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Agroforestry options for degraded landscapes in Southeast Asia

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Abstract

In Southeast Asia 8.5% of the global human population lives on 3.0% of the land area. With 7.9% of the global agricultural land base, the region has 14.7% and 28.9% of such land with at least 10% and 30% tree cover, respectively, and is the worlds' primary home of 'agroforests'. Landscapes in the region include the full range of 'forest transition stages', as identified in global analysis. A long tradition of top-down national reforestation and tree planting programs has not had success proportional to the efforts and resources allocated. By contrast, farmers in the region have a long tradition of retaining (and managing natural regeneration of) useful trees among planted trees (e.g. tree crops or timber) and annual crops to prevent degradation and avoiding the labour costs of weed control. Meanwhile, state-controlled forests have lost a lot of their diverse tree cover, both legally and illegally. The restoration agenda includes four levels of intensity and stakeholder involvement: RI. Ecological intensification within a land use system, RII. Recovery/ regeneration, within a local social-ecological system, RIII. Reparation/recuperation, within rules and rewards set by the national policy context, RIV. Remediation, requiring international support and investment. Major opportunities for restoring the multifunctionality of landscapes in the region are formed by resolution of existing conflicts over multiple claims to 'forest' land stewardship. The chapter summarizes lessons learnt in 26 landscapes, grouped in seven 'degradation syndromes': Degraded hillslopes, Fire-climax grasslands, Over-intensified mono-cropping, Forest classification conflicts, Drained peatlands, Converted mangroves and Disturbed soil profiles. It also addresses two overarching concerns: disturbed hydrology and supply-sheds at risk. In each landscape a Drivers-Pressures-State-Impacts-Responses analysis of the Social-Ecological System supported a diagnosis beyond the primary degradation symptoms. Appropriate actions reflect six requirements for effective restoration: 1) community involvement, aligned with values and concerns, 2) rights, 3) knowledge and knowhow of sustainable land use practices, 4) markets for inputs (incl. soil amendments, tree germplasm, labour) and outputs (access, bargaining position), 5) local environmental impacts (often primarily through the water cycle and agrobiodiversity) and 6) global connectivity, including interactions with climate and global biodiversity agendas. All six can be a 'starting point' for restoration interventions, but progress is typically limited by several (or all) of the others. In our analysis all 17 Sustainable Development Goals can contribute to, and benefit from a coherent rights-based approach to restoration through agroforestry with specific technologies and choice of species dependent on local context and market access.

Key Words: agroforest, community-based forest management, forest transition, rights-based approach, Sustainable Development Goals

11.1. Introduction

Land degradation is a pervasive, systemic phenomenon that occurs in all parts of the terrestrial world and can take many forms (IPBES, 2018). In Southeast Asia, like elsewhere, farmers have long understood that investing in avoiding land degradation and in the restoration of degraded land makes sound social and economic sense, and they have invested in trees as part of their landscapes and farming systems. In doing so, they connect the three scales at which agroforestry is relevant: plot-level, multifunctional landscapes and the interface of agricultural and forestry policies (van Noordwijk et al. 2019a). In this chapter we will discuss examples of these three scales, within a 'systems' framing of degradation and restoration as related processes and relating restoration options to the specificities of context and purpose. The aim of restoration, as interpreted here, is to create the agro-ecological conditions in which sustainable intensification is ecologically, socially and economically feasible, enhancing functionality. Agro-ecology is defined by its goals and approach, rather than by a specific choice of method (HLPE, 2019), but agroforestry can be an important component of locally adapted land use systems. Degradation and restoration involve concepts of (agro)ecosystem structure (e.g. vegetation, soils), function (e.g. nutrient, carbon and water cycles), land users (gearing structure and function towards their interests), ecosystem services (ES) and ES-beneficiaries and ways they can influence land users (Fig. 11.1).

What is now understood as agroforestry has emerged in many forms across Southeast Asia (de Foresta et al. 2000; van Noordwijk et al. 2019d). It can, now that policy recognition across the usually segregated agricultural-forestry continuum has been confirmed in high-level policy documents of the ASEAN network of Southeast Asian nations (Catacutan et al. 2019), be an important part of the solution for achieving Sustainable Development Goals in a densely populated region (147 km^{-2}) with 8.5% of the human population (663 M in 2019) living on 3.0% of the global land area and an average tree

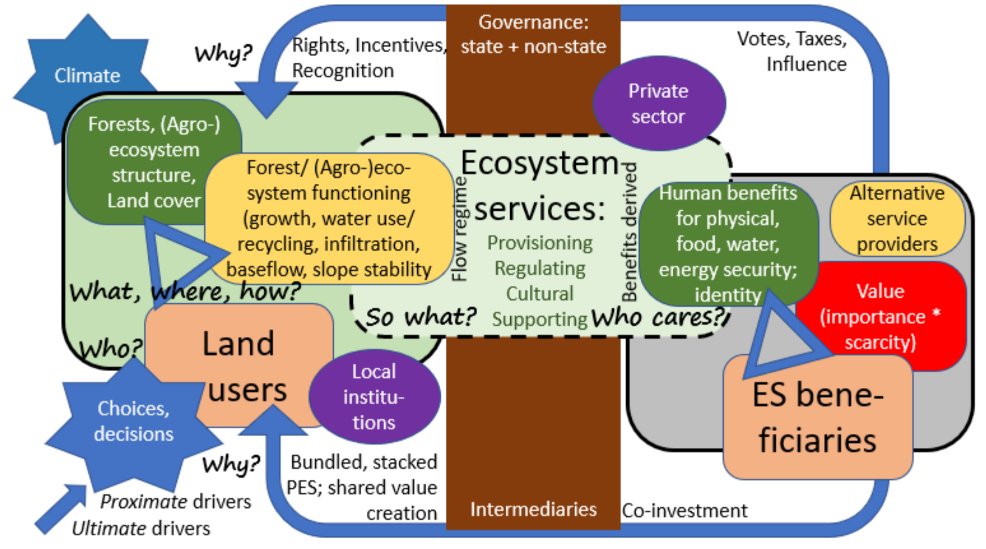

Figure 11.1. Cascade of (agro)ecosystem structure to function and functionality ('ecosystem services', ES) from a human perspective that relates 'degradation' and 'restoration' concepts that generally involve ES beneficiaries beyond the direct land users, which they need to influence; Proximate drivers shape decisions by land users within the landscape; Ultimate drivers influence land use decisions and who uses land for what (Namirembe et al. 2017)

cover on agricultural lands of 33% (Zomer et al. 2019). With 7.9% of global agricultural land base, the region has 14.7% and 28.9% of such land with at least 10% and 30% tree cover, respectively (van Noordwijk et al. 2019d). As elsewhere, tree cover on agricultural lands is positively related to rainfall in Southeast Asia (van Noordwijk et al. 2019d). Degradation-to-restoration shifts operate in a complex multi-stakeholder environment and need to be understood as processes in social-ecological systems, nested within broader policy feedback loops (Fig. 11.2).

Land use options such as agroforestry and their constraints as solutions for degraded landscapes in Southeast Asia can be interpreted in a Drivers-Pressures-State-Impacts-Response (DPSIR) framework (Kristensen, 2004). Restoration actions need first to address and deflect higher-level drivers (**D**) of degradation, otherwise progress at specific locations leads to negative 'leakage' effects elsewhere. They then need to disentangle the social and ecological pressures (**P**) to which specific landscapes respond, in response to the drivers. A typology of degradation cause-and-effect relations and their intensity and feedback loops is needed to go beyond system state (**S**) metrics of areal extent (X million ha) and get sufficient clarity on the ecological and social impacts of degradation (**I**) that stakeholder coalitions for change can emerge that want to coinvest in a response (**R**) to restore landscape multifunctionality, at driver, pressure and system level. Restoration will have to be prepared for ongoing trends and will have implicit relevance for (or explicit reference to) climate change adaptation. Although restoration efforts will often require financial support that requires relevance for specific (siloed) objectives (Van Noordwijk 2018), it will have the best chance of lasting success if it enhances synergy between all 17 Sustainable Development Goals (SDGs), and links a rights agenda to land use practices (and the knowledge supporting it), markets and local and global ecosystem services (Fig. 11.2).

Within the definitions of degradation and restoration (**Box 11.** 1), we recognize four levels of intensity of 'restoration' efforts:

- RI. Ecological intensification within a land use system,
- RII. Recovery/regeneration, within a local social-ecological system,
- RIII. Reparation/recuperation, within a national policy context,
- RIV. Remediation, requiring international support and investment.

Box 11.1 Definitions

For this chapter we define

- **Degradation:** Loss of functionality of e.g. land or forests, usually from a specific human perspective, based on change in land cover with consequences for (at least one category of) ecosystem services,
- **Degraded lands**: Lands that have lost functionality beyond what can be recovered autonomously by existing land use practices in a defined, policy-relevant time frame,
- **Restoration:** Efforts to halt ongoing and reverse past degradation, by aiming for increased functionality (not necessarily recovering past system states),
- **Syndrome:** Set of concurrent diagnostical indicators, not necessarily linked to a common cause or driver.

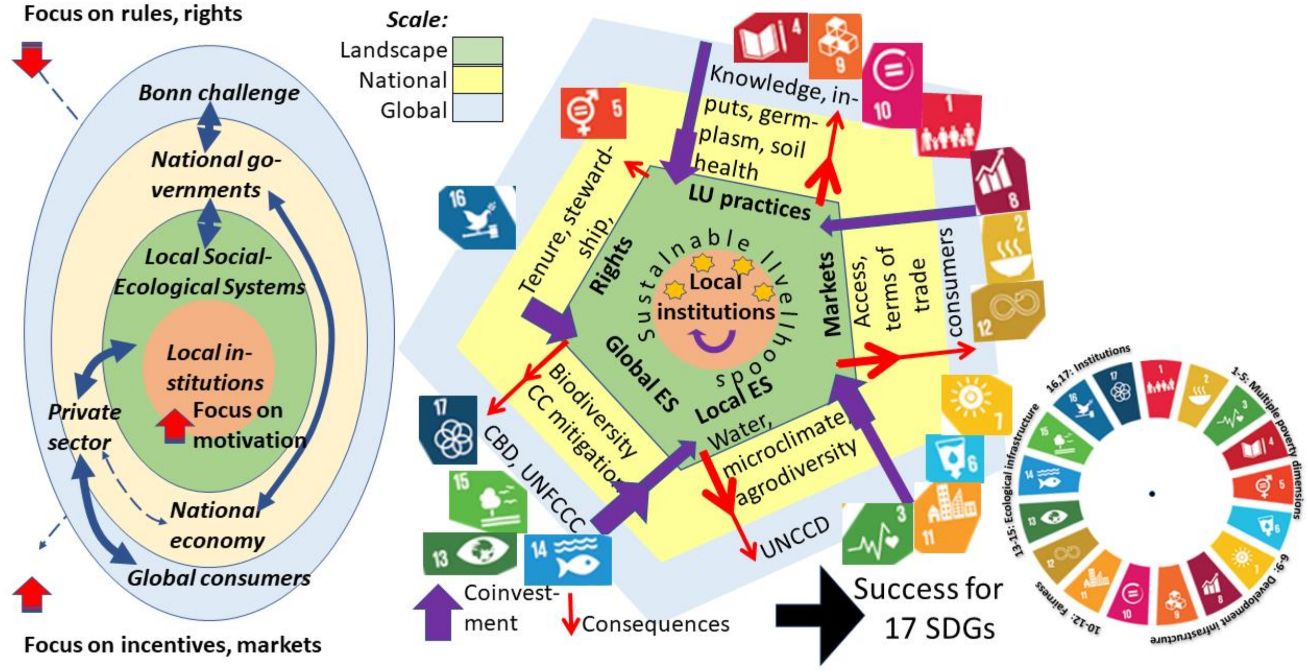

Figure 11.2. Multiscale perspective on restoration efforts (top-down with a focus on rights, or bottom-up starting from incentives) and on the five aspects (rights, land use practices, markets, local and global ecosystem services) that along with intrinsic and social motivation need to synergize

These four levels relate to a nesting of (Fig. 11.3) of farming (land use) within landscapes as local social-political systems, within national entities, within an interconnected global system of common but differentiated responsibility for staying within ‘planetary boundaries’ (van Noordwijk and Catacutan, 2017; van Noordwijk et al. 2018). While stopping the early-stage drivers of a forest transition and triggering a reversal by natural regeneration is possible in some contexts, in many others restoration must speed up the progression towards functional tree cover that might occur at slower pace without intervention (van Noordwijk and Villamor 2014; Dewi et al. 2017). The counterfactuals for judging the impact of specific interventions will rarely be constant: business as usual will either involve continued degradation or slow steps towards recovery of functions.

National programs for reforestation have been tried in many different forms in the various countries of SE Asia, but with limited success, relative to the efforts and budgets allocated. More than a decade ago the rapid spread of degraded but partially recovering, secondary forest was analysed for SE Asia (Chokkalingam and de Jong 2001), with

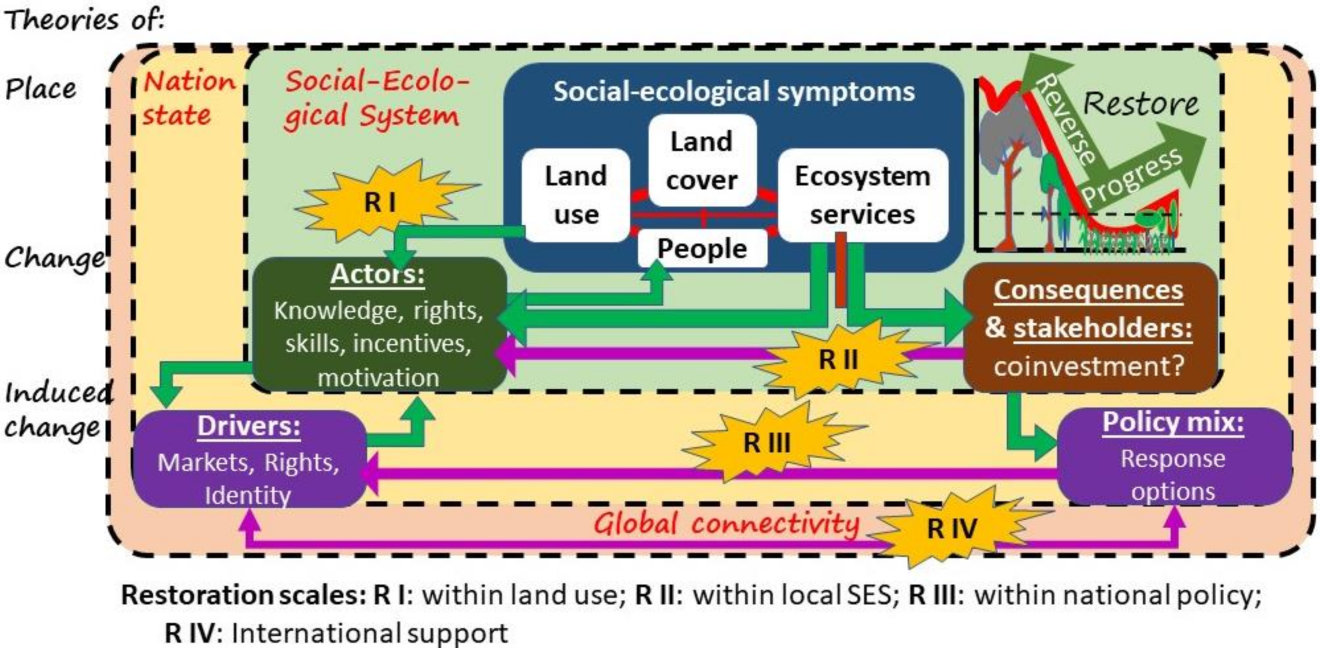

Figure 11.3. Nested scales of social-ecological-policy systems in relation to the four intensities of restoration discussed in this chapter

specific attention to the 'agroforest' part hidden within national statistics (De Jong et al. 2001). Agroforestry became recognized as an essential part of a more effective reforestation paradigm for the region (Roshetko et al. 2008b). When, however, global funding support for an increase of tree cover became available within the Kyoto protocol, confusion about forest definitions and eligibility of state forest lands proved to be a major bottleneck (van Noordwijk et al. 2008). Regardless of global funding, Southeast Asia has a rich experience in both degradation and restoration, with its diversity in biophysical settings (mainland and insular), high biodiversity (interface to two biogeographical domains), human cultural, linguistic and historical diversity, early participation in continent-wide and global trade and exchange, high current population density and resource pressure, linked to rapid progress on achievement of national development goals. Based on methods described elsewhere (Dewi et al. 2017), a classification of Southeast Asian watersheds in six stages of 'forest transition' involved various quantitative aspects of tree cover and human population density (Fig. 11.4).

