy closure and its projection on the ground is not a straightforward process. While direct field measurement may require more time and effort, using a profile model allows exploration of canopy closure on any position in a stand of trees.

The amount of light received at any point in space is calculated by exploring a range of directions (combination of azimuth and zenith angles). Each time a beam originating from that point intercepts a crown envelop of a given porosity it reduces its contribution correspondingly. Total canopy openness at that point is obtained by summing up results for elementary beams. The weight of each beam is determined by the relative surface of the associated sky vault fraction.

From this information and the elevation grid, the software then computes the canopy openness either at regular grid points or at irregular spacing defined by the user or else for each tree of the stand.

Objectives

SLIM aims to produce three-dimensional visualizations of tree stands and to compute canopy closure (canopy porosity) at individual tree or plot level.

Steps

The steps to use the tool are:

1. Profile measurement of a stand (tree diameter, height and crown shape)
2. Crown porosity estimation of each individual tree or species' group
3. Data tabulation and model calibration

Example of application

SLIM can be used to visualize canopy stand at plot level. When compared to hemispherical photographs, SLIM was able to produce similar configuratiosn (Figure 14.1).

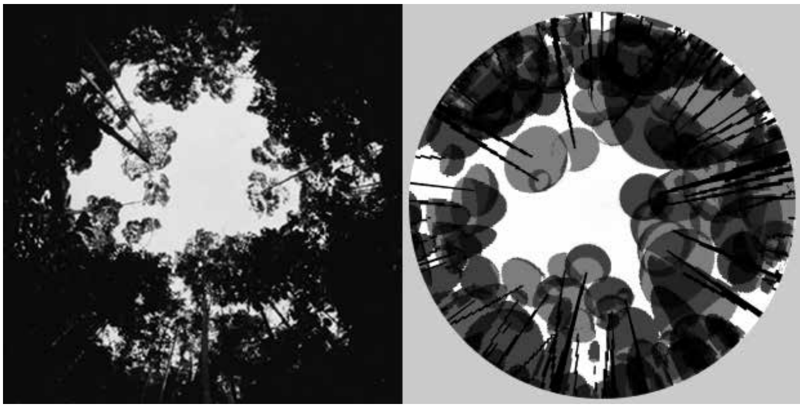


Figure 14.1. A set of hemispherical photographs was used to test SLIM predictions. Left picture was taken by camera and right picture was generated by SLIM for the same point in a real forest (left) and forest data input to SLIM (right)

Detailed stand measurement can also be visualized to better understand the configuration of the stand from various positions (figures 14.2, 14.3, 14.4, 14.5).

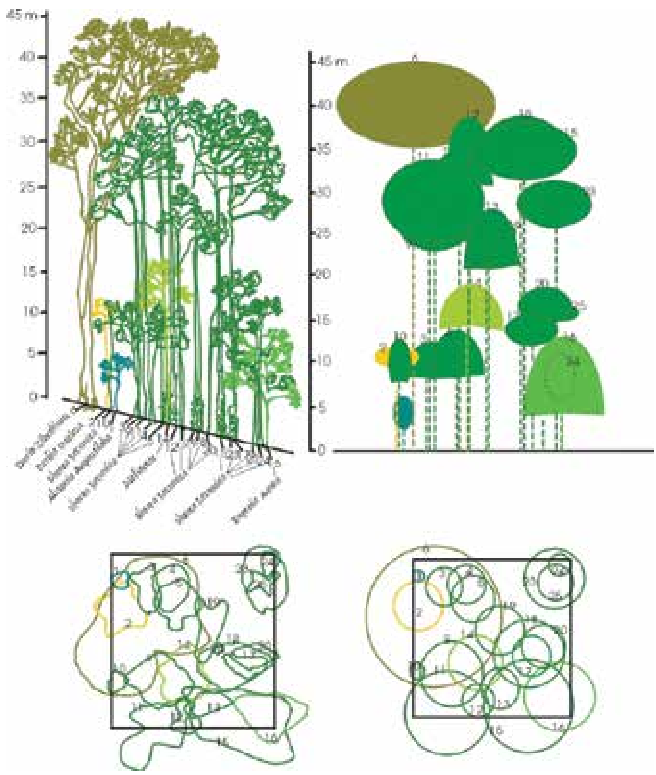


Figure 14.2. A simplified 3D description of the trees composing a stand

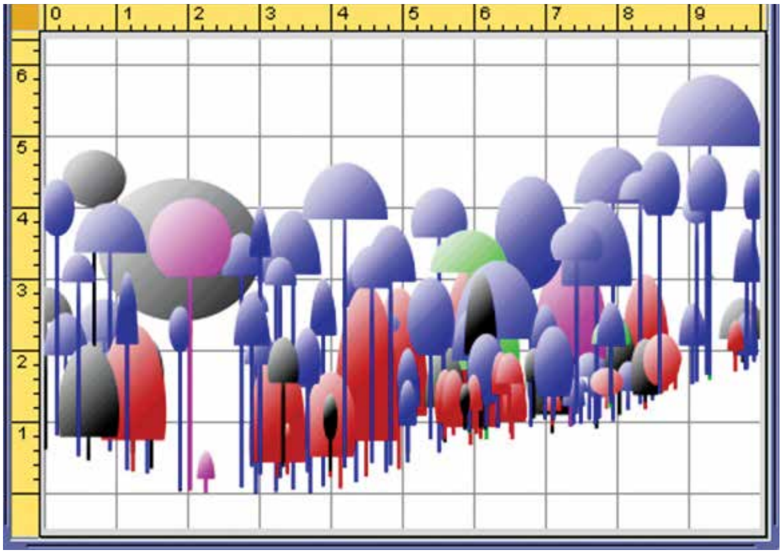
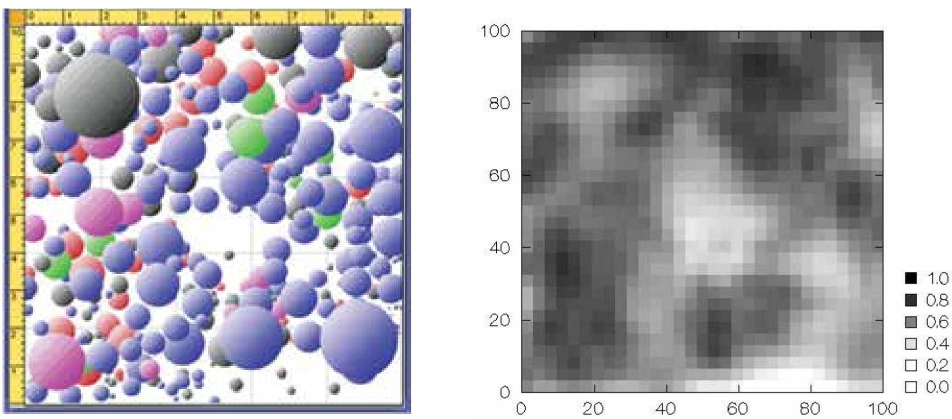


Figure 14.3. An elevation grid interpolates individual tree altitude



Aerial view of a one-hectare stand of Damar agroforest in Sumatra

Map of canopy closure of stand

Figure 14.4. Depictions of canopy openness in SLIM

A visualization of a damar (*Shorea javanica*) agroforest stand is shown in Figure 14.5. From this simplified 3D geometry of the stand, researchers can explore canopy openness in any position within a plot.

Figure 14.5. Three-dimensional view generated by SLIM of a 1 hectare stand of damar agroforest in Sumatra, Indonesia

■ Key references

Vincent G, Harja D. 2002. SLIM software: a simple light interception model for multi-species, multistrata forests. *Bois et Forets des Tropiques* 272(2):97–100.

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

Website: http://worldagroforestry.org/regions/southeast_asia/resources/slim

15 | Water, nutrient and light capture in agroforestry systems (WaNuLCAS): at the plot level

Ni'matul Khasanah, Betha Lusiana, Rachmat Mulia and Meine van Noordwijk

Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) is a tree–crop–soil interactions model at plot level with daily time steps. The model simulates interactions between crops and trees in sharing and competing for aboveground resource, that is, light, and belowground resources, that is, nitrogen, phosphorous and water. The model can be used to assess the performance (production and profitability) of agroforestry systems under different management regimes with different spatial and temporal configurations.

Introduction

A focal point in assessing the performance of agroforestry systems is how trees and crops use resources of light, water and nutrients and at what point their interaction becomes competitive or complementary. Tree–crop–soil interactions occur both in space and time. Thus, in modelling agroforestry systems a balance should be maintained between dynamic processes and spatial patterns, between temporal and spatial aspects.

The WaNuLCAS model (van Noordwijk and Lusiana 1999, van Noordwijk et al 2004) was developed to deal with a wide range ofagroforestry systems: hedgerow intercropping on flat or sloping land; fallow–crop mosaics or isolated trees in parklands; with minimal parameter adjustments. The model was developed using the STELLA platform and based on physiology and above- and belowground architecture of trees and crops. Trees and crops interact and share resources (light, water and nutrients) (Figure 15.1) in four soil layers and four horizontal zones (Figure 15.2A). Their interactions are interpreted in different modules (Figure 15.2B).

Assessment of tree–crop interaction in different systems and practices such as agroforestry can be tested and analyzed directly in the field by establishing experiments but this requires a lot of time, labour and cost. The assessment is needed to manage trees and crops in order to maximize production and to minimize negative competition. WaNuLCAS can be used to overcome these limitations.

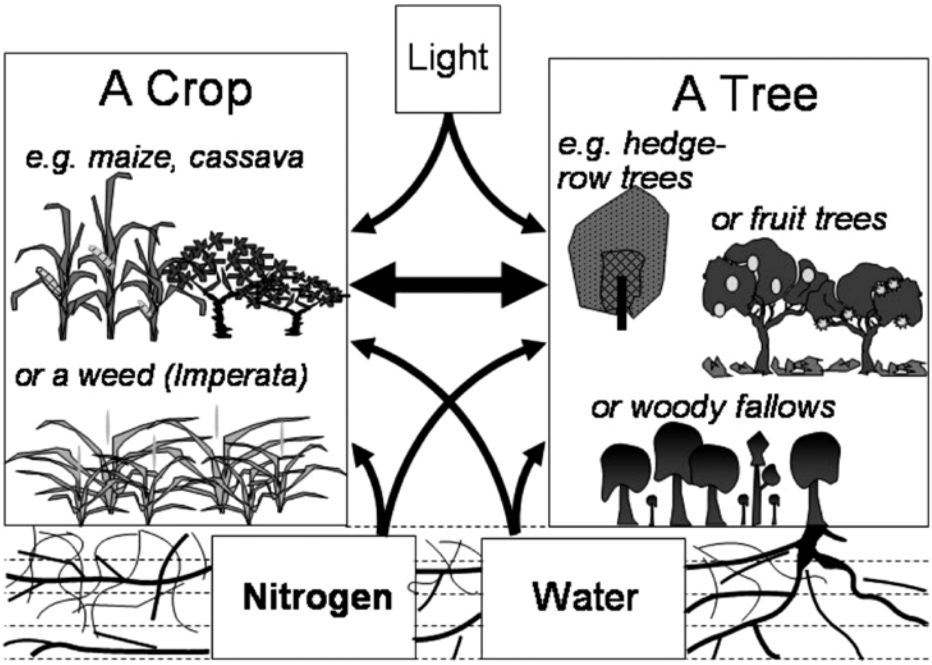


Figure 15.1. Components in WaNuLCAS

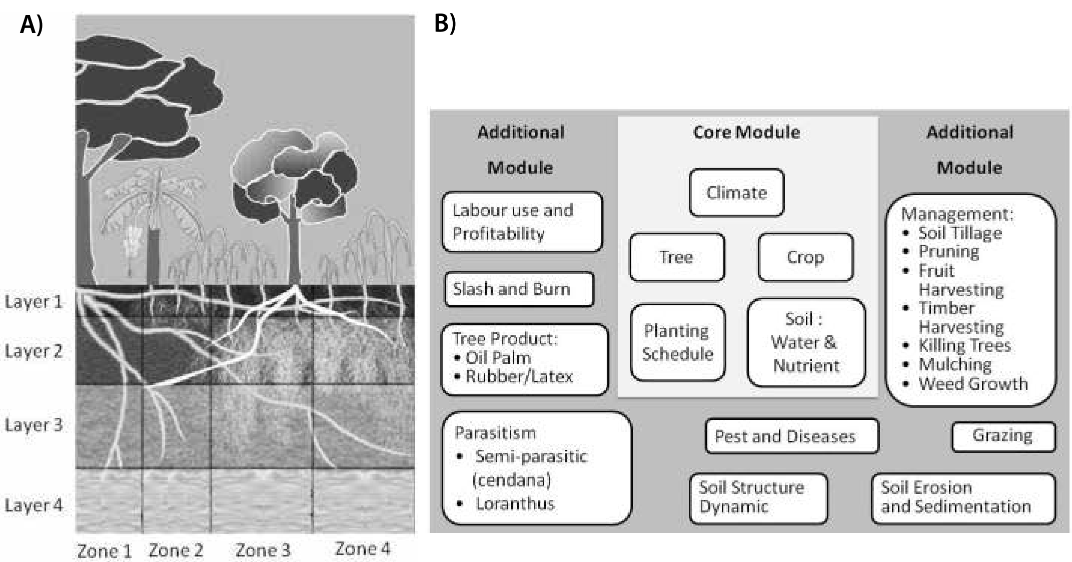


Figure 15.2. A) General layout of zones and soil layers in WaNuLCAS. B) Modules in WaNuLCAS that represent trees and crops sharing light, water and nutrient resources

Objectives

The objectives of WaNuLCAS are:

1. to explore new agroforestry practices before they are applied in the field;
2. to explore tree–crop interaction that cannot be done in the field.

Steps

Steps involved in WaNuLCAS application:

1. model parameterisation for calibration and validation test;
2. model calibration and validation;
3. model performance evaluation by comparing measured and simulated data; and
4. simulation of scenarios.

Example of application

In Indonesia, a decreasing forest area and a logging moratorium have seen timber production increasingly coming from smallholding systems. Inadaquate tree management in these systems has often led to low quality timber and hence low revenues for farmers. Researchers carried out ex-ante analysis with WaNuLCAS to explore the effect of different management practices on growth and production of intercropped teak and maize.

