

# THE TROPICAL LIMESTONE FOREST ECOSYSTEM: A REVIEW OF DISTINCTIVE CHARACTERISTICS

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## ABSTRACT

The tropical limestone forest is found distinctive and different from other tropical forest ecosystems. Therefore, understanding the characteristics of this ecosystem is needed for conservation and management considerations. The paper presented the most typical features of the tropical limestone forest ecosystem. The terrain shows steep slopes, thin and discontinuous soil cover and high rock outcrop cover. Soils are poor in most minerals and nutrients. The ecosystem has high plant diversity and endemism. Quarrying and mining limestone, logging and agricultural activities are major threats to tropical limestone forests. This is a fragile ecosystem, vulnerable to disturbances, difficult to recover, and thus should be careful in management, conservation, and development.

**Keywords:** *Distinctive characteristics, ecosystem, limestone, tropical forest.*

## 1. Introduction

Tropical limestone forests and karsts often contain high plant diversity combined with a high degree of endemism, and they can consequently be referred to as ‘arks of biodiversity’ [4]. Many karst species are specialists for rocky, dry and alkaline sites [2]. These areas are home to many rare, threatened and endangered species and they usually offer a tremendous variety of ecologically, economically and scientifically valuable species. For humans, limestone areas are usually difficult to access due to their rugged topography and steep slopes, however, logging and forest disturbances are still widespread [13, 19].

The limestone forest ecosystem is very vulnerable to disturbances, difficult to recover, and unfortunately still poorly understood. In northern Vietnam, for example, there have been recently some plantation activities in formerly disturbed limestone sites; however, they are not really successful. Incorrect species selection for sites is suggested as an important reason for this failure [6, 22]. In Cuc Phuong National Park of northern Vietnam, *Garcinia fagraeoides* grows more slowly in the plantation than in natural forests due to the unsuitable soil type [18]. In southern China, *Excentrodendron tonkinense* was cultivated and grows well; however, there exist several abnormal developments of trees such as no fruit, fruits dropped before

maturation, no fertile or viable seeds [17]. Severe disturbances of this site may also result in loss of vegetation cover, risk of fire and soil erosion and take much time to recover.

The tropical limestone forest is found distinctive and different from other tropical forest ecosystems. Therefore, understanding the characteristics of this ecosystem is needed for conservation and management considerations. This paper presented the most typical features of the tropical limestone forest ecosystem, including the terrain and soil characteristics, the plant diversity and endemism, the threats to the plant diversity and the vulnerability of limestone forest to disturbance.

## **2. Contents**

### **2.1. Terrain and soil characteristics of limestone forest**

Limestone was constituted millions of years ago by corals, shells, algae, and other marine organisms on the floor of ancient oceans before tectonic movements lifted it above sea level. Over the years, erosion first removed the sediment cover and then sculptured the limestone into what is called “karst landscapes” [21]. Limestone areas have two karst formations in the tropics: “tower” karst and “cockpit” karst. Tower karsts consist of isolated hills with steep, cliff sides (slopes of 60° to 90°), while cockpit karsts include a regular series of conical hills with gentle slopes (30° to 40°) [13]. Under impacts of climate conditions, dissolution of limestone leads to different shapes; ridges and peaks with sharp edges, deep furrows in steep rock faces, and patterns of polygonal depressions in horizontal rock surfaces. These shapes

often create an inhospitable landscape and may be very difficult to traverse.

Carbonate rocks are usually exposed on the surface, thus karst terrain has a thin and discontinuous soil cover [5]. The steeper slopes contain often bare limestone with little soil in fissures. At the base of limestone hills, limestone is commonly covered by sediments brought from outside the area. However, those alluvial soils are influenced by runoff and erosion from the limestone and possibly support distinctive vegetation types [13]. Soils over limestone are often deficient in minerals except for calcium and magnesium. The excessive presence of these two elements and the lack of aluminum and phosphorus, together with the limestone topography, affect the nature of vegetation and create a large number of endemic species in limestone areas. Due to the large underground drainage of karst areas through fissures of the rock, habitats of limestone hills are generally drier than others, and therefore organisms living on limestone must cope with drier and harsher conditions than on other substrates [21].