Land cover is directly observable with current remote sensing tools, but loss of tree cover as symptom does not necessarily imply land degradation beyond the resilience of vegetation to return to its main functions and eventually form and structure. At 'gap' level a temporary loss of cover is indeed part of the normal successional cycles of forests – but there are questions of spatial and temporal scale: over what distance can effective seed dispersal complement any location-specific survival in seedbanks, and over what time period can plant structures survive for vegetative recovery from stumps or roots, and as seeds in a seedbank. Many authors have described that traditional 'shifting cultivation' or 'swidden/ fallow' rotation systems did maintain options for swift recovery of a desirable woody vegetation, while crossing some poorly quantified threshold of cropping intensity leads to fire cycles in grass-based vegetation that can arrest natural succession for many years (Cairns 2007,

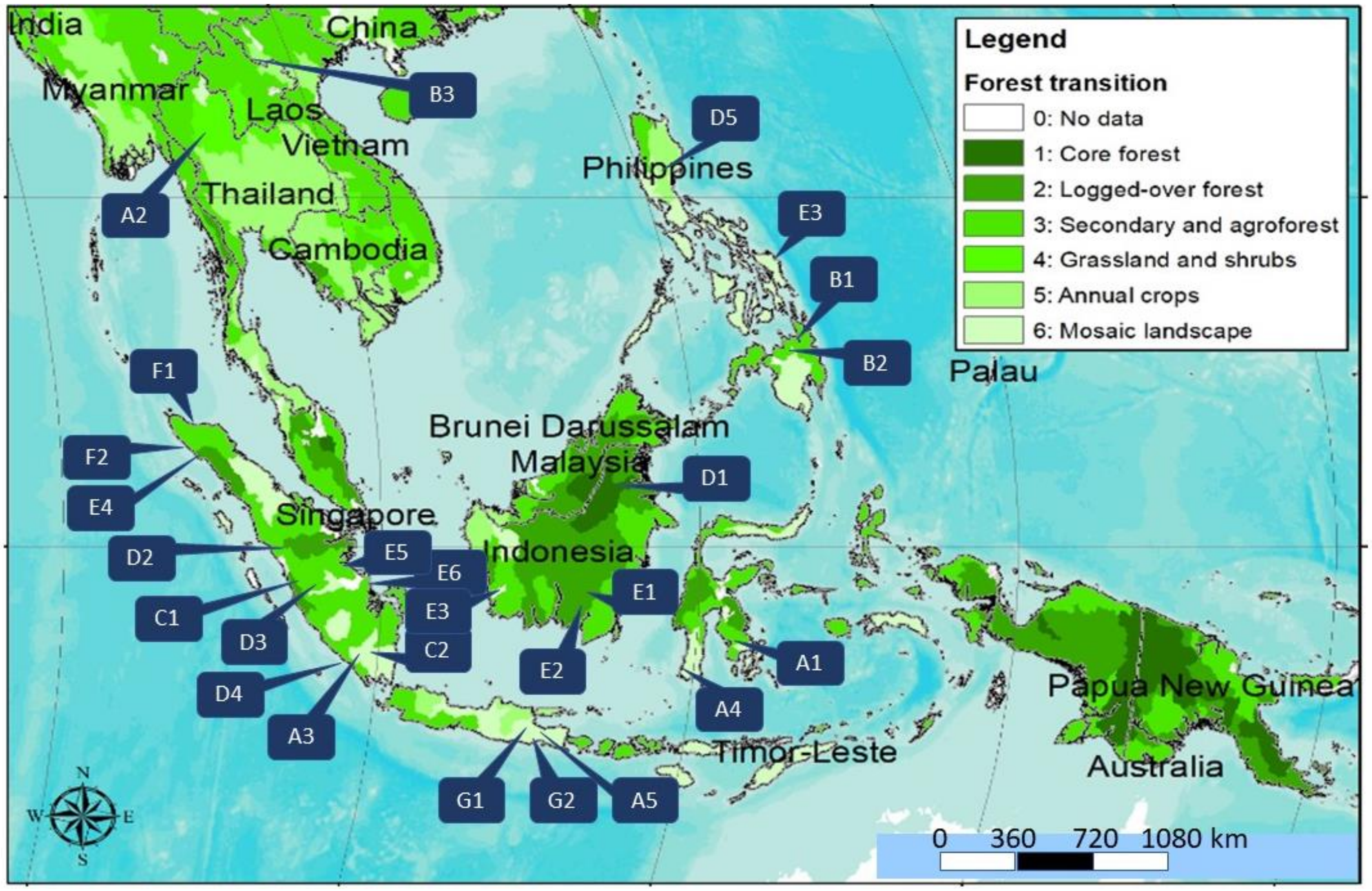

Figure 11.4. Map of SE Asia with forest transition stage classification at sub-watershed level (Dewi et al. 2017) with a set of specific landscapes A1…G2) that is listed in Table 11. 1 and discussed in this chapter

2015; Xu et al. 2009). In fact, the shift towards actively assisted woody vegetation in agroforestry-based fallow has effectively dealt with the threshold in many parts of Southeast Asia, operating in environments of 10-100 and 100-1000 tree species in (agro)forests, rather than the 1-10 that are common in drier parts of the world (van Noordwijk et al. 2019b). Reliance on natural regeneration, rather than a focus on tree planting, has been advocated as a tool for large-scale forest restoration in the tropics (Chazdon and Guariguata 2016), but depends on ecological as well as social context. Brazil's current law for the protection of native vegetation (known as the "New Forest Law") allows for ecological restoration through agroforestry systems, as long as they maintain or improve the area's basic ecological functions (Miccolis et al. 2016, 2019) – as far as we know there is no comparable statement in any of the Asian laws, although the ecological practice would certainly justify this type of legal recognition.

Beyond the regeneration capacity of a diverse woody vegetation and its consequences for restoration (Wills et al. 2017), degradation can also affect soil conditions, with soil organic matter as indicator of many chemical, physical and biological aspects of soil health. In Swidden – Fallow cycles it is common for breakdown of soil organic matter (conventionally measured in the C_{org} concentration) to provide part of the nutrient basis of crop production, with subsequent recovery on fallows. Crossing a critical swidden-fallow time ratio, however, can induce a downward trend of C_{org} and lead to a 'degraded soil', that will have lower soil

Box 11. 2 Soil carbon transition curves in relation to land use intensification

In the third quarter of the 20th century a remarkable shift occurred in upland Southeast Asian soils where a long period of soil degradation and declining soil organic C (C_{org}) concentrations was reversed into an upward trend (Minasny et al. 2012). Beyond the phenomenon of 'soil carbon transitions' as such, the interpretation of underlying drivers and causes is debated in the literature (van Noordwijk et al. 2015; Minasny et al. 2017). The pattern is consistent with a reasonable set of simplifying assumptions, but also sensitive in its details to several parameters.

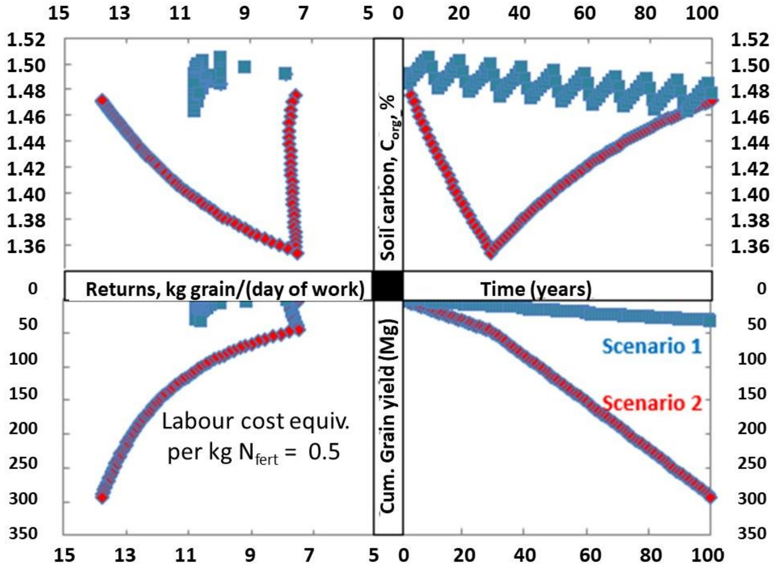

Figure 11.5. Four-quadrant representation of output of the SimpleCropCorg model for two scenarios (continued fallow-crop rotations) and permanent cropping first without and then with specific N inputs from fertilizer or N2-fixing crops

If fallow periods that rebuild soil organic matter are sufficiently long relative to the cropping period ('shifting cultivation' or 'long fallow'), sustainable grain production is feasible at acceptable returns to labour (Fig. 6). Higher grain yields per unit land can be achieved, along with degrading soils and declining yields per unit labour, by shortening the fallow periods -- but this is an unsustainable degradation scenario. A shift to increased nitrogen input, through active biological N_2 fixation and/or industrial fertilizer is needed to reverse the degradation, with effects on 'grain yield per unit labour' (including the labour needed to earn the costs of fertilizer inputs) depending on fertilizer costs. Depending on how far degradation had proceeded after first intensification ('no more fallows') before the second phase of intensification starts, it will take time to rebuild the soil organic matter pool with increased crop root inputs, but recovery is possible. Economic and climate mitigation (greenhouse-gas emission) effects per unit land and per unit labour accompany this C-transition, with details depending on local socio-ecological context, reflected in a range of parameters for the simple model presented here. The "*SimpleCropCorg*" model was set up to generate soil carbon transition curves that are consistent with simple assumptions about soil carbon dynamics during fallow and cropping stages. The model provides estimates of yield, organic matter dynamics, yield per unit labour and net GHG emissions per unit yield and is available at https://doi.org/10.34725/DVN/WDVCU5. The results in terms of grain yield per day of work, and thus farm-level attractiveness of the second intensification transition point, depend on both fertilizer prices relative to labour costs, and several technical efficiency coefficients that are specified in the model. Rather than claiming to be representative of the full range of conditions, the model shows that soil C recovery based on crop root residues is in the range of possibilities.

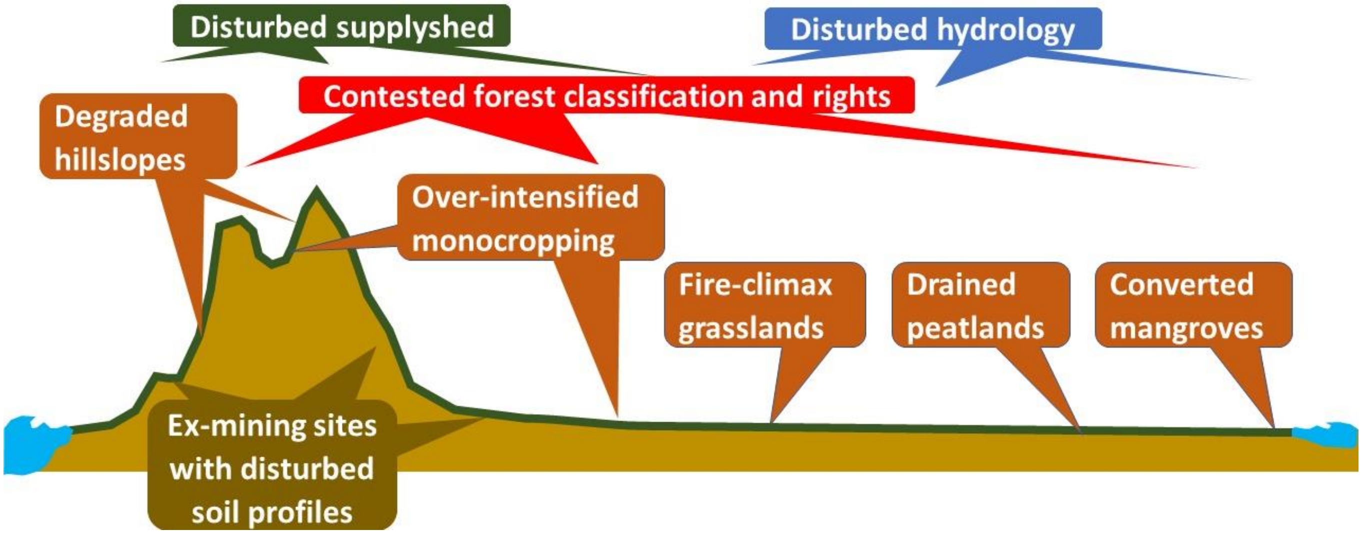

Figure 11.6. Approximate positions in the landscape (such as a schematic cross-section of Sumatra island) of seven degradation syndromes and associated restoration cases and two overarching concerns discussed in this chapter

fertility and crop production, further limiting the inputs of roots and crop residue to the soil. Interventions that support biological nitrogen fixation (by inclusion of woody or herbaceous leguminous plants) or use of industrial fertilizer can break the negative trend and lead to recovery (**Box 11.** 2). The roles of agroforestry in this type of recovery have been extensively studied and reviewed (van Noordwijk et al. 2019c).

Examples of success (and failure) of agroforestry-based land restoration in Southeast Asia for the rest of this chapter will be drawn from seven settings (A. degraded hillslopes, B. fire-climax *Imperata* grasslands, C. mangroves (and associated acid sulphate soils), D. drained peatlands, E. mining practices, F. over-intensified monocultures and G. disturbed hydrology) (Fig. 11.6).

Across the seven examples of restoration in SE Asia, we find relevance for four 'modalities' of restoration: 1. Leave alone, 2. Assisted regeneration, 3. Planting/growing of trees, 4. Soil and water management (**Table 11.** 1).

11.2 Contextualising degradation and restoration

11.2.1. Local community initiative as starting point

At the centre of **Figure 11.**2 local institutions are depicted as the linchpin of restoration. A main reason for degradation is, strange enough, the human coping capacity. Gradual loss of functionality can be compensated by increasing efforts to obtain the resources and services needed elsewhere. Dealing with symptoms by adaptation, rather than with underlying causes, allows the environment to further slide away from a desirable state. Triggers for actions that no longer accept *status quo* have in many of the landscapes we know been 'disasters', events that exceeded the local coping[1]. Behind many of the ES-supportive agroforestry landscapes are stories of landslides, floods, fire and haze episodes, or other disasters that gave a platform to the local voices who strive for change.