The study considered a three-treatment factorial: 1) initial teak density (1600 trees ha^{-1} (2.5 x 2.5 m), 1111 trees ha^{-1} (3 x 3 m) and 625 trees ha^{-1} (4 x 4 m)), 2) thinning (light (25%), moderate (50%) and heavy (75%) of tree density); and 3) pruning (40% and 60% of crown biomass). Researchers compared intercropping with both teak and maize monocultures to examine the trade-offs in different management options. An economic evaluation using profitability analysis was also carried out that took into account the cost of labour (for thinning and pruning) and its effect on additional timber revenue.

Result 1. Trade-off between trees and crops

Cumulative maize yield in the first years of teak growth was negatively correlated with tree density and 10–38% higher when tree density was reduced. All intercropping practices produced higher wood volume when compared with monoculture because the trees benefited from crop management and fertilization.

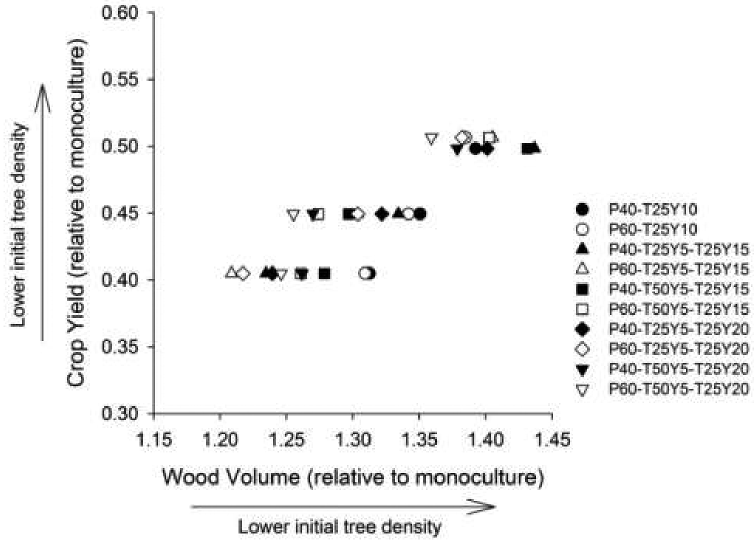


Figure 15.3. Trade-off analyses between tree and crop performance for various scenarios

Note: P: pruning, T: thinning, Y: Year; i.e P40-T25Y5-T25Y15: 40% crown pruned, thinning 25% at year 5 and 25% at year 15. Wood volume is the volume of remaining trees in field at year 30 (harvest time)

Result 2. Wood volume

Maximum wood volume (m^3 ha^{-1}) was provided by the system with initial tree density of 625 trees ha^{-1}: 25% of it was thinned at year 5 and another 25% at year 15; 40% of the crowns were pruned at years 4, 10 and 15. However, greater stem diameter per tree was provided by 50% of thinning at year 5 rather than 25% of thinning at year 5.

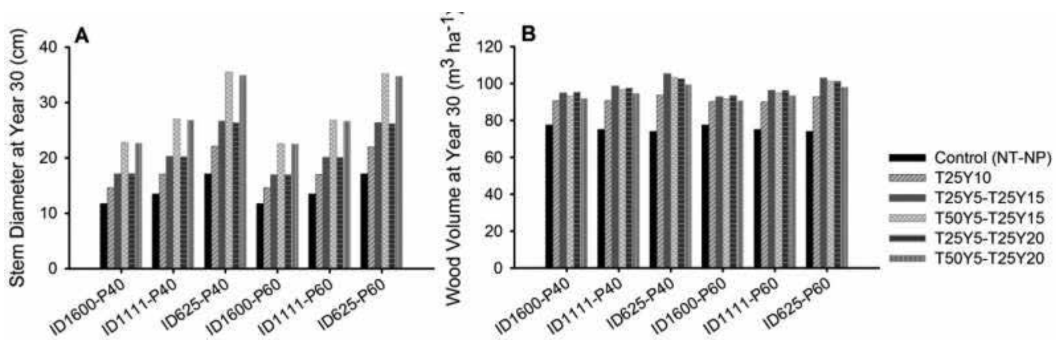


Figure 15.4. A) Wood volume, m3 ha^{-1}; and B) stem diameter, cm; presented at various treatments

Note: P: pruning, T: thinning, Y: Year, ID: initial tree density, i.e. T25Y5-T25Y15: thinning 25% at year 5 and 25% at year 15; ID1600-P40: initial density 1600 and 40% crown pruned. Wood volume is the volume of remaining trees in field at year 30 (harvest time)

Result 3. Economic analysis

The highest NPV and return to labour was provided by the system with initial tree density of 625 trees ha^{-1}: 50% of it was thinned at year 5 and another 25% at year 15; 40% of the crowns were pruned at years 4, 10 and 15.

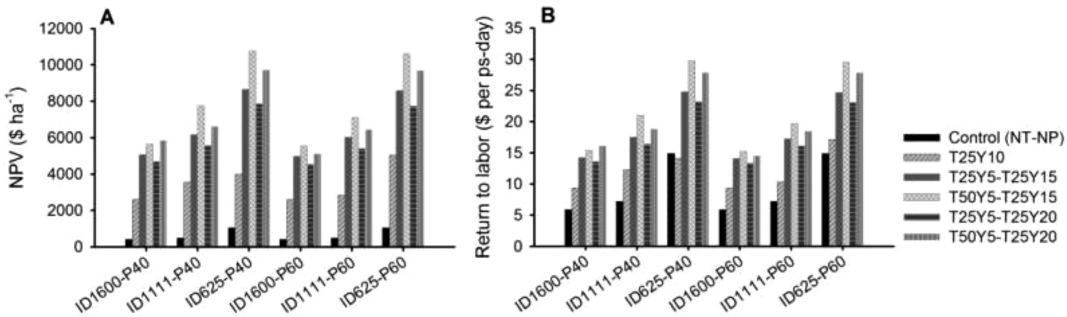


Figure 15.5. A) NPV; and B) return to labour; presented at various treatments

Note: P: pruning, T: thinning, Y: Year, ID: initial tree density, i.e. T25Y5-T25Y15: thinning 25% at year 5 and 25% at year 15; ID1600-P40: initial density 1600 and 40% crown pruned. Wood volume is the volume of remaining trees in field at year 30 (harvest time)

How to get WaNuLCAS?

WaNuLCAS can be downloaded from http://worldagroforestrycentre.org/regions/southeast_asia/resources/wanulcas.

Further reading

Khasanah N, Perdana A, Rahmanullah A, Manurung G, Roshetko J, van Noordwijk M, Lusiana B. 2013. *Trade-off analysis and economic valuation of intercropping teak (*Tectona grandis*)–maize under different silvicultural options in Gunung Kidul, West Java*. Paper presented at the Tropentag Conference 2013, 17–19 September 2013, Stuttgart-Hohenheim, Germany.

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, Lusiana B, Khasanah N, Mulia R. 2011. *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 Regional Program.

16 | Spatially explicit individual-based forest simulator (SExI-FS): for management of agroforests

Degi Harja and Gregoire Vincent

The Spatially Explicit Individual-based Forest Simulator (SExI-FS) simulates tree-to-tree interactions in multispecies agroforests. The model uses an object-oriented approach whereby each tree is individually modelled. Individual trees interact by modifying their neighbours' environment and competing for two major aboveground resources: space and light. An optimum scale for 3D representation of the agroforest plot is 1 hectare.

Introduction

The structural complexity of traditional agroforestry systems defies classical forestry approaches in optimizing management practices. To cope with this complexity, farmers have adopted tree-by-tree management, which is closer to gardening than to the usual tropical forestry or estate crop management model. Care and regular tending of individual trees can involve transplanting seedlings, selective cleaning and felling, and adjusting harvesting intensity.

The way that farmers approach these traditional systems appears to be in line with two basic tenets of biology: first, all individuals are different with their own particular behaviour and physiology resulting from a unique combination of genetic and environmental influences and, second, interactions are inherently local. Based on these premises, SExI-FS was developed to explore different management scenarios. SExI-FS provides insights about the critical processes and parameters of a system's dynamics in a complex agroforest. It also allows for the exploration of prospective management scenarios and helps with assessing the relevance of current management techniques. More direct applications of SExI-FS include using the model to compare the financial returns from alternative scenarios, such as the financial returns of rotational agroforests against those of permanent agroforests. The schematic diagram of SExI-FS is shown in Figure 16.2.

Objectives

The major objective of the model is to achieve a coherent and dynamic representation of a complex agroforestry system. This includes predicting the dynamic growth of a mixed-tree stand, its potential productivity and aspects of tree-growth competition. Graphical user interfaces help the user to explore various scenarios and plot designs and to predict the performance and productivity of each species' component (Figure 16.1).

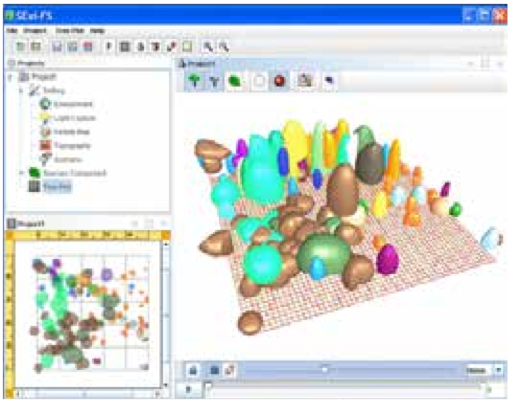


Figure 16.1. SExI-FS includes 3D visualization interfaces for a better view of a simulated scenario

Steps

SExI-FS (http://worldagroforestrycentre.org/regions/southeast_asia/resources/SExI-FS) runs on any platform that supports Java Virtual Machine (http://java.sun.com).

Species-specific parameterizations required for the model are: growth rate function, allometric relationship diameter at breast height (DBH) with height, allometric relationship of DBH with crown width and species' sensitivity to light. Ecological parameters include topography, soil-fertility map and parameters related to how light is captured by trees.

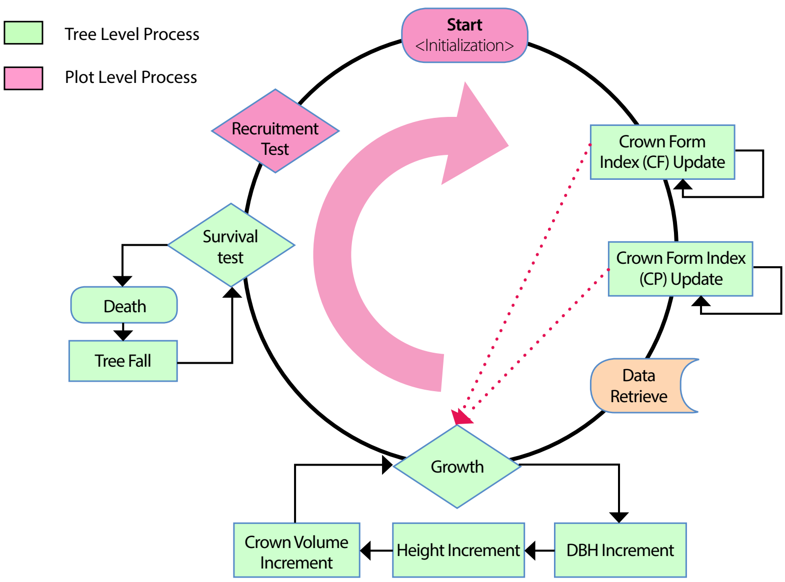


Figure 16.2. Main loop in the SExI-FS computer model. The loop runs on a yearly basis and starts with an initialization. Next, the tree-crown attributes, Crown Form Index (CF) and Crown Position Index (CP) are updated. Tree growth is then computed (diameter, height, and crown volume increment). At each step and for each tree, a survival test is undertaken. Finally at the stand level, a recruitment test is conducted

Case study: SExI-FS with RaLMA

SExI-FS has been used to explore the performance of various agroforestry scenarios (Harja et al 2005) and the potential role of trees in reducing the risk of landslides.

In the district of Bogor, West Java province, Indonesia, urban development had led to a significant reduction in tree cover and the conversion of agroforests to other land uses. This had triggered large landslides that caused the loss of lives as well as major economic losses and damage to infrastructure. In February 2007, about 300 households were considered to be at risk from landslides and were advised by the government to evacuate.

A bioengineering strategy for reducing land movement and preventing accidents requires information on the location of trees that have a confirmed capacity to anchor soil. The rate of root development will determine the options for stabilization. The study of areas at risk in Bogor could contribute to the development of prevention strategies, particularly in the context of climate-change adaptation, when the incidence of periods of extreme rainfall is expected to increase and the need for landslide prevention will become more pronounced.

The use of SExI-FS was aimed at exploring differences between tree species in terms of root development (in both the topsoil and in deeper layers of soil) that contribute to differences in soil binding and anchoring that can reduce downslope movement (at the level of the tree-root system).

Landslide risk needs to be evaluated at the hill-slope rather than at the tree level. For this reason, we recorded all trees in a 50 x 50 m plot and measured the indices of root anchoring (IRA) and binding (IRB) of tree species under local conditions (Figure 16.3). The SExI-FS model was able to simulate the role that trees can play to reduce the risk of landslide by quantifying the IRA and IRB within a tree plot (Figure 16.4).

The result of simulations of plot-management sensitivity scenarios showed that it was better to maintain plot density at an optimum size. This is because increasing plot density above the optimum size does not significantly increase plot root binding (although plot root anchoring does increase).

The selection of species based on IRB and IRA (van Noordwijk et al 2006) values is an acceptable approach to reducing landslide risk. Other considerations are farmers' preferences and the costs and benefits of various agroforestry scenarios.