### **2.2. Plant diversity and endemism of limestone forest**

Among tropical ecosystems, limestone karsts have been recognized as ‘arks’ of biodiversity and often contain high degrees of endemism [4]. Appearance and species composition of limestone forest are distinctive to other forest types and its number of species found is particularly high, especially when a comparison is made per unit area [21]. Variable microhabitat conditions that are often created by the varied topography, in combination

with complex patterns of substrates and levels of rock-outcrop exposure can support high floral diversity, meanwhile edaphic isolation and species-poor dispersal capabilities make some plants have to adapt to highly alkaline soils, shallow soil layers, and dried and rocky sites (Figure 1a). The following examples are pieces of evidence for high levels of richness and endemism of karst-associated plant species:

High plant diversity in tropical limestone vegetation has been recorded in many studies. Surveys in northern Vietnam have revealed approximately 2,000 vascular plant species in karst areas [19]. Although limestone habitats in Peninsular Malaysia occupy only 260 km<sup>2</sup> (0.2% of the land area), 1,216 angiosperm species, or 13% of the total Malayan flora have been found [3]. The high plant diversity can be associated with a variety of ecological niches provided by complicated terrain and variable climate conditions. For example, most of the dipterocarps associated with limestone in Sabah occur in ravines and on less steep slopes with deep soils, while cliff faces and summits with little soil are occupied by herbaceous species and bryophytes [9]. The limestone flora of different habitats indicates many differences in species composition; Sabah is noticeably poorer in species of Balsaminaceae, Gesneriaceae, Ericaceae and Orchidaceae than Sarawak, while is richer in species of Dipterocarpaceae, Meliaceae and Urticaceae, compared to Peninsular Malaysia.

High species endemism also occurs on tropical limestone with some species even being restricted to a single limestone hill or a group of neighboring hills [9, 10, 20, 21]. In Peninsular Malaysia, 21.4% of 1216 of karst-associated angiosperm species are endemic,

and 11% are found only on limestone [3]. Species composition is found quite different on limestone; 60% of the 73 plant species recorded in Mulu limestone forests did not occur in other lowland forest types [14]. The result of the complete floristic survey in Xishuangbanna, south-west China, has revealed 1,394 vascular plant species in the limestone forests, of which the species found only on limestone make up 10% and the dominant species account for 12% of the total limestone flora [25]. In Cockpit Country, in central-western Jamaica, 101 of over 150 plant species identified are endemic to the area [16].

However, the karst species richness is expected to continue rising, because many of the limestone areas have been not explored botanically [2, 21]. Multiple plant species, even new to science, remain unidentified, due to the difficulty of investigating in tropical karst terrain [4]. Surveys of limestone ecotype in northern Vietnam have discovered a new monotypic plant genus (*Grushvitzkya stellata*), new orchids, and an outstandingly new gymnosperm tree species - *Xanthocyparis vietnamensis* that is entirely restricted to karsts [1]. The Institute of Ecology and Biological Resources recorded 14 new Orchidaceae species in Cao Bang. In the Bat Dai Son Nature Reserve of Ha Giang province, one of gymnosperms recorded in a mossy forest patch on the limestone mountain summit is new to Viet Nam's flora. Five of 69 mammal species residing in limestone sites of Viet Nam are endemic and 26 are rare species. Limestone caves generally provide habitats for bats; for instance, in Quang Binh province, 37 species have initially been recorded in these habitats [6].



**Figure 1: The limestone forest floor in Northern Vietnam: (a) a small and a bigger statured tree *Garcinia fagraeoides* in the rock fissures, (b) development of climbers after disturbances. Photos by: Ngo The Long.**

### 2.3. Threats to the plant diversity of limestone forest

Quarrying and mining limestone are major threats to tropical limestone flora, particularly in Southeast Asia [4, 20]. In Thailand, over 20% of limestone karsts have already been quarried for cement, lime and hard core, and many have entirely disappeared from the landscape [21]. These activities permanently change the landscape and influence hydrology, as well as cause the extinction of some site-endemic species [16]. Due to the limestone' vulnerability, in Malaysia, for quarrying activities, environmental impact assessment is compulsory. In the investigation of the five limestone hills in Kelantan, Malaysia, 84 species found on the two hills designated for quarrying were not occurred on the other three hills [10]. The quarrying may result in the fact that complete hills are possibly

consumed with the total destruction of all plant life in just a few years.

Other important threats to limestone forests include logging and agricultural activities. Although these limestone areas are usually difficult to access due to their rugged topography and steep slopes, woody tree extraction and cultivation are common [13, 19]. Logging activities and land clearing for development may cause localized extinction of species, alternation of microclimate, soil erosion, and changes in species composition, particularly when non-native species colonize and inhabit natural regeneration [16]. In the karst condition, humidity is one of the limiting factors, and deforestation produces considerable drying of habitats. Limestone retains very little rainwater, thus the vegetation tends to dry out seasonally and is then easy to get fire [21]. Farmers are often used fire to clear a small patch for farming; it may spread quickly

out of control and damage vegetation on entire hillsides [16]. A fire at the foot and on the lower slopes of limestone hills also burns the organic soil layer, which, no longer anchored together by tree roots, is then easily washed away in subsequent rains. All aboveground animal communities may be seriously influenced, and many possibly disappear entirely, leaving large limestone areas barren [21]. Some other threats to karst species include an unsuitable collection of valuable and endemic plants, excessive hunting, use of caves for establishing temples and resorts, and eco-recreation activities also make worse for ecosystem balance and are particularly threatening to endangered species [4, 8].

