WATER-RELATED ISSUES AND PROBLEMS
OF THE HUMID TROPICS
AND OTHER WARM HUMID REGIONS

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DECISION TIME FOR CLOUD FORESTS

WWF

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NETHERLANDS COMMITTEE FOR
IUCN
THE WORLD CONSERVATION UNION

PREFACE

At a Tropical Montane Cloud Forest workshop held at Cambridge, U.K. in July 1998, 30 scientists, professional managers, and NGO conservation group members representing more than 14 countries and all global regions, concluded that there is insufficient public and political awareness of the status and values of Tropical Montane Cloud Forests (TMCF). The group suggested that a science-based “pop-doc” would be an effective initial action to remedy this. What follows is a response to that recommendation. It documents some of the scientific information that will be of interest to other scientists and managers of TMCF, but not overwhelming for a lay reader who is seeking to become more informed about these remarkable ecosystems. The purpose of this booklet, therefore, is to:

- Impart an understanding of what these TMCFs are and how they function, based on the best science currently available, incomplete though that information is;
- Engender an appreciation of the values of TMCFs and why they are important to humans and our biological consorts on this planet Earth;
- Develop an awareness of the forces that threaten these ecosystems and cause the losses that are resulting from our resource development activities;
- Arouse a concern that will influence the way and speed with which research, management, protection and policy are carried out.

Donor institutions and development agencies are especially invited to read this document. Conservation NGOs are urged to use this information to raise awareness among the stakeholders in TMCFs, and to work with decision-makers in halting the degradation and disappearance of these valuable and unusual forests. Information about the TMCF Initiative and the supportive organizations that made this booklet possible, is given on the final page.

We believe decision time for cloud forests is here. Let us see if we can convince you, and move you to action!

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1. UP IN THE CLOUDS

With increasing elevation on wet tropical mountains, distinct changes in forest appearance and structure occur. At first, these changes are gradual. The tall and often buttressed trees of the multi-storied lowland rain forest, whose main canopy normally extends to heights of 25 - 45 m above the ground (with some large individuals reaching heights of 60 m or more), gradually give way to a new forest formation, *lower montane forest*. With a mean canopy height of up to 35 m in the lower part of the montane zone and individual emergent trees as high as 45 m, lower montane forest can still be quite impressive. Yet, with two rather than three main canopy layers, the structure of lower montane forest is simpler than that of lowland forest (Figure 1). Also, the large buttresses and climbers that are so abundant in the lowland forest have all but disappeared and on the branches and stems epiphytes (orchids, ferns, bromeliads) become more numerous with increasing elevation. The change from lowland to lower montane forest seems largely controlled by temperature as it is normally observed at the elevation where the average minimum temperature drops below 18 °C. At this threshold many tree species that are typical of lowland forest are displaced by a floristically different assemblage of montane species. On large equatorial inland mountains this transition usually occurs at an altitude of 1200 - 1500 m but it may occur at much lower elevations on small outlying island mountains and away from the equator.
(Figures 1 and 2).

As we continue our climb through the lower montane zone, it is clear to the observant eye that the trees not only become gradually smaller but also more 'mossy' (changing from ca. 10% to 25-50% moss cover of the bark). There is usually a very clear change from relatively tall (15-35 m) lower montane forest to distinctly shorter-statured (2-20 m) and much more mossy (70-80% bryophytic cover) *upper montane forest* (Figure 1).