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[1] For an example see: https://agroforestri.ub.ac.id/2017/10/23/vlog-1-petani-agroforestri-di-ngantang-malang-manajemen-af-dan-kesuburan-tanah/

Table 11.1. Degradation syndromes and studied restoration efforts through agroforestry with examples in Southeast Asia contextualised in the 'forest transition' stage of the surrounding subwatershed

Degradation syndromes, example landscapes	Forest transition stage	Rights, re-cognition, co-management&	Restoration modalities#	ES-co-invest-ment@	Reference
A. Degraded hillslopes					
1. Kendari, SE Sulawesi	3	Stable	2,3		Wartemberg et al. 2019
2. N Thailand	3(4)	Stable	1,2		Box 11. 3
3. Sumberjaya, Lampung	6	HKM	2,3		Van Noordwijk et al. 2019i
4. S Sulawesi	6	Stable	3,4		Mulyoutami et al. 2015
5. Rejoso, E Java	6	Stable	3,4	New	Leimona et al. (2019)
B. Over-intensified monocropping					
1. Claveria, Philippines	3	Ex land reform	3,4		Mercado et al. 2005
2. Lantapan, Philippines	4(6)	Stable	3,4		Catacutan and Mercado 2003
3. NW Vietnam	5	Stable	3,4		Box 11. 4
C. Fire-climax grasslands					
1. Lake Singkarak, W Sumatra	3	Stable	2,3	RUPES	Burgers and Farida, 2017
2. North Lampung	6	Stable	3		Purnomosidhi et al. 2005
D. Forest classification conflicts					
1. Setulang, N. Kalimantan	2	Partly contested	1,2	Failed1	Wunder et al. 2008
2. Batang Toru, N Sumatra	3	Partly contested	1,2		Martini et al. 2012
3. Lubuk Beringin, Jambi	3	Hutan Desa	2,3 2,3	RUPES	Akiefnawati et al. 2010; Villamor et al. 2014a; Dewi et al. 2013
4. Krui, W. Lampung	3	KDTI	2,3	RUPES	Kusters et al. 2007
5. Kalahan, Philippines	4	Indigenous claim			Leimona et al. 2009
E. Drained peatlands					
1. Ex-Mill-ha-rice, C Kalimantan	2	Contested	3	Failed2	Galudra et al. 2011
2. Pulang Pisau, C Kalimantan	2	Several Hutan Desa	2,3,4	BRG	Suwarno et al. 2018 Tata and Tampubon 2016
3. Lamandau, C Kalimantan	3	Stable	1,2	REDD+	Janudianto et al. 2011
4. Tripa, Aceh	3	Contested	1,2,3		Tata et al. 2014
5. TanJaBar, Jambi	3	Partly contested	2,3,4		Galudra et al. 2014; Tata et al. 2016
6. Musi Banyu Asin & Ogan Komering Ilir, S Sumatra	3	Partly contested	2,3,4	BRG	Box 11. 5
F. Converted mangrove					
1.Pidie: post-Tsunami	3	Stable	3		Roshetko et al. 2008a
2. Aceh Barat: post- Tsunami	3	Stable	3		Lusiana et al. 2011
3. Post typhoon Haiyan, Philippines	6	Stable	2,3		Carlos et al. (2015)
G. Disturbed soil profiles					
1. Bangsri: sand mining	5	Stable	3,4		Box 11. 6, Hairiah (2018)
2. Kali Konto: Kelud ash	6	Stable	2,3,4		Van Noordwijk et al. 2019e

Notes: & Tenure regimes: HKM community forestry agreement, Hutan desa village forest agreement, KDTI special forest designation; # Modalities 1. Leave alone, let natural processes prevail; 2. Assisted/ managed natural regeneration; 3. Tree planting/ growing; 4. Soil and water management interventions; @ ES-co-investment: RUPES (Leimona et al. 2015), BRG: Indonesian Peat Restoration Agency, Failed1: attempts for biodiversity-based finance, Failed2: Australian C project

Change will only happen and be sustained if it has local support, often in the form of collective action and coinvestment of time, land, skills, social capital and (often more limited) financial resources. Awareness that ongoing degradation is a risk, even before disasters observed elsewhere are locally replicated, can be supported by external contacts (television, social media), but more often by local people who temporarily lived or visited elsewhere and can share their experience and expectations.

A similar process of adaptation preventing a challenge to underlying drivers may well be at the heart of accepting existing inequalities, including a gender imbalance in rights, respect, responsibilities and rewards. As gender equality is a central part of the Post-2015 sustainable development agenda it deserves attention in all parts of the DPSIR analysis (Villamor et al. 2014a). Differences in opportunities, challenges, preferences and responses between men and women are important in the relationship between poverty, climate change and land degradation (Kabeer 2005; Meinzen-Dick et al. 2014; Catacutan et al. 2015). In designing land restoration options, the links between gendered land-use choices (i.e., preferences of new land use options) and their implications to ecosystem services provision needs specific attention (Catacutan and Villamor 2016). Often, men and women have contrasting views and choices regarding land, which could influence future land uses and management practices (Villamor and van Noordwijk, 2016). Coalitions for restoration of environmental functionality are more effective when women and young people of all genders are involved, beyond existing gender and age hierarchies in formal decision making. Environmental degradation often affects women disproportionately, with girls prevented from attending school by being tasked to fetch water from far-away wells with clean water a 'poster child' image. Benefits of restoration can thus accrue to most vulnerable groups in local societies – if only they get a voice in decisions on when, what and where and how. Reviving collective action for resetting the clock on environmental degradation can be a starting point for further challenge to existing hierarchies – one of the reasons that 'powers that be' may be reluctant and resist transformative actions that disrupt not only ongoing degradation but also the existing hierarchies that tolerated, or even benefitted, from them.

While slowly creeping, locally driven, degradation is a common cause of loss of functionality, degradation can often be traced to externally mediated or initiated resource extraction (e.g. timber, coal, mineral deposits) or modification (e.g. roads, reservoir construction, externally managed plantations). In this context, the concept of 'Free and prior informed consent' (FPIC) may need to be broadened to assessing and adopting social safeguards for all planned programs (de Royer et al. 2013). As such interventions tends to offer short-term employment it may 'buy votes' in local community discourses, while causing uncompensated costs to others. Once awareness of such change has passed a threshold, where it starts to further grow as an issue of concern beyond then initial advocates, conflicts arise with the external agents and the government entities and officials that 'legalized' these actions through permits in exchange for (il)legal levies and fees. Depending on political context and strength of local voices (e.g. in elections), conflict resolution may be initiated, and a restoration agenda furthered.

It is here that the lack of formal recognition of agroforestry exacerbates problems in a policy and spatial planning framework that only recognizes 'agriculture' (usually within a fully privatized land ownership perspective) and various 'forest' categories that exclude local access and use. While forestry laws have over the past decades accommodated forms of 'community-based forest management' in many countries, the implementation is often slow and far behind on publicly stated targets. Its administrative procedures and multi-layered approval remain complex (Akiefnawati et al. 2010; de Royer et al. 2018) and its basic assumptions of the constitutional legality of state forest claims (hence community-based forest management rather than community forestry) remain presumptuous in the absence of legally prescribed gazettement of state forest claims. An undifferentiated 'community' perspective is often as misaligned with collective action formats as the agricultural assumption of fully private property rights regimes. In-between, new ways of identifying individual and collective rights and responsibilities remain needed. Traditional resource management, known as 'adat' in Indonesia[2] (De Royer et al. 2015), provided such middle ground but often needs updating and change to immediate pressures and opportunities. The 'bundle of rights' with regards to land is currently understood (Galik and Jagger; van Noordwijk and Catacutan 2017) to include:

- ***Access***: entering a defined physical property
- ***Harvest/withdrawal***: obtaining 'products' of a resource
- ***Management***: regulating internal use patterns and transforming or improving the resource
- ***Alteration***: changing the set of goods and services provided (and stated objective reflecting this)
- ***Exclusion***: determining access rights for others
- ***Alienation***: selling or leasing some or all other rights

Restoration activities commonly interact with all such rights but need to be based on an understanding that they don't necessarily coincide with a single concept of 'ownership'.

Action to modify land use, including restoration, starts with dissatisfaction with status quo, visions of alternative futures, trust in agents of change and realistic step-by-step pathways out of the current situation (Villamor et al. 2014a). Too often extension' designs have assumed that lack of technical know-how of the steps involved would be the limiting step. Farmer-to-farmer approaches to extension provide a more all-round answer to the requirements for change, even if in technical terms it may not be superior to expert advice as basis of extension (Martini et al. 2017). Hybrid approaches are becoming more common in 'rural development' programs and need to be embraced in 'restoration' versions of such (van Noordwijk et al. 2019h).

11.2.2. Methods for system analysis of restoration in a nested governance world

A two-way classification of 'contextualized issues' and 'adaptive solutions' can help clarify the 'what?', 'where?' and the technical side of 'how?' of restoration. It has implications for the social dimensions of 'who?', 'so what?' and 'who cares?' and the entry-points to 'driver' level solutions, but these require a third, process-oriented dimension. Process-wise, success is understood to depend on effective diagnosis and ways of addressing I. Community-driven motivation and responsive polycentric governance structures, II. Rights and tenurial security, III. Means, knowledge of and skills in sustainable land management practices, IV. Markets for inputs and outputs and V. the generation of downstream ecosystem service benefits. Together these can initiate adaptive learning cycles that create turning points (from decline to recovery) in local tree

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[2] As 'adat' forms the central letters of degradation, its demise can be seen as one of the causes and its reinvention as part of the solution

cover transition curves and create co-benefits that justify coinvestment.

The purpose of the initial characterization is to allow interested outsiders, like yourself, to connect to the insider's perspective of those who live in the area, with the expectation that a more systematic analysis can also provide new insights for those who know the place, but who may take many of its features for granted.

Six leading questions to understand landscapes as socio-ecological system (Minang et al., 2015) can connect an understanding of past degradation and what it takes to initiate restoration (Fig. 11.7):

Why? Assessing past degradation and its drivers,

Who? Settlement history and ethnicity, tenure perspectives, gender differentiation,

What? Land use practices, their productivity and resource dependency,

Where? Spatial structure of landscape as land use imposed on underlying geomorphology,

So what? Effects of current situation on ecosystem functions and targets for restoration,

Who cares? Identifying livelihoods goals, stakeholders in restoration.

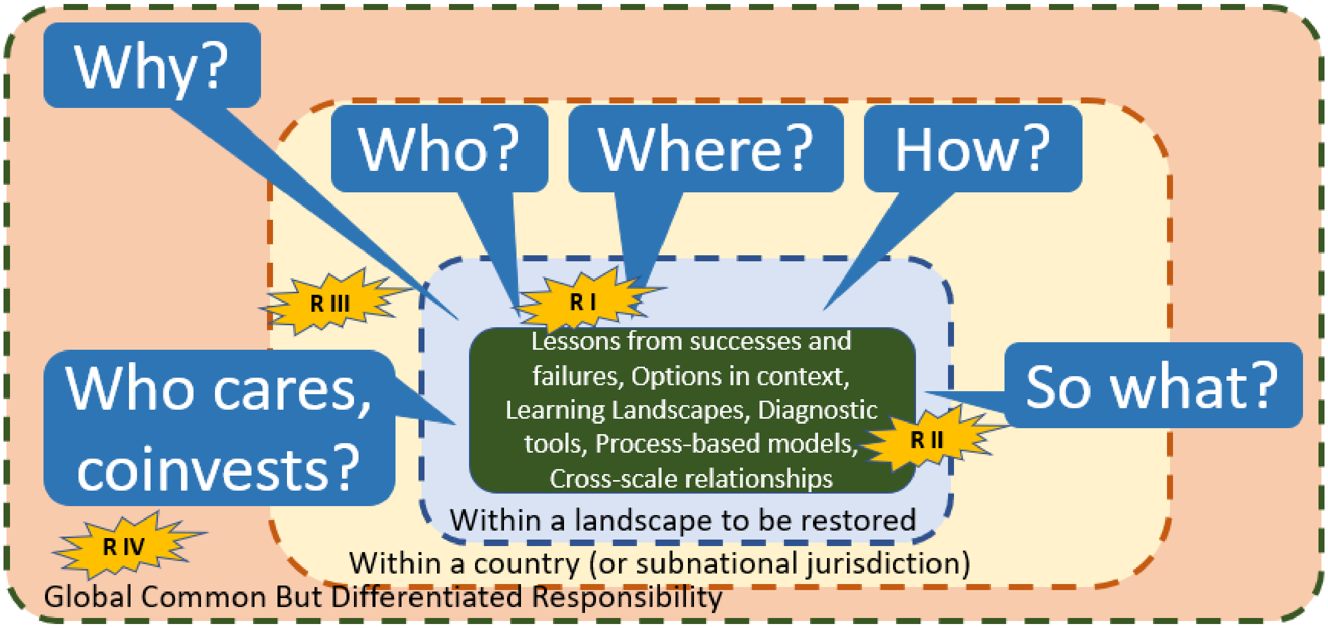

Figure 11.7. Six questions that drive a social-ecological systems understanding of the Drivers-Pressures-State-Impacts-Responses (DPSIR) loops around degradation and restoration, with agroforestry as part of a broader livelihoods and nature-based solutions agenda

