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Distribution patterns of trees in paddy field landscapes in relation to agro-ecological settings in northeast Thailand

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ABSTRACT

Deforestation accompanied by the expansion of agricultural land makes tree resources less available in many regions in the tropics, and small-scale farmers often incorporate trees with agricultural lands to meet their demands for food, timber, fuelwood, or fodder. This study analyzed the distribution patterns and management of multiple tree species grown in the rice paddy fields of a forest-depleted region in northeast Thailand – a region whose forestland represents only 16.32% of the total land area. Twenty villages from 11 provinces were selected for the remote sensing analysis of tree density and microhabitat. Interview surveys were conducted among villagers on their tree use and management, and field observations were performed to determine tree species' composition. The average tree-unit density (based on the number of tree crowns, either of a single tree or of cohesive trees, appearing in satellite images) was 6.27 units/ha, and was correlated with both density on the levee (5.30 units/ha on average) and levee length per unit paddy area (475.25 m/ha on average). The levees were more significant as tree habitats in the villages on the floodplain where the early introduction of agricultural machinery and direct seeding reduced the number of trees inside the fields where rice crops are grown. In total, 79 tree species representing 66 genera and 33 families were observed in the paddy fields. Remnant trees from the original forest, mostly *Dipterocarpaceae* and *Fabaceae*, have decreased due to cutting for use as timber and fuel. More recently, eucalypt and teak for timber, and mango and tamarind for edible fruits, have been planted on the levees as income sources. Farmers have recognized that while leaf litter fertilizes the soil, excess shading reduces the rice yield. The coppicing of eucalypt and pollarding of *Mitragyna diversifolia* were conducted for the sustainable harvest of timber and fuelwood, and also to avoid creating excess shade. Paddy rice fields are the monoculture of a staple crop, but they can harbor multiple trees on their levees, which play a counteractive role in forestland decline.

1. Introduction

Forests have been rapidly replaced by agricultural land in current tropical landscapes (e.g., Wester and Yongvanit, 2005). To meet rising demands for food at the lowest possible cost to biodiversity, two contrasting methods have been employed: land sharing, which integrates biodiversity conservation and food production on the same land using wildlife-friendly farming methods, and land sparing, which consists of separating land for conservation from land for crops, with high-yield farming facilitating the protection of remaining natural habitats from agricultural expansion (Phalan et al., 2011). Land sparing has been implemented in the form of demarcation between monoculture fields and protected areas (e.g., ADB and UNEP, 2004). However, land demarcation, often conducted through top-down decision-making, may not be consistent with the local land-use customs (e.g., Wester and Yongvanit, 2005). Small-scale farmers have elaborated on various forms of land sharing using some forms of agroforestry and organic farming (Phalan et al., 2011), which have been evaluated in terms of sustainable food production, socioeconomic benefits, and ecological services (e.g., Nair et al., 2005).

Paddy fields are primarily used as agricultural land for staple crop production in mainland Southeast Asian countries (ADB and UNEP, 2004) and also harbor a variety of trees that play multifunctional roles in local livelihoods (Takaya and Tomosugi, 1972; Grandstaff et al., 1986; Watanabe, 1990 Prachaiyo, 2000; Vityakon, 2001; Vityakon et al., 2004;

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Kosaka et al., 2006; Natuhara et al., 2012; Miyagawa et al., 2013). Previous studies on paddy-based land sharing were primarily conducted in a small number of villages or in experimental fields. As deforestation has rapidly progressed in Southeast Asia's mainland (ADB and UNEP, 2004), one must compile the latest information on tree distribution in the local land sharing system on a regional scale – information not represented in forestry statistics.

In the northeast region of Thailand in 2008, the percentage of remaining forest area was the lowest in the country, i.e., only 16.32% of the total area (Royal Forest Department, 2014). Soil erosion and salinization have also become problems over most of the region due to land clearing and intensive farming (Prachaiyo, 2000). Our preliminary surveys (Kosaka et al., 2006; Miyagawa et al., 2013) posed a hypothesis that trees in paddy fields are not randomly dispersed, but rather depend on the villages' history of land use and the local demographics, landforms, microhabitat, and human management practices.

The objective of this study was to test the above-mentioned hypothesis in the extensive area of northeast Thailand and to consider the feasibility of sustainable agriculture and resource utilization in this forest-depleted region.

2. Materials and methods

The northeast region of Thailand (14°7–18°26′N, 100°54′–105°37′E) was home to 21,953,183 people in 2006 (National Statistical Office, 2014) and covers an area of 168,854 km^2 (Fig. 1a and b).

Twenty villages from 11 provinces (Fig. 1b) were classified into two groups according to their landform: 6 were located on the floodplain and 14 were on the low terrace (Tables 1 and 2).

