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Ecosystem recovery indicators as decision criteria on potential reduction of fallow periods in swidden systems of Northern Thailand

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ABSTRACT

Crop rotations in today's swidden systems of Northern Thailand typically include five to ten years of fallow. Regarding ecosystem functions, these systems are relatively close to secondary forests when compared to modern agricultural systems; but they are under pressure for intensification, i.e. shortened fallow periods. In general, criteria are needed to decide whether fallow duration can be reduced, safeguarding ecosystem restoration and provision of food and income for farmers. Acknowledging that a comprehensive assessment would cover multiple aspects, our study focuses on the role of fallow duration on tree structural and biodiversity related variables.

We studied recovery indicators of tree communities at two potential broad-leaved forest climax sites that differ in soils, forest type and agricultural intensification: An intensive system of one-year upland rice, then one- to two-year maize cultivation with synthetic inputs followed by six years fallow; and an extensive system with one-year upland rice cultivation without agrochemicals and ten years fallow. Contrasting systems were chosen to test the applicability of our indicators, not to compare their management practices. From 2010 to 2011, eight variables related to stand structure and tree diversity were either monitored or surveyed in chronosequence plots of 6 × 50 m representing different fallow ages. For each variable, means per fallow year were compared by least squares means (LS-means), and quadratic regressions from mixed models were fitted. Significant differences between LS-means and optima of regressions served to distinguish fallow stages and served as indicators of recovery and system stability. Stepwise multiple regressions confirmed fallow age as main determinant for most variables.

Numbers of tree species and diversity index recovered to levels of the previous rotation within the respective fallow time, but in both systems were far from climax communities, probably due to seed-bank depletion and shift toward resprouting species. While species dominance changed over time in the extensive system, the intensive system was dominated by a single species.

In the extensive system only tree density passed a peak during the fallow period, while biomass-related variables approached plateaus. In combination with the replacement of early fallow species, this points to the onset of competition and transition between successional stages. For the intensive system, no structural variable passed a maximum. With only one of eight indicators on the extensive site fulfilling the statistical criterion of passing a peak during the prevailing fallow time, reducing fallow periods is not recommended for our cases.

Generally, combining LS-means and quadratic regression allowed assessing fallow duration based on distinct successional stages at different sites. The approach should include various relevant site-specific indicators, in our case representing biomass and carbon storage, species and structural diversity, considered crucial for both sites.

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1. Introduction

1.1. Changing role and perception of shifting cultivation in Northern Thailand

The mountainous North of Thailand is home to numerous ethnic groups and their respective cultural and agricultural practices. The main staple crop for most groups is rice, grown as paddy or upland rice. Paddies are cultivated continuously, but limited in area by soil conditions, water availability and topography (Wade et al., 1999; Lennartz et al., 2009). Upland rice is typical for extensive agriculture as it requires less water and labour for field preparation, however, depletes soil fertility when grown for more than two or three consecutive periods and is susceptible to weed pressure (Schmidt-Vogt, 1998). Traditionally, upland rice is not cultivated during more than three consecutive periods without a longer fallow period of 10 to 15 years (Schmidt-Vogt, 2000; Wangpakapattanawong, 2001). This system is called “shifting cultivation” or “swidden cultivation” (Kunstadter et al., 1978) and usually includes slash & burn practice. Sustainability of swiddening is contested. On the one hand, burning and expansion into natural forests are mostly perceived as environmentally unfriendly (Ding et al., 2012; Van Do et al., 2010). On the other hand, it has been stated that farm system level nutrient balances are not *per se* negative where nutrients from uplands fields (mostly by erosion) flow into paddies (Schmitter et al., 2010; Dung et al., 2008). A general trend towards intensification – mechanization, increasing amounts of synthetic inputs and shortened fallow periods – can be observed (Schmidt-Vogt et al., 2009) owed to the government‘s forest protection policies and an increasing population which both limit agricultural area per household, and due to improved infrastructure and market access. Still, agricultural practices among ethnic groups differ strongly. Most groups, like the Lahu community of Bor Krai in our case study, have reduced fallow periods to 5 or 6 years (or even less, in accordance with the trends described by (Schmidt-Vogt et al., 2009)), switched from shifting cultivation for subsistence to cash cropping and heavily rely on pesticide and fertilizer use. On the other hand, particularly small groups in remote areas adhere to the traditional way of farming (i.e. fallow duration of 10 years or longer). These communities, e.g. the Karen of Nong Khao in our study, are often seen as role models for environmentally friendly production (Forsyth and Walker, 2008), but are experiencing increasing internal and external pressure to intensify their systems (Wangpakapattanawong, 2001). In this context, various models of reduced fallow periods up to complete abandonment of swidden farming have been observed (Schmidt-Vogt et al., 2009). Indicators are sought to determine to which degree fallow periods can be reduced without jeopardizing the systems’ resilience and ecological sustainability. Such objective criteria might take external pressure off the farmers.

