DEVELOPING A NETWORK OF LONG-TERM RESEARCH FIELD STATIONS TO MONITOR ENVIRONMENTAL CHANGES AND ECOSYSTEM RESPONSES IN ASIAN FORESTS

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The University of Tokyo Forests Press
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CHAPTER 10

MONTANE FOREST DYNAMICS BASED ON LONG-TERM ECOLOGICAL RESEARCH AT KOG MA WATERSHED AREA IN NORTHERN THAILAND

Dokrak MAROD, Prateep DUENGKAE

1. Introduction

Thailand is situated in a hot and humid climate zone in the middle of Southeast Asia. In addition, Thailand is also a bridge between two major biogeographical regions, the Indochinese to the north and the Sundaic region to the south, which causes Thailand to have a rich natural diversity. The kingdom contains approximately 5,000 plant species (about 8% of the total world plant species), 4,591 species of vertebrate animals and about 83,000 species of invertebrate animals (mostly insects; Office of Natural Resources and Environmental Policy and Planning 2009). However, more than half of the existing plant species are unknown and unidentified. Over the last three decades, rapid population growth has been the basic cause of natural habitat destruction and conversion, particularly in northern Thailand, which has led to the loss of biotic resources (Delang 2002; Virapongse 2017). This human-caused change creates disturbed forest areas, through increasing shifting cultivation, orchard development, and upland rice cultivation (Charnsungnem & Tantanasarit 2017). The continuous loss of natural habitats within the country results from a complex variety of causes, such as social, economic, politic and cultural forces (Braatz 1992). Thailand puts considerable effort into evaluating the biodiversity inventory, ecological studies of various ecosystems and individual species, and biotechnology for sustainable uses of natural biological resources.

Recently, one of the most important issues for the forest monitoring program is forest dynamics responses to the various disturbances. And long-term ecological research (LTER) based on permanent plots is particularly important for detection of these responses, especially those responses that are related to specific environmental changes. In addition, integration of long-term monitoring efforts with the ongoing research at these permanent plots is deemed especially important for addressing specific research questions. There are several LTER sites in Thailand, covering various forest types (Table 10-1). The goal of LTER sites is to promote demonstration sites for sustainable forest management to decision-makers, scientists, local people, and the public. The specific objectives are to: (1) investigate critical ecological baseline information; (2) establish ecological meta-data for data sharing, exchanges, and efficient syntheses by scientists; and (3) monitor the dynamics of biodiversity at local and regional scales to gain an understanding of the consequences of changes in biodiversity for rehabilitating the deteriorated ecosystems and for reducing threats to biodiversity.

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However, there was no official network to coordinate the sites. Consequently, the idea of promoting and coordinating the LTER network in Thailand has been discussed since early 2001 when the Kasetsart University, Faculty of Forestry (KUFF), hosted the First Regional Workshop on International Long-term Ecological Research (ILTER) in 2001 with technical support from the East-Asia Pacific ILTER network.

KUFF, the focal point for Thailand LTER, has worked to set up a research network under the research criteria of global warming, which required research in various forest types ranging from deciduous to evergreen forests. In addition, the towers for studying carbon sequestration had already been established on the sites. Based on the existing towers and various ecosystems, three LTER sites were selected for the KUFF LTER network. These are Kog Ma Watershed (in the north), Sakaerat Environmental Research Station (in the northeast), and Mae Klong Watershed (in the west), which included two evergreen forest types (montane and dry evergreen forest) and two deciduous forest types (mixed deciduous and dry dipterocarp forest). All selected sites are managed mainly by KUFF and the Department of National Parks, Wildlife and Plant Conservation (DNP). In addition, KUFF had promoted the first two LTER sites as the University Forest. However, this chapter described only LTER, including both flora and fauna, at Kog Ma watershed area, northern Thailand.