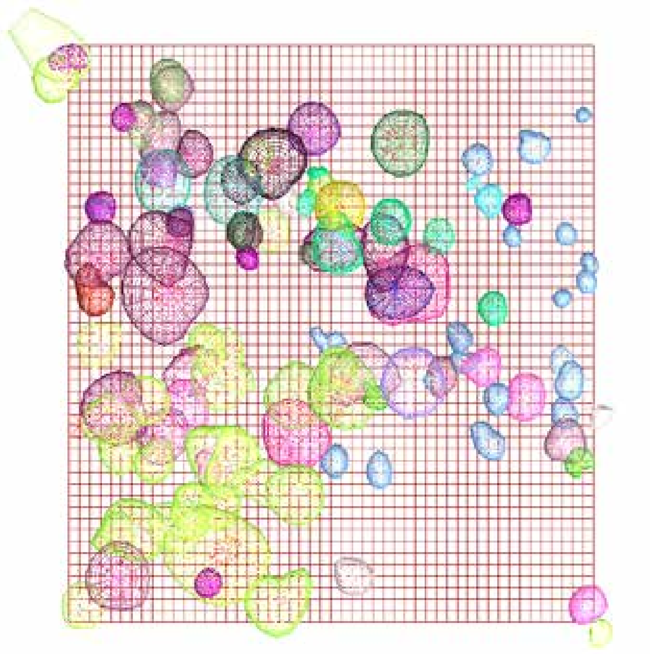


Figure 16.3. A schematic aerial view of all trees in a 50 x 50 m plot

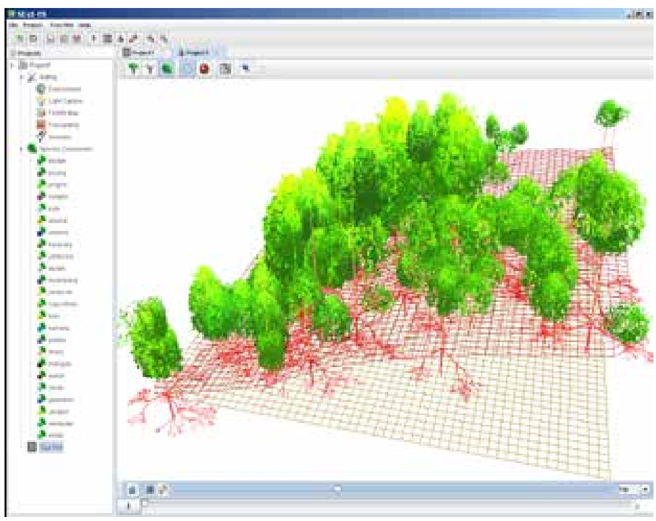


Figure 16.4. Representation of canopy and root systems in the 50 x 50 m plot using SExI-FS, showing how the trees' anchoring and binding function prevented landslides

Key reference

Harja D, Vincent G. 2008. *Spatially Explicit Individual-based Forest Simulator: user guide and software.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Marseille, France: Institut de Recherche pour le Développement.

17 | Adopt and learn: modelling how decisions are made and the flow of information

Meine van Noordwijk, Betha Lusiana and Desi A. Suyamto

Adopt and Learn is a simple model of an 'adoption' process. It explores how farmers learn of new technology or information and eventually make a decision to adopt or not. The model is useful for understanding factors influencing the success or failure of a technology-dissemination project, including the role of extension agents. The model works at community scale with a diversity of agents and their multiple learning styles.

Introduction

Adoption of 'new' or 'better' land-use practices, compared to the existing ones, depends on many factors. These factors can be broken down into two main factors: internal and external factors. How and by whom (agent of change) the technology was disseminated are external factors that influence farmers' perceptions and trust of the technology. Internal factors relate to the style of learning of the farmers themselves, whether they tend to be 1) conservative, that is, resisting change and preferring 'old' technology'; or 2) experimental, that is, always trying new and quickly discarding 'old' technology. Usually, farmers' learning styles will be in-between the two extremes: they will be willing to experiment but need experience or to see how others experience the new technology before they make a decision to adopt or not.

Adopt and Learn was developed to simulate such a situation. The model was initially developed as a module to be incorporated into dynamic models of land-use change. The model assumes that farmers make decisions among the options available on the basis of their perceptions of the relative merits of these options for local conditions. Farmers also take into account the specific constraints and availability of resources on their farms. The perceptions of the relative merits can change with time on the basis of experience obtained through external contacts with extension agents.

Objectives

Adopt and Learn provides an analytical framework for understanding factors influencing the success or failure of a technology dissemination project, including the role of extension agents.

Steps

Adopt and Learn was developed in the STELLA programming language and can be incorporated as a module in more comprehensive models. Specifically, the model explores eight aspects.

1. The expected performance of the 'new' technology with existing practices, taking into account local resource options and constraints.

2. The variability of performance of the 'new' technology' in the various local settings (different farmers with different learning styles; different plots with different inherent soil fertility; and different financial capital). The variability measures the degree of risk involved in the 'new' technology project to fail in meeting its minimum targets.
3. The actual year-to-year performance of the 'new' technology' in the various local settings.
4. The divergence between farmers' perceptions of the 'new technology' with distribution of actual performance carried out by all farmers.
5. The way actual experience with the performance of land-use options (managed using 'new' technology) in the local environment can lead to changes in perception ('learning style').
6. The way decisions are made, in particular how relative preference is given to the option that is perceived to be the best ('prioritization').
7. The fraction in the total population that follows an 'experimental' strategy in its learning style (with the remainder assigned the 'conservative' strategy).
8. The impact of 'adaptation' or local fine-tuning of the performance of the various options, indicated by increase in average performance mean and/or increase in stability.

Adopt and Learn simulates the interactions between the above factors and allows users to focus on five important questions.

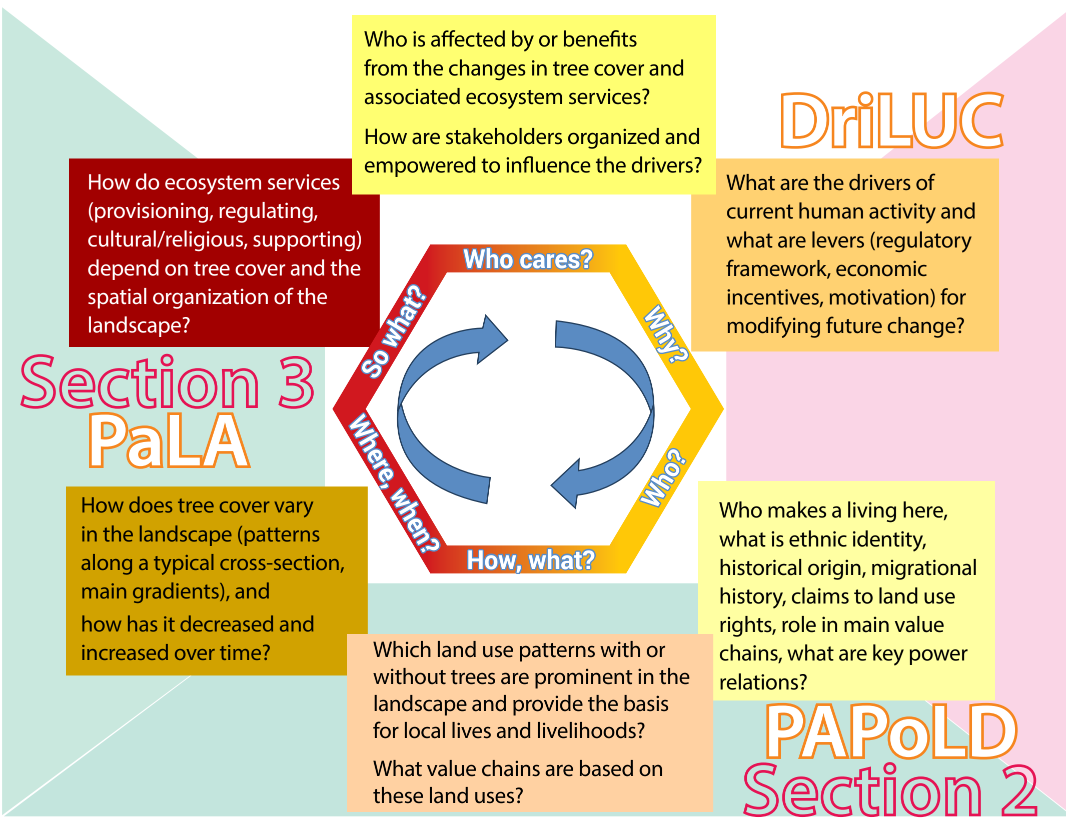
1. How long will it take before 'superior' land-use options will become the preferred choice for the two strata of farmers (conservative and experimental)?
2. What impact will the 'adopt and learn' process have on the actual benefits that the farmers gained in both groups, relative to that prior to use of 'new technology'?
3. Does the magnitude of fraction of experimenters modify the time to adoption and the actual benefits achieved by the conservatives?
4. Under what conditions can the exposure of farmers to the 'perceptions' of extension agents help in the adoption process?
5. How long can we expect the transient state with mosaics of different land-use types to last and contribute to agrobiodiversity?

Example of application

Adopt and learn concept is at the heart of the scheme used in Figure 8.2 to explore gender differentiation of land-use decisions (Villamor et al 2014).

SECTION 03

Landscape: ecosystem services, tradeoffs



18 | Analysis of land-use and -cover trajectory (ALUCT)

Sonya Dewi and Andree Ekadinata

Analysis of land-use and -cover trajectory (ALUCT) provides basic spatial information to support other tools in appraising watershed functions, agrobiodiversity conservation and carbon stocks, and building land-use and land-use-change scenarios.

Introduction

Maps representing the landscape have to represent land cover (what is there), land use (what it's used for) or some combination of the two. Land-cover maps can be derived from the multi-spectral reflectance of the Earth's surface recorded from satellite or airborne sensors, supported by ground information of spatial patterns and processes (Thomas et al 2004). A land-use interpretation will generally require further information sources beyond current cover. Different interpreters may come up with different maps from the same satellite imageries because the potential legend categories of land-use/-cover maps are infinite. Figure 18.1 shows multiple concepts of forest leading to differed deforestation rates.

ALUCT plays an important role in several of the tools described in this book, including RaCSA, RHA, RABA, FALLOW, RaTA and DriLUC.

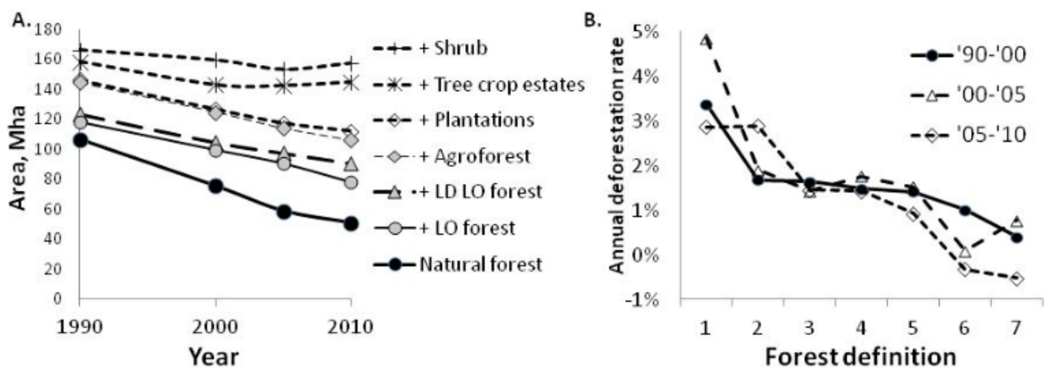


Figure 18.1. Dependence of Indonesia's 'deforestation rate' on the operational definition of forest
Source: van Noordwijk et al 2013

Objectives

The ALUCT procedure was designed to form a systematic approach to spatial analysis, where the intended users of information in interdisciplinary contexts and with science-policy interfaces in mind, interact with the distinctions that can technically be made.

Steps

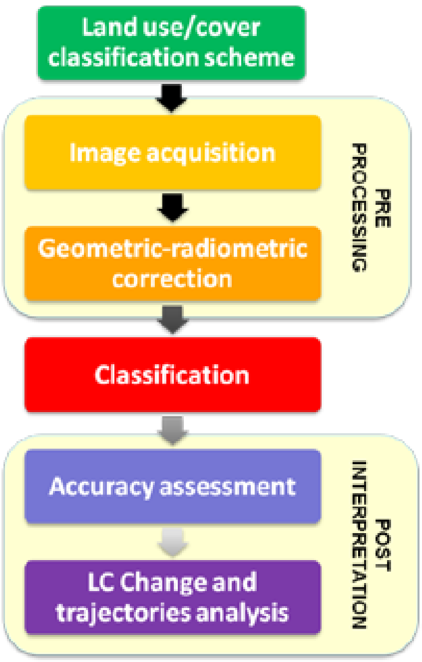


Figure 18.2. The ALUCT workflow

1. *Clarification of the questions*, leading to the level of detail needed in the legend of land-cover types and the resolution of images needed to do so
2. *Image acquisition* and *pre-processing*: selecting the resolution, spectral properties and source of the images, selecting an image date relevant to the study and of sufficient quality (low cloud cover)
3. *Image classification* based on field-tested sample points and/or pre-established spatial patterns
4. *Post-interpretation analysis* focussed on the research questions of interest, usually linking 'land use' and system lifecycles to the land-cover types that can be recognized

1. Clarifying the questions: designing legend categories

In deciding on legend categories, the researchers have to consider: 1) the information content and its limitation for specific image sources ; 2) the on-the-ground reality of agents and drivers of land-use systems and land-use changes; 3) the description of each category of land use and land cover; 4) and the application of the produced maps.

Often, remote-sensing specialists tend to focus on what is technically achievable without much consideration of what should be recognized and so classification efforts result in empirical representation only, unguided by any theoretical basis. To avoid this, legend categories should be designed such that they can reveal differences among categories in providing environmental services, as results of varying drivers, and as perceived by land managers, especially farmers and local people, as an integral part of their livelihoods, that is, local use value. Figure 18.3 provides an example of legend categories in the context of measuring GHG emissions of oil palm plantations in Indonesia. For this purpose, the researchers specified the oil palm categories: old, mature and young.

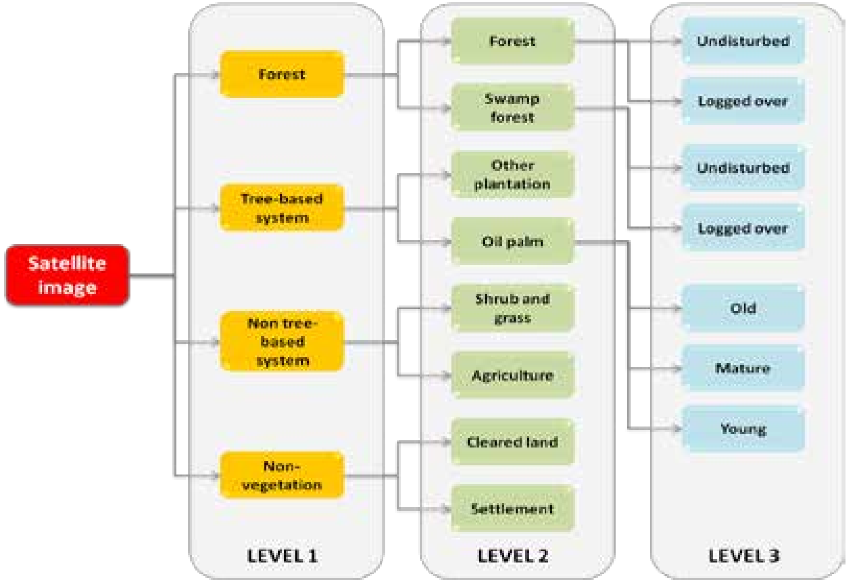


Figure 18.3. Land-use-system legend categories in a hierarchical classification structure

2. Image acquisition and pre-processing

Time coverage, spatial resolution, and *amount of cloud cover* are three main criteria used in selecting the best satellite images for any study. Middle-resolution satellite images, such as Landsat (30 m resolution) and SPOT (20 m resolution) are usually used for basic studies (Figure 18.4), with high resolution imagery, such as IKONOS and RapidEye (< 1 m) for specific areas. Coarser resolution but frequent data acquisition, such as SPOT Vegetation, NOAA-AVHRR and MODIS, are commonly used for regional and global monitoring of changes. In the tropics with high incidence of cloud cover, sometimes a combination of optical and radar imageries is necessary.