Satellite images (Digital Globe, 2001–2013) were analyzed to measure the tree distribution patterns using the Quantum GIS software version 1.6.0. Three plots, varying from 10 to 100 ha each with increasing density of trees (sparse, medium, and dense) were selected in paddy field areas of each village by visual examination of the images. The plots were selected within a 2 km radius from the center of each village. Paddy fields were distinguished in the images by the netlike appearance of levees (Fig. 2a and b). The length of the paddy levees was also measured using the Calculate Geometry tool of ArcView GIS 10.

The tree distribution patterns of each plot were analyzed by counting the number of tree crowns and by determining their microhabitats. Due to difficulties in distinguishing trees standing either singly or in small groups from the satellite images, the number of tree crowns (either of single tree or of cohesive trees; Fig. 2c and d) was counted for calculating the tree-unit density on behalf of the tree-individual density. The microhabitat of each tree was recorded by determining the location of each tree crown either inside the paddy fields where rice plants were grown or on the paddy levees (Fig. 2b). The tree-unit density was thus calculated for both the field and levee, which equaled the total tree density. This process was repeated three times for each village.

Field surveys were conducted in 2 villages (V3 and V4) in March 2012, 16 (V5–V20) in August 2012, 2 (V1 and V2) in May 2013, and all 20 villages (V1–V20) in December 2013. The village headmen and accompanying persons were interviewed in a semi-structured manner regarding the period of land use since village establishment, the former land cover and vegetation, the process of reclamation, the current population and number of households, the use (either subsistence or commercial) and management (planting, protecting, or cutting) of trees in the paddy fields, the tree species with either positive or negative effects on rice growth, rice cultivation systems (i.e., cropping season, cultivars, usage of machines, pests, and natural disasters), fuel consumption, forest management, and other income sources such as cash crop production, the sale of non-timber forest products, or wage labor. To cross-check the interviewed information, tree species in the paddy fields were recorded by 30-min observation in the villages of V5–V20. Nomenclature of the tree species followed that of Smitinand and Larsen (1970–1996) and Santisuk and Larsen (1997–2013).

Tree-unit densities were compared using a one-way ANOVA, and Pearson's correlation coefficients were calculated between tree-unit density and the period of land use, the number of households, the human population, and the levee lengths per paddy area using Excel Statistics 2012.

3. Results

3.1. Factors influencing the tree-unit density in paddy fields

In total, the average tree-unit density of the study area was 6.27 unit/ha (SD = 2.54), ranging from 2.01 to 10.10 (unit/ha) between sites. Therein, the average tree-unit density in the fields was significantly lower than the average tree-unit density on the

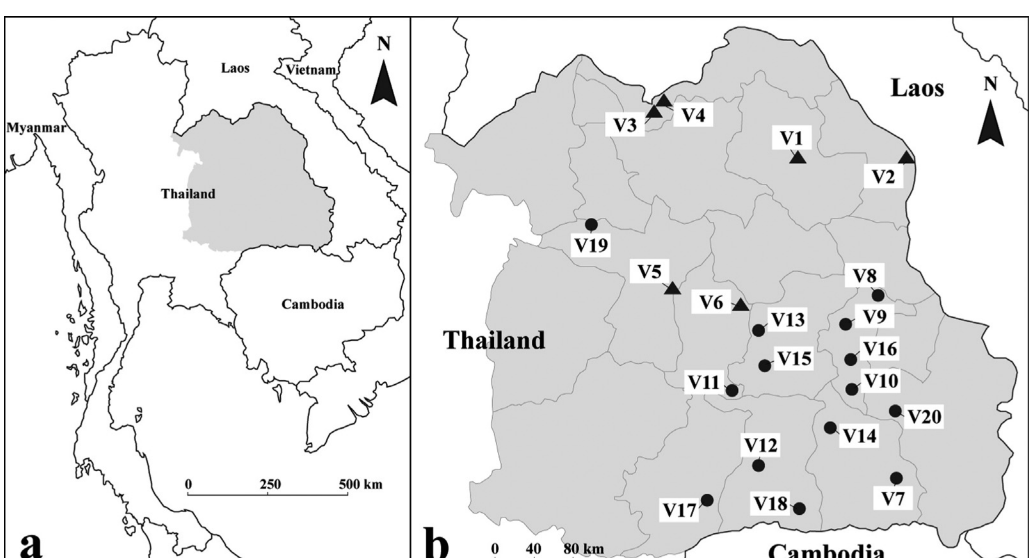

Fig. 1. Map of the study sites. (a) Area of northeast Thailand (gray area) and (b) location of 20 selected villages. Six villages were located on the floodplain (V1–V6, triangle) and 14 were on the low terrace (V7–V20, circle).