Figure 10-1: Location of significant LTER sites in Thailand
2. Kog Ma LTER Site

Kog Ma (KM) watershed area is situated on the east facing slope of Mount Pui in Doi Suthep-Pui National Park (DSPN), 10 km west of Chiang Mai province, northern Thailand (Kume et al. 2007). It has been a small field research station run by the KUFF since 1963, with initial funding from the United States Operations Mission and later support from the regular research budget of Kasetsart University. The project’s first phase (1963–1985) was run with the collaboration of KUFF and the University of Colorado. During the second phase (1997–present), The University of Tokyo took the place of the University of Colorado (Rahman, 2006).

DSPN is characterized as a subtropical climate with a long dry season alternating with a short wet season, with elevations ranging from 312 m to 1,656 m a.s.l. The average annual precipitation during 1997–2013 from Kog Ma weather station at elevation 1200 m a.s.l. is about 1,736 mm, with most of the rainfall occurring in August (335 mm), during the rainy season. The average annual temperature is 17.7°C with a minimum temperature of 12°C and a maximum temperature of 23.1°C (Glomvinya et al. 2016). Geologically, the area contains steep hills and valleys consisting of high-grade metamorphic complex rocks and sandstone (Rhodes et al. 2005). The soils consist of Reddish Brown Lateritic (Thailand classification) or Ustults (USDA Soil Taxonomy), with half sand content and a high porosity (60–74 %) (Tangtham 1974; Hashimoto et al., 2004). Soil texture varies along elevational gradients from sandy soil and sandy clay loam at lower elevations, to mostly sandy clay loam and clay soil at elevations above 1,000 m a.s.l. The four types of forest in DSPN, are based on Marod et al. (2014), and mixed deciduous forest (MDF), deciduous dipterocarp forest (DDF), pine forest (PF), and lower montane forest (LMF). LMF is the main type in the Kog Ma watershed area, with a top canopy height of 40 m. Fagaceae is the dominant family, represented by members of the genera Castanopsis, Lithocarpus, and Quercus (Tangtham, 1974).
<table>
<thead>
<tr>
<th>Site</th>
<th>Forest type</th>
<th>Plot size (ha)</th>
<th>Elevation (m a.s.l.)</th>
<th>Annual rainfall (mm)</th>
<th>Tower height (m)</th>
<th>Institution/responsibility</th>
<th>Established</th>
<th>Research topics</th>
</tr>
</thead>
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<tr>
<td>Kog Ma, northern</td>
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<td>16</td>
<td>1,200–1,450</td>
<td>1,995.3</td>
<td>45</td>
<td>KUFF, DNP</td>
<td>2010</td>
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<td>300–350</td>
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<td>1,684</td>
<td>42</td>
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<td>Forest dynamics</td>
</tr>
</tbody>
</table>

Remark: KUFF (Faculty of Forestry, Kasetsart University); MU (Maejo University); KMIT (King Mongkut’s Institute of Technology Ladkrabang); TISTR (Thailand Institute of Science and Technological Research); JSPS (Japan Society for the Promotion of Science); DNP (Department of National Parks, Wildlife and Plant Conservation); CTFS (Center for Tropical Forest Science); FFPRI (Forestry and Forest Products Research Institute).
3. Methodology

3.1. Plant diversity and dynamics

In 2010, a 16-ha permanent plot (18°54′N, 98°54′E) was established for assessment of forest dynamics and related studies (Fig. 10-2), with elevations ranging from 1,250–1,450 m a.s.l. The LMF plot was gridded into 10 × 10 m subquadrats, and the position of the trees was recorded. All trees with a diameter at breast height of (DBH, at 1.3 m height) ≥2 cm were tagged and identified, and their girth was measured to the nearest mm. (Fig. 10-3A). Tree monitoring has been done every two years since 2010, including mortality and recruitment. Specimens for unidentified species were collected, and compared to previously identified specimens archived at the Forest Herbarium, Department of National Parks, Wildlife and Plants Conservation. All the nomenclature used was based on Smitinand (2014). A transit compass (Ushikata Co.) and a wooden tripod were used for topographic survey. All 10-m corner plots were fixed in place by a compass and a measuring tape on a level distance, then, a topographic map was produced. To detect the dominant species, an importance value index (IVI) was calculated based on the summation of relative density, relative dominance and relative frequency (Krebs 1972). Mortality (M) and recruitment (R) rates, parameters of forest dynamics, were calculated following Condit et al. (1995).