#### **2.4. Vulnerability of limestone forest to disturbance**

The tropical limestone forest ecosystem is found very susceptible to disturbances and difficult to restore. The influence of disturbance on the local limestone biodiversity depends on the nature of the disturbance, the type of habitat, and the vulnerability of individual species [21]. Severe disturbances of the site may result in loss of vegetation cover, risk of fire and erosion of the usually thin topsoil layer. After the limestone vegetation destroyed, most of the soils will be eroded away to the mountain feet due to the impacts of heavy rains in humid tropical climate regions, thin topsoil layers and erect cliffs. Moreover, limestone mountain areas uncovered by forest canopies, together with high-temperature fluctuations, result in the strong weathering of rocks which makes them fissure and fall down to the mountain feet, threatening the life and production of local people. Limestone hills after such disturbances are often typically developed by vegetation covers of climbers, grassland

and non-native plant species, and can take decades to restore limestone vegetation to its healthy native state under the wet tropical climate [21, 22] (Figure 1b). This is determined in great part by the time needed to develop a new soil layer. For example, in harvested limestone forests, in northern Vancouver Island, British Columbia, soil erosion is recorded to be the main damaging consequence, and complete recovery of the forest on the barren limestone slopes requires at least some centuries [7]. In Vietnam, preliminary investigations found a poor regeneration status in disturbed limestone forests that may take much time to retrieve [6]. For instance, the logging is still affecting rare tree species 30 years later in Xuan Son National Park. The researchers found that the regeneration rate of specialized rare tree species was much slower in previously logged areas than in unlogged forests [12]. Also, the regeneration of animal diversity generally depends on the regeneration of the vegetation cover. Planting native tree species in secondary limestone forests may also help restore soil layers and create a right environment for plants to regenerate on the site. In order to restore the original vegetation, undisturbed vegetation remnants are still present in the proximate surroundings of the site, which acts as a seed source. For many animals on limestone, monoculture tree plantations are inadequate because of not offering the diverse habitats and not hosting the native forest plant species [21].

Disturbances of limestone areas also lead to a considerable loss of species, even extinction of site-endemic species. For example, an investigation in Ba Be National Park, northern Vietnam, recorded above 231 species of butterflies in primary forests, while from 116 to 146 species in fairly mature secondary forests,

and only 65 species in actively disturbed forests [21]. In Guangxi, China, disturbances have resulted in a severe loss of plant species, in that only 26.6% of the vascular plant species in the natural reserve area survived in disturbed karst areas [24]. Many prosobranch snails are facing risks of extinction as a result of disturbances on limestone hills in Sabah, Malaysian Borneo [15]. In Peninsular Malaysia, as the limestone karsts are not effectively protected, 17 plant species are now extinct and 12% of the flora are endangered [21]. The Malaysia's Ministry of Natural Resources and Environment has highlighted limestone as one of Malaysia's most vulnerable ecosystems [10]. Due to the high level of endemism, the destruction of limestone sites will result in the disappearance of the endemic species that are not found elsewhere [11].

### 3. Conclusions

The paper presented the most typical characteristics of tropical limestone forests. The terrain shows steep slopes, thin and discontinuous soil cover and high rock outcrop cover. Soils are poor in most minerals and nutrients. The ecosystem has high plant diversity and endemism. Quarrying and mining limestone, logging and agricultural activities are major threats to tropical limestone forests. This is a fragile ecosystem, vulnerable to disturbances, difficult to recover, and thus should be careful in management, conservation and development.

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## HỆ SINH THÁI RỪNG NÚI ĐÁ VÔI NHIỆT ĐỚI: TỔNG QUAN VỀ CÁC ĐẶC ĐIỂM ĐẶC TRƯNG

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### TÓM TẮT

Rừng núi đá vôi nhiệt đới rất đặc trưng và khác biệt so với các hệ sinh thái rừng nhiệt đới khác. Bởi vậy, việc hiểu về hệ sinh thái này là rất cần thiết cho việc bảo tồn và quản lý. Bài báo trình bày những đặc điểm đặc trưng nhất của hệ sinh thái rừng núi đá vôi nhiệt đới. Địa hình thường rất dốc, nhiều đá nổi, tầng đất mỏng và không liên tục. Đất nghèo các chất khoáng và dinh dưỡng. Hệ sinh thái có tính đa dạng cao và nhiều loài đặc hữu. Khai thác đá và chế biến mỏ đá vôi, khai thác gỗ và các hoạt động nông nghiệp là những mối đe dọa chính đối với rừng núi đá vôi nhiệt đới. Đây là hệ sinh thái rất mỏng manh, nhạy cảm với các tác động, khó phục hồi, do đó cần thận trọng trong quản lý, bảo tồn và phát triển.

**Từ khóa:** Đá vôi, đặc điểm đặc trưng, hệ sinh thái, rừng nhiệt đới.