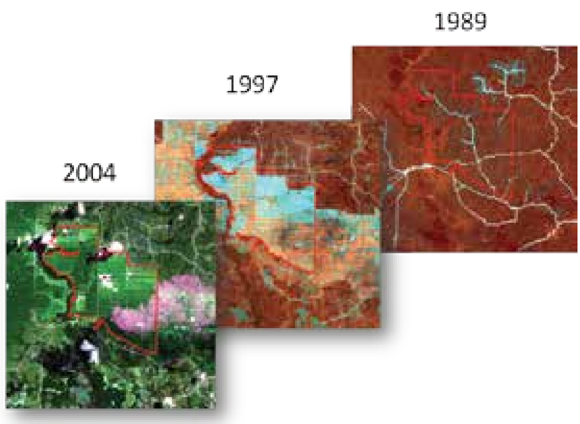


Figure 18.4. Time-series Landsat image

3. Image classification

There are several options for image classification, ranging from visual interpretation, which relies on manual delineation and ground familiarity of the operator, through to unsupervised classification, which uses statistical analysis to differentiate spectral reflectance based on digital numbers only. Between the two extreme approaches there are gradients and hybrid approaches, such as supervised classification and a mix of object-based and unsupervised classification. There is no one best approach within the huge variation involved with mapping, resolution of imageries and objectives of the mapping. However, three main principles, regardless of the approaches, should be observed: 1) given the same imageries and legend categories, the resulting maps should not be too different; 2) using ground information is a 'must' in assessing the accuracy of the maps; 3) for a map to be useful the accuracy has to be high enough; as a rule of thumb, 80% accuracy should be achieved.

4. Post-interpretation analysis

Once a series of maps is produced from multi-year image acquisitions, several analyses can be conducted in conjunction with other data layers, such as land-use plans and road network:

1. temporal changes of areas of each land-use and land-cover class, for example, primary forest cover declines from x hectares in 1990 to y in 2000;
2. trajectories of changes of each particular area in the landscape and areas of each trajectory, for example, x hectares of primary forests in 1990 converted into rubber plantations in 2005 and settlements in 2010;
3. areas of each land-use and land-cover class within a particular zone, for example, x hectares of oil-palm in the protected forest zone in 1990;
4. trajectories of changes within particular zones, for example, x hectares of secondary forests converted to oil-palm plantations in the protected forest zone and y hectares in the production forest zone between 1990 and 2000.

Example of ALUCT in a study of oil-palm plantations in Indonesia

To analyze the plantation history and associated 'carbon debt' of plantation establishment, ALUCT was deployed in two pilot areas in Indonesia using time-series, land-cover maps from satellite images. In the context of understanding carbon debt, data was required to cover a sufficient time period of before and after plantation establishment. To get a complete picture of the area, it was also necessary to quantify the changes in the plantation's surrounding area. Therefore, three main outputs from the analysis were:

1. time-series, land-cover maps covering the period before and after oil-palm establishment;
2. land-cover-change quantification of the estate area and its surroundings; and
3. land-cover trajectories for the period of analysis.

Legend categories were designed in a hierarchy and structured within three levels, from general to finer classes (Figure 18.3). 'Forest' as a class was separated further into 'dry' and 'swamp' forest of different density, that is, 'undisturbed', 'logged-over high density' and 'logged-over low density'. This separation is important as we know that by lumping together varying densities of forests the uncertainty of magnitude of carbon stock is huge, which has consequences for the conclusion of the study if not managed properly. The hierarchy itself was designed such that the classification process was most efficient. Time-series, orthorectified, Landsat images covering the periods 1989, 1997, 2001 and 2004 were used to produce the land-cover maps (Figure 18.4).

The object-based hierarchical classification approach (Ekadinata and Vincent 2011) was used at the stage of image classification. In this approach, image classification began with a series of image segmentations. The result is called multiresolution image segments, which serve as a basis for the hierarchical classification system (Figure 18.5).

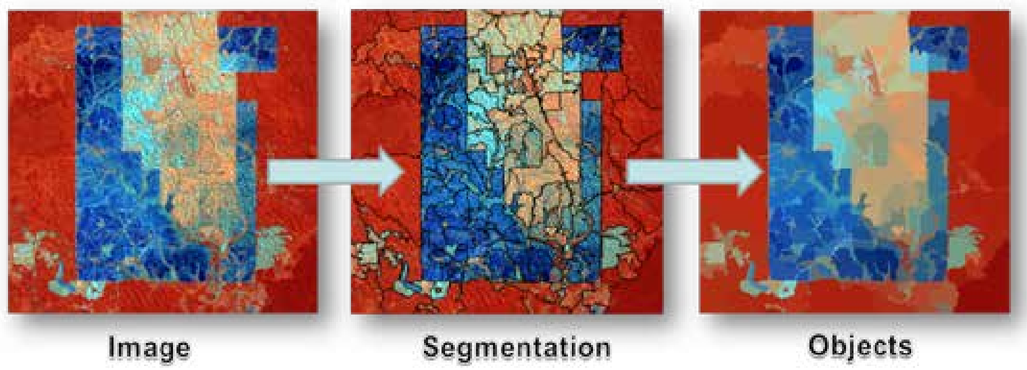


Figure 18.5. Multiresolution image segments

Following the segmentation process, image classification was conducted using the hierarchical structure developed in Step 1. The hierarchy is divided into three levels. At each level, land-cover types were interpreted using spectral and spatial rules. Level 1 consisted of general classes, such as 'forest', 'tree-based systems', 'non-tree-based systems' and 'non-vegetation'. These classes could be easily distinguished using visual inspections and a simple vegetation index. The result of Level 1 was further classified in Level 2, using field reference data. A 'nearest neighborhood' algorithm was used to distinguished a total of nine land-cover types: 'forest', 'swamp forest', 'oil palm', 'shrub', 'grass', 'agriculture', 'cleared land' and 'settlement'. Some of the classes in Level 2 were further classified in more detail in Level 3. At this level, spectral value was not the only parameter used. Spatial characteristics, such as distance to settlement, proximity to visible logging roads, forest concession status, and plantation maps could be used as rules in the classification. At the end of the classification process, an accuracy assessment was conducted by comparing the resulting maps of most recent imagery with the data collected in the field.

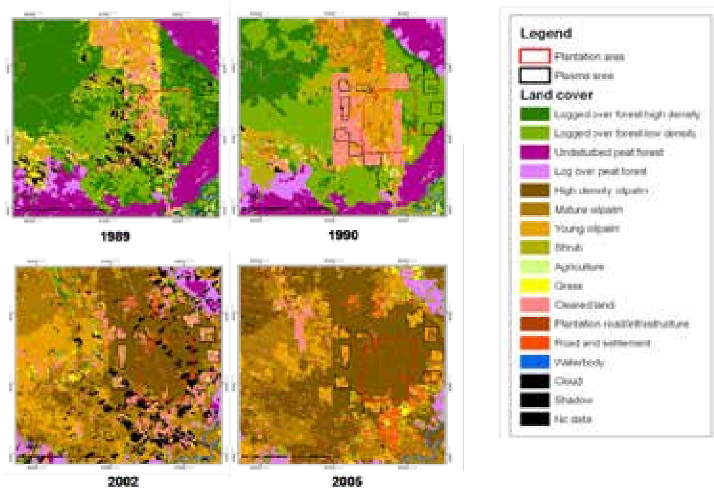


Figure 18.6. Time-series, land-cover map

The last step in ALUCT is the land-cover-change analysis itself. Two forms of analysis were conducted for each study site: area-based-change and trajectories. These were conducted for three zones: 1) plantation areas; 2) plasma[1] areas (if any); and 3) all areas outside plantation and plasma. The result provided an indication of the overall trend of land-cover changes in an area and its surrounding.

Further information was needed on the location and trajectories of changes, so a trajectories analysis formed the next step. Trajectories of changes are the summaries of a change sequence over all time periods, observed at pixel level (Figure 18.7 and 8). In the context of understanding the carbon budget for oil-palm plantations, types of trajectories were designed to be able to capture changes in carbon stock caused by land-cover changes.

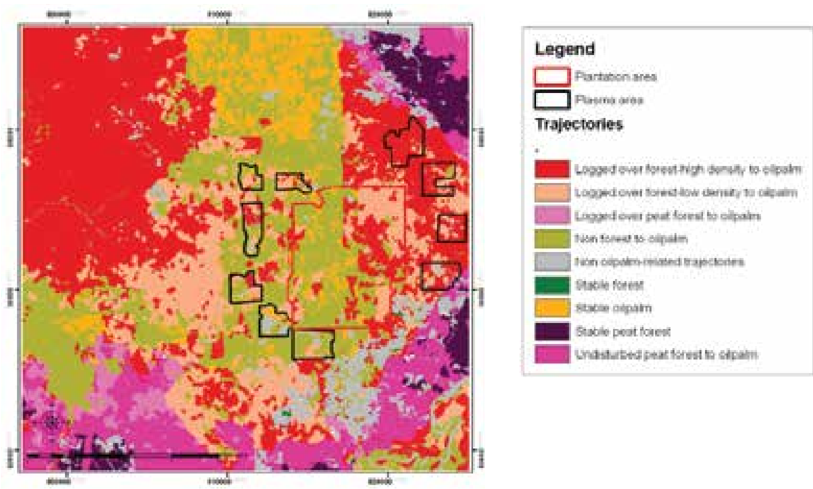


Figure 18.7. Trajectories map

[1] 'Plasma' in this context describes a scheme whereby a large plantation forms a 'nucleus' around which there are smallholding plantations, the 'plasma'.

The trajectories map showed all oil-palm-related sequences of changes, the locations and spatial patterns in the study area. Trajectories analysis clearly showed that more than 40% of conversions inside plantation areas started from logged-over forest. Nearly half were in the high-density, logged-over forest areas.

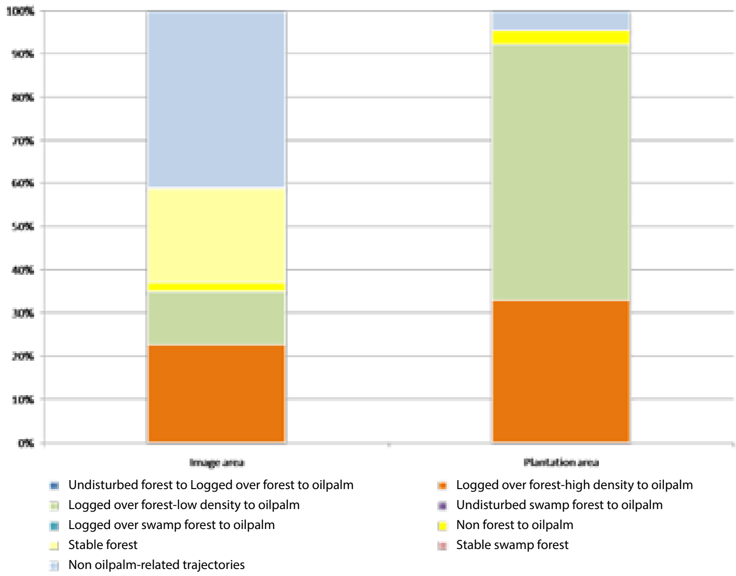


Figure 18.8. Summary of trajectories analysis

Often, for quick and qualitative references, publicly available maps, such as those provided by Google Earth, are very useful (Figure 18.9). As many of the scenes are available in graphic format of high resolution, interpreters also use these as additional data to assist interpretation, especially if GPS points of data in the field are scarce.

Figure 18.9. Google Earth: a public-domain perspective on how oil-palm plantations are spatially and chronologically linked to logging concessions in Kalimantan, Indonesia

Key references

Dewi S, Khasanah N, Rahayu S, Ekadinata A, van Noordwijk M. 2009. *Carbon footprint of Indonesian palm oil production: a pilot study*. Bogor, Indonesia:World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. http://worldagroforestry.org/sea/publications?do=view_pub_detail&pub_no=LE0153-09.

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.

Useful websites

http://www.google.com/earth/index.html
http://rst.gsfc.nasa.gov/Front/overview.html (online remote-sensing tutorials)

19 Trade-off matrix between private and public benefits of land-use systems (ASB Matrix)

Thomas P. Tomich and Meine van Noordwijk

The Trade-off Matrix between Private and Public Benefits of Land-use systems (ASB Matrix) provides in one table an overview of key characteristics of land-use systems that coexist in a landscape and form alternatives to each other. The rows form the land-use systems and the columns hold key characteristics that are of local, national and/or global concern, such as employment, profitability, sustainability, biodiversity and carbon stock.

Introduction

Policy-makers need accurate, objective information on which to base their inevitably controversial decisions. The ASB Matrix can help them consider the difficult choices they must make. In the ASB Matrix, natural forest and the land-use systems that replace it are scored against different criteria reflecting the objectives of different interest groups. To enable results to be compared across locations, the systems specific to each are grouped according to broad categories, ranging from agroforests to grasslands and pastures (Tomich et al 1998).

The ASB Matrix is a key example of a 'boundary object' (Clark et al 2011). It is the result of 'boundary' work at the interface between science, policy and local concerns and reflects the effort to jointly define knowledge products and a legitimate pathway to derive them.

Objectives

The objective of the ASB Matrix is to summarize and synthesize information about the multiple functions that land-use systems fulfil in a landscape, combining economic and environmental perspectives, and to allow quantitiative trade-offs between the functions to be explored (with true win-win solutions as a rare exception). The method of deriving the matrix is aimed at two types of boundary work: between the various disciplines of science; and between science, policy and local stakeholders.