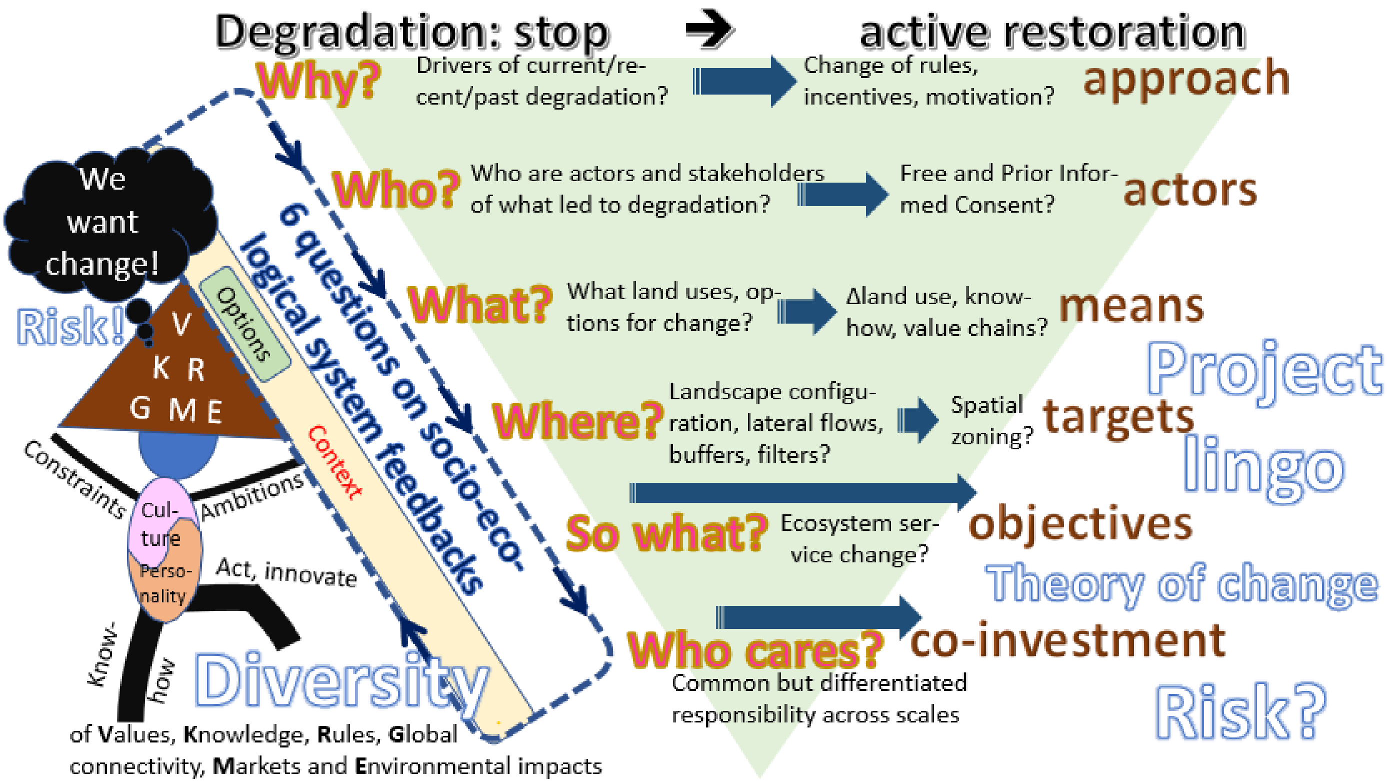

Figure 11.8. Project design terminology related to the six primary questions for analysis of a Social-Ecological System to understand 'options-in-context' once local actors are committed to change

Table 11.2. Assessment steps in a negotiation support process based on the NSS toolbox (van Noordwijk et al. 2013)

	Who	What	Where	So what	Who cares	Why
Initial appraisal	Poverty, livelihoods (Papold)	Participatory landscape appraisal (PALA)			Drivers of observed land use change (DriLUC)	
Detailed assessments of options	Livelihoods and land use: trees, agroforestry technology and markets (10 tools, 5 models)		Ecosystem services and tradeoffs (11 tools, 8 models), e.g. rapid hydrological appraisal (RHA) for hydrology		Transformations, governance, rights (8 tools) e.g. RATA for tenure claims, WNoTree for degradation diagnostic	
Synthesis	Negotiation support as process (5 tools)					
	Planning of strategic restoration interventions in local context					

A range of methods is available to find answers to the six categories of questions and support the development of 'theories of induced change' that can be used for project designs (Fig. 11.8). The negotiation support toolbox developed in Southeast Asia (van Noordwijk et al. 2013) is focussed on the divergence of three knowledge systems: local ecological knowledge, public/ policy knowledge (the underpinning of policies) and science (of a full range of disciplines). The toolbox starts with three initial appraisals, and then proceeds after a first reconciliation of the three knowledge systems, zooming in on aspects that may provide traction for change.

Innovative gender research methods are available to better understand gender issues in local context and identify gender-responsive solutions/approaches that foster transformational change in agriculture, forestry, health and food security, value chains, payments for ecosystem services, property rights, and landscape management (van Noordwijk et al. 2013; Catacutan et al. 2014; Colfer et al. 2015; Andeltova et al. 2019).

11.3. Seven degradation syndromes and restoration actions through agroforestry

Syndromes here refer to a set of concurrent diagnostical indicators, not necessarily linked to a common cause or driver. Just as in the medical use of the syndrome concept, further diagnostics are needed to assess appropriate courses of action.

11.3.1. Degraded hillslopes

In land-scarce parts of Southeast Asia farmers found ways to establish woody perennials along contours in their swiddens and by doing so reduce erosion and facilitate the rapid establishment of fallows (Fig. 11.9). The farmer-developed technology became the inspiration for a Sloping Agricultural Land Technology (SALT) that was widely promoted. Establishment of regularly pruned hedgerows on sloping land became one of the most popular forms of agroforestry in the 1980's. Farmers in the Philippines, however, modified the technology to suit their needs: they developed hedgerow establishment methods that required less labour, eliminated grasses that were too competitive with crops, stopped planting trees that were initially intended to produce green manures, and planted species that might provide direct cash returns (Fujisaka 1993). The different systems they used controlled soil erosion equally and effectively, although grazing of hedgerows by neighbours' cattle was a problem. Replacing nitrogen fixing trees by a managed regeneration of grass, in naturally vegetated strips, as start of terrace risers (Garrity 1996) reduced the need for labour-intensive pruning, but it still led to differential soil fertility or 'scouring' within the terraces formed (Agus et al. 1999). Elsewhere, the economic interest of farmers shifted from the food crops in swidden to the products that introduced (e.g. *Hevea brasiliensis*) and local (e.g. *Durio zibethinus*) trees could provide. Although there was considerable soil movement in the plot in the year of slash-and-burn land clearing, little of that

Box 11. 3 Supporting indigenous trees with restricted means of dispersal in NW Thailand

In many parts of Southeast Asia agriculture switched from swidden-fallow systems on sloping land to an agroforest pathway, where the trees and other components, such as rattan (Tata 2019a), tubers or mushroom, became more important than the annual crops in the swiddens (Cairns, 2007, 2015). Elsewhere, however, the surrounding forest matrix had lost much of its' diversity and the spontaneous establishment of desirable forest species became slow and unreliable (Wangpakapattanawong et al. 2010). To deal with such situations a forest restoration approach with 'framework' species was developed (Elliott et al. 2003), where the rapid establishment of a tree canopy was expected to attract seed dispersants and facilitate establishment of a wider array of species. As little knowledge existed of the specific nursery requirements for a wide array of desirable forest tree species, research focussed on filling these knowledge gaps. Rather than by a lack of biological-technical knowledge, however, the experience of (agro)forest restoration in NW Thailand shows that the social aspects of transforming conflicts over control and ownership into a win-win opportunity for all are the most challenging step towards success (Elliott et al. 2019).

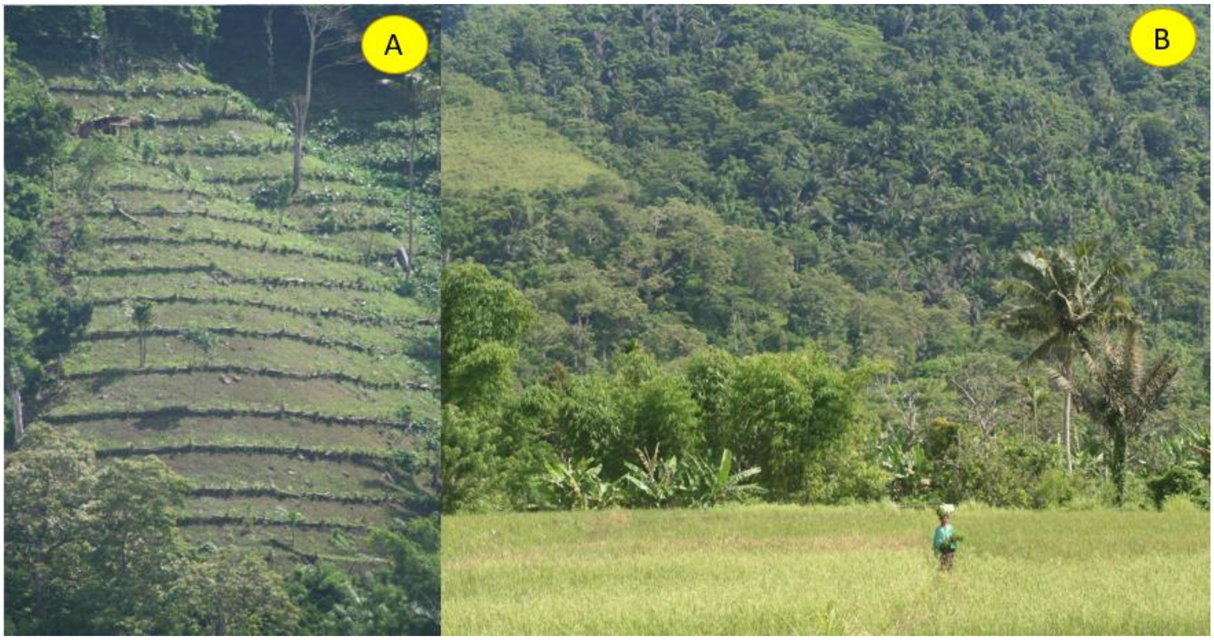

Figure 11.9. Establishment of local woody species (including *Leucaena leucocephala*) as practices in parts of Flores (Indonesia) became the inspiration if a contour hedgerow intercropping system for restoring degraded slopes, with less tree diversity than found in the area where the technology originated (Photographs: Meine van Noordwijk/World Agroforestry)

reached the streams and a fertile zone next to the stream facilitated subsequent agroforest management (Rodenburg et al. 2003). In some cases, however, external support for establishment of desirable trees was found to be needed (**Box 11.** 3).

11.3.2. Fire-climax grasslands

In the early 1990'ties *Imperata cylindrica* ('alang-alang', or 'cogon') dominated grasslands were estimated to occupy 35 Mha in tropical Asia, roughly 4% of the total land area, with 8.5 Mha in Indonesia alone (Garrity et al. 1996). These grasslands were closely associated with annual fires that prevented the natural succession to secondary forests, and effective fire control was a key step towards ecological restoration (Wibowo et al. 1996). Where some of these grasslands were found on degraded hillslopes, with shallow and compacted soils that enhanced surface runoff and downstream flooding, others were not less fertile than the forest soils from which they had been converted had been, once the litter layer had been removed by slash-and-burn land clearing (Santoso et al. 1996). The grasslands were widely seen as an underutilised resource that could be reclaimed for more intensive food crop production or smallholder timber-based agroforestry (van Noordwijk et al. 1996; Purnomosidhi et al. 2005), deflecting pressures for further forest conversion (Garrity et al. 1996). Agroforestry-based technologies for reclamation of *Imperata* grasslands were popularized, with assisted natural regeneration (allowing tree seedlings to escape the early competition and fire risks) as low-cost alternative to the use of herbicides (Friday, 1999; Murniati, 2002). A number of studies pointed to local success in replacing *Imperata* grasslands with diverse agroforests once local communities had secured rights to restore on their own terms (de Foresta and Michon 1996). A recent reconfirmation that such is indeed possible is provided by Burgers and Farida (2017) for the Lake Singkarak area in West Sumatra. As a large part of the grasslands was found to be part of ‘State Forest’ lands, their continued existence came to be seen as a symptom of property right conflicts and market failures to allow higher-value land uses to emerge (Tomich et al. 1996). At least part of the fires that gave rise to *Imperata* grasslands were attributed to conflict (‘fire as a weapon’) between local people and large-scale forest plantation concessions that occupied lands they saw as their own (Tomich et al. 1998). Subsequent analysis has shown that widespread Imperata grasslands were indeed transient phase in the land use history of many parts of Sumatra, even when their extent was still increasing in Kalimantan and areas further east in Indonesia (Ekadinata et al. 2010). Analysis of long-term land cover change in Southeast Sulawesi by Kelley et al. (2017) suggested that the smallholder tree crop economy likely produced both forest loss and *Imperata* grassland restoration in this region. The study by Zhang et al. (2019) in the Philippines showed that hydrological ‘restoration’ deep infiltration of rainfall in reforested *Imperata* grasslands may take decades rather than years, depending on how far the grasslands had been compacted after the old tree root channels of preceding forest vegetation had been lost.

Once economically more attractive (e.g. land with logging rights and expected income) options have become closed off, the reclamation of *Imperata* (and similar) grasslands is technically feasible, both by smallholders (establishing adequate tree cover to shade out the grass, with less than 20% of solar radiation reaching the understorey according to Purnomosidhi et al. 2005) and large-scale operators (often relying more heavily on the use of glyphosate and other herbicides). Property rights, including a rationalisation of forest classifications, have been a starting point for most restoration successes analysed so far.

11.3.3. Over-intensified mono-cropping

A vast extent of agricultural land in Southeast Asia is under over-intensified monoculture systems (e.g., maize, rice, sugarcane, pineapple, cassava, banana etc.,). As part of ‘modernization’ large areas of these systems have become mechanized, with high chemical input use and, where they are practiced on upland sloping lands with inadequate soil conservation. The application of soil and water conservation technologies in mono-cropped sloping fields, is considered labour and capital intensive, making it difficult to convince farmers to shift their practice. Consequently, every year, an enormous amount of fertile topsoil is being lost and chemical inputs are wasted---this process undermines future land productivity, causing farm yields to decline while input costs increase. Consequently, local and national economies experience significant losses, threatening the sustainability of agricultural systems. **Box 11.** 4 describes a case study in Vietnam, where efforts to re-introduce agroforestry as part of restoration depend on finding tree species with good market demand and accepted/supported by the government.

Fortunately, much is now known about various ways to control soil erosion while at the same time, further increasing productivity and enhancing the long-term sustainability of intensive farm production (Catacutan 2008. In Mindanao island in the Philippines, contour farming and agroforestry have proven to drastically control soil loss by retaining fertile soil and chemical inputs in the fields. These practices first involve the establishment of grass strips along contour lines, which enables farmers to produce more high-quality forage for their livestock, and second, the combination of high-value tree crops (Mercado et al. 2005). This agroforestry model dramatically enhances farm income compared to open-field maize mono-cropping and enable farmers to create a diversified and integrated farming system

Box 11. 4 Promoting agroforestry as sustainable agricultural practice in Northwest Viet Nam

Agroforestry options for land restoration vary considerably within the Viet Nam (Mulia et al. 2018). Northwest Viet Nam covers an area of about 5.64 million ha and is home to ethnic minority groups. The region is mountainous with 60% of lands having slopes at or steeper than 15 degrees (Staal 2014). Many local people rely on agriculture for livelihood (Beck 2017), with shifting cultivation and maize monoculture as common agricultural practices on the fragile sloping lands (Hoang et al. 2017). The region had a poverty rate of 13.8% in 2016 compared to the national rate of 5.8% (Viet Nam statistic year book 2017). Incidences of soil erosion and declining agricultural yield owing to soil degradation are common across the region (Hoang et al. 2017, Zimmer et al. 2018).

Hoang et al. (2017) recommended agroforestry system i.e. integration of trees into agricultural lands with contour planting for Northwest Viet Nam. The annual crops can be combined with timber or fruit trees and strips of grass for fodder or market as additional source of income. Roshetko et al. (2017) implied that this recommended practice is simple and low cost with proven conservation measure and has direct positive environmental and economic benefits such as more permanent soil cover, improved soil structure and infiltration, diversified agricultural products and income, higher carbon storage and soil organic matter. La et al. (2016) provide guidance for establishing the system.

According to Zimmer et al. (2018), adoption rate by farmers in the Northwest region to the recommended practices was slow due to lack of knowledge and lack of financial backup during the transition from the current into new practices. Hoang et al. (2017) identified that farmers still felt uncertain on the market access of new products and had difficulty in accessing credits for investment. To enhance the adoption rate, the government's supports in providing better access to market e.g. through improved infrastructure and information network, better access to credit, more certainty in terms of land tenure-ship by providing land use certificate, and better extension system to increase knowledge and skills in plot management option, are necessary.