To study seedling regeneration, the forest gap and crown areas were selected for detecting seedling establishment under contrasting light conditions (Fig. 10-3B). Nine forest gap areas >200 m² were selected along with nine areas under crown cover adjacent to each of the gaps, for a total of 18 sites. Five seedling quadrats, 1 × 1 m, were established in each site (total 90 quadrats). All seedlings were tagged and identified. Monthly monitoring was done starting in August 2012, during which newly recruited and dead seedlings were recorded. In addition, light and temperature at each site were automatically recorded using Hobo Data Loggers (Pendant Temperature/Light Data Logger).

Figure 10-3: A 16-ha permanent plot established (A) and seedling quadrat (B).

3.2. Wildlife diversity

(1) Diversity of small mammals

A total of 81 live traps, 15 × 15 × 30 cm, were set up at a spacing of 40 × 40 m, and then, the traps were baited with ripe banana fruit during monitoring (Fig. 10-4A). In addition, a total of 49 pitfall traps, 150 × 30 cm, were established at a spacing of 50 × 50 m (Fig. 10-4B). Monitoring was done every month over four consecutive nights, from December 2012 to December 2013. All traps were opened in the afternoon, 15:00–17:00, and observed twice a day, 7:00–10:00 and
15:00–17:00, during the days associated with the consecutive nights. All trapped mammals were marked by PIT tags using 2×8 mm microchips. The serial number was first recorded, and then the microchips were placed under the back skin between their shoulders (Fig. 10-4C). Data about the mammals was recorded, including the species, sex, age, and weight, all body parts were measured and recorded using a vernier caliper (Fig. 10-4D), and then the mammal was released to the nature.

(2) Diversity of birds
In the 16-ha plot, seven 60m-wide linetranssects separated by 50 m were conducted, and gap and closed canopy conditions were classified along each line. Monthly monitoring of birds was accomplished in the morning (7:00–10:00) and in the afternoon (13.00–16.00) from December 2011 to November 2012, using binoculars (40 × 42 mm) and telescopes (50 × 150 mm). All birds that were directly and indirectly (vocal) observed were recorded and identified based on Nabhitabhata et al. (2012). In addition, nine forest gaps (FG), adjacent distance about 10 m from the closed canopy (UCC), were selected for the locations of mist nets (each 2.5 × 9 m, 1 m in height, with six shelves) (Fig. 10-5A). Forest gaps in this study refer to foliage-free areas (200–600 m²) where windthrow had toppled dead trees. During the monitoring, the nets were open from dawn (06:00) to dusk (16:00). In addition, nets were checked every 30 min, but more frequently during the morning and evening hours when birds were most active; the nets were closed during periods of rainfall. All birds were identified by species, aged (juvenile or adult) and sexed, and then they were ringed and released at the original capture points (Fig. 10-5B) based on the protocols of the Department of National Park, Wildlife and Plant Conservation of Thailand. Then, a similarity index, using either the presence/absence of species or species attributes (Krebs 1989), was produced for each area to compare birds between the different areas.

Figure 10-4: Wildlife diversity observation; A) live trap, B) pit fall trap, C) PIT tagged, and D) body measured.
3.3. Plant and wildlife interaction

To study the interaction between frugivores and fruits, fruit trees were monitored during the fruiting period from May 2015 to April 2017. Eight fruit plant species were selected including *Madhuca floribunda*, *Castanopsis acuminatissima*, *Garcinia speciosa*, *Ficus semicordata*, *Choerospondias axillaris*, *Helicia nilagirica*, *Scheffera* sp., and *Musa acuminata*. The monitoring was done when they provided fruits. Camera traps (Scout Guard, Model 5G560C) were setup for at least three individual trees per species, and were focused on the fruit position, whether on the tree trunk, a branch or on the ground due to fallen fruits. The camera traps were placed about 2 m away from the fruits (Suzuki et al. 2007; Fig. 10-5C and D). All camera traps were programmed to record the date and the time of the day. The camera traps were checked every month, during which the batteries were renewed and the memory cards were replaced. The monitoring period for the camera traps continued until the fruit completely rotted or was dispersed. In addition, frugivore species were identified based on the video from the camera traps. The numbers of fruits utilized by frugivores were counted based on the total recorded on the video. Then, the proportion of fruit eaten by each frugivore was determined.

