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Dry forest community types and their predicted distribution based on a habitat model for the central dry zone of Myanmar

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ABSTRACT

Tropical dry forests are some of the world's most endangered ecosystems, but are the least studied habitats. The lack of information on their ecology and distribution is a constraint for restoration and conservation of these forests. The last study to describe dry forest communities in Myanmar was conducted in the 1960s, and was based on their physiognomy and the dominant tree species. We investigated the species composition of the dry forest communities in the central dry zone of Myanmar, and developed environmental distribution models. Based on presence/absence vegetation surveys, we classified the community types using TWINSPAN. We obtained 14 statistically significant basic community types, which we combined into five alliances and two orders. Community types were generally divided into two groups at the order level: woody communities in the forest landscapes and in the anthropogenic (agricultural and residential) landscapes. *Tectona hamiltoniana* and *Terminalia oliveri* were abundant in the forest landscapes, whereas *Prosopis juliflora* and *Borassus flabellifer* were common in the anthropogenic landscapes. *Acacia catechu* and *Waltheria indica* were distributed in communities with intermediate characteristics between the forest and anthropogenic landscapes. Communities in the anthropogenic landscapes lacked species from the forest landscapes. Forest landscape communities were endemic to Myanmar's dry zone, and *T. hamiltoniana* was dominant. A novel community of alien *P. juliflora* which is common to the world's dry forests, was detected in the anthropogenic landscapes. We predicted the distribution of dry forest communities across the study area using a logistic regression model based on landscape types and mesoscale environmental variables. Landscape was the most significant factor that explained the distribution of the communities, followed by elevation. The forest landscape communities, especially the *Shorea siamensis*–*T. hamiltoniana* and *T. hamiltoniana*–*T. oliveri* forest alliances were rare in the study area. The limited area of these communities suggested their importance for conservation planning.

1. Introduction

A complete inventory of Earth's biological communities would provide crucial information for conserving biodiversity and for sustainable use of natural resources. Even though forest is one of the world's well-described ecosystems, efforts to enumerate forest communities based on their species composition have been lacking in some regions of the world. In the meantime, alien species are spreading (for example, Aung and Koike, 2015) and forest vegetation types are changing due to the creation of "novel ecosystems" composed of these species (Martinuzzi et al., 2013).

Tropical dry forests are some of the world's most endangered ecosystems, but despite this, they are among the least-studied tropical habitats and are less protected than tropical rain forests (Murphy and Lugo, 1986; Janzen, 1988; Bullock et al., 1995; Miles et al., 2006; Stoner and Sanchez-Azofeifa, 2009; Mooney, 2011). Tropical dry forests are distributed throughout the tropical regions that experience several months of severe drought each year (Bullock et al., 1995), and they have high species diversity, including many endangered species (Gentry, 1995; Medina, 1995). However, these forests have received little attention from the conservation section, and most research, policy, and conservation efforts are directed toward rain forest protection (Murphy and Lugo, 1986; Bullock et al., 1995; Dirzo et al., 2011).

Mainland Southeast Asia is home to only a small proportion of the world's tropical dry forests (Miles et al., 2006). The ecology and distribution of these forests have not been well studied

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compared to neotropical forests (Sanchez-Azofeifa et al., 2005), and this is particularly the case in Myanmar. Recent studies have investigated the structure, composition, and dynamics of tropical dry forests in continental Southeast Asia and southern India (Bunyavejchewin et al., 2011; Suresh et al., 2011), but little is known about Myanmar's dry forests due to limited research and the nation's political isolation.

Myanmar has one of the highest biodiversity in the Indo-Pacific region (Myers et al., 2000), and its forest types range from mangrove forest in the south to alpine forests in the north (Kermode, 1964; Leimgruber et al., 2005). Myanmar's dry forests are found in the arid and semi-arid regions in the middle of the country, which is known as the central dry zone, at elevations below 1200 m, where mean annual rainfall is 1000 mm, and there is a prolonged dry period of 6 months each year (Troup, 1921; Stamp, 1924, 1925; Champion, 1936; Kermode, 1964). Because the region is isolated from arid areas of India, Thailand, and China by humid mountains (Hijmans et al., 2005), Myanmar's dry forest landscapes have developed specialized vegetation types dominated by *Tectona hamiltoniana* (FAO, 1987; Critical Ecosystem Partnership Fund, 2012), along with many other endemic species. In the 1990s, Myanmar's dry forest experienced the highest deforestation rate among all forest types in that country (Leimgruber et al., 2005) due to conversion to agriculture, shifting cultivation, and development projects (Songer et al., 2009).