Steps

Construction of the table relies on the use of methods for a consistent classification of land-use systems (see RAFT) that is compatible with spatial analysis (ALUCT), profitability analysis (LUPA) and the derivation of time-averaged carbon stock (RaCSA). The final choice needs to be made in an interdisciplinary team where categorization of initial classifications that are based on various disciplinary preferences and limitations is jointly considered. The resulting list must be explicit in all distinctions that are important in current public discourse and policy debates, as well as reflecting local knowledge and concerns.

Before beginning, it will be good to discuss with policy-makers (through in-depth interviews and participation in meetings where policy issues are being discussed) which columns and possibly new indicators are relevant. The list for the sample matrix can be taken as a starting point.

Data collection for the various cells in the matrix will, to the degree possible, have to be based on co-location of socio-economic and ecological sample points to ensure that the system properties are aligned, and trade-off estimates are unbiased.

Example of application

The ASB Matrix was first used in the Alternatives to Slash and Burn (ASB) project phase 2 synthesis report for Indonesia in 1998 (Figure 19.1). The numbers and indicators have subsequently been refined.

In 2005, the increasing interest in reducing greenhouse gas emissions led to the profitability and carbon stock data of the matrix becoming the basis of the opportunity cost method (see REDD Abacus).

Table S1. The ASB matrix as a boundary object

	Global environmental concerns		Agronomic sustainability			National policymakers' concerns		Smallholders concerns/ adoptability by smallholders	
	Carbon storage	Biodiversity	Plot-level production sustainability			Potential profitability	Labor requirements	Returns to labor	Household food security
Land use system	Aboveground tC/ha (time-averaged)	Aboveground (plants), species per standard plot	Soil structure	Nutrient export	Crop protection	Returns to land (private prices), $/ha	Labor person, d/ha/y	Dollars per person-day (private prices)	Entitlement path (operational phase)
Forest	306	120	0	0	0	0	0	0	NA
Community-based forest management	120	100	0	0	0	5	0.2–0.4	4.77	$ + consumption
Commercial logging	94	90	−0.5	0	0	1,080	31	0.78	$
Rubber agroforest	79	90	0	0	−0.5	0.70	111	1.67	$
Rubber agroforest with clonal material	66	60	−0.5	−0.5	−0.5	878	150	2.25	$
Oil palm	62	25	0	−0.5	0	114	108	4.74	$
Upland rice/bush fallow	37	45	0	−0.5	−0.5	−62	15–25	1.47	Consumption
Continuous cassava/imperata	2	15	−0.5	−1.0	−0.5	60	98–104	1.78	$ + consumption

ASB created the ASB Matrix to show the relationship between alternative land uses (including natural forest) and key evaluation criteria. The matrix served as a "boundary object" at the interface of a variety of information users (who defined the rows and columns of the matrix) and scientists (who devised the metrics and conducted the measurements that fill the cells). Reproduced here is the original version of the matrix as reported in an internal ASB report in 1998 (1). A fuller discussion of the matrix and its uses, together with the final version of the matrix for a number of ASB cites, has been published in the project's final report (2).

1. Tomich TP, et al. (1998) *Alternatives to Slash-and-Burn in Indonesia, Summary Report of Phase II. No. 8* (International Center for Research in Agroforestry, Bogor, Indonesia).
2. Tomich TP, et al. Balancing agricultural development and environmental objectives: assessing tradeoffs in the humid tropics. *Slash-and-Burn Agriculture: The Search for Alternatives*, eds Palm CA, Vosti SA, Sanchez PA, Eriksen PJ (Columbia Univ Press, New York), pp 415–440.

Figure 19.1. ASB Matrix for humid lowlands of Sumatra as represented in Clark et al (2011)

Key references

Tomich TP, Lewis J, eds. 2003. *Balancing rainforest conservation and poverty reduction*. Policybrief 5. Reprinted July 2004. Nairobi: Alternatives to Slash and Burn. http://www.asb.cgiar.org//PDFwebdocs/Policybrief5.pdf.

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 Academy of Sciences of the United States of America*. DOI:10.1073/pnas.0900231108.

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20 Rapid hydrological appraisal (RHA): watershed functions and management options

Meine van Noordwijk, Betha Lusiana and Beria Leimona

Rapid hydrological appraisal (RHA) diagnoses the hydrological situation of a landscape and perceptions and ecological knowledge of its important stakeholders: local, general public and scientific domains. These perceptions and knowledge include information concerning trade-offs between local decisions on land-use practices that influence watershed functions, types of local institutions that can increase effective management of the watershed, and social relationships among stakeholders. The RHA enables an appraisal of the opportunities for negotiating land-use agreements that include rewards for protecting and rehabilitating watershed functions.

Introduction: watershed functions under threat

Water supplies are increasingly unreliable and insufficient during dry seasons; water quality at sources is increasingly poor and damaging floods are becoming more frequent. Improved watershed functions to circulate and store freshwater is an essential solution for such pressing problems. A number of initiatives are working to protect the critical functions of watersheds, including through providing incentives for people in the uplands to modify their land-use practices.

Land use can significantly affect water quantity and quality, water flow regularity, and watershed capacity to prevent landslides and erosion and to stop sedimentation in downstream areas. However, developing an effective incentive system requires clarity of the relationship between land use and provision of environmental services that are of sufficient value to stakeholders to become the basis for rewards (see general introduction to this volume).

Moreover, there are often substantial differences in perceptions among stakeholders in identifying watershed problems and their causes and providing solutions for improved watershed functions. Downstream stakeholders may perceive that only natural forests with high tree density can guarantee provision of environmental services. Upland land-users may encourage more open land-cover types, such as agroforestry, or even open-field agriculture or pasture, to meet their need for livelihoods and watershed functions. On the other hand, a government's response to this situation can either improve the situation or even worsen it, triggering conflict among stakeholders.

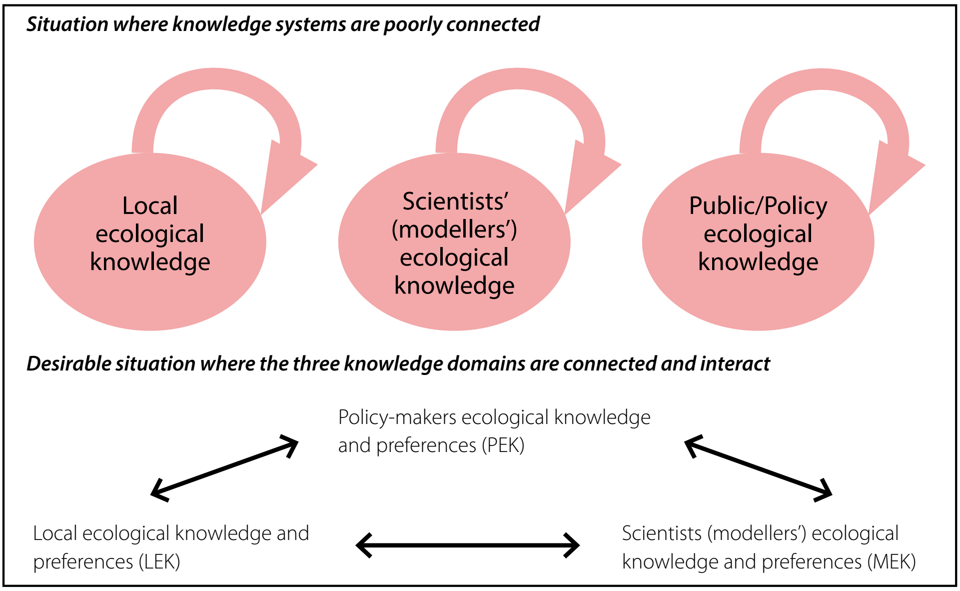

Figure 20.1. Disconnected and desirable interrelationships between three ecological knowledge systems
Note: compare with Figure 0.7

Developing a range of plausible scenarios for change may help negotiations among stakeholders. Appreciation of the various quantitative indicators probably varies by stakeholder group. Therefore, it's important to include the varying perspectives of 'local upland', 'local lowland', 'public policy' and 'ecological hydrology' in any negotiation process (Figure 20.1).

To understand the differing perceptions and their degree of similarity, we use RHA.

Objectives

RHA combines the participatory appraisal process and the use of computer-based, landscape-hydrological simulation models to:

- compare the overlap between stakeholders' perceptions of current and past patterns, process and impacts of land and water use;
- assess biophysical parameters of the watershed and its hydrological and environmental characteristics; and
- project forward the hydrological and environmental implications of current trends or future challenges in land- and water- use patterns through modelled land-use scenarios.

For negotiation purposes, the RHA contributes to a better knowledge system, thus, all stakeholders will be able to:

- understand local land-use patterns, the benefits they provide, alternative land-use options and the drivers of change;

- understand the impact of local land-use changes on watershed functions and the potential 'buyers' who are willing to provide incentives to maintain or enhance specific services; and
- evaluate the level of investment in future negotiations that can lead to a rewards mechanism that will deliver on stakeholders' expectations.

Steps

The approach includes the following activities, which can be carried out in less than 6 months.

1. Land cover/land-use change analysis (see ALUCT).
2. Exploration of the local knowledge of stakeholders about hydrological functions, water movement and the consequences of different land-use options for the landscape.
3. Exploration of the local knowledge of policy-makers about hydrological functions, water movement and the consequences of different land-use options for the landscape.
4. Compilation and analysis of existing hydrological data on the watershed, including a scenario analysis of plausible land-cover change and the likely impact on watershed functions. While watershed functions can include a range of hydrological functions, the RHA focuses on the subset that relates directly to surface water flows. These hydrological functions of watersheds include the capacity to 1) transmit water to freshwater stocks and flows; 2) buffer peak rain events; 3) release water gradually; 4) maintain water quality (sediment, nutrient, pollutants, bacteria leading oxygen demand); and 5) reduce mass wasting, such as landslides.

Table 20.1. Local, public/policy-makers', and modellers/hydrologists' ecological knowledge components

Local ecological knowledge	
Goal	Locally specific analysis of the problem and its causes and effects
Source of information	Key informants and village members
Documents needed	Base map as a foundation for participatory mapping
Questions asked and topics explored	Where are the 'hotspots' within the watershed that cause degradation? What are the existing land-use patterns in the watershed? Who contributes to the current land-use patterns? Why have these land-use patterns developed? What are examples of areas that decrease or buffer watershed degradation? Do good practices for solving watershed problems exist? What are those practices?
Public or policy-makers' ecological knowledge	
Goal	Analyse perceptions regarding watershed-level environmental and water resource problems and their causes and effects
Source of information	Government officers, community leaders and the general public, including downstream stakeholders
Documents needed	Base and thematic maps Environmental reports and watershed profiles
Questions and topics	What and where do watershed problems occur? Who caused the watershed problems? What are the reasons?
	What are the past and current 1) land-use; 2) forest-cover; 3) river-flow; 3) water quality and use; 4) lake; and 5) river problems?
	Are any development projects planned within the watershed? Will these projects cause environmental degradation?

Modellers or hydrologists' ecological knowledge	
Goal	Plausible land-use-change scenarios to analyse drivers and effects on watersheds
Source of information	Land-use modeller and hydrologist
Documents needed	Spatial data: topographic, landform, geology, soil, natural vegetation, land-use time-series and administrative maps Climatic data: daily rainfall Hydrological data: daily water level
Questions and topics	What changes have occurred in the watershed? What are the land-use-change drivers?
	How do land-use changes affect water balance and use within the watershed?
	What are the main indicators affecting watershed water quantity and quality?
	What are the land-cover effects on watershed water balance and river flow?

Case study: RHA at Lake Singkarak, West Sumatra, Indonesia

The first RHA was conducted at Lake Singkarak in West Sumatra, Indonesia, to assess the hydrological situation in the context of developing a payments for environmental services scheme aimed at rewarding the upland poor for protecting or rehabilitating watershed functions.

The study focused on the relationship between the operations of a local hydroelectricity company, fluctuations in the level of the lake, the water quality in the lake and the land cover in the catchment areas that contribute water to the lake. Payments made by the power company to the local government can, in part, be seen as rewards for maintaining or improving environmental services. Nevertheless, there was no shared understanding of the relationship between land cover and the environmental services provided.

The Singkarak Basin hosts rice fields (17%), agricultural crops (15%) and forests (15%). Rice fields occur in the lowland area, below 1000 masl and with slopes of less than 30%, commonly found in the southern part of the basin. Besides rice, other crops—mostly vegetables—are also found in the lowland plains up to 1000 masl. Mixed gardens, shrubs and grass are found in smaller patches all over the basin. In the higher elevations and where the slopes are steeper along the western range of the basin and on the upslopes of Mt Merapi, forest is the dominant land-cover type.

The study included consultations that found there was broad agreement on the need to maintain a clean lake and productive landscapes on hills and irrigated plains that met the food and livelihoods needs of the population and produced electricity for the provinces of West Sumatra and Riau. There was a widely held perception that the landscape was not currently meeting these expectations. The power company was not able to provide as much electricity as needed; fluctuations in water levels were of concern to the people living around the lake; water quality in the lake was poor; the population of the endemic fish, *ikan bilih*, was declining and two prior attempts to rehabilitate the *Imperata* grasslands in the area had not been very successful.

Stakeholders disagreed on the best approaches to watershed management, particularly with regard to reforestation and other means for achieving land rehabilitation. While policy-makers favoured reforestation, using either the local *Pinus merkusii* or another fast-growing tree species, villagers were convinced that reforestation with pine trees caused streams to dry up whereas natural forests provided regular stream flows during the dry season.

A water balance model confirmed a higher water use by pine trees owing to canopy interception and transpiration as compared to more open landscapes but no substantial differences between pine and natural forests. The model further suggested that the performance of the hydroelectric plant was only mildly influenced by land cover (Figure 20.2). Compared to the land-use mosaic at the time, an increase or decrease of 5% of the maximum electricity production could be expected, while the variation between wet and dry years of the 1991–2002 period was much larger. A change in the average annual rainfall owing to climate change would likely have a strong effect on the plant's performance. Declining water quality in the lake and weed infestation would offset any gains in water supply that could result from land degradation. Reforestation with fast-growing evergreen trees would slightly affect the plant's access to usable water. A basic assumption underlying payments for environmental services is that the supply of these services depends on the activities of those receiving the payments. For the power company, this assumption was not supported by evidence.

Payments made by the company could have various rationales.