Figure 10-5: Bird diversity observation, A and B, and fruit-frugivore interaction study, C and D.

4. Results and Discussion

4.1. LMF structure and dynamics

A total of 29,308 individual trees (DBH ≥ 2 cm) was found in 2010 which included 219 species belonging to 137 genera and 59 families, along with approximately 20 unidentified species (Marod et al. 2015). The dominant family with the greatest species number was Lauraceae (19 species) followed by Euphobiaceae (17 species), Fagaceae (12 species), Fabaceae (11), and Rubiaceae (8 species). However, the family Fagaceae yielded the greatest tree density (204.5 individuals/ha), followed by Lauraceae (94.5 individuals/ha), Euphobiaceae (79.3 individuals/ha)
and Theaceae (46.1 individuals/ha). The top ten dominant tree species (DBH ≥4.5 cm) based on the IVI were *Castanopsis acuminatissima* (35.5 %), *Schima wallichii* (14.9 %), *Castanopsis armata* (13.1 %), *Styrax benzoides* (10.0 %), *Manglietia garrettii* (9.1 %), *Persea Gamblei* (8.1 %), *Vernonia volkamerioliola* (8.5 %), *Syzygium toddlioides* (6.9 %), *Litsea martabanica* (6.7 %), and *Castanopsis tribuloides* (6.7 %). The species in the families of Fagaceae and Lauraceae were the most dominant in both the canopy and the subcanopy in this forest, similar to other tropical montane forests (Nakahsizuka et al. 1992; Ohsawa et al. 1995; Pendry & Proctor 1997; Buot & Okitsu 1998; Sri-Ngermyuang et al. 2003), so this forest can be classified as an ‘oak-laurel forest’ (Tagawa 1995). In addition, some temperate species such as *Betula alnoides*, *Podocarpus neriifolius*, and *Shima wallichii* can also be found in the plot.

The DBH size class distribution for most species had a negative exponential growth form, or reversed J-shape, which included many individuals in the small size classes (Rubin et al. 2006). This result indicates a good rejuvenation potential in this forest, however, the size class distribution varied among species (Fig. 10-5). The distribution of the dominant species, such as *C. acuminatissima* and *C. tribuloides* (Fig. 10-5A and B), had a negative exponential growth form, while the *B. alnoides* distribution had a unimodal form (Fig.10-5C), indicating discontinued regeneration. Regeneration of *B. alnoides* probably requires some specific environmental conditions for seedling establishment, such as strong light in a gap opening (Huth & Wagner 2006).

Figure 10-5: DBH class distribution based on logarithmic plotted of some species in lower montane forest; A) *Castanopsis acuminatissima*, B) *Castanopsis tribuloides*, and C) *Betula alnoides* (after Marod et al. 2015).

LMF dynamics for trees (DBH ≥5 cm) and sapling (DBH <5 cm) during 2010–2014, varied among censuses. The average recruitment rate was greater than the mortality rate, 5.82±0.52 and
3.60±0.73 %/yr, respectively. In addition, basal area (BA) rapidly increased in the first two years, from 32.88 to 34.59 m²/ha, but increased only slightly in the later period, 34.80 m²/ha (Marod et al. 2016) due to the loss of big trees with high BA through windthrow (Fig. 10-6). However, their loss created big gaps that may provide suitable environments for tree regeneration, especially among pioneer species. In addition, the spatial distribution of individual trees along an elevational gradient varied among species. Abundant species, such as *C. acuminatissima*, preferred higher elevations, and were mostly distributed on the ridges, while, *C. tribuloides* was distributed throughout the entire plot, in particular, adjacent to the valley (Fig. 10-7A and B). In contrast, *Podocarpus inerifolius* had limited distribution at the higher elevations in the plot (Marod et al. 2016).