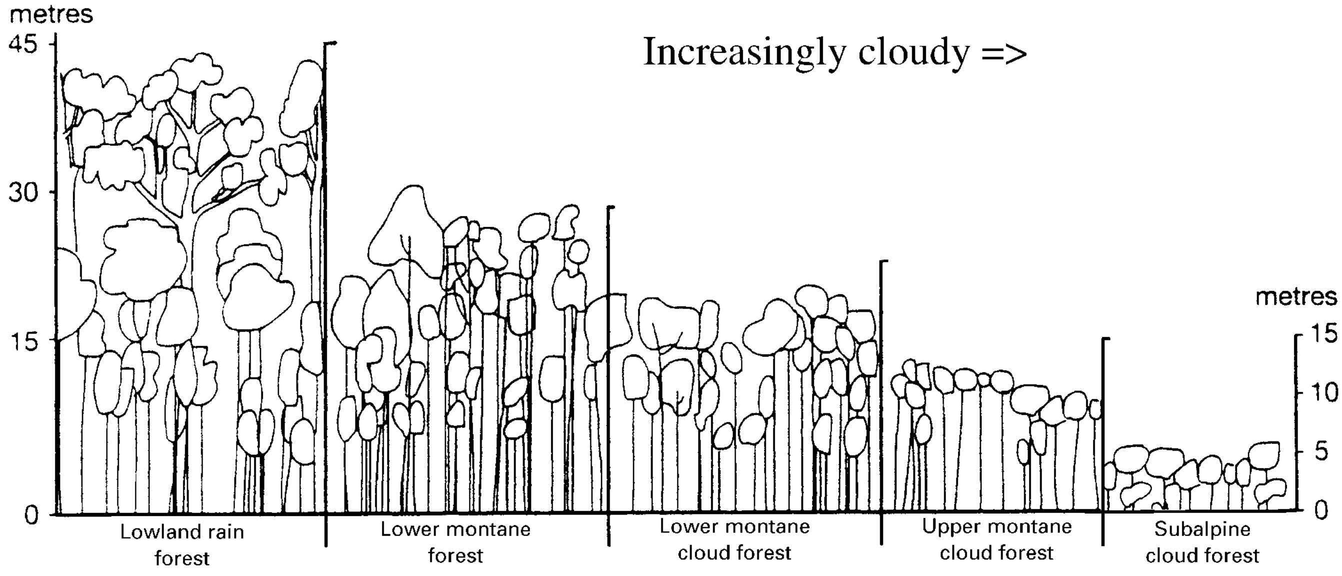

Figure 1. Generalized altitudinal forest formation series in the humid tropics.

Although the two forest types are not separated by a distinct thermal threshold this time, there can be little doubt that the transition from lower to upper montane forest coincides with the level where cloud condensation becomes most persistent. On large mountains in equatorial regions away from the coast this typically occurs at elevations of 2000 - 3000 m but incipient and intermittent cloud formation is often observed already from ca. 1200 m upwards, i.e. roughly at the bottom end of the lower montane zone. However, on small oceanic island mountains the change from lower to upper montane-looking forest may occur at much lower altitudes (down to less than 500 m above sea level; Figure 2).

Upon entering the zone of frequent cloud incidence, the floristic composition and overall appearance of the forest change dramatically. Leaves become smaller and harder, and no longer exhibit the elongated tips that characterize the leaves of forest formations at lower elevations. Twigs, branches and stems become festooned with liverworts, filmy ferns, lichens and mosses, in addition to the bromeliads, orchids and ferns that were already abundant in the lower montane belt. Mosses also start to cover rocks and fallen trunks on the soil surface. With increasing elevation and exposure to wind-driven fog, the tree stems become increasingly crooked and gnarled, and bamboos often replace palms as dominant undergrowth species. The eerie impression of this tangled mass wet with fog and glistening in the morning sun has given rise to names like 'elfin' forest or 'fairy' forest to the more dwarfed forms of these upper montane forests. Soils are wet and frequently waterlogged, peaty and acid. Indeed, in areas with high and year-round rainfall and persistent cloud, these upper montane forests are not hospitable places.

On drier mountains away from the oceans, where cloud incidence is less pronounced, the atmosphere is often more pleasant, however, and in many of these areas the forests have been cleared to make way for pasture or temperate vegetable cropping after harvesting of the useful timber species (see Section 4).

Aerial view of tall lower montane forest not subjected to frequent cloud at ca. 1500 m, Cordillera de los Andes, Colombia (photo by A.M. Cleef).