1. Compensation for damage caused by the hydroelectricity company to the farmers along the Ombilin River whose waterwheel irrigation systems were disturbed and to farmers with rice fields surrounding the lake affected by increased flooding.
2. Shared responsibility for maintaining the quality of the water in the lake as the hydroelectricity company modified outflow rates and increased debris accumulation.
3. Tax payments to the local government.
4. Payments to enhance goodwill with the local community.
5. Payments for environmental services conditional on the delivery of these services.

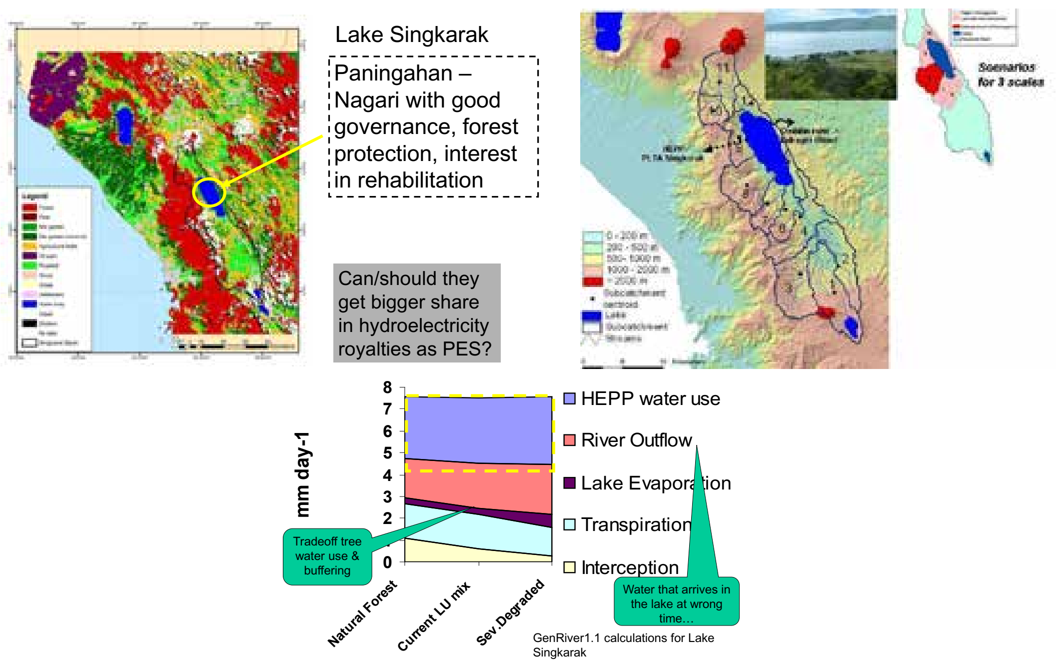

Figure 20.2. Summary of a rapid hydrological appraisal of Lake Singkarak

Table 20.2. State of knowledge before and after the RHA of Lake Singkarak

Before RHA Singkarak	After RHA and follow-up negotiations
▪ Deforestation seen as the main cause of all problems, including electricity blackouts ▪ Tree planting seen as major solution ▪ Belief that the village with most tree cover should get highest share of royalties ▪ Reduction in fish population linked to deforestation.	▪ Focus on lake and water quality ▪ More awareness of the impacts of climate variability ▪ Less blaming of upland deforestation for blackouts ▪ Less focus on tree planting as the principle solution to environmental problems ▪ *Ikan bilih* problem is understood to be caused by polluted breeding grounds and overfishing ▪ Adjust scale of institution in managing the watershed ▪ *Management implications from local perspectives* o Reforestation uses trees with low evapotranspiration. o Local wisdom maintains clean water stream in the upstream and conserving native *ikan bilih* ▪ *Management implication for watershed management and RWS* o Upstream village level: maintaining current intact environment, that is, biodiversity conservation such as organic coffee, voluntary carbon market scheme and watershed services o Villages surrounding the lake: improving water quality of the lake and river

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21 | Rapid landslide mitigation appraisal (RaLMA): managing trees for improved slope stability

Meine van Noordwijk, Kurniatun Hairiah and Degi Harja

Trees can protect slopes from landslides, but can also be a risk factor. Rapid Landslide Mitigation Appraisal (RaLMA) explores local knowledge and the science of landslides and their relationship to trees. The result is an analysis of which trees have complementary functions in protecting slopes. However, not building houses in the likely pathway of landslides remains the primary way to avoid human loss of lives.

Introduction

Major landslides have become have become almost yearly phenomena in Southeast Asia, killing hundreds of people and causing major economic damage.

Heavy rainfall on wet soil on hill slopes can trigger the movement of large amounts of soil. The root systems of forest vegetation and trees play an important role in holding the soil together and the removal of trees and subsequent decay of tree roots may be part of the reason behind the growing number of landslides in the region. Ironically, trees contribute to the build-up of soil that eventually becomes too heavy for the steepness of the slope. Landslides, or slope instability, can also be caused by the construction of roads and other structures that interfere with the paths of water flow down a slope.

In public discussions, landslides in Southeast Asia are often attributed to deforestation. However, other factors need to be considered when it comes to understanding landslides and how to prevent them.

A. No one would notice landslides (which are a natural part of soil–vegetation processes, especially on geologically young soils in steep terrains) if there were no people living nearby. People can become victims of landslides simply by being in the wrong place at the wrong time.
B. The increased use of a landscape by people normally involves reducing tree cover and increasing infrastructure, which may intensify the occurrences of landslides. Where the slope incisions of roads lead to slope instability, the correlation with the loss of tree cover is only indirect.
C. Tree roots play a real role in protecting the soil profile and the decay of tree roots and tree felling eventually increases the risk of landslides.

Only in case C does it make sense to expect that tree planting will reduce the risk of landslides once the young trees have established their root systems.

The complexity of the relationship between the causes and effects of landslides, the destruction of evidence by the landslide itself and the occurrence of landslides after cases of extreme rainfall make it desirable to have a relatively fast and inexpensive appraisal method that can be used by local natural resource managers to take precautionary measures and/or to respond to early signs of slope instability. Changing rainfall patterns in the light of global climate change make the need for such tools even more urgent.

Objectives

RaLMA is designed to provide a basic understanding of the way tree roots can contribute to slope stability and how tree and agroforestry management can enhance or maintain slope stability and protect people and ecosystems from the damage caused by landslides.

Steps

1. Conduct a spatial analysis of the landscape and gather data on the recent history of land-cover change. This includes identification of the area; characterization of the soils and of the potential planes of weakness in the soil profile; characterization of the geological substrate and of the process of soil formation (including colluvial soils derived from previous slope instability); characterization of the slope and recent changes in land cover; and characterization of climate and extremes in rainfall distribution.
2. Explore local ecological knowledge (LEK) of cause and effect relations, local regulations concerning changes in tree cover and local people's preferences about trees in the landscape.
3. Explore policy-maker's ecological knowledge (PEK) of cause and effect relations; considering whether existing land-use plans take landslide risk into account and investigating stakeholders' preferences and aspirations with regard to the presence of trees in the landscape;
4. Explore modellers´ ecological knowledge (MEK) of site-specific risks and of the likely timing of response to mitigation actions. It is important to bear in mind that trees on slopes have both positive and negative effects on stability. Negative effects include:

   a. the aboveground biomass adding weight and wind exerting a lateral force; and

   b. highly porous soil supported by active soil fauna feeding on the litter layer increases infiltration and the likelihood of positive pore pressure after heavy rainfall.

   The positive effects include

   a. binding topsoil into a root mat that either moves as a whole, or stays in place; and

   b. the anchoring of this rooted layer to the subsoil through vertical roots.

   Whether the effects are positive or negative depends on the species and age of the tree and the type of tree management involved (see Figure 21.1).
5. A synthesis of the outputs of the steps, which can inform local negotiations between the different stakeholders involved in landscape management.

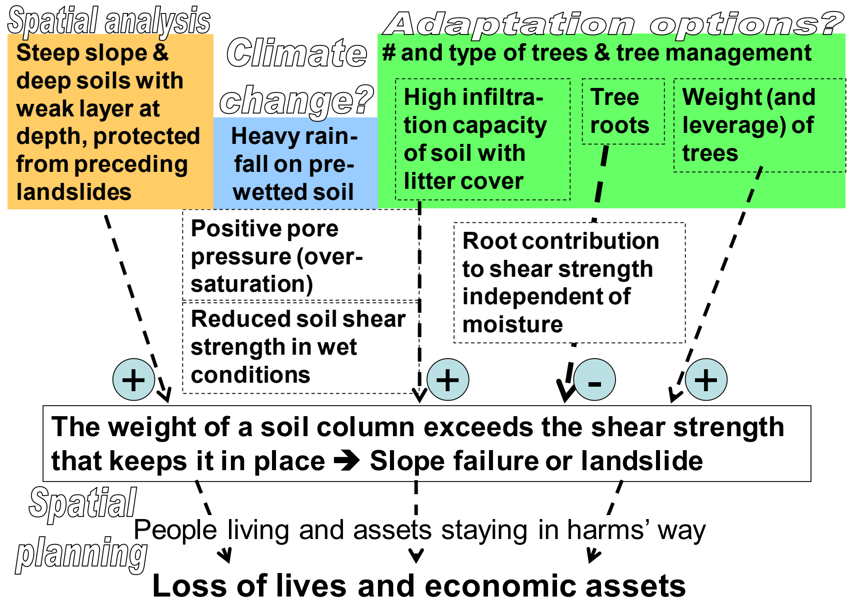


Figure 21.1. Schematic diagram showing the relationships between landslides and soil, climate and vegetation

Compiling parameters for MEK of trees and landslide risk:

- Survey of tree species and tree population density in the landscape in relation to signs of previous landslides.
- Inventory of proximal tree root architecture of the major species that grow in the area to assess soil binding and soil anchoring properties; two tree root indices —Index of Root Anchoring (IRA) and Index of Root Binding (IRB)—can be used to evaluate tree suitability for stabilizing slopes.
- Standardized strength measurement of tree roots in relation to their lignin content.
- Estimation of dynamic root pattern at the hill-slope scale using the SExI-FS and the IRA and IRB parameters derived from the survey.

Case study

Case studies from different parts of Indonesia (West Lampung, West and East Java) suggest a number of options for implementing a 'right tree in the right place' management approach to mixed agroforestry systems. Such an approach can help to reduce the risk of landslides on slopes and can be combined with biomass carbon storage as a contribution to climate-change mitigation.

Research was carried out between January and May 2008 in the Bukit Sentul area of the Bogor district in West Java. The research took place in areas that had been classified as being at high risk of landslides. Based on geological maps and the recent occurrence of landslides, the survey focused on the Ciherang and Cibadak sub-catchments and was followed by an inventory of tree species and population density in the selected area.

Four types of landslides occurred in the village of Karang Tengah: 1) overland; 2) slope failure (topple); 3) creep; and 4) road-cut. Sixty percent of the total were superficial landslides. Factors affecting landslides were found to include rainfall intensity, topography (slope > 45%) and features of the soil profile: the existence of bedrock or compacted soil layer as a sliding plane; and the existence of unstable soil layers, such as sandy loam layers in the subsoil, with a low soil shear strength owing to higher sand content.

Figure 21.2. Durian tree protecting, through its superficial roots, a slice of land from sliding

Vegetation in the study area was dominated by homegarden types of agroforests with banana (non-woody), *Maesopsis eminii* (an introduced timber species), *Pangium edule* (a source of oil and spice), *Ceiba pentandra* (kapok) and *Sandoricum koetjape* (a local fruit tree) dominating. The highest tree population density was found in agroforestry systems near the scarps of overland landslides. The weight of the aboveground tree biomass probably increased the risk of landslides.

The local fruit tree species, 'duku' (*Lansium domesticum*), 'kemang' (*Mangifera kemanga*), 'limus' (*Mangifera foetida*), 'mindi '(*Melia azedarach*) and durian (*Durio* sp) (Figure 21.2) played a relatively important role in anchoring the soil (where the IRA was higher than 2.0). A mix of tree species with deep roots, and of ground cover species with intense and strong fine roots, provided the highest slope stability in the area.

The SExI-FS model was able to simulate the role of trees in reducing the risk of landslides through the quantification of the IRB and IRA of species in a tree plot (Figure 21.3). The simulation showed that increasing plot density over the optimum size did not significantly increase root binding.

The combined results of the LEK, MEK and PEK studies helped inform discussions concerning the choice of species while at the same time taking into account direct economic gain, the local utility of species and landslide risk.

The primary recommendation that might be given by advisers visiting a village at risk of landslides would be to look for another location for the village but the options for doing so are limited. Maintaining the tree root mat of the village homegardens, avoiding houses with rigid walls that collapse under pressure and encouraging traditional flexible building materials such as bamboo may help to reduce the risk to locals in the short term.

Figure 21.3. RaLMA process and 3D reconstruction using SExI-FS

Key reference

Hairiah K, Widianto, Prayogo C, Kurniawan S, Harja D, Khasanah N, van Noordwijk M. 2008. *The role of trees outside forest in anchoring soil and reducing landslide risk during high rainfall episodes*. TroFCCA project on the role of tropical forests in climate change adaptation.

22 | Participatory water monitoring (PaWaMo)

Subekti Rahayu, Rudy H. Widodo, Meine van Noordwijk and Bruno Verbist

Participatory Water Monitoring (PaWaMo) involves local community members in measuring and monitoring water flow using several simple quantitative indicators. These indicators can be used as an index for assessing and comparing the patterns of relationship between river flow and rain as a basis for monitoring changes of hydrological functions at sub-watershed level.

Introduction

Well-maintained watershed functions are caused by well-managed river flows, especially when supported by social institutions that maintain a balance between individual and public interests. Today, people increasingly realize that by planting trees with economic value in their agricultural system they are also maintaining watershed functions at the same time because trees help stabilise hill slopes as well as prevent soil loss through erosion and water flow. However, issues related to watershed management are not only a matter of planting an amount of critical land with trees. Watershed management has different dimensions and each problem requires a different approach.

Overcoming problems of landscape management requires open communication between everyone involved (researchers, community members and government policy-makers) leading to negotiation and agreement in joint rehabilitation actions. Integrated understanding about a watershed and its characteristics is required to inform these processes, including 1) the interaction between landscape and rainfall; and 2) the landscape as water organisms' habitat functioning as an indicator of water quality and pollution levels.

Objectives

PaWaMo is a way of answering 1) how local communities and scientists together can assess the 'weak points' of a landscape that greatly affect the circumstances of downstream areas; 2) how to monitor sediment in river water; 3) what are the physical and chemical characteristics of a river's water; and 3) how to use water organisms to assess the quality of a river?

