

Chapter 10.4

Vegetation Structures and Ecological Features of the Upper Timberline Ecotone

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10.4.1 Introduction: Neotropical Timberline Ecotones and the Special Case of Cordillera Real

The position of the upper timberline varies considerably along the neotropical cordilleras. Reviewing a north–south profile, differences between western, central, and eastern chains and/or escarpments become obvious. This is best demonstrated by an example from northern Chile and north-western Argentina at the southern limit of the Neotropics around 23 °S: While tree stands are missing completely on the western escarpment of the high Atacama, apart from small groups in creek and salar habitats (Richter and Schmidt 2002), the eastern part around Jujuy shows a *Polylepis* timberline at around 4000 m a.s.l. (Kessler 1995). At 550 km further north, open *Polylepis* woodland climbs up to 4800 m a.s.l. with smaller treelets reaching even 5100 m on Sajama and Parinacota near the border of Bolivia and Chile (Jordan 1983; Hoch and Körner 2005).

Polylepis, sometimes joined by *Gynoxis* trees in the Central Andes of Peru and in central Ecuador, is the most prominent member of South American tree- and timberlines. In some cases low soil temperatures with mean air temperatures of between 5.5 °C and 7.5 °C are seen as a main ecological trigger explaining their uppermost occurrence in an altitudinal belt. This comes close to the 7 °C mean for soil temperatures at 50 cm soil depth as postulated by Walter (1973; see also Körner 1999). In contrast to this finding, Bendix and Rafiqpoor (2001) give proof that thermal growth conditions can drop temporarily to 1.9 °C with a yearly average temperature of about 4.25 °C within a *P. incana* forest at Papallacta in northern Ecuador at 4060 m a.s.l.

In the northernmost part of the neotropical mountains Holarctic elements form the timberline. *Pinus* and *Cupressus* are the uppermost tree genera at about 4000 m a.s.l. between Central Mexico and Guatemala (Beaman 1962; Ern 1974; Lauer 1978; Veblen 1978). Between the northern coniferous and the southern *Polylepis* timberline the transitory cordillera in Costa Rica and western Panama is characterized by a relatively low treeline at about 3400 m a.s.l. Here a few woody genera such as *Quercus*, *Vaccinium*, and *Viburnum* from the northern hemisphere meet

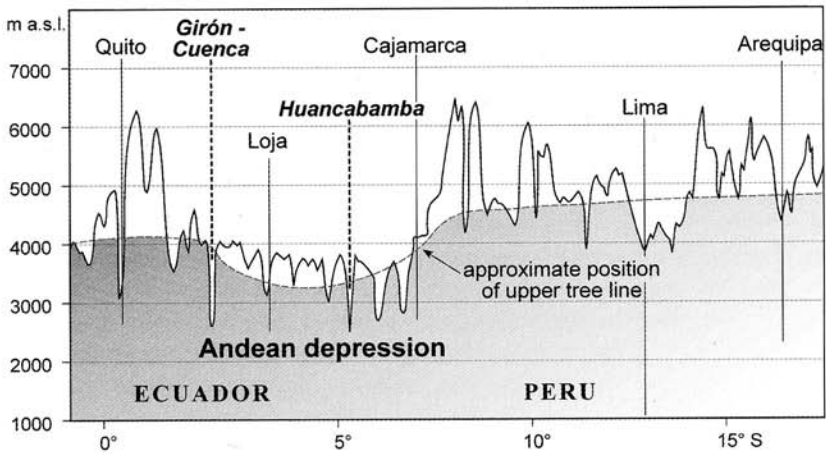


Fig. 10.4.1 Position of the upper tree line and lowest glacial stands within the Neotropical section of the Andes (western escarpment of the main chain)

Drimys, *Clusia*, *Miconia*, *Myrsine*, *Schefflera*, *Prumnopitys*, and *Weinmannia* from the south (Kappelle et al. 1995; Weber 1958). At this point it becomes obvious that tree diversity of the “low neotropical timberline”, containing a mixture of geo-elements, is much richer than of the “high neotropical timberlines” further north and south.