Figure 11.10. Typical agricultural sloping lands in Northwest Viet Nam with low tree cover and serious soil erosion (Photo credit: Rachmat Mulia, World Agroforestry)

that dramatically increase income and protects land resources from degradation. Such agroforestry models were widely adopted predominantly by maize farmers in Mindanao via the Landcare approach---a social approach to technology dissemination that capitalizes on the collective action of farmers, extension workers, and researchers with support from local governments (Cramb et al. 2007). Farmer-leaders were trained by extension workers and researchers, to produce quality germplasm, and were supported to establish nurseries, to ensure availability of seedlings for a variety of tree species that farmers incorporate into their maize fields (Catacutan and Mercado 2003). Landcare groups were formed to facilitate farmer-to-farmer learning exchanges, and to reach out for financial and further technical support. Measured in terms of rate and extent of agroforestry adoption and social capital, the success of Landcare in Mindanao was quite remarkable and an inspiration for similar landscapes elsewhere.

11.3.4. Forest classification conflicts

When practitioners of a ‘landscape approach’, seeking to enhance the multifunctionality of landscapes they facilitate, were asked to rank a range of factors that currently limit progress, they identified roughly half of such factors operating at and potentially modifiable within the landscape, and about half that originate at higher levels of governance (Langston et al. 2018). Among the latter the classification scheme for forest institutional regimes (typically including production, (watershed) protection and (biodiversity) conservation forests) are a major constraint, especially where the current situation on the ground no longer matches the planned situation and/or when classifications were imposed that from their start clashed with local use and claimed rights. Fay and Michon (2005) argued that in redressing forestry institutions, forestry regulatory frameworks may in parts of the landscape (especially where production is prioritised) best be replaced by an agrarian one. In name community-based forest management has achieved a higher profile. However, from a community perspective current forest tenure reforms are still limited in effectiveness by the restricted nature of the area that falls under their regime, the type of use that are allowed and the bureaucratic procedures (Larson and Pulhin 2012). Southeast Asia is no exception in this respect.

In Indonesia, the first significant progress in recognizing agroforests as successful examples of local resource management that should not be burdened by misinterpretations that they represent natural forest came in the Krui landscape at the west coast of Lampung (Kusters et al. 2007). This breakthrough helped in framing further legal options when the Forestry Law was revised, after the political transition to a democratic government. Next steps in making community-based forest management applicable in a coffee agroforestry landscape in a watershed protection setting were initiated in Sumberjaya (van Noordwijk et al. 2019i). A rubber agroforest landscape at the edges of the Kerinci Seblat National Park in Lubuk Beringin became the first to get ‘Village Forest’ (or ‘Hutan desa’) rights within this protection forest category (Akiefnawati et al. 2010). Other locations followed, although at a slower pace than envisaged, and in those that had obtained rights, a general sense of disappointment was recorded, that active restoration and use of the area remained burdened by procedures and rules (De Royer et al. 2018). A positive exception may be Lubuk Beringin that was able to convert its recognition and status to become a local focus for water-based tourism, with economic opportunities for especially women and youth. Examples elsewhere in Southeast Asia of how indigenous agroforestry has facilitated restoration, despite not being recognized in existing regulation (Cairns 2007, 2015).

3.5. Drained peatlands

Peatlands were mostly avoided in early human settlement patterns in Southeast Asia, as access is not easy, land clearing does not result in fertile soils and the subsidence after clearing makes areas even more vulnerable to flooding (van Noordwijk et al. 2014). Local drainage to transport logs became enlarged for canals to drain peat water. Once dry, peat soils shrink (causing the surface level to subside) and don't easily rewet, making them susceptible to fire. At landscape scale peat fires, which don't burn hot and clean, cause a large amount of haze that is toxic to all living organisms. Moreover subsidence implies the area becomes even more vulnerable to flooding in the rainy season. On the shallower edges of peatland, part of the soil (especially that with a mangrove history) developed the acid-sulphate syndrome when the pyrite concentrations in deeper layers became aerated and extremely acid. Large-scale plantation development only became economically attractive when other land became scarce (and complex by the land tenure conflicts that often emerged), and technical options for deep drainage became available, and attracted resources from national and international 'development' agencies. Many of these projects failed, as acid-sulphate soils developed, subsidence disturbed the drainage systems and the drainage dramatically increased vulnerability to fire.

Sago, a wetland-adapted palm, has been an important resource for local food and marketable products in various parts of Southeast Asia, but it has lost much of its ground, when the wetlands where it grew were converted to paddy rice fields (as documented for SE Sulawesi, for example, by Kelly

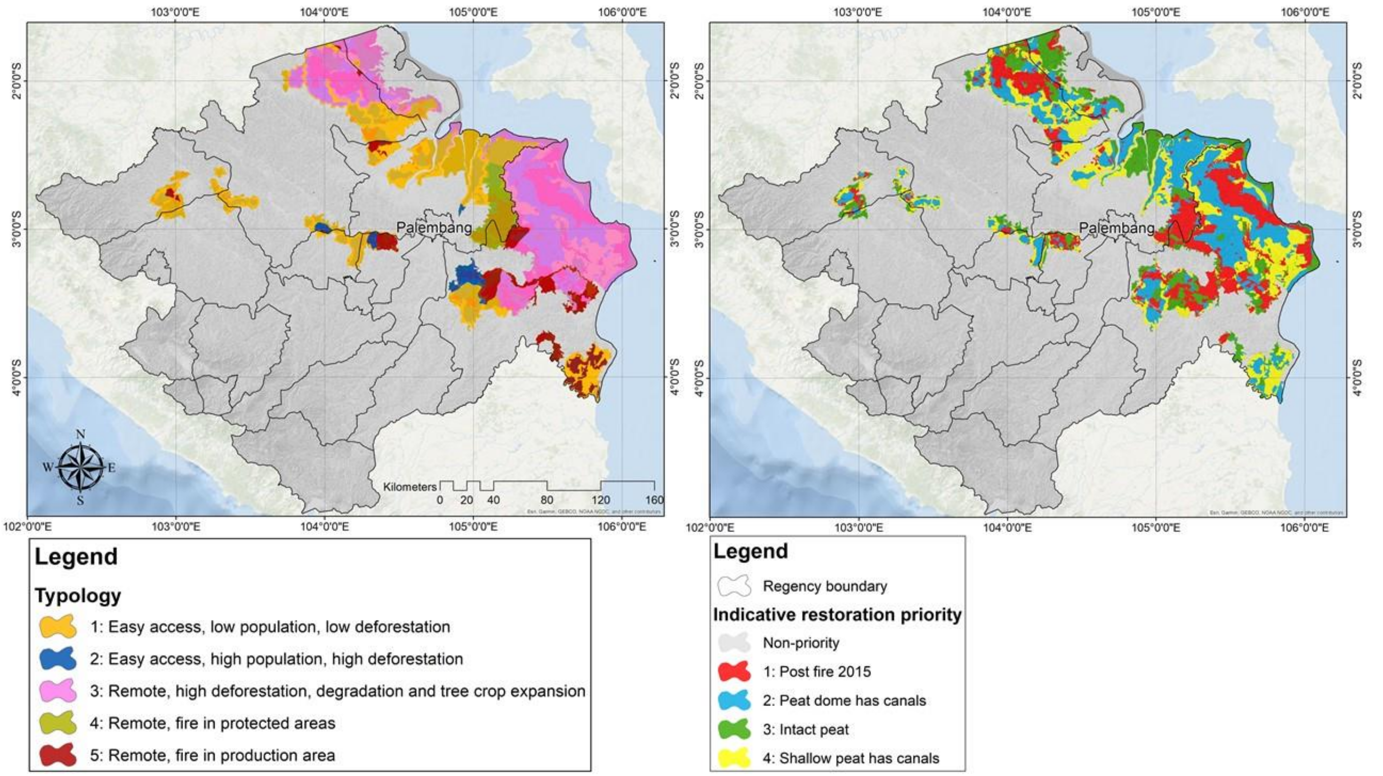

Figure 11.11 Intervention maps of peat ecosystems restoration: (a) zonation and prioritization of conservation, protection and production functions; (b) typology of fire risks, degradation risks, socio-economic conditions and access

et al. 2017). Elsewhere, sago stands were replaced by that of another palm, less tolerant of wet peatland conditions: *Elaeis guineensis* (oil palm). On shallower, sapric peatlands, such conversion was economically attractive (though the initial investment in drainage was higher than that for non-peat areas), on fresh forest peatlands, the conversion was a financial as well as economic disaster (Veloo et al. 2015). Current restoration primarily depends on rewetting and canal blocking, but face mixed responses from local communities, while the mandated restriction

Box 11. 5. Prioritizing peat restoration opportunities in South Sumatra (Indonesia)

South Sumatra was a major part of the 2015 land and forest fires in Southeast Asia, competing with Riau and Jambi as the three peat-rich provinces of Sumatra (Ekadinata et al. 2013, Tata et al. 2015, Dewi et al. 2015). When the Peat Restoration Agency (Badan Restorasi Gambut-BRG) was created and developed its Peat Ecosystem Restoration Plan (Rencana Restorasi Ekosistem Gambut or RREG), the province was a logical target. Understanding the driving factors of peat degradation is instrumental in managing and restoring degraded peat. At national level, the Ministry of Environment and Forestry has launched a regulation on Peat Ecosystem Protection and Management Plans applicable to all Peat Hydrological Units (which include peat domes and their transitions to rivers) in Indonesia. In South Sumatra the driving factors cover three of the five aspects mentioned in Figure 11.2: Rights (policies and policy gaps on land allocation and management, especially for large scale plantations), Knowledge on land use practices (lack of awareness and knowledge to manage peatland sustainably, related to the socio-economic conditions of local people), and Markets (Logging concessions, illegal logging to meet demand of pulp mills, oil palm and fastwood plantations). It had negative impacts on the other two: local health (by loss of clean air as local ecosystem service), and loss of global services (C emissions, biodiversity loss). The three groups of drivers identified induce pressures on (agro)forest conversion, especially through the construction of canals to provide easier access to peatlands and/or drain them, with associated social and tenurial conflicts. Smallholder farmers also contribute to worsen the fire risks through their traditional rice planting using fire for land clearing (*sonor* systems), which produce quite low economic benefits (Suyanto, 2007).

The process in developing the RREG consisted of: (i) diagnostic process on the baseline condition of peatland in South Sumatra, particularly in districts Musi Banyu Asin and Ogan Komering Ilir; (ii) zoning and medium-term peat restoration planning. The first level zoning of the peat hydrological unit categorises two main functions: protection (protected zone) and production (cultivation zone). Further the second level zoning was conducted based on the typology of the degradation level and the drivers of degradation, to ensure a more targeted action plan in each setting. Figure 11.11(a) presents the resulting zonation of conservation, protection and production areas. Figure 11.11(b) shows the typology of peat hydrological sub-units based on function, fire risks, deforestation and land use changes, socio-economic conditions and access. For each of the types identified, main actions for interventions are proposed within 3 categories: (i) community awareness raising programs; (ii) institutional capacity development; (iii) sustainable livelihood options. Restoration actions involve the (partial) closure of drainage canals, reliance on natural or assisted natural regeneration, and/or planting of trees that tolerate wet conditions in their root zones and don't depend on drainage below the now mandated 40 cm below the soil surface.

The RREG development proved to be useful not only in terms of the output, but also through its inclusive planning process that increased awareness and built social capital among the stakeholders. To our knowledge, South Sumatra RREG is the only document that was produced inclusively with a provincial team. South Sumatra RREG has been published in 2019 by BRG and South Sumatra Government Regulation has been issued and enacted.

on drainage in plantations (requiring groundwater levels to be no deeper than 40 cm) are not easy to achieve in practice with existing (tree) crops (Khasanah and van Noordwijk 2019; Tata 2019b). In this context there has been strong interest in ‘wetland agroforestry’ as part of (or relative of) ’paludiculture’ (Widayati et al. 2016; van Noordwijk et al. 2019e). The number of local tree species that can be used in wet peatland agroforestry, however, is still limited (Tata et al. 2018).

As the haze resulting from peatland fires became recognized as a major human health hazard, besides disturbing public and economic life, prevention of haze episodes as experienced in 2015 became a government priority (with targets that events at the time of writing in 2019 show have only been partly achieved). Revisions of provincial land use and ‘green economy’ development plans became a major target for a more coordinated government prevention plus restoration response (**Box 11.** 5).

3.6. Converted mangroves

Part of the human victims of the December 2004 Tsunami could have been avoided if people would have not lived at the coastline, especially in places that had been converted from mangroves, or in zones directly behind mangroves where the protective effect of this vegetation had been diminished by the creation of aquaculture, mostly shrimp ponds (Budidarsono et al. 2007). Elsewhere, other coastal tree-based vegetation was found to have a similar effect, proportional to the direct flow resistance provided by trees (Bayas et al. 2011). From this analysis it is understandable that initial ‘restoration’ efforts after the Tsunami focussed on mangrove restoration. Despite considerable planting effort, the success rate of re-establishing mangrove was, however, small (van Noordwijk et al. 2019e), as issues of property rights and alternative livelihoods were not simultaneously addressed. In other contexts, with longer timeframes for preparation,

Figure 11.12. Mining effects in Bungo district (Jambi, Indonesia) A. Scar left behind when a species-rich rubber agroforest (studied by ICRAF researchers) became converted to an open-cast coal mine as the deeper carbon stocks had more market value than those related to current vegetation; B. Converting of subsoil white sands to a slurry, passed over a gold retrieval filter, before left of the soil surface (Photo credit: Meine van Noordwijk/World Agroforestry)

mangrove restoration has had a mixed and partially contested success rate (https://oceanwealth.org/applications/mangrove-restoration/; Lovelock and Brown, 2019). In the coastal areas affected by the Tsunami, establishment of a diverse, economically attractive tree cover has had more success than those targeting mangroves specifically.

3.7. Disturbed soil profiles, including ash deposition and ex-mining sites

Surface mining for coal and metals, and the overhaul of river sediments in search for gold deposits affects relatively small areas but leaves behind deep scars (Fig. 11.12) that can decades or centuries to become part of landscapes with positive functions. Such mining provides short-term employment, and some revenue to local police and local government, but otherwise leaves substantial social costs of a disturbed environment. Where mining is more technically advanced and planned, restoration of the remaining (or reconstructed) soil profiles is mandated as part of mining permits. Some of the soils can still have high metal contents and be unsuitable for crops for human consumption; in such cases timber production can be the most economic alternative land use. Elsewhere agroforestry as provider of local food is possible.

Box 11. 6 describes a case study of sand mining on volcanic slopes where agroforestry development for mid-slope positions has to be part of the landscape-level solution to avoid further degradation and assist in restoration of damage already done. In this case study the local sand mining was found to interact with climate change and loss of biodiversity (Hairiah 2018).