Steps

Watershed functions can be looked at in two ways: 1) supply aspects, which consist of river-water quantity (discharge), time, river-flow quality; and 2) demand aspects, which consist of availability of clean water and prevention of floods, landslides and mud puddles (Figure 22.1). Limited access to clean water is a main determinant in poverty and poor health. The problem of insufficient and untimely water supply for downstream communities can be dealt with using two approaches.

1. Technical approach, usually applied in the river body in the middle of a watershed through, among other means, increasing water flow to prevent flooding in critical areas, building dams or reservoirs as temporary water holders and/or building pipelines or water catchments (ponds, water towers) to distribute drinking water from upstream to downstream consumers.
2. Land-use approach in upstream areas, that is, by designating forests as protected and/or managing land in view of buffered water delivery.

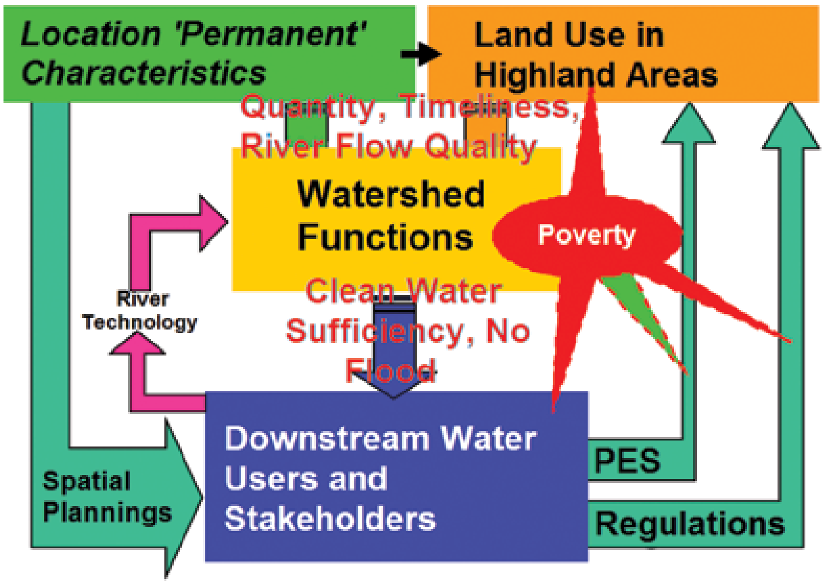


Figure 22.1. Reciprocal relations in a watershed

Note: Between 1) upstream areas that provide watershed functions in terms of quantity, time and quality of river water; and 2) area characteristics, both permanent (such as geology and topography) and non-permanent (such as land-use types and their impacts on downstream areas). PES = Payments for Environmental Services

Case study: water quality biomonitoring in Way Petai, Sumberjaya, Lampung province, Indonesia

Conversion of forests to shrubland, coffee gardens and rice fields in the Way Besai watershed, Sumberjaya, Lampung province, Indonesia, has reduced water quality. Biomonitoring activities using macroinvertebrates were performed in the upstream part of the Way Petai River—one of the Way Besai tributaries—to assess the impact of land-use conversion on water quality.

Six sample plots in forests, shrubland, coffee gardens and rice fields were established along the Way Petai River during the wet and dry seasons in 2005. The result of data observation and analysis based on the Family Biotic Index is shown in Figure 22.2.

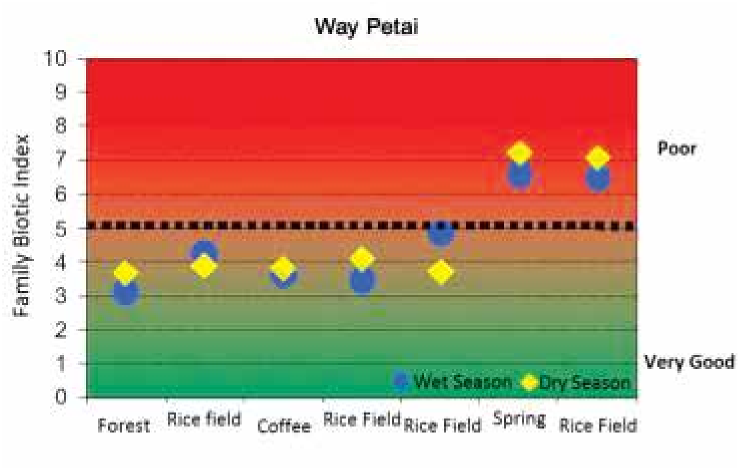


Figure 22.2. Water quality in upstream part of Way Besai River based on Family Biotic Index
Source: Andy Dedecker and Ans Mouton (dry season 2005 data); Indra Suryadi (wet season 2005 data)

Figure 22.2 shows that the quality of river water flowing through the forest is better than that in rice fields and coffee gardens. As for the spring, the water quality was classified as poor because of human use of the water for washing and bathing. In addition, the spring was located near a traditional market and rice fields, so that market garbage and pesticide residues from the fields contaminated the river near the spring. The bad water quality around the spring affected the water quality in the rice fields that were located downstream from the spring. Water quality during wet seasons was nearly equal to dry seasons.

Key reference

Rahayu S, Widodo RH, van Noordwijk M, Suryadi I, Verbist B. 2013. *Water monitoring in watersheds*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

23 | Rapid agro-biodiversity appraisal (RABA)

Laxman Joshi, Endri Martini and Hesti Lestari Tata

The Rapid Agro-Biodiversity Appraisal (RABA) is a diagnostic tool designed to measure the perceptions of different stakeholders about biodiversity conservation and to assess the feasibility of establishing a 'rewards for environmental services' mechanism in a target area.

Introduction

With rapid deforestation taking place across the tropics, the associated biodiversity loss has become a global concern. Until recently, most of the approaches to biodiversity conservation were based on a spatial segregation of functions focused on protected areas and on intensive agriculture (to reduce pressure on natural forests). The results of such endeavours, however, have been less than satisfactory. A second approach maintains biodiversity within productive landscapes.

A combination of the two approaches is most likely to retain biodiversity and agricultural production but there is always the threat of competition between conservation and economic development. Specific incentives might be needed to ensure that the conservation aspect of these systems is not lost in the process.

RABA is a tool for appraising the perspectives of stakeholders regarding biodiversity conservation and the feasibility of providing rewards for environmental services (RES) in biodiversity-rich areas. RABA uses techniques and tools based on rapid rural appraisal, stakeholder analysis and local ecological knowledge. It captures the perspectives of sellers, buyers and intermediaries and generates initial data necessary for these groups to develop a rewards system (Figure 23.1).

RABA is not a stand-alone tool for assessment of detailed biodiversity richness. Selecting an area for establishing a RES mechanism is normally based on credible information about the richness or uniqueness of existing biodiversity that may be verified through local consultations. For areas where reliable biodiversity data are unavailable, the Quick Biodiversity Survey (QBSur) of indicator flora and fauna can be used as a complementary tool.

Objectives

1. Assist potential investors to explore the benefits of agrobiodiversity conservation.
2. Assist the managers of richly agrobiodiverse landscapes to understand their key selling points for investment in conservation.
3. Provide cost-effective approaches to intermediaries (brokers).

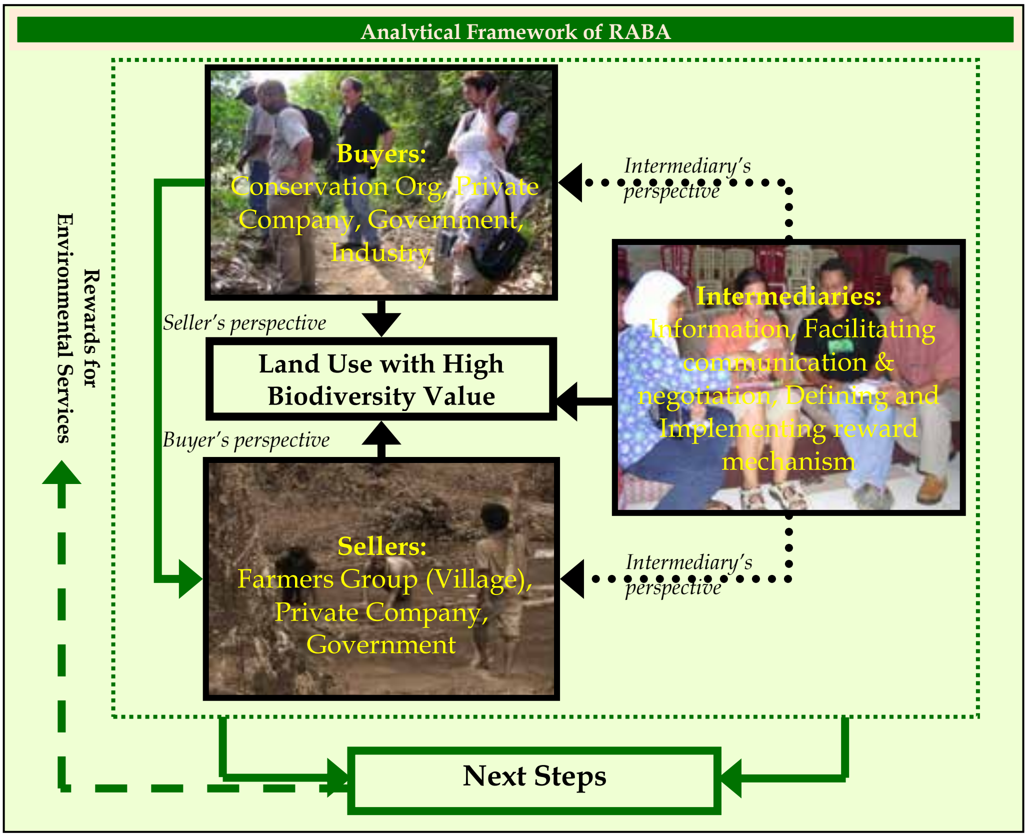


Figure 23.1. RABA analytical framework

Steps

RABA involves four steps: 1) scoping; 2) identifying potential partners; 3) negotiating agreements; and 4) monitoring and evaluating compliance and outcomes (Table 23.1). Each step requires addressing a number of questions, which are detailed in the table below. As an analytical framework, RABA offers insights into, and guidance on, the important elements that should be considered in developing a RES mechanism.

Table 23.1. Steps in a RABA appraisal

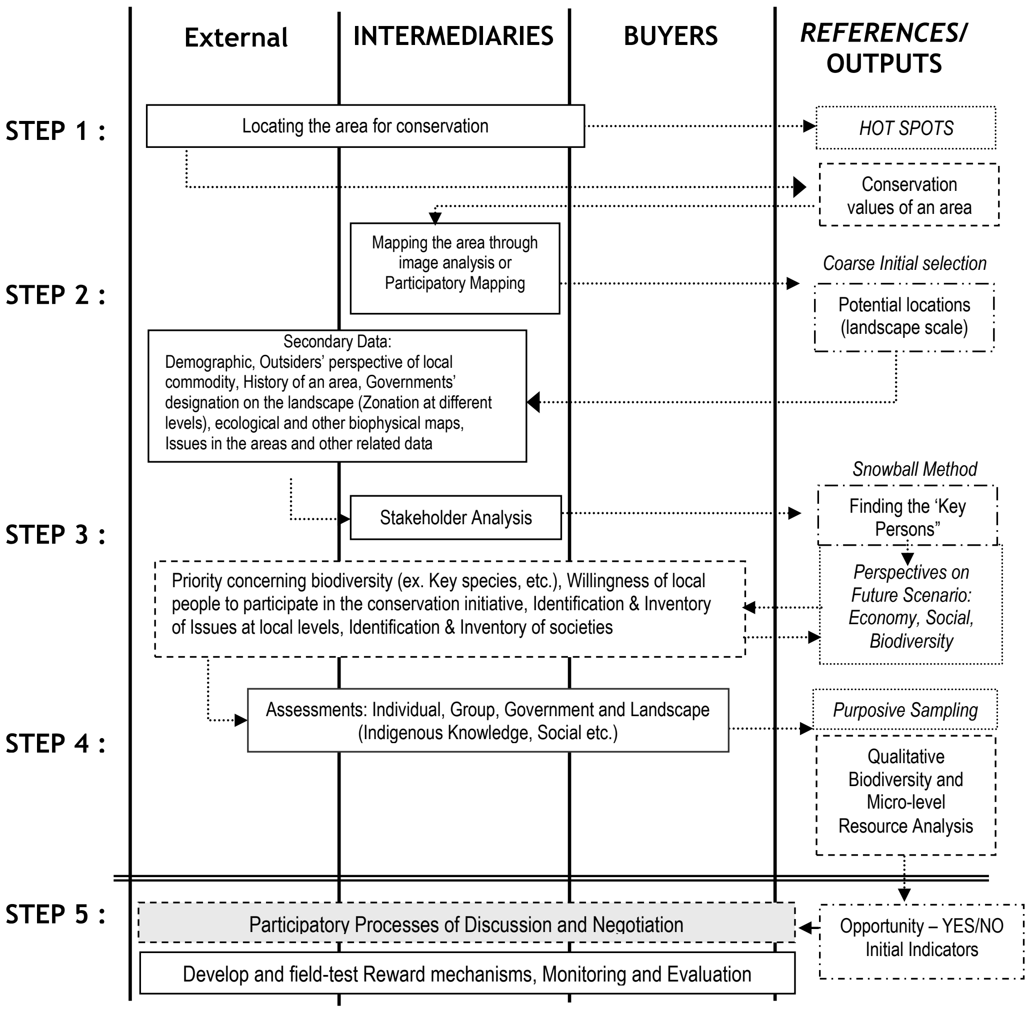
Steps	*Rapid Agrobiodiversity Appraisal*	Sellers' perspective Communities that manage or control biodiversity-rich agroecosystems	Buyers' perspective Institutions interested in conserving agrobiodiversity
Scoping		• What do we have that is of interest to outside stakeholders? • What is the downside of conservation? • How can we benefit from maintaining biodiversity? • What 'willingness to pay' can we expect?	• Where are the areas under threat? Where are conservation activities most needed? What species and ecosystems are under threat? • Who can effectively influence conservation uses in these areas? • What 'willingness to sell' can we expect?
Identifying potential partners		• Whom should we talk to? • What documentation do we need?	• Who can effectively and equitably represent all local actors? • Does local government represent local interests?
Negotiating agreements		• How do we balance the restrictions that may be imposed on us with any rewards?	• How do we know we can trust the sellers? What are the guarantees?
Monitoring and evaluating compliance and outcomes		• How can we deal with defectors and free riders in the community? • How will we know the buyer is satisfied?	• How will compliance (at output level) be monitored? • How will outcomes be monitored?