A second, less known low neotropical timberline interrupts the high one of *Polylepis* stands in the northern part of the Andes (Venezuela, Columbia, northern-central Ecuador) and in the Central Andes (central-southern Peru, Bolivia, northern Chile, north-western Argentina). This is between 3 °S and 7 °S, within the so-called Amotape–Huancabamba Floristic Zone (Weigend 2002) of the Andean Depression, once again presented by an upper timberline rich in tree species (Fig. 10.4.1). Very few peaks of the Andean chain in this region transgress 4000 m a.s.l. and only few stands of *P. weberbaueri* are known from the south of this section (6 °S at around 3300 m; Baumann 1988). This timberline depression results from the absence of the usually superposing *Polylepis* belt, which is combined with extremely high precipitation in the eastern chain of the cordilleras in northern Peru and southern Ecuador, since the genus tends to avoid perhumid mountain regions (Kessler 1995).

10.4.2 Study Area and Methods

Three study areas of different character are located in the northern half of the Cordillera Real, which forms part of the northern Huancabamba Depression. Towards the tectonic rupture of Girón–Cuenca as the northern borderline of the depression zone, only one adjacent mountain complex follows north of the Rio

Zamora breach, which is the Nudo de Loja (syn. Cordillera de Saraguro). The southward continuation of the 60 km north–south running Cordillera Real is the Cordillera de Sabanilla or Cordillera de Amaluza. In these adjoining mountain chains the uppermost timberlines exhibit elevations similar to those in the Cordillera Real (between 2600 m and 3400 m a.s.l.). The minimum and maximum extensions raise the question as to whether the driving force for treeless sites in the timberline ecotone is always the same.

Two of the three study areas are located at lower altitudes corresponding to “low timberline sites” within the vast zone of the “low Neotropical timberline”. One is Cerro del Consuelo in the upper part of the RBSF terrain, between 2730 m and 3040 m a.s.l. (Fig. 10.4.2: upper sketches) and the second is Paso El Tiro on the road from Zamora to Loja, between 2790 m and 2820 m a.s.l. The third area corresponds to a “high timberline site” within the zone of the “low Neotropical timberline”, situated between 3160 m and 3360 m a.s.l.

For floristic research eight transects of 50×2 m, corresponding to a method recommended as a sampling method for projects in the tropics by the Missouri Botanical Garden (2007), were established in each area. Each of the eight transects at different altitudes was divided in ten sections of 5×2 m, which were sampled individually during fieldwork. All plant species were collected and life form distributions were recorded, including values of percentage coverage for similarity analysis. Collected specimens were identified in the Herbario de la Universidad Nacional de Loja.

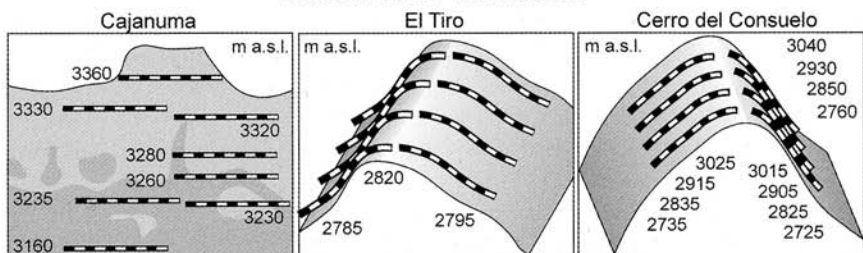
Climate data presented are drawn from a network of 14 automatic weather stations installed since 1997. An extraordinarily high rainfall input within the timberline belt of the Cordillera Real can be verified, as confirmed by the data from four automatic weather stations at 2670 m (TS1 in RBSF), 2830 m (El Tiro), 2930 m (Cerro del Consuelo), and 3400 m (Páramo de Cajanuma). Five-year means of annual precipitation range between 1500 mm year⁻¹ (El Tiro) and 5000 mm year⁻¹ (TS1; Emck 2006). According to radar extrapolation (Rollenbeck, personal communication; see Chapter 8 in this volume) even this amount might be exceeded in some remote mountain areas of the surroundings.

10.4.3 Results and Discussion

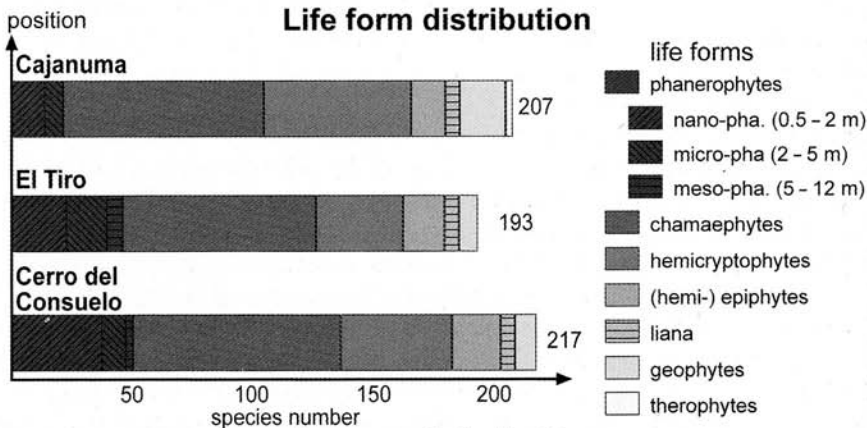
10.4.3.1 Floristic Composition and Plant Diversity at Three Timberline Sites