The first plant ecological surveys in Myanmar were conducted more than 135 years ago by Kurz (1875, 1877), who traveled and collected plants for a report on the vegetation types in the Peguyoma area at the south end of the dry zone, which provided detailed botanical descriptions. A botanical collection in the central dry zone was done by Collett and Hemsley (1890). Troup (1921), Champion (1936) and Kermode (1964) subsequently classified the forest types in Myanmar based primarily on snapshot physiognomy (Whittaker, 1962), relying on the working plan of the Myanmar forest department and their own experience. Vegetation classification by Stamp and colleagues in the 1920s (Stamp and Lord, 1923; Stamp, 1924, 1925) described both climax and seral vegetation types in Myanmar. Myanmar's vegetation classification system was based on physiognomy, focusing on the commercial forest types for timber production purposes (Kermode, 1964), but forest types in the dry zone have not yet been analyzed with respect to their species composition. Although physiognomic classification is useful for describing some of the dominant species and for supporting the management of a broad area (Beard, 1980), it gives relatively little information on the community composition and species diversity, and therefore cannot support conservation or sustainable management.

Due to a lack of information, no vegetation map of Myanmar's dry zone has been created based on a species composition survey, and the area of each vegetation type is not yet known quantitatively. Predictive spatial modeling would provide such information, as this approach allows vegetation maps to be produced by relating vegetation data to remotely sensed environmental attributes (Franklin, 1995; Guisan and Zimmermann, 2000). Large-scale environmental data are readily available and can serve as low-cost surrogates for modeling poorly surveyed areas (Ferrier et al., 2002; Ferrier and Guisan, 2006; Arponen et al., 2008). Forest type classification based on the floristic composition and predicted distribution maps would provide key support for forest resource management, rehabilitation of degraded forests, and restoration activities.

To provide some of this essential data, we conducted extensive vegetation surveys to address the following questions concerning the species composition of the forest communities in Myanmar's dry zone forest: What woody vegetation types are present in the dry zone of Myanmar? Have alien species affected the composition of these communities? What is the most suitable environment and potential area of each community? Does the traditional classification based on physiognomy and the dominant trees correspond to a more refined classification based on species composition in all layers of the community? To address these questions, we first classified the dryland forest communities based on a floristic vegetation survey, and then constructed models to predict the occurrence of local forest community types based on large-scale topographic, climate, and landscape data.

2. Materials and methods

2.1. Study area

The study area is situated in the central dry zone of Myanmar (21°13′47″N to 22°07′45″N, 94°54′54″E to 95°52′55″E; Fig. 1). It covers an approximate area of 10,000 km^2 (100 km × 100 km), and is part of a dry zone with typical dry forest vegetation. Being located in the rain shadow of the country's tropical zone, it experiences monthly temperatures that range from a minimum of 10 °C in January to a maximum of 43 °C in May, and receives an average annual rainfall of 600 mm (with a range from 500 to 1000 mm; Ministry of Forestry, Myanmar, 2005). The region has a prolonged annual dry period that averages 6 months. Most of the study area is covered by flat plains and undulating topography composed of Holocene and Pleistocene rocks and sediments, where most agricultural lands are situated, with forests situated primarily on steep slopes. The main rivers that traverse the area are the Ayeyarwaddy, Chindwin, and Mu rivers, which flow from north to south. Soils in the study area are sands and sandy clay loams (Thet and Pritchett, 1981).

2.2. Vegetation survey

Before our vegetation sampling in the central dry zone, we carried out a reconnaissance survey of the region in February 2010 to help us choose a representative area that included all the plant community types in the agricultural, residential, and forest landscapes. We located a 100 km × 100 km study area using Google Earth (https://www.google.com/earth/) and Myanmar forest department maps. We then carried out a vegetation survey of all vascular plant species in the study area from February to March 2011. We established a total of 1139 sample plots (each 15 m × 15 m) in areas with woody vegetation in order to cover all the accessible parts of the study area (Fig. 1). In each sample plot, we recorded all vascular plant species, including understory herbs. Because many planted species regenerate naturally in the study area, we included these in our vegetation survey to assess the current condition of the woody vegetation types. The location of each sample plot was recorded using a Garmin GPS unit, with an approximate two-dimensional positioning accuracy of 10 m. Species identification was done in the field according to species checklists (Kyi, 1992, 1997; Kress et al., 2003; Dry Zone Greening Department, 2006), and uncertain species were collected and later identified by staff of the Forest Research Institute Herbarium in Myanmar.

2.3. Landscape types and environmental gradients

To produce a predictive vegetation distribution map using an environmental model, environmental data covering the entire map area is required. Landscape types in the study area in 1 km spatial resolution were categorized as agricultural, forest, residential, or water body by hand annotation of the Google Earth image. There were scattered hedgerow vegetation and cultivated fields