RABA process

The initial stages of RABA consist of acquiring, collating and analysing data. The selection of a location for establishing RES can be based on available data and secondary information. Identifying land uses and assessing potential threats to biodiversity in the location are also important. Spatial analysis can provide baseline data to be used in pinpointing areas with potential for conservation. Participatory mapping can be a useful tool but spatial analysis using satellite imagery and aerial photographs is more objective and can help in planning and future monitoring. The next step is to identify threats to biodiversity in the area of interest and opportunities to counter these threats. Areas that are either severely or minimally threatened may not be of interest to potential buyers of environmental services. The optimal threat level is difficult to measure and depends on the context. Secondary data (biophysical, ecological, socioeconomic and policy) enriches the understanding of past, current and possible future situations.

Stakeholder analysis can help to identify people and institutions that have vested interests in resource management in the area. Stakeholder analysis is a four-step process: 1) identifying key stakeholders; 2) assessing their interest and potential impact; 3) assessing their influence and importance; and 4) outlining a strategy for their involvement in conservation. Understanding power relations between and within stakeholder groups and conflicts, current and future, is necessary for developing appropriate strategies for conservation and RES. Awareness of stakeholders' expectations is also essential.

Assessing local perceptions of agrobiodiversity indicates the relative importance that local people assign it and hence the potential for conservation. Various aspects—such as tenure and rights to land, social strata, economy and livelihoods, local knowledge about the environment and agrobiodiversity, institutions, threats and opportunities—can be explored using various tools and methods.



Case study: Rubber agroforests in Bungo district, Jambi province, Indonesia

Bungo district in Jambi province is located between three national parks—Bukit 12, Bukit 30 and Kerinci Seblat)—on the island of Sumatra, Indonesia. The area harbours many endemic species and, at the same time, has been significantly altered by human activities. Like many other districts in the area, Bungo is rapidly losing its forests. Previously dominant lowland tropical forests with rich biodiversity have been replaced by monoculture cultivation. Habitat for most flora and fauna is disappearing very fast and now exists only in small 'island' national parks and reserves. Fortunately, 'jungle rubber' (old, complex rubber agroforestry) systems are still commonly practised in Bungo. Previous research in Bungo indicates that these agroforests are becoming increasingly important as a reservoir of forest diversity and now provide some of the services valued in natural forests. As the financial gains from monoculture plantations are much higher than from jungle rubber, conversion to monocultures is taking place rapidly. Providing rewards for the environmental service of agrobiodiversity conservation in rubber agroforestry systems was proposed as a way to offset the opportunity costs from alternative land uses. Hence, RABA was developed and tested in the area. A graphical depication of the summary of the findings can be found below.

Value

- Sumatra is one of the hotspots in terms of biodiversity and little of its lowland forest are protected
- Jungle rubber is similar to secondary forest in structure and richness
- Jungle rubber gives good income to farmers
- Buffer zone for the nearby forest and protected areas

Opportunity

- People perceive that the most tangible environmental service of jungle rubber is watershed functions and not agrobiodiversity conservation.
- Increasing productivity of jungle rubber through improvement but not losing the environmental-service benefit from it
- Participatory land use planning

Trust

- Lack of trust between local people and government
- Local people are willing to negotiate with outsiders if there is a benefit for them

Threat

- Conversion to monoculture crops (rubber or oil palm)
- Top-down attitude in respect to land use change
- Increasing price of rubber

Figure 23.2. Graphical depiction of the summary findings of a rapid agrobiodiversity assessment in Bungo district, Jambi

The results of the RABA application in Bungo provided sufficient evidence and confidence to proceed with developing a RES mechanism. The understanding and recognition of environmental services provided by jungle rubber have increased, both among local villagers and external stakeholders. Efforts to develop long-term benefits through ecocertification of jungle rubber are underway.

Key reference

Kuncoro SA, van Noordwijk M, Martini E, Saipothong P, Areskoug V, Eka Dinata A, O'Connor T. 2006. *Rapid Agrobiodiversity Appraisal (RABA) in the context of environmental service rewards.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia RegionalProgram. http://www.worldagroforestrycentre.org/sea/Publications/searchpub.asp? published=1496

24 | Quick biodiversity survey (QBSur)

Hesti Lestari Tata, Nurhariyanto, Pandam N. Prasetyo, Jihad, Laxman Joshi and Endri Martini

The Quick Biodiversity Survey (QBSur) diagnoses the 'biodiversity health' of a landscape, including its agricultural components that are usually not considered as niches providing ecosystem services. QBSur provides information on the diversity of plants, birds and bats; the biodiversity gradient of areas with high and low biodiversity levels; and perceptions of local stakeholders on (agro-) biodiversity and their interests in conservation.

Introduction

Biological diversity (biodiversity) is the number, variety and variability of living organisms, which can be described in term of genes, species and ecosystems. Biodiversity plays an important role in sustaining the world's ecosystems. The conversion of forests to intensive agriculture and monoculture plantations leads to a loss of biodiversity in any landscape. Generally, the rich biodiversity in natural or managed systems does not provide tangible benefits: a reason why local people may not be interested in conservation initiatives.

Payment for agrobiodiversity conservation involves extensive consultations with both beneficiaries and providers of conservation services. These environmental services' providers usually live in agricultural landscapes with high local and global biodiversity values or which harbour species of special interest, such as tigers, orangutans, rhinos or endangered birds. Data on such high-value species and biodiversity richness are usually available. Occasionally, however, where detailed and current biodiversity data are unavailable or need to be validated, a rapid survey may provide sufficient information necessary for instigating a full RABA. The QBSur was developed for this purpose. Besides information on vegetative species, QBSur also studies animal diversity, such as birds and bats, which play important roles in the ecosystem as pollinators, seed dispersal agents and biological controllers. Furthermore, humans as an integral component in an ecosystem play the most important role, exercising direct influence over land-cover changes. Thus, local people's understanding of local activities and their effects on biodiversity are also captured in the QBSur.

Objectives

A QBSur assesses the biodiversity of plants, birds and bats within a landscape, identifying areas of higher and lower biodiversity and the links between them, as well as providing a detailed picture of the health of the biodiversity. Perceptions of the local people with regard to local practices and the use of resources as well as perceptions of biodiversity are analyzed.

Steps

QBSur uses indicator plant and animal groups. The animal groups, which include dung beetles, bats, small mammals, primates and birds, can be modified depending on their importance in the locality but the survey technique should be maintained for consistency and data comparison.

The QBSur can be conducted in two weeks in consultation with experts. A local guide who is knowledgeable about local plants and animals is necessary for the field work.

Indicator animals and plants are surveyed along kilometre-long transects; the layout and frequency of sample points are determined by the animal groups being surveyed (Figure 24.1). Time and other resources permitting, the number of transects can be increased to improve the accuracy of survey data.

In general, the survey, identification, data analysis and reporting can be completed in about six weeks.

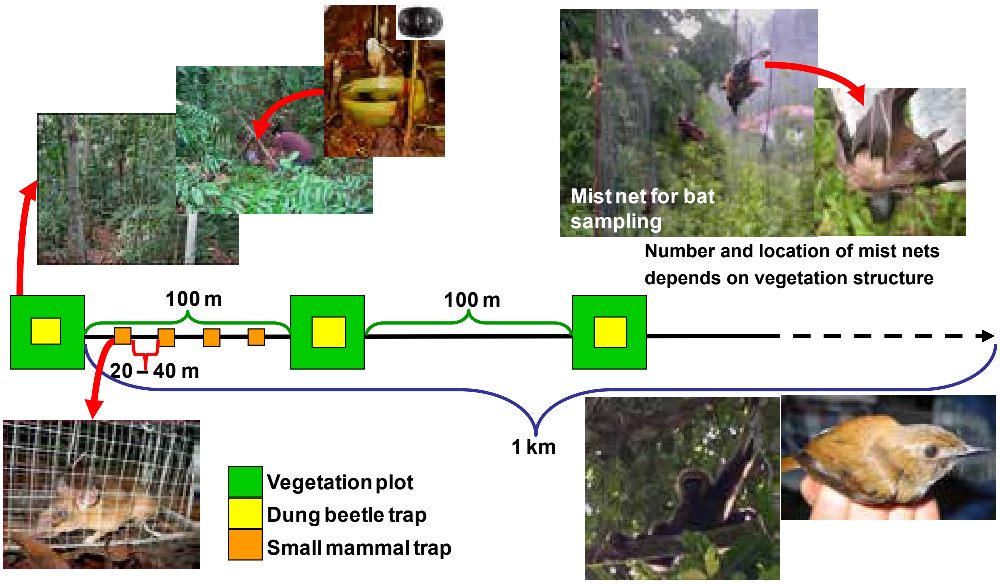


Figure 24.1. Sampling locations of vegetation plots and dung beetle and small mammal traps along a transect

Case study: QBSur of a rubber estate

Rubber plantations in Dolok Merangir, Indonesia, have a long history. The first was established in 1916 for the Goodyear tyre company. In 2005, the Dolok Merangir and neighbouring Aek Tarum plantations were sold to Bridgestone, a tyre company based in Japan. We conducted a QBSur focussing on the diversity and species' composition of vegetation in the plantations compared with the surrounding smallholdings and forests. The QBSur resulted in recommendations on how to improve biodiversity on the Bridgestone estate.

Summary of findings

- All farmers perceived that rubber agroforests were the most important land use as they could provide sources of income, food and environmental services. The second-most important land use was smallholding oil palm, followed by smallholding rubber monoculture. These provided the main cash income for households.

- People's understanding of biodiversity was closely associated with livelihoods' patterns and social practices, as biodiversity contributed to their daily needs and was related to specific knowledge. However, the boom in palm-oil production and its high prices had influenced farmers' decisions in conserving high-biodiversity ecosystems.
- Forest loss was followed by an increase in tree-based systems, such as rubber monoculture and oil palm. Smallholding rubber areas decreased while oil-palm plantations rose dramatically during the period 1970 to 2010. Early conversion of the forest at Dolok Merangir implied relatively stable, non-forest, land-use systems for a longer period of time and, by the time of the QBSur, the rubber plantations had developed into a mature system. The old rubber systems provided a more stable habitat for the different biodiversity components in the plantation area and this might benefit biodiversity conservation.
- Vegetation analysis was conducted in the three habitats of rubber plantation, rubber smallholding and forest. Rubber plantations had the lowest vegetation diversity owing to the intensive management practices to increase latex productivity. On the other hand, farmers traditionally grew various useful species in their agroforests through protecting seedlings, maintaining plant diversity at all stages. The species' composition of the tree stage was completely different. The sapling and pole stages on the plantations and rubber smallholdings were dominated by rubber trees as this was the productive stage for latex and hence the farmers maintained the rubber and minimized competition from other trees.
- Carbon and nitrogen are two important elements in soil organic matter. Soil analysis at the rubber plantations and smallholding rubber sites indicated that the carbon–nitrogen ratio was relatively constant across all soil depths but was slightly lower than in forest soil. This implied that the nitrogen content on the rubber plantations and smallholding sites was higher than in the forest soil. Fertilizer application may have affected the nitrogen content at these sites. In addition, soil fertility on the smallholding and rubber plantation sites was lower compared to forest soil.
- Bird diversity was analyzed in four habitats (forest, rubber smallholding, rubber plantation and emplacement) and 728 individual birds were recorded, consisting of 142 species from 42 families. The types of bird, categorized by feeding habit (guild type), decreased with vegetation type. Forests were the most diverse for bird species, with 17 guilds. This implied that the rubber plantations did not provide a suitable environment for some birds with specific roles. The differences in the tree composition of the three habitats of the plantations and their surroundings influenced bird species' richness, diversity and composition.
- Additionally, a large number of raptor bird species were found in the rubber plantations, such as the Brahminy Kite *(Haliastur indus)*, the White-bellied Sea Eagle *(Haliaeetus leucogaster)*, the Black Eagle *(Ictinaetus malayensis),* the Crested Hawk-eagle *(Spizaetus cirrhatus),* Blyth's Hawk-eagle *(Spizaetus alboniger)* and the Crested Serpent Eagle *(Spilornis cheela)*. All these raptors are protected under Indonesian laws and regulations. Moreover, the high number of raptors implied that this area was important as part of their home range. The availability of food in the rubber plantations and their surroundings was important in supporting the population.
- Based on the bird protection status published by the International Union for Conservation of Nature and Natural Resources, within the four habitats we recorded 12 species that were categorized as 'near threatened' and two species categorized as 'vulnerable'. In addition, one bird species listed in CITES Appendix I—*Rhinoplax vigil* (Helmeted Hornbill)—was encountered in the forest habitat.

- Bat diversity in the three habitats was studied to identify the level of species' richness and their roles and functions in the habitat. We live-trapped 234 individual bats from three families, consisting of 11 species, with eight of the species in the suborder Megachiroptera (fruit eaters) while the rest were Microchiroptera (insect eaters). Insect-eating bats play an important role as predators of mosquitoes and other plant pests, while the Megachiroptera are pollinators and seed dispersal agents. According to the IUCN status lists, all the bat species encountered in the study area were categorized as 'least concern'. The low value of bat diversity along each transect illustrated that the rubber plantations were in an alarming condition owing to the imbalance in the number of individuals of each species within the community.

Recommendations from the QBSur

Buffer zones, such as rubber agroforestry smallholdings, play a role as corridors for animals to reach forests. Vegetation in rubber agroforests supports bird and bat diversity. To improve biodiversity in the area, we recommended preserving the intermediary vegetation, such as in riparian areas, along the main roads, sealed roads in the plantation and on steep slopes.

As an intermediary region could be a corridor between one region and another on the border of a plantation, we recommended to not only plant rubber trees but also a mix of other trees to provide food and places for nesting and resting for birds and bats (subject to the fruit not being preferred by humans, so it is left for the animals).

Trees with a narrow canopy would minimize light competition with the rubber trees that make up the main commercial crop in the plantations. Several suitable species for planting are *Ficus* species, *Canarium indicum* (canarium nut) and *Syzigium polyanthum* ('salam'). Bamboo could be planted along the river banks to support birds and bats by providing places for nesting. In addition, other tree species, such as *Inga (Euphorbiaceae), Sonneratia (Lythraceae)* and *Palmae* can also support bats.

■ Key references

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