Interior of tall lower montane forest at ca. 1700 m in the Cordillera de los Andes, Colombia. Note the abundance of non-mossy epiphytes (photo by Th. van der Hammen).

A third major change in vegetation composition and structure typically occurs at the elevation where the average maximum temperature falls below 10 ^{o}C. Here the upper montane forest gives way to still smaller-statured (1.5 - 9 m) and more species-poor *subalpine forest* (or scrub). This forest type is characterized not only by its low stature and gnarled appearance but also by even tinier leaves, and a comparative absence of epiphytes. Mosses usually remain abundant, however, confirming that cloud incidence is still a paramount feature of the prevailing climate. On large inland equatorial mountains the transition to subalpine forest is generally observed at elevations between 2800 and 3200 m. As such, this type of forest is encountered only on the highest of mountains, mostly in Latin America and Papua New Guinea, where it may extend to ca. 3900 m.

It will be clear from the preceding descriptions that most lower montane, and all upper montane and subalpine, forests are subject to various degrees of cloud incidence.

So, welcome to the tropical montane cloud forest with its various gradations!

Definitions, names and classification of these remarkable vegetation complexes are myriad, as well as frustratingly overlapping and, at times, contradictory. Based on the preceding descriptions of montane forest types we distinguish the following forest types that become increasingly mossy with elevation: (i) lower montane forest (tall forest little affected by low cloud but often rich in epiphytes); (ii) lower montane cloud forest; (iii) upper montane cloud forest; and (iv) subalpine cloud forest. In doing so, we include the widely adopted broad definition of cloud forests as ‘forests that are frequently covered in cloud or mist’ while recognizing the important influence of temperature and humidity on overall montane forest zonation. However, as argued more fully below, to these should be added a more or less ‘a-zonal’ cloud forest type: (v) low-elevation dwarf (or ‘elfin’) cloud forest.

Interior of mossy upper montane cloud forest at ca. 2500 m elevation, Mount Kinabalu, Sabah.

Gnarled subalpine cloud forest at 2900 m, Mount Kinabalu, Sabah (photos by L.A. Bruijnzeel)