1.2. Managed secondary forest succession in swidden systems

Natural regeneration is the cheapest and in many ecosystems the most effective way to restore disturbed sites, to maintain tree species diversity of the secondary forest and avoid soil degradation by minimizing exposure to erosive and drying elements (Kleinman et al., 1995). Various agricultural systems mimic plant succession (Ewel, 1999) to make use of natural system dynamics (e.g. Analogue Forestry, permaculture) (Ribeiro Filho et al., 2013). While the focus of the systems studied here is on annual monocrops as typical pioneer elements, the entire rotation represents a type of managed succession. The short annual cropping cycle of one to two years is integrated in a comparably long fallow period. During cropping phases, annuals and resprouting rootstocks of woody plants coexist. Later, farmers use the characteristics of fallow vegetation (biomass, dominance of certain tree species) as indicators to reinitiate the cropping cycle (Norgrove and Hauser, 2016).

Agricultural practices include significant system disturbances like slashing, burning and planting, which lead to changes in water and nutrient balances and plant community structure. In consequence, recovery rates (resprouting, seed bank, fallow biomass) and species composition of secondary forests depend on cropping cycle and fallow duration, weeding practices, stump treatment, burning and fertilizer application. Managed systems that rely on a larger proportion of resprouting late-successional tree species establish a higher biomass in a shorter time than such starting from seeds. This shortens the grass- or herb-dominated pioneer stage and leads to earlier canopy closure and changes in microclimate, favouring shade tolerant species and diversity of woody species. Apart from temporal and management aspects, the spatial characteristics of the system, e.g. size of disturbed area or connectivity between undisturbed locations, determine fallow regeneration.

1.3. Ecological indicators

Even in the traditional systems, socio-economic, political and cultural changes nowadays call for shortened fallows or extended cropping cycles. In order to make such far-reaching management decisions, indicators for monitoring recovery of ecosystems need to be defined. In this study we focus on tree structural and diversity-related indicators in forests as climax stages at both study sites. Further, structural diversity of the tree community, embedded into a mosaic of crops, early and late-successional communities, is an important foundation for biodiversity of the entire ecosystem. While environmental factors like soil organic matter, light absorption by canopy or microclimate change during succession, biomass and plant species-related variables integrate biophysical growth conditions. They are thus good indicators of change in ecosystem resilience and recovery. We follow the methods described by Cavallero et al. (2015) and identify such changes by optima or significant differences between fallow years of non-linear structural variables.

1.4. Research objectives

The main aim of this study was thus to analyze secondary succession patterns of tree species composition regarding stand structure and species diversity in short-term fallow rotations at two contrasting sites in Northern Thailand over time under imminent shortening of fallow periods. Appropriate fallow duration was assessed from an ecological standpoint of plant ecosystem recovery with reference to the end of the current rotation cycle. Extension of fallow times was not studied as it is not an option for farmers. As appropriate fallow duration depends on multiple criteria, biological indicators were to be selected that stand for both stand structure and diversity. To justify further reduction of fallow duration the majority of indicator variables needed to pass a peak within the currently practiced fallow duration. Secondly, it was of interest whether observed indicators and trends were generic across the contrasting sites and systems selected for our study.

Three main hypotheses guided this research:

1. Dominant species composition shifts during succession even in short-fallow rotations of 6–10 years as practiced by Northern Thai ethnic groups. Species composition and diversity can thus serve as indicators to characterize fallow stage.
2. Non-linear temporal changes in tree cover and density, height and aboveground biomass can be used to assess structural recovery dynamics in short-time fallows.
3. Both indicator groups can be applied at sites with contrasting natural forest vegetation. The method has thus the potential for generic use to assess sustainability of fallow periods from the perspective of plant structural variables and species diversity.

This analysis of indicators, alongside with the assessment of soil properties and socio-economic criteria, should lay the foundation to derive appropriate fallow duration for system recovery.