Figure 11.13. A. Sand mining and B. the soil profile it leaves behind; C. Agroforestry as provider of food, firewood and cash income; D. development of water storage for small-scale irrigation of vegetables under tree cover as major alternative to involvement in sand mining (Photo credit: Kurniatun Hairiah/Brawijaya University)

Box 11. 6 Sand mining on a volcanic mountain slope

Volcanic eruptions disrupt adjacent land areas where volcanic ash is deposited, but also create temporary employment as the sand-sized fraction in the riverbed can be extracted as building material. More disruptive that that, older sand deposits in the landscape can also be mined, leaving land behind without any topsoil. A recent study of the Bangsri subcatchment of the Brantas basin (East Java, Indonesia) on the western slope of the active Semeru (Mahameru) mountain (highest top on Java) showed the challenges this type of sand mining creates for any restoration or subsequent use of this part of the landscape. The upper slopes in the sub-catchment are part of the Bromo Tengger Semeru National Park (TNBTS), with the mid-slope zone mostly classified as production forest (managed as part of the Perhutani estate) or agroforestry (owned and managed by farmers) with partial or 'closed' canopy. Land use systems (LUS) in the lower slopes, are monoculture agriculture and settlements that tend to lead to an ‘open’ canopy. The area was selected as pilot for a national scheme to combine the land restoration agenda of the UN-CCD with the climate change adaptation agenda of the UNFCCC. Details of a diagnostic study were provided in Hairiah (2018). There is evidence of a wetter and more variable rainfall regime that, combined with the poorly consolidated volcanic ash imply a high risk of landslide disasters and high sediment concentrations in the river. The diagnostic study found that climate change effects on local livelihoods are exacerbated by the sand (volcanic ash) mining activities, operated by communities living in and outside the Bangsri watershed.

According to focus group discussions (FGD) and interviews with farmers sand mining is, for the short term and at current prices, indeed more profitable than farming. However, the long-term decline of usable agricultural land increased pressures on the mid-slope parts of the landscape. After sand mining, despite efforts to bring back topsoil, low macropore connectivity inhibits infiltration and the development of plant roots. Production costs on such land are high and yields low. It became clear that for the watershed as a whole to regain the resilience it needs, the longer-term costs of sand mining will have to be recovered from those who benefit in the short term, likely reducing the pressure. This requires coordination between the local community, village authorities and watershed authorities, dealing with the current external beneficiaries. Such measures need to be accompanied by labour-absorbing efforts in the middle-zone agroforestry in the landscape where local water storage increases opportunities for vegetable crops under partial tree canopy (Fig. 13).

4. Two overarching concerns

As indicated in Fig. 11.5, two aspects of degradation and restoration concerns operate at a more aggregate scale than the syndromes discussed so far: hydrological functions and supply-sheds for value chains at risk.

4.1. Disturbed hydrology

A recent review of the role of agroforestry in ‘nature-based solutions’ to the regular and dependable supply of water of good quality (van Noordwijk et al. 2019g) discussed the scale relations and tradeoffs, both upstream-downstream in watersheds, and upwind-downwind in precipitationsheds (Ellison et al. 2019). While on small islands agroforestry is a natural concepts for integrating land use (Van Noordwijk 2019), elsewhere agriculture tends to be the user whose needs gets prioritized and (restored) forests the supplier of water, to be supported by environmental service policies (Minang et al. 2019). Five aspects of vegetation (leaf area index throughout the year (phenology), litter layer, soil macroporosity, rooting depth and possible influences on rainfall) are now understood to govern the main hydrological functions (Jones et al. 2019) and respond over different temporal and spatial scales to land cover and land use change. As a point of reference for attributing floods and droughts to 'degradation' trees can be read as history books that, through their growth rings, allow reconstruction of frequency and severity of past climate variability (Chen et al. 2019).

The main 'degradation' issues that trigger restoration activities remain concerns over water quality (sediment load), short response times to extreme rainfall events causing flooding by lack of buffer functions, and limited recharge of groundwater reserves. Interactions within a watershed between degrading or restoring hillslopes, riverbeds and surrounding riparian flow buffering areas are well understood in eco-hydrological models, but attention in restoration still tends to go to the hillslopes rather than downstream buffering functions. Some new metrics (van Noordwijk et al. 2017) allow inclusion of agroforestry interventions in watershed restoration planning. In terms of water quantity the increase in demand by trees with a different phenology to native vegetation remains a concern. Recent data analysis for increase of rubber (*Hevea brasiliensis*) expansion in mainland Southeast Asia showed that impacts depend on the elevation at which conversion occurs, as well as the nature of the vegetation replaced by rubber plantations (Ma et al. 2019).

A quantitative diagnosis was also found to be needed to clarify the relative importance of different altitudinal zones on the Rejoso watershed, planned source of piped drinking water for Indonesia's second largest city. Zone-specific agroforestry interventions were proposed and are currently being tested. Social differentiation was also noted, with a test of group-level versus individual contracts for watershed restoration at high and midlevel land uses ongoing (Leimona et al. 2019).

4.2. Supply-sheds at risk

Another entry-point for higher-level concerns over degradation and potential source of co-investment in restoration have become the value chains of commodities produced in tropical landscapes. Concerns over rising prices due to shortfall of production in degrading landscapes, interacts with concerns of global consumers who don't want to be (or feel) responsible for the degradation that is reported in the press as a consequence of their consumption patterns. With these concerns, the response of 'certification' has become important in several (but not all) tropical commodities, with mixed effects on 'shifting blame' as well as 'resolving issues' (Leimona et al. 2018).

Where consumer boycotts and certification response represent a top-down response, there is also an increase in its bottom-up complements, especially where 'jurisdictional' approaches take 'green growth' initiatives, and articulate regional identity as brand that can be dynamically managed interacting with the outside world and its shifting concerns and standards. Agroforestry as basis of the production of tropical commodities coffee, cacao, rubber and even palm oil (Slingerland et al. 2019) as well as energy (van Noordwijk et al. 2019f) can tell an attractive story that combines social and ecological concerns. Emerging global assessments of the economics of land degradation (Nkonya et al. 2016) have an interesting challenge to combine all such costs and benefits. The range of methods required to help agroforestry meet its full potential in such issues keeps expanding (van Noordwijk and Coe, 2019).

Table 11. 3. Overview of characteristics for the seven degradation syndromes in the SE Asian landscapes studied (relative importance is indicated by number of asterisks) and issues identified

Degradation syndrome and forest transition (FT) stage of landscapes studied	I. Community-driven motivation to reverse degradation	II. Rights and tenurial security	III. Means, knowledge of and skills	IV. Markets for inputs and outputs	V. Local & downstream, ecosystem benefits	VI. Global ecosystem benefits
SDG-links	2,3,4,5,10,16	5,10,16	4,5,8,17	1,2,8,9,12	3,6,7,11	13,14,15,17
A. Degraded hill-slopes FT 3-6	Landslides, flash-floods	* Local bylaws, sharecropping CBDR	* Supporting functional tree diversity	* Limited quality of tree nurseries	** Water quality and flow persistence	* Impacts on downstream wetlands, coral reefs
B. Over-intensified mono-cropping FT 3-5	Relationship with agricultural input enterprises	(*) Contract farming	** Soil health management	** Risk management	* Foregone LER$_M$ benefits	(*) Crop-specific certification
C. Fire-climax grasslands FT 3-6	Fire risks, Relationship with forestry enterprise	** Tenure, Fire as weapon	* Local fire control	* Risk for tree crops	** Escaping fires	* C emissions
D. Forest classification and local rights FT 2-4	Legality of agroforestry, respect for communities	** Ineffective forest tenure instruments	(*) Respect for local knowledge	(*) Often ‘remote’ locations	** Local ES taken for granted	* Global biodiversity benefits
E. Drained peatlands FT 2-3	Haze, Relationship with plantation enterprises	** Land preparation without burning; Rewetting mandates, enforcement? ~ peatland hydrology	** Rewetting techniques, water management, paludiculture options	* Shortage of paludiculture products	** Haze control, fire risks	** Transboundary haze control agreement Globally relevant C emissions
F. Converted mangroves FT 3-6	Flood risk, Relationship with shrimp and charcoal enterprises	* Existing protection rules ignored	* Options to ‘work with nature’	** Emerging certification	** Coastal fish breeding grounds	** Protection of adjacent coral reefs
G. Disturbed soil profiles FT 5-6	Relationship with mining enterprise	** Uncontrolled local mining practices	** Recovery - remediation techniques	(*) Markets for ‘mining’	* Impacts on hydrology	(*) Pollution of downstream wetlands

4. Discussion

The ‘forest transition stage’ information of site-level studies to issues and solutions has some predictive value for the type of interventions that are most appropriate (Table 11. 3): sorting out rights issues and focussing on market access in the early stages of transition, supporting nurseries of excellence and diversity in the middle and supporting soil and water interventions on the later stages. Yet, as a ‘Theory of Place’ underpinning ‘Theories of Change’ the current forest transition stage typology needs further refinement.

Across all the ‘degradation syndromes’ studied we found strong confirmation that at least five of the six ‘aspects’ in Figure 11.2 are important: 1. Local institutions and motivation, 2. Rights and their impacts on who is using land, 3. Land use practices and associated knowledge and knowhow, 4. Markets for inputs and outputs, 5. Local environmental services (often the starting point for ‘degradation’ assessments and often related to disturbed hydrology). In the absence of strict law enforcement *de facto* rights matter more than formal ones, as the Krui example showed for Indonesia (Kusters et al. 2007): the recognition by forest authorities of the *damar* agroforests as farmer-made meant that the formal procedure for individual farmer permits was not deemed necessary. This is similar to the Niger case of farmer-managed natural regeneration where practice was ahead of formal recognition (Garrity and Bayala 2019). The recently adopted ASEAN agroforestry policy guidelines (Catacutan et al. 2019) provide a conducive environment for targeted actions for inducing change at the landscape level, but only if bottom-up initiatives can connect with such top-down support.

Less clarity was obtained on aspect 6. Global connectivity, where it seems arbitrary and outside of local control whether or not global discourses pick up on the issues that are locally identified. This has led to disappointment in developing Payments for Ecosystem Services (PES) schemes (Wunder et al. 2008) and the lack of success stories for REDD+, despite all the preparatory efforts that went into this idea (Agung et al. 2014). There has been more progress with locally led co-investment schemes for environmental services that focussed on aspect of the disturbed hydrology (Leimona et al. 2015), although metrics for performance-based arrangements remain elusive (van Noordwijk et al. 2016). Co-investment has become a central paradigm for the various stakeholders to define their take on the common but differentiated responsibility for degraded landscapes (Namirembe et al. 2017). However, it remains an art that is difficult to grasp for ‘planners’.

Where ‘restoration’ is to be managed as a program or project, it requires ‘metrics’ as markers of progress and clarity on targets. The four intensities of restoration (Box 11. 1) clarify that ‘restoration’ has no fixed endpoint, other than, through engagement of and often coinvestment by, external stakeholders bringing issues within the reach of farmer-level ecological intensification within a land use system. A recently introduced metric (van Noordwijk et al. 2018) of the ‘multifunctionality Land Equivalent Ratio’, LER_M, (the amount of land needed to provide all of the products and services a land unit provides, if all functions would be segregated into specialized ways of providing the same) may in future serve as a single metric that can mark progress. Multifunctionality is, like beauty, in the eye of the beholder: what is improvement for one (e.g. transforming mixed rainforest to a fastwood plantation) can be degradation for somebody else.

While SE Asia stands out in its current prevalence of agroforests, nuclei of similar farmer-developed tree-based land uses are found elsewhere as well. The current analysis for SE Asia may have to be followed up by a global comparative study. Globally additional syndromes (including overgrazing, overharvesting) will have to be included, but the same six aspects, the four intensities, the SDG framework and proposed multifunctionality performance metric are likely as relevant globally.

When we can combine a 'theory of place' (at the what? where? level of system states), with a theory of change (impacts on stakeholders leading to responses and efforts to change drivers and pressures), we may see opportunities for a 'theory of induced change' that clarifies entry-points for external stakeholders to 'nudge' and 'coinvest' in the local social-ecological system (Minang et al. 2019), transforming from 'degrading' to 'restoring' phases. The rapid succession of 'theories of induced change' associated with international initiatives such as Integrated Conservation Development Projects, Reduced Emissions from Degradation and Deforestation, Global restoration commitments (Bonn challenge), Ecosystem-based Adaptation, Community-Based Adaptation, Climate-Smart Agriculture or Green Growth is hard to understand at the grassroots level, and has supported a new class of intermediaries and entrepreneurs in the landscapes, who often lack the deeper understanding of local social-ecological systems needed to make real progress (Langston et al. 2019; Minang et al. 2019).

The SDG framework is probably still the best platform for discussing and increasing coherence, as the SDGs can be mapped to all six aspects identified and allows primary agenda holders (at landscape, national and global scales) for all separate SDGs to come together to make progress for each set of indicators.

5. Conclusions

All six aspects identified (1. Local institutions and motivation, 2. Rights, 3. Knowledge and know-how of land use practices, 4. Markets for inputs and outputs, 5. Local ecosystem services 6. Global connectivity) can be a starting point for restoration interventions, but progress is typically limited by several (or all) of the others, with the first as major challenge where priority setting has been essentially top-down. Entry points such as Integrated Conservation Development Projects, Reduced Emissions from Degradation and Deforestation, Global restoration commitments (Bonn challenge), Ecosystem-based Adaptation, Community-Based Adaptation, Climate-Smart Agriculture or Green Growth are all permutations of the current Sustainable Development Goals agenda, and are best seen as a continuum, rather than as silo's competing for donor attention. They all need to deal with the current drivers of degradation and find ways to facilitate and support locally-led recovery of landscape multifunctionality. The SE Asian experience with agroforestry, despite its lack of formal recognition in formal agricultural or forestry policies until recently, offers lessons to learn across a wide range of 'degradation syndromes', acknowledging that a more careful and location-specific diagnosis has to be a first step towards successful interventions.

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References

Agung P, Galudra G, van Noordwijk M, Maryani R (2014) Reform or reversal: the impact of REDD+ readiness on forest governance in Indonesia. Clim Policy 14: 748-768.

Agus F, Garrity DP, Cassel DK (1999) Soil fertility in contour hedgerow systems on sloping oxisols in Mindanao, Philippines. Soil Till Res 50(2): 159-167.

Akiefnawati R, Villamor GB, Zulfikar F, Budisetiawan I, Mulyoutami E, Ayat A, van Noordwijk M (2010) Stewardship agreement to reduce emissions from deforestation and degradation (REDD): case study from Lubuk Beringin's Hutan Desa, Jambi Province, Sumatra, Indonesia. Int For Rev 12(4): 349-360.

Andeltová L, Catacutan D C, Wünscher T, Holm-Müller K (2019) Gender aspects in action-and outcome-based payments for environmental services—Tree planting conservation auctions. Ecosyst Serv 35: 13-22.

Bayas JL, Marohn C, Dercon G, Dewi S, Piepho H, Joshi L, van Noordwijk M, Cadisch G (2011) Influence of coastal vegetation on the 2004 tsunami wave impact in West Aceh. Proc. Nat. Acad. of Science 108: 18612–18617.

Beck U (2017) Local transformation: a commune-level analysis. In: Tarp F (Ed.) Growth, structural transformation, and rural change in Viet Nam: a rising dragon on the move. Oxford University Press, Oxford. pp 51-67.

Budidarsono S, Wulan YC, Budi LJ, Hendratno S (2007) Livelihoods and forest resources in Aceh and Nias for a sustainable forest resource management and economic progress. ICRAF Working Paper No. 55. World Agroforestry Centre, Bogor (Indonesia).