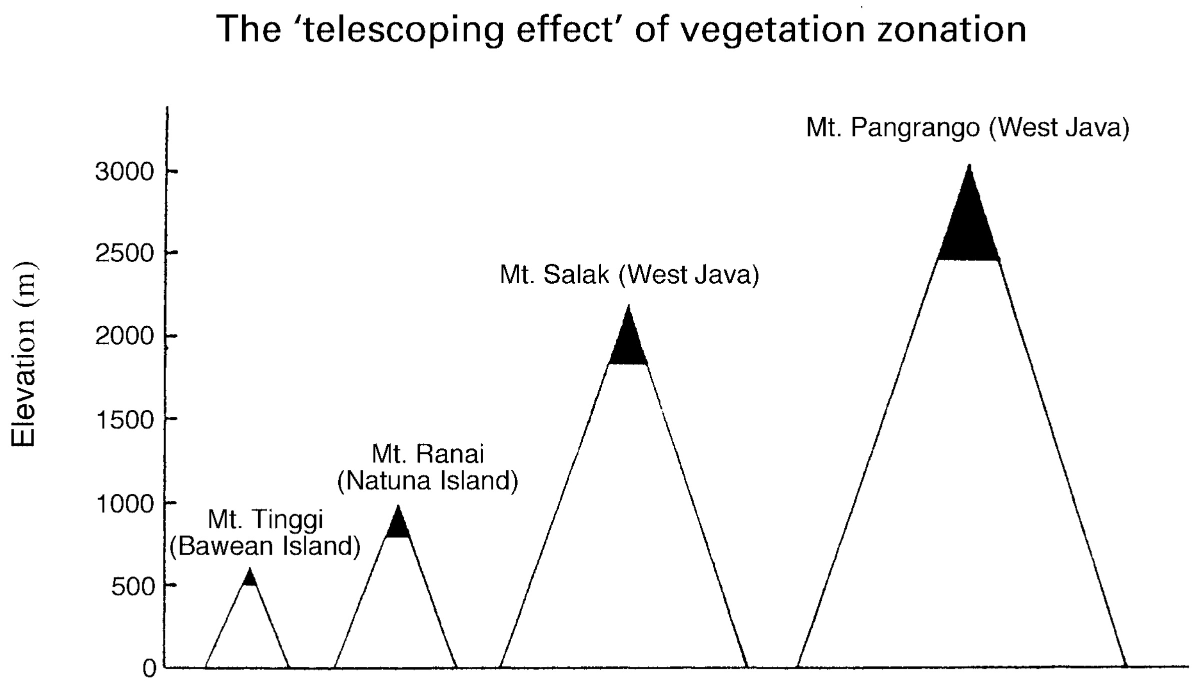

Figure 2. The 'telescoping effect' on the occurrence of mossy forest at contrasting altitudes on differently sized mountains in South-east Asia.

We have already noted the large variation in elevation at which one forest formation may replace another. For example, the transition from lower to upper montane forest is mainly governed by the level of persistent cloud condensation. Cloud formation, in turn, is determined by the moisture content and temperature of the atmosphere. Clearly, the more humid the air, the sooner it will condense upon being cooled during uplift (for example, when the air is blown against a mountain side). Therefore, the further a mountain is removed from the ocean, the drier the air tends to be and thus the longer it will take to cool to its condensation point and the higher will be the associated cloud base. Likewise, for a given moisture content, the condensation point is reached more rapidly for cool air than for warm air. Thus, at greater distance from the equator, the average temperature, and thus the altitude at which condensation occurs, will be lower.

Superimposed on these global atmospheric moisture and temperature gradients are the more local effects of sea surface temperatures and currents, the size of a mountain and its orientation and exposure to the prevailing winds, as well as local topographic factors.

It goes almost without saying that sea surface temperatures influence the temperature of the air overhead and thus the 'starting point' for cooling. Also, where warm, humid ocean air is blown over a comparatively cold sea surface, a low-lying layer of persistent coastal fog tends to develop. Well-known examples of this situation are the fog-ridden west coast of California where tall coniferous forests thrive in an otherwise sub-humid climate, and the coastal hills of Chile and Perú, where, under conditions approaching zero rainfall, forest groves are able to survive solely on water stripped from the fog by the trees themselves (see also Section 2).

The occurrence of low-statured mossy, upper montane-looking forest at low elevations on small, outlying mountains has puzzled scientists for a long time. This phenomenon is commonly referred to as the ‘mass elevation’ or ‘telescoping’ effect (Figure 2). The sheer mass of larger mountains exposed to intense radiation during cloudless periods has long been believed to raise the temperature of the overlying air, thus enabling plants to extend their altitudinal range. Whilst this may be true for the largest mountain ranges it is not a probable explanation for mountains of intermediate size on which the effect is also observed (Figure 2). Instead, the contraction of vegetation zones on many small coastal mountains must be ascribed to the high humidity of the oceanic air promoting cloud formation at (very) low elevations rather than to a steeper temperature lapse rate with elevation associated with small mountains. Further support for this contention comes from the observation that the effect is most pronounced in areas with high rainfall and thus high atmospheric humidity.

Whilst the cloud base on small tropical islands is often observed at an elevation of 600 – 800 m, dwarf cloud forests reach their lowermost occurrence on coastal slopes exposed to both high rainfall and persistent wind-driven cloud. Examples from the equatorial zone include Mount Payung near the western tip of Java, and Mount Finkol on Kosrae island (Micronesia) where dwarf forest is found as low as 400 - 500 m. An even more extreme case comes from the island of Gau in the Fiji archipelago where the combination of high precipitation and strong winds has led to the occurrence of a wind-pruned dwarf cloud forest at an altitude of only 300 – 600 m above sea level.