![Figure 10-6: Gap creation based on big trees felt down.](image)

![Figure 10-7: Tree spatial distribution in lower montane forest; A) Castanopsis acuminatissima, and B) Castanopsis tribuloides. Black dots represent individual trees (after Marod et al. 2016).](image)
4.2. Seedling regeneration with contrasting light conditions

Light conditions were significantly different between the gaps and subcanopy soon after gap creation (P<0.001) (Pimrat et al. 2015), whereas light conditions were similar in the later years due to rapid plant succession in the gaps. A total of 104 species of seedlings representing 80 genera and 48 families were found during August 2012 to July 2015. Two seedling groups were classified based on their light adaptation: light demanding species (pioneer species) and shade tolerant species (native species). Seedlings of the families Fagaceae and Lauraceae had the greatest species number (10 species for each), followed by Euphobiaceae and Rutaceae (7 species for each). The light demanding species, such as Macaranga indica and Litsea martabarnica, were found mostly in gaps, while shade tolerant species, such as Syzygium zeylanicum and Pyrenaria diospyricarpa, were mostly distributed under the closed canopy. However, some dominant species, such as C. acuminatissima and C. tribuloides, regenerated well under both conditions. In addition, the recruitment rate of seedlings was higher than the mortality rate in both gap and closed canopy (26.67 and 13.39 %/yr, respectively) and under the canopy (34.02 and 16.59 %/yr, respectively). These results indicate that gap creation, particularly caused by the loss of big trees, is the main factor maintaining plant species diversity among the pioneer species in LMF. This finding can apply for the restoration program, in which suitable species should be selected, especially relating to light adaptation.

4.2. Wildlife diversity

Low species diversity of small mammals was found from the total 6,760 trap nights (4,212 trap nights for live trap and 2,548 trap nights for pitfall). A total of 252 individuals representing 12 small mammal species (11 genera, 6 families, and 4 orders) were captured (Saosoon et al. 2014). Trap success was 19.19 % and 4.90 % for live traps and pitfall, respectively. The overall Shannon-Wiener index ($H'$) value in LMF at Doi Suthep-Pui was 2.31, with the highest monthly value occurring in June ($H' = 2.03$). The relative abundance of small mammals in the study area was grouped into five categories: abundant, common, moderately common, uncommon, and rare. The number of species per category was 2, 1, 5, 1 and 3 species, respectively. Rattus tanezumi and Tupaia belangeri were the most abundant, consistent with a previous report (Elliott et al. 1989). The maintenance of large populations by these species indicates the highly adaptative nature of these species, particularly to environmental changes.

A total of 86 species of birds were observed, representing 26 families and 8 orders. The species were classified as 82 resident and 4 winter visitors (Siri et al 2013). The Shannon-Wiener indices ($H'$) were not significantly different between the closed canopy ($H' = 2.97$) and the forest gap ($H' = 2.98$) sites (P>0.05). The highest $H'$ in the closed canopy areas was found in September and the lowest occurred in July. While in the canopy gap areas the highest $H'$ was found in July and the lowest occurred in January. These results indicate that bird species diversity varied spatially and temporally. In addition, the natural forest gaps played an important role in maintaining diversity among the understory birds (Siri et al. 2019). In total, 958 individual birds belonging to 65 species were captured by the mist net over 25,920 sampling hours between January 2015 and December 2017. Among these, 475 individuals from 51 species were under closed canopies, whereas 483 were from 47 species in forest gaps. The number of bird species in gaps increased rapidly and consistently through the first year following gap creation. Forest gap localities contained 48 % of the understory birds in the area. Foliage–gleaning insectivores were the dominant bird feeding guild in both areas. Nomadic bird species, such as Erythrura prasina, were found only in the first year following the development of gap creation. Overall, the forest gaps created by natural disturbances had no negative impact on the diversity of understory bird communities in this study.
The relationship between bird communities and their environments are important elements of community ecology, which is greatly influenced by habitat quality (Nakwa et al. 2008). Overall, the forest gaps created by natural disturbances had no negative impact on the diversity of understory bird communities in this study. This finding showed that the natural forest gaps that are created by intermediate disturbance promote a relatively high biodiversity of birds in this ecosystem.