Burgers P, Farida A (2017) Community management for agro-reforestation under a voluntary carbon market scheme in West Sumatra. In: S Namirembe, B Leimona, M van Noordwijk, PA Minang PA (Eds.) Co-investment in ecosystem services: global lessons from payment and incentive schemes. Nairobi: World Agroforestry Centre (ICRAF).

Cairns M (2007) Voices from the forest: integrating indigenous knowledge into sustainable upland farming. Earthscan, London. pp826.

Cairns MF (2015) Shifting cultivation and environmental change: Indigenous people, agriculture and forest conservation. Routledge, London. pp1030.

Carlos C, Delfino RJ, Juanico DE, David L, Lasco R (2015) Vegetation resistance and regeneration potential of Rhizophora, Sonneratia, and Avicennia in the Typhoon Haiyan-affected mangroves in the Philippines: Implications on rehabilitation practices. *Clim. Disaster Dev. J. http://dx. doi. org/10.18783/cddj. v001. i01. a01*.

Catacutan DC, Mercado A (2003) Technical and Institution-Building for Sustainable Upland Development: Landcare in the Philippines. In: R Serrano, R Agangan (Eds). Sustainable Upland Development. Los Banos, Laguna, Philippines: PCARRD, pp 149-170.

Catacutan DC (2008) Care of Soil. R Lal (ed.). Encyclopedia for Soil Science. Taylor & Francis, New York (USA). pp 342-344.

Catacutan DC, McGaw E, Llanza M (Eds) (2014) In Equal Measure: A user guide for gender analysis in agroforestry. World Agroforestry Centre. Los Banos, Philippines.

Catacutan DC, Naz F, Nguyen H (2015) Gender Dimensions of Agroforestry Adoption in Vietnam. Int For Rev. 17(S4).

Catacutan DC, Villamor GB (2016) Gender roles and land use preferences— implications to landscape restoration in Southeast Asia, Chapter 6.2 In: Chabay I, Frick M, Helgeson J (Eds.), Land Restoration: Reclaiming Landscapes for a Sustainable Future. Academic Press: Boston, pp. 431-440.

Catacutan DC, Finlayson R, Perdana A, Lusiana B, Leimona B, Simelton E, Öborn I, Galudra G, Roshetko JM, Vaast P, Mulia R, Lasco R, Dewi S, Borelli S, Yasmi Y (2019) Policy guidelines for agroforestry development adopted by ASEAN. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 329−351.

Chazdon RL, Guariguata MR (2016) Natural regeneration as a tool for large-scale forest restoration in the tropics: prospects and challenges. Biotropica, 48(6), pp.716-730.

Chen F, Shang H, Panyushkina I, Meko D, Li J, Yuan Y, Yu S, Chen F, He D, Luo X (2019) 500-year tree-ring reconstruction of Salween River streamflow related to the history of water supply in Southeast Asia. Clim Dyn https://doi.org/10.1007/s00382-019-04948-1

Chokkalingam U, de Jong W (2001) Secondary forest: a working definition and typology. Int For Rev 3(1): 19-26.

Colfer C, Catacutan D C, Naz F (2015) Gender in Agroforestry: Synthesis of Special Issue. International Forest Review. Vol. 17(S4).

Cramb RA, Catacutan DC, Culazero-Arellano Z, Mariano K (2007) The “Landcare” approach to soil conservation in the Philippines: an assessment of farm-level impacts. Aust J Exp Agric 47: 721-726.

de Foresta H, Michon G (1996) The agroforest alternative to Imperata grasslands: when smallholder agriculture and forestry reach sustainability. Agroforest Syst 36: 105-120.

de Foresta H, Kusworo A, Michon G, Djatmiko WA (2000) Ketika kebun berupa hutan: Agroforest khas Indonesia sebuah sumbangan masyarakat. ICRAF, Bogor. pp249.

de Jong W, van Noordwijk M, Sirait M, Liswanti N (2001) Farming secondary forests in Indonesia. J Trop For Sci 13(4): 705-726.

de Royer S, Galudra G, Pradhan U (2013) Assessing and adopting social safeguards in all planned programs (AASSAPP). In: van Noordwijk M, Lusiana B, Leimona B, Dewi S, Wulandari D (eds.) Negotiation-support toolkit for learning landscapes. World Agroforestry Centre (ICRAF), Bogor, pp 240-244.

de Royer S, Visser L E, Galudra G, Pradhan U, van Noordwijk M (2015) Self-identification of indigenous people in post-independence Indonesia: a historical analysis in the context of REDD+. Int For Rev 17(3): 282-297.

de Royer S, van Noordwijk M, Roshetko J (2018) Does community-based forest management in Indonesia devolve social justice or social costs? Int For Rev 20(2): 167-180.

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

Dewi S, van Noordwijk M, Dwiputra A, Tata HL, Ekadinata A, Galudra G, Sakuntaladewi N (2015) Peat and land clearing fires in Indonesia in 2015: Lessons for polycentric governance. ASB Policy Brief 51. ASB Partnership for the Tropical Forest Margins. World Agroforestry Centre (ICRAF). Nairobi (Kenya),

Dewi S, van Noordwijk M, Zulkarnain MT, Dwiputra A, Prabhu R, Hyman G, Gitz V, Nasi R. (2017) Tropical forest-transition landscapes: a portfolio for studying people, tree crops and agro-ecological change in context. Int J Biodiv Sci Ecosyst Serv Man 13(1): 312-329.

Ekadinata A, van Noordwijk M, Dewi S, Minang P A (2010) Reducing emissions from deforestation, inside and outside the 'forest'. ASB Policy Brief 16. ASB Partnership for the Tropical Forest Margins. World Agroforestry Centre (ICRAF). Nairobi (Kenya),

Ekadinata A, van Noordwijk M, Budidarsono S, Dewi S. (2013) Hot spots in Riau, haze in Singapore: the June 2013 event analyzed. ASB Policy Brief 33. ASB Partnership for the Tropical Forest Margins. World Agroforestry Centre (ICRAF). Nairobi (Kenya), 6p

Elliott S, Navakitbumrung P, Kuarak C, Zangkum S, Anusarnsunthorn V, Blakesley D (2003) Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. For Eco Man 184: 177-191.

Elliott S, Chairuangsri S, Kuaraksa C, Sangkum S, Sinhaseni K, Shannon D, Nippanon P, Manohan B (2019) Collaboration and conflict—developing forest restoration techniques for northern Thailand's upper watersheds whilst meeting the needs of science and communities. Forests 10(9): 732.

Ellison D, Wang-Erlandsson L, van der Ent R, van Noordwijk M (2019) Upwind forests: managing moisture recycling for nature-based resilience. Unasylva 251.

Fay C, Michon G (2005) Redressing forestry hegemony when a forestry regulatory framework is best replaced by an agrarian one. For, Trees Livel 15(2): 193-209.

Friday K S (1999) Imperata grassland rehabilitation using agroforestry and assisted natural regeneration. World Agroforestry Centre.

Fujisaka S (1993) A case of farmer adaptation and adoption of contour hedgerows for soil conservation. Exp Agric 29(1): 97-105.

Galik C S, Jagger P (2015) Bundles, duties, and rights: A revised framework for analysis of natural resource property rights regimes. Land Econ 91: 76-90.

Galudra G, van Noordwijk M, Suyanto S, Sardi I, Pradhan U, Catacutan D (2011) Hot Spots of Confusion: Contested Policies and Competing Carbon Claims in the Peatlands of Central Kalimantan (Indonesia). Int Forest Rev 13: 431-441.

Galudra G, van Noordwijk M, Agung P, Suyanto S, Pradhan U (2014) Migrants, land markets and carbon emissions in Jambi, Indonesia: land tenure change and the prospect of emission reduction. Mitig Adapt Strateg Glob Change 19(6): 715-732.

Garrity D P (1996) Tree-Soil-Crops interaction on slopes. Tree-crop interactions. CAB. Wallingford. UK.

Garrity D P, Soekardi M, van Noordwijk M, De La Cruz R, Pathak P S, Gunasena H P M, Van So N, Huijun G, Majid N M (1996) The Imperata grasslands of tropical Asia: area, distribution, and typology. Agroforest Syst 36(1-3): 3-29.

Garrity DP, Bayala J (2019) Zinder: farmer-managed natural regeneration of Sahelian parklands in Niger. In: van Noordwijk M (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. Bogor, Indonesia. pp 132-152.

Hairiah K (2018) Climate change adaptation and mitigation in the Bangsri micro watershed East Java. Final Report of CCCD Project. UB- KLHK –UNDP. pp61

HLPE (2019) Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. www.fao.org/cfs/cfs-hlpe.

Hoang L T, Roshetko J M, Pham H T, Pagella T, Nguyen M P (2017) Agroforestry: the most resilient farming system for the hilly Northwest of Viet Nam. Int J Agric Syst 5(1): 1-23.

IPBES (2018): Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. R Scholes, L Montanarella, A Brainich, N Barger, B ten Brink, M Cantele, B Erasmus, J Fisher, T Gardner, T G Holland, F Kohler, J S Kotiaho, G Von Maltitz, G Nangendo, R Pandit, J Parrotta, M D Potts, S Prince, M Sankaran, L Willemen (eds.). IPBES secretariat, Bonn, Germany. 44 pages

Janudianto ME, Widayati A, Mulyoutami E, van Noordwijk M (2011) Recognizing traditional tree tenure as part of conservation and REDD+ strategy: Feasibility study for a buffer zone between a wildlife reserve and the Lamandau river in Indonesia's REDD+ Pilot Province. ASB Policy Brief 22. ASB Partnership for the Tropical Forest Margins. World Agroforestry Centre (ICRAF). Nairobi (Kenya),

Jones JA, Wei X, Archer E, Bishop K, Blanco JA, Ellison D, Gush M, McNulty SG, van Noordwijk M, Creed IF (2019) Forest-Water Interactions Under Global Change. Chapter 24. In: D F Levia et al. (Eds) Forest-Water Interactions. Ecological Studies 240. Springer Nature, Switzerland. https://doi.org/10.1007/978-3-030-26086-6_24

Kabeer N (2005) Gender equality and women's empowerment: A critical analysis of the third millennium development goal 1. Gender Dev 13, 13-24.

Kelley L C, Evans S G, Potts M D (2017) Richer histories for more relevant policies: 42 years of tree cover loss and gain in Southeast Sulawesi, Indonesia. Glob Ch Biol 23(2): 830-839.

Khasanah N, van Noordwijk M (2019) Subsidence and carbon dioxide emissions in a smallholder peatland mosaic in Sumatra, Indonesia. Mitig Adapt Strat Glob Ch 24: 147–163.

Kristensen P (2004) The DPSIR framework. Natl. Environ. Res. Inst. Den. 10.

Kusters K, de Foresta H, Ekadinata A, van Noordwijk M (2007) Towards solutions for state vs. local community conflicts over forestland: the impact of formal recognition of user rights in Krui, Sumatra, Indonesia. Hum Ecol 35(4): 427-438.

La N, Catacutan D C, Roshetko J M, Mercado A R, Tran H M, Vu T H, Pham H T, Do V H, Nguyen M P (2016) Agroforestry guide for sloping lands in Northwest Viet Nam. World Agroforestry Centre (ICRAF). Ha Noi, Viet Nam.

Langston J, McIntyre R, Falconer K, Sunderland T J C, van Noordwijk M, Boedihartono A K (2019) Discourses mapped by Q-method show governance constraints motivate landscape approaches in Indonesia. PLoS ONE 14(1): e0211221.

Larson A M, Pulhin J M (2012) Enhancing forest tenure reforms through more responsive regulations. Conserv Soc 10(2) p.103.

Leimona B, Joshi L, van Noordwijk M (2009) Can rewards for environmental services benefit the poor? Lessons from Asia. Int J Comm 3(1): 82-107.

Leimona B, van Noordwijk M, de Groot R, Leemans R (2015) Fairly efficient, efficiently fair: Lessons from designing and testing payment schemes for ecosystem services in Asia. Ecosyst Serv 12: 16-28.

Leimona B, van Noordwijk M, Mithöfer D, Cerutti PO (2018) Environmentally and socially responsible global production and trade of timber and tree crop commodities: certification as a transient issue-attention cycle response to ecological and social issues. Int J Biodiv Sc Ecosyst Serv Man 13(1): 497-502.

Leimona B, McGrath FL, Khasanah N (2019) Sharing knowledge and value for nurturing socioecological production landscapes: a case of payment for ecosystem services in Rejoso watershed, Indonesia. In: Saito O (Ed.) Sharing Ecosystem Services: Building More Sustainable and Resilient Society. Springer Nature, Singapore

Lovelock CE, Brown B M (2019) Land tenure considerations are key to successful mangrove restoration. Nat Ecol Evol 3(8): 1135-1135.

Lusiana B, van Noordwijk M, Suyamto D, Mulia R, Joshi L, Cadisch G (2011) Users' perspectives on validity of a simulation model for natural resource management. Int J Agric Sust 9(2): 364-378.

Ma X, Lacombe GC, Harrison P, Xu J, van Noordwijk M (2019) Expanding rubber plantations in Southern China: evidence for hydrological impacts. Water 11: 651.

Martini E, Roshetko JM, van Noordwijk M, Rahmanulloh A, Mulyoutami E, Joshi L, Budidarsono S (2012) Sugar palm (*Arenga pinnata* (Wurmb) Merr.) for livelihoods and biodiversity conservation in the orangutan habitat of Batang Toru, North Sumatra, Indonesia: mixed prospects for domestication. Agrofor Syst 86(3): 401-417.

Martini E, Roshetko JM, Paramita E (2017) Can farmer-to-farmer communication boost the dissemination of agroforestry innovations? A case study from Sulawesi, Indonesia. Agrofor Syst 91(5): 811-824.

Meinzen-Dick R S, Kovarik C, Quisumbing A (2014) Gender and Sustainability. Ann Rev Env Res 39: 29-55.

Mercado A R, Catacutan D C, Stark M, Laotoco M A C, Lasco R D, Banaticla M R N (2005) Enhancing adoption of soil conservation practices through technical and institutional innovations: NVS and Landcare. In: Proceedings of The Symposium on Sustainable Agricultural Development of Marginal Upland Areas in the Philippines, Quezon City, Philippines. pp. 12-24.

Miccolis A, Peneireiro F M, Marques H R, Vieira, D L M, Arcoverde M F, Hoffmann M R, Rehder T, Pereira A V B, (2016) Agroforestry Systems for Ecological Restoration: How to reconcile conservation and production. Options for Brazil's Cerrado and Caatinga biomes. Brasília: Instituto Sociedade, População e Natureza – ISPN/World Agroforestry Centre (ICRAF), (https://www.worldagroforestry.org/publication/agroforestry-systems-ecological-restoration-how-reconcile-conservation-and-production

Minang PA, van Noordwijk M, Freeman OE, Mbow C, de Leeuw J, Catacutan D (eds). 2015. Climate-Smart Landscapes: Multifunctionality In Practice. World Agroforestry Centre (ICRAF). Nairobi (Kenya). 404 pp

Miccolis A, Peneireiro F M, Marques H R (2019) Restoration through agroforestry in Brazil: options for reconciling livelihoods with conservation. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 205- 227.

Minang P A, van Noordwijk M, Duguma L A (2019) Policies for ecosystem services enhancement. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia) pp 311-323.