The two lower areas show a rather regular timberline pattern with a gradual shift from slope forests towards dwarf forests and herbaceous formations on top of the ridges. In contrast, the Cajanuma area at higher altitude presents an irregular timberline structure. In the latter case, a mixture of dense elfin forests and uniform *Chusquea* bamboo stands, *Neurolepis* dwarf bamboo patches and mixed shrub

Position of transects



Life form distribution



Degree of similarity

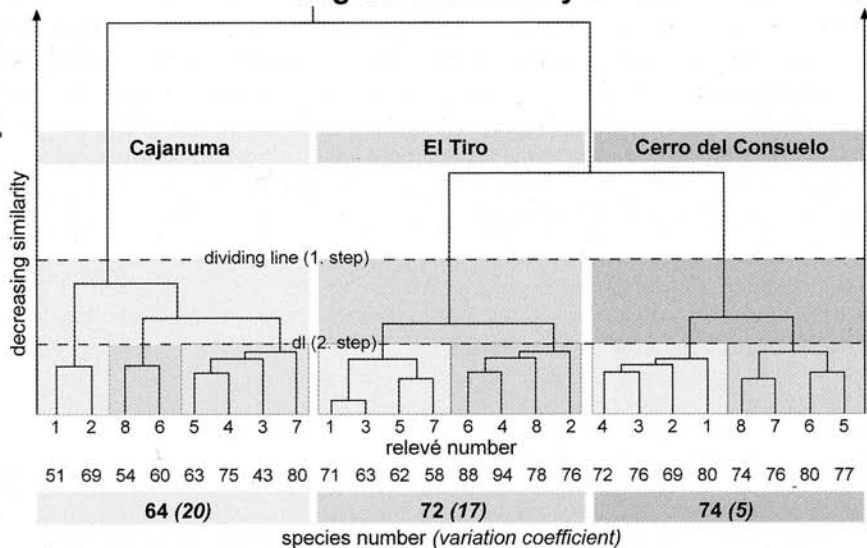


Fig. 10.4.2 Comparative overview of the community similarity and plant formation structure within the three timberline study areas. *Above* Position of the eight transects within each area. *Center* Life form numbers for the three areas and species numbers. *Below* (Dis-)similarity of the species composition between each transect and the three areas [presence/absence data, Jaccard index; *bottom*: species number (and variation coefficient) per transect]

páramos was found interspersed with tree stands, forming a complicated ecotone complex. Consequently, some of the physiognomic aspects of the transects vary considerably. Some of them are species-poorer bamboo formations without any trees, while others reveal species-richer fog forests and include all types of life forms available. Disturbances cause differently sized gaps in this area [landslides, soil creeping, possibly also rare wildfires under irregular climatic conditions, and even burrowing mammals such as agoutis (*Solenodon* spp)]. All transects show a multi-layered coverage of vascular plants ranging between 95% and 205%. Lowest values correspond to some of the dwarf bamboo páramos and highest to mixed shrub páramos with small trees containing epiphytes, while elfin forests hold an intermediary position. In addition, cryptogams cover 20–90% of the surface and supplementary trunk and branch envelopes occur too.

The gradual transition from dense forests towards open woodland and scattered trees, which is a typical feature of many *Pinus* and *Polylepis* timberlines in drier Neotropical mountains, does not exist in any of the research areas. In contrast, the perhumid climate of the low timberline ecotones investigated here explains not only a much denser coverage but also the presence of additional life forms such as lianas and hemi-epiphytes. Interestingly, most (165 species = 39% of the total) are dwarf shrubs up to 50 cm in height, while grasses and herbs hold the second position (99 species = 23% of the total, see also Fig. 10.4.2, centre). Among the 76 species of phanerophytes (18% of the total), the crude climatic conditions lead to a decreasing number of taller subclasses, as 44 nano-forms are followed by 23 micro- and only nine meso-forms. The latter does not occur in the cooler and wetter high timberline area of Cajanuma (Table 10.4.1).

The total of 39 timberline tree species found is surprisingly high, compared to the “high neotropical timberline” and especially with respect to sub- or extratropical equivalent ecotones. This is even true for the lower amounts per area shown in Table 10.4.1, where the limited number of shrubs and small trees for Cajanuma once again hints to harsher growth conditions. Six woody genera are among the ten first species-rich taxa, with *Miconia* (first rank = 26 spp), *Weinmannia* (second rank = 11 spp), *Symplocos* (joint fourth = 9 spp), *Ilex* (joint fourth = 9 spp), *Brachyotum* (joint fourth = 9 spp), and *Disterigma* (ninth rank = 7 spp). The differences in numbers of tree species between El Tiro and Cerro del Consuelo trace back to the broader altitudinal range of the latter research area, which covers a vertical distance of 310 m (Fig. 10.4.2, top).

Table 10.4.1 Species number of woody life forms on the eight transects (800 m²) in the three areas investigated

Tree life forms	Number of species		
	Cajanuma (3200 m a.s.l.)	El Tiro (2800 m a.s.l.)	Cerro del Consuelo (2850 m a.s.l.)
Nano-phanerophytes (0.2–2.0 m)	16	22	37
Micro-phanerophytes (2–6 m)	12	15	19
Meso-phanerophytes (6–18 m)	0	7	2

In difference to the number of shrub and tree species, no significant variations between the total amounts of vascular species are notable between the three areas, with 205 ± 12 species per 800m^2 plot found. The total of 422 species encountered in the three areas likewise reflects the tropical aspect of vegetation. Still more remarkable is the fact that only 30 species (i.e. 7.1%) are shared by all three areas. Species numbers per transect range between 43 (Cajanuma, dwarf bamboo páramo) and 94 (El Tiro, mixed formation extending from herbaceous to forested stands) with a mean of 70 species per transect. The highest variation was found at Cajanuma (20%). This is easily explained by the great diversity of plant formations. The reason for the considerable difference between the deviation rates of El Tiro and Cerro del Consuelo (17% compared with 5%) in contrast, traces back to different wind impacts (see Section 10.4.3.2). Windward and leeeffects are much stronger at El Tiro (see Section 10.4.3.2) than at Cerro del Consuelo and hence create more pronounced differences in species composition. This explains a clear separation of the four western from the eastern transects in the dendrogram. All sites of higher species richness (even valid for the short sections) are located on the exposed eastern sides with its mixed formation structures, while the forested western sides have lower species numbers (uneven relevé numbers in the dendrogram, Fig. 10.4.2, bottom). This contrast between the two aspects is lacking at Cerro del Consuelo where wind is of minor importance.

The dendrogram in Fig. 10.4.2 shows that the degree of species dissimilarity within an area is highest at Cajanuma, where the dividing line separates three assemblies instead of two at El Tiro and Cerro del Consuelo. The between-area similarity rate underlines the diverging character of Cajanuma. This might be explained not only by environmental factors in this elevated study area but also by its location west of the main crest-line. The shorter and straighter pass-way between Cerro del Consuelo above and El Tiro at the western margin of the same San Francisco Valley might facilitate seed interchange.

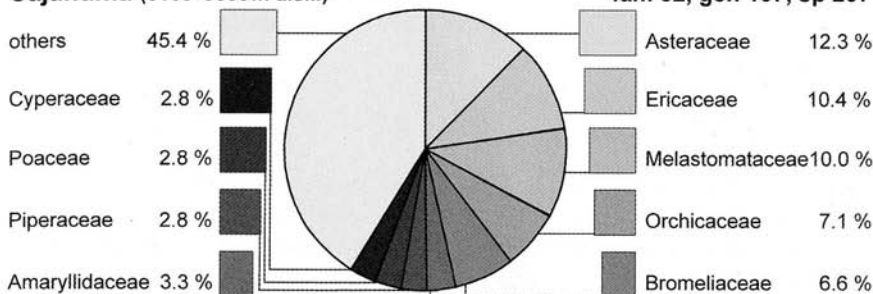
The floristic composition of the three areas indicates similar as well as diverging traits (Fig. 10.4.3). With regard to the family structure, the five first ranked families are the same in all study sites: Asteraceae, Bromeliaceae, Ericaceae, Melastomataceae, and Orchidaceae account for the most frequent species, while in the next four positions only Poaceae still form a prominent group in each of the areas. The ranking of the first five families varies in the sense that the worldwide-distributed Asteraceae and Ericaceae dominate at the higher reaches while the tropical group of Melastomataceae is strongest in the two lower timberline ecotones. *Miconia* (Melastomataceae), the species richest genus overall, is less present at the highest area of distribution. *Tillandsia* (Bromeliaceae), the third-ranked genus of the total species pool, is always well distributed while *Weinmannia* as the second-ranked genus shows more variety among its area members. Apart from the woody genera *Miconia*, *Weinmannia*, and *Brachyotum*, the two climber groups of *Mikania* and *Bomarea* are conspicuous associates in each of the three areas.

Communities can be separated by some frequent woody species in the timberline ecotone. *Hedyosmum cumbalense* and *H. scabrum* as well as *Weinmannia pubescens* and *W. rollottii* are important timberline members in Cajanuma and are not registered in the other two areas. Instead, the latter harbor *Clusia elliptica* and *C. ducoides*,

Family composition

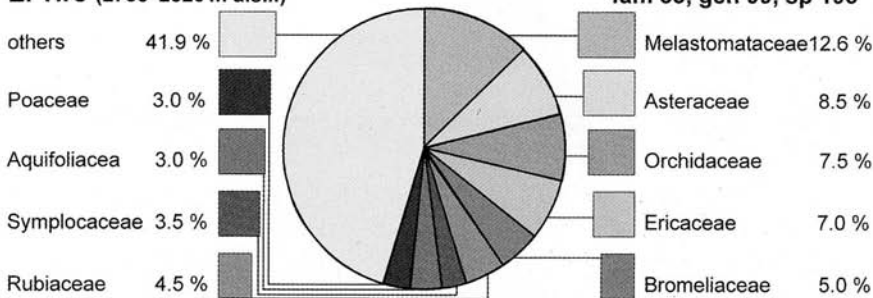
Cajanuma (3160–3360 m a.s.l.)

fam 52, gen 107, sp 207



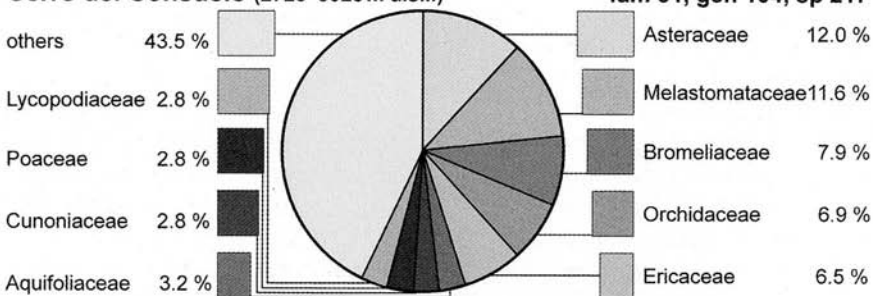
El Tiro (2785–2820 m a.s.l.)

fam 55, gen 99, sp 195



Cerro del Consuelo (2725–3025 m a.s.l.)

fam 51, gen 104, sp 217



Most important genera

Cajanuma

<i>Miconia</i>	10
<i>Tillandsia</i>	7
<i>Bomarea</i>	7
<i>Disterigma</i>	7
<i>Puya</i>	6
<i>Gaultheria</i>	5
<i>Mikania</i>	5
<i>Weinmannia</i>	4
<i>Brachyotum</i>	4
<i>Elaphoglossum</i>	5

El Tiro

<i>Miconia</i>	15
<i>Symplocos</i>	7
<i>Ilex</i>	6
<i>Tillandsia</i>	5
<i>Brachyotum</i>	5
<i>Mikania</i>	4
<i>Weinmannia</i>	4
<i>Cinchonia</i>	4
<i>Bomarea</i>	4
<i>Polypodium</i>	4

Cerro del Consuelo

<i>Miconia</i>	13
<i>Tillandsia</i>	7
<i>Ilex</i>	7
<i>Lycopodium</i>	6
<i>Epidendrum</i>	6
<i>Weinmannia</i>	6
<i>Mikania</i>	6
<i>Symplocos</i>	5
<i>Brachyotum</i>	5
<i>Bomarea</i>	5

Fig. 10.4.3 Percentage of the contribution of the first nine most important plant families, and species numbers of the first most important genera per study area

Hedyosmum translucidum, *Miconia jahnii*, *Ocotea* sp., *Schefflera* sp. 1, and *Weinmannia fagaroides*. In all three areas *Clethra revoluta*, *Cybianthus marginatus*, *Graffenrieda harlingii*, and *Miconia radula* play an important part.