4.3. Plant and Wildlife interaction

To detect the fruit utilization by frugivores, all recorded trees in a 16-ha plot, totalling 189 species, 131 genera and 60 families were reviewed and classified. The results showed only forty six species of plant-frugivores (24.34 % of all plant species) in 40 genera and 29 families were found. They were divided into three groups based on fruit characteristics, including size, type, and color (Reungkate et al. 2013). Considering plant-frugivore traits, frugivores preferred the small fruits (73.9 %), followed by fresh fruit types, drupe and berry. Fruit colors were apparently also an important selection criterion, in which purple-black color (33.0 %) was the most selected, followed by green (20.5 %) and brown (19.3 %). These results indicate fruit plants have several traits related to seed dispersal by wildlife.

In addition, the results of fruit utilization by frugivores based on camera traps showed that the total efforts were approximatively 705 trap-nights or 16,920 trap-hours by 24 camera traps. As a result, 13 frugivorous species were recorded (389 clips), which included seven species of mammals; Callosciurus erythraeus, Dremomys rufigensis, Hylopetes phayrei, Tamiops mcclellandi, Paradoxurus hermaphroditus, Paguma larvata and Macaca nemestrina, and six species of birds; Hemixos flavala, Alophoixus pallidus, Pycnonotus flaviventris and Ixos mcclellandii (Reungkate et al. 2016). The frugivores mostly utilized fruit trees of Madhuca floribunda (8 species), followed by Castanopsis acuminatissima (5 species) and Ficus semicordata (5 species). Most frugivores preferred to use fruits of Madhuca floribunda (Fig. 10-8) even though the density of adult trees was only 0.19 individual/ha, indicating it is the favorite

Figure 10-8: Frugivores utilized fruits of Madhuca floribunda; A) Paguma larvata, B) Paradoxurus hermaphroditus, C) Callosciurus erythraeus, and D) Dremomys rufigensis.
fruit for frugivores in this forest. The seed of *C. acuminatissima* is covered by a thick cupule with sharp spines, a deterrent to most animals, so this seed was utilized only by rodents, because they are able to destroy the spiny cupule and access the protected seed using their gnawing incisors and powerful jaw muscles (Corlett 2017). In addition, they also used fruits of the wild banana (*Musa acuminata*), which were found mostly in the gaps. It can provide fruit throughout the year (Marod et al. 2010; Peres 2000) and is classified as a keystone species for frugivores, along with fig trees (Shanahan et al. 2001). The roles of frugivores in plant regeneration, particular in seed dispersal, are very important. This knowledge can be applied to the selection of planting species suitable for restoration programs, which may increase the success of the restoration programs.

5. Conclusions

LTER is very important for quantifying the ecological responses to environmental changes caused by both natural and anthropogenic disturbances. It is a useful tool for tackling large-scale emerging problems related to disturbances, such as species extinctions, climate change detection, mitigation and adaptation, and can provide key information for resource management under a rapidly increasing human population. These results showed that natural gap creation, with the attendant increase in light, was an important factor for maintaining the biological diversity in LMF, while the relationships identified between plants and frugivores were shown to be a crucial factor in forest regeneration. This knowledge is useful information for applied science, such as management of forest ecosystems which is now charged with maintaining biodiversity. In addition, LTER is also the main platform for collaborative studies that promote multidisciplinary research and support evidence-based policymaking and decision making related to ecosystem management.

Although ecological studies in Thailand have been done for a long time, only a few LTER programs have been established. Meanwhile, problems related to the loss of biodiversity due to environmental changes and human destruction have reached a critical point. These issues are among the ecological challenges that demand rapid solutions. While our studies using the LTER site in Mae Klong Watershed have provided us with some important information regarding plant species that are appropriate for a restoration program, we have had little experience with large-scale ecosystem management. Collaborative efforts through the international LTER network can aid us in promoting the detection and mitigation of changes in our forest ecosystems, and will likely provide information that will prove useful on both regional and global scales. So we contend that the permanent plots maintained under KUFF should be included in the network.

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Montane forest dynamics based on long-term ecological research in northern Thailand


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