Minasny B, McBratney A B, Hong S Y, Sulaeman Y, Kim M S, Zhang Y S, Kim Y H, Han, K.H., (2012) Continuous rice cropping has been sequestering carbon in soils in Java and South Korea for the past 30 years. Glob Biogeochem Cyc 26(3).

Minasny B, Malone B P, McBratney A B, Angers D A, Arrouays D, Chambers A, Chaplot V, Chen Z S, Cheng K, Das B S, Field D J (2017) Soil carbon 4 per mille. Geoderma, 292: 59-86.

Mulia R, Nguyen M P, Do H T (2018) Forest and crop-land intensification in the four agro-ecological regions of Viet Nam: impact assessment with the FALLOW model. In: Mulia R, Simelton E (eds) Towards low-emissions landscapes in Viet Nam. World Agroforestry (ICRAF), Bogor (Indonesia) pp. 89-110.

Mulyoutami E, Roshetko JM, Martini E, Awalina D (2015) Gender roles and knowledge in plant species selection and domestication: a case study in South and Southeast Sulawesi. Int For Rev 17(4): 99-111.

Murniati A P (2002) From Imperata cylindrica grasslands to productive agroforestry. PhD thesis Wageningen University, Tropenbos International, Wageningen (the Netherlands).

Namirembe S, Leimona B, van Noordwijk M, Minang PA (eds) (2017) Co -investment in ecosystem services: global lessons from payment and incentive schemes. World Agroforestry Centre (ICRAF), Nairobi (Kenya).

Nkonya E, Mirzabaev A, Von Braun J (eds) (2016) Economics of land degradation and improvement: a global assessment for sustainable development. Cham, Germany: Springer Open.

Purnomosidhi P, Hairiah K, Rahayu S, van Noordwijk M (2005) Smallholder options for reclaiming and using Imperata cylindrica L.(alang-alang) grasslands in Indonesia. In: C A Palm, S A Vosti, P A Sanchez, P J Ericksen, A S R Juo (eds) Slash-and-burn agriculture: the search for alternatives. Columbia University Press, New York. pp. 248-262.

Rodenburg J, Stein A, van Noordwijk M, Ketterings Q M (2003) Spatial variability of soil pH and phosphorus in relation to soil run-off following slash-and-burn land clearing in Sumatra, Indonesia. Soil Till Res 71(1): 1-14.

Roshetko J M, Idris N, Purnomosidhi P, Zulfadhli T, Tarigan J (2008)a Farmer extension approach to rehabilitate smallholder fruit agroforestry systems: the" Nurseries of excellence (NOEL)" program in Aceh, Indonesia. In IV International Symposium on Tropical and Subtropical Fruits 975: 649-656.

Roshetko JM, Snelder DJ, Lasco RD, Van Noordwijk M (2008)b Future challenge: a paradigm shift in the forestry sector. In: Snelder DJ, Lasco RD (eds) Smallholder tree growing for rural development and environmental services (). Springer, Dordrecht. pp. 453-485.

Roshetko J M, Mercado A R, Martini E, Prameswari D (2017) Agroforestry in the uplands of Southeast Asia. Policy Brief no. 77. Agroforestry options for ASEAN series no. 5. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Jakarta, Indonesia: ASEAN-Swiss Partnership on Social Forestry and Climate Change.

Santoso D, Adiningsih S, Mutert E, Fairhurst T, van Noordwijk M (1996) Soil fertility management for reclamation of Imperata grasslands by smallholder agroforestry. Agroforest Syst 36(1-3): 181-202.

Slingerland M, Khasanah N, van Noordwijk M, Susanti A, Meilantina M (2019) Improving smallholder inclusivity through integration of oil palm with crops. Chapter 5.2 in R Jezeer, N Pasiecznik (eds). Exploring inclusive palm oil production. ETFRN and Tropenbos International, Wageningen, the Netherlands. pp. 147-154.

Staal S (2014) A situational analysis of agricultural production and marketing, and natural resources management systems in northwest Vietnam. International Livestock Research Institute for CGIAR Research Program, Nairobi.

Suwarno A, Hein L, Weikard HP, van Noordwijk M, Nugroho B (2018) Land-use trade-offs in the Kapuas peat forest, Central Kalimantan, Indonesia. *Land Use Pol 75*: 340-351.

Suyanto S (2007) Underlying cause of fire: different form of land tenure conflicts in Sumatra. Mitig Adapt Strat Global Change 12(1), pp.67-74.

Tata HL, van Noordwijk M, Ruysschaert D, Mulia R, Rahayu S, Mulyoutami E, Widayati A, Ekadinata A, Zen R, Darsoyo A, Oktaviani R, Dewi S (2014) Will funding to Reduce Emissions from Deforestation and (forest) Degradation (REDD+) stop conversion of peat swamps to oil palm in orangutan habitat in Tripa in Aceh, Indonesia? Mitig Adapt Strat Global Change 19: 693-713.

Tata H L, van Noordwijk M, Sakuntaladewi N, Bastoni B, Tampubolon A P, Susmianto A, Widayati A (2015) Stopping haze when it rains: lessons learnt in 20 years of Alternatives-to-Slash-and-Burn research in Indonesia. ASB Policy Brief 45. ASB Partnership for the Tropical Forest Margins. World Agroforestry Centre (ICRAF). Nairobi (Kenya),

Tata HL, Tampubolon AP (2016) Participatory approach in the peat swamp management of two different forest statuses in Central Kalimantan. In: Proceedings 15th International Peat Congress 2016. pp: 582-586.

Tata HL**,** Van Noordwijk M, Jasnari, Widayati A (2016) Domestication of *Dyera polyphylla* (Miq.) Steenis in peatland agroforestry systems in Jambi, Indonesia. *Agrofor Syst* 90: 617-630.

Tata H L, Muchugi A, Kariba R, van Noordwijk M (2018) Genetic diversity of Dyera polyphylla (Miq.) Steenis populations used in tropical peatland restoration in Indonesia. Mires Peat 21: 1-14.

Tata HL (2019)a Is smallholder maintaining biodiversity in rattan agroforest? IOP Conference Series: Earth and Environmental Science 298(1), 012034

Tata HL (2019)b Mixed farming systems on peatlands in Jambi and Central Kalimantan provinces, Indonesia: should they be described as paludiculture? Mires Peat 25(8): 1-17

Tomich TP, Kuusipalo J, Menz K, Byron N (1996) Imperata economics and policy. Agroforest Syst 36(1-3): 233-261.

Tomich TP, Fagi AM, de Foresta H, Michon G, Murdiyarso DM, Stolle F, van Noordwijk M, (1998) Indonesia's fires: smoke as a problem, smoke as a symptom. Agroforest Today, 10: 4-7.

van Noordwijk M, Hairiah K, Partoharjono S, Labios RV, Garrity DP (1996) Food-crop-based production systems as sustainable alternatives for Imperata grasslands? Agroforest syst 36(1-3): 55-82.

van Noordwijk M, Suyamto D, Lusiana B, Ekadinata A, Hairiah K (2008) Facilitating agroforestation of landscapes for sustainable benefits: tradeoffs between carbon stocks and local development benefits in Indonesia according to the FALLOW model. Ag Ecosyst Env 126: 98-112.

van Noordwijk M, Lusiana B, Leimona B, Dewi S, Wulandari D (eds) (2013) Negotiation-support toolkit for learning landscapes. World Agroforestry Centre (ICRAF), Bogor, Indonesia.

van Noordwijk M, Villamor GB (2014) Tree cover transitions in tropical landscapes: hypotheses and cross-continental synthesis. GLP Newslet, 10: 33-37

van Noordwijk M, Matthews R, Agus F, Farmer J, Verchot L, Hergoualc'h K, Persch S, Tata HL, Lusiana B, Widayati A, Dewi S (2014) Mud, muddle and models in the knowledge value-chain to action on tropical peatland conservation. *Mitig Adapt Strat Glob Change 19*(6): 887-905.

van Noordwijk M, Goverse T, Ballabio C, Banwart S, Bhattacharyya T, Goldhaber M, Nikolaidis N, Noellemeyer E, Zhao Y, Banwart S A, Noellemeyer A (2015) Soil carbon transition curves: reversal of land degradation through management of soil organic matter for multiple benefits. in: Banwart S, Noellemeyer E, Milne E (Eds.) Soil Carbon: Science, Management and Policy for Multiple Benefits. SCOPE report 71. CAB International, Wallingford (UK). pp 26-46.

van Noordwijk M, Kim YS, Leimona B, Hairiah K, Fisher LA (2016) Metrics of water security, adaptive capacity and agroforestry in Indonesia. Curr Op Env Sust 21: 1-8.

van Noordwijk M, Tanika L, Lusiana B (2017) Flood risk reduction and flow buffering as ecosystem services: I. Theory on a flow persistence indicator. Hydrol Earth Syst Sci 21: 2321–2340.

van Noordwijk M, Catacutan D M (2017) Common but differentiated responsibility for restoration and avoided degradation of commons: who pays for basic rights? Chapter 21 in: Namirembe S, Leimona B, van Noordwijk M, Minang P A (Eds.) Co -investment in ecosystem services: global lessons from payment and incentive schemes. World Agroforestry Centre (ICRAF), Nairobi (Kenya).

van Noordwijk M (2018) Integrated Natural Resource Management as pathway to poverty reduction: innovating practices, institutions and policies. Agric Syst 172: 60-71.

van Noordwijk M, Duguma L A, Dewi S, Leimona B, Catacutan D M, Lusiana B, Öborn I, Hairiah K, Minang P A (2018) SDG synergy between agriculture and forestry in the food, energy, water and income nexus: reinventing agroforestry? Curr Opin Environ Sustain 34: 33-42.

van Noordwijk M (2019) Small-island agroforestry in an era of climate change and sustainable development goals. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia) pp 201-213.

van Noordwijk M, Coe R (2019) Methods in agroforestry research across its three paradigms. In: van Noordwijk M (Ed.) Sustainable Development Through Trees on Farms: Agroforestry in its Fifth Decade. World Agroforestry (ICRAF), Bogor, Indonesia. pp 325-346.

van Noordwijk M, Coe R, Sinclair FL. (2019)a. Agroforestry paradigms. In: van Noordwijk M (Ed.) Sustainable Development Through Trees on Farms: Agroforestry in its Fifth Decade. World Agroforestry (ICRAF), Bogor, Indonesia. pp 1-12.

van Noordwijk M, Rahayu S, Gebrekirstos A, Kindt R, Tata HL, Muchugi A, Ordonez JC, Xu J. (2019)b. Tree diversity as basis of agroforestry. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 13-38.

van Noordwijk M, Barrios E, Shepherd K, Bayala J, Öborn I (2019)c. Soil science as part of agroforestry. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 53-80

van Noordwijk M, Zomer R J, Xu J, Bayala J, Dewi S, Miccolis A, Cornelius J, Robiglio V, Nayak D, Rizvi J (2019)d. Agroforestry options, issues and progress in regional contexts. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia) pp 97-120.

van Noordwijk M, Hairiah K, Lasco R, Tata H L (2019)e. How can agroforestry be part of disaster risk management? In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 215-229.

van Noordwijk M, Khasanah N, Garrity D P, Njenga M, Tjeuw J, Widayati A, Iiyama M, Minang P A, Öborn I (2019)f. Agroforestry's role in an energy transformation that reverses climate change. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp241-260.

van Noordwijk M, Bargues-Tobella A, Muthuri CW, Gebrekirstos A, Maimbo M, Leimona B, Bayala J, Ma X, Lasco R, Xu J, Ong CK. (2019)g. Agroforestry as part of nature-based water management. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 261-287.

van Noordwijk M, Duguma L A, Dewi S, Leimona B, Catacutan D, Lusiana B, Öborn I, Hairiah K, Minang P A, Ekadinata A, Martini E, Degrande A, Prabhu R (2019)h. Agroforestry into its fifth decade: local responses to global challenges and goals in the Anthropocene. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 347-368.

van Noordwijk M, Leimona B, Amaruzaman S (2019)i. Sumber Jaya from conflict to source of wealth in Indonesia: reconciling coffee agroforestry and watershed functions. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. World Agroforestry (ICRAF), Bogor (Indonesia). pp 153-165.

Veloo R, Van Ranst E, Selliah P (2015) Peat characteristics and its impact on oil palm yield. NJAS-Wag J Life Sci 72: 33-40.

Villamor GB, Chiong-Javier E, Djanibekov U, Catacutan D, van Noordwijk M (2014)a Gender differences in land-use decisions: shaping multifunctional landscapes? Curr Op Env Sust 6: 128-133.

Villamor GB, Le QB, Djanibekov U, van Noordwijk M, Vlek PLG (2014)b Biodiversity in rubber agroforests, carbon emissions, and rural livelihoods: An agent-based model of land-use dynamics in lowland Sumatra. Env Mod Softw 61: 151-165.

Villamor G B, van Noordwijk M (2016) Gender specific land-use decisions and implications for ecosystem services in semi-matrilineal Sumatra. Glob Environm Chan 39: 69-80.

Wangpakapattanawong P, Kavinchan N, Vaidhayakarn C, Schmidt-Vogt D, Elliott S (2010) Fallow to forest: applying indigenous and scientific knowledge of swidden cultivation to tropical forest restoration. For Ecol Man 260(8): 1399-1406.

Wartenberg AC, Blaser WJ, Roshetko J, van Noordwijk M, Six J (2019). Soil fertility and Theobroma cacao growth and productivity under commonly intercropped shade-tree species in Sulawesi, Indonesia. Plant Soil https://link.springer.com/article/10.1007%2Fs11104-018-03921-x.

Wibowo A, Suharti M, Sagala APS, Hibani H, van Noordwijk M (1996) Fire management on Imperata grasslands as part of agroforestry development in Indonesia. Agroforest Syst 36(1-3): 203-217.

Widayati A, Tata HL, van Noordwijk M (2016) Agroforestry in peatlands: combining productive and protective functions as part of restoration. Policy Brief no. 70. Agroforestry options for ASEAN series no. 4. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program; Jakarta, Indonesia: ASEAN-Swiss Partnership on Social Forestry and Climate Change.

Wills J, Herbohn J, Moreno MOM, Avela M S, Firn J (2017) Next-generation tropical forests: reforestation type affects recruitment of species and functional diversity in a human-dominated landscape. J Appl Ecol 54(3): 772-783.

Wunder S, Campbell BM, Frost P, Sayer JA, Iwan R, Wollenberg L (2008) When donors get cold feet: the community conservation concession in Setulang (Kalimantan, Indonesia) that never happened. Ecol Soc 13(1).

Xu J, Lebel L, Sturgeon J (2009) Functional links between biodiversity, livelihoods, and culture in a Hani swidden landscape in southwest China. Ecol Soc 14(2).

Zhang J, Bruijnzeel LA, Quiñones CM, Tripoli R, Asio VB, van Meerveld H J (2019) Soil physical characteristics of a degraded tropical grassland and a ‘reforest’: Implications for runoff generation. Geoderma 333: 163-177.

Zimmer HC, Le TH, Duc L, Baynes J, Nichols JD (2018) Why do farmers still grow corn on steep slopes in northwest Vietnam? Agroforest Syst 92(6): 1721–1735

Zomer RJ, Oborn I, Xu J (2019) Tree cover on agricultural land in the Asia-Pacific region. Working Paper 294. Bogor, Indonesia: World Agroforestry (ICRAF) Southeast Asia Regional Program. DOI: 10.5716/WP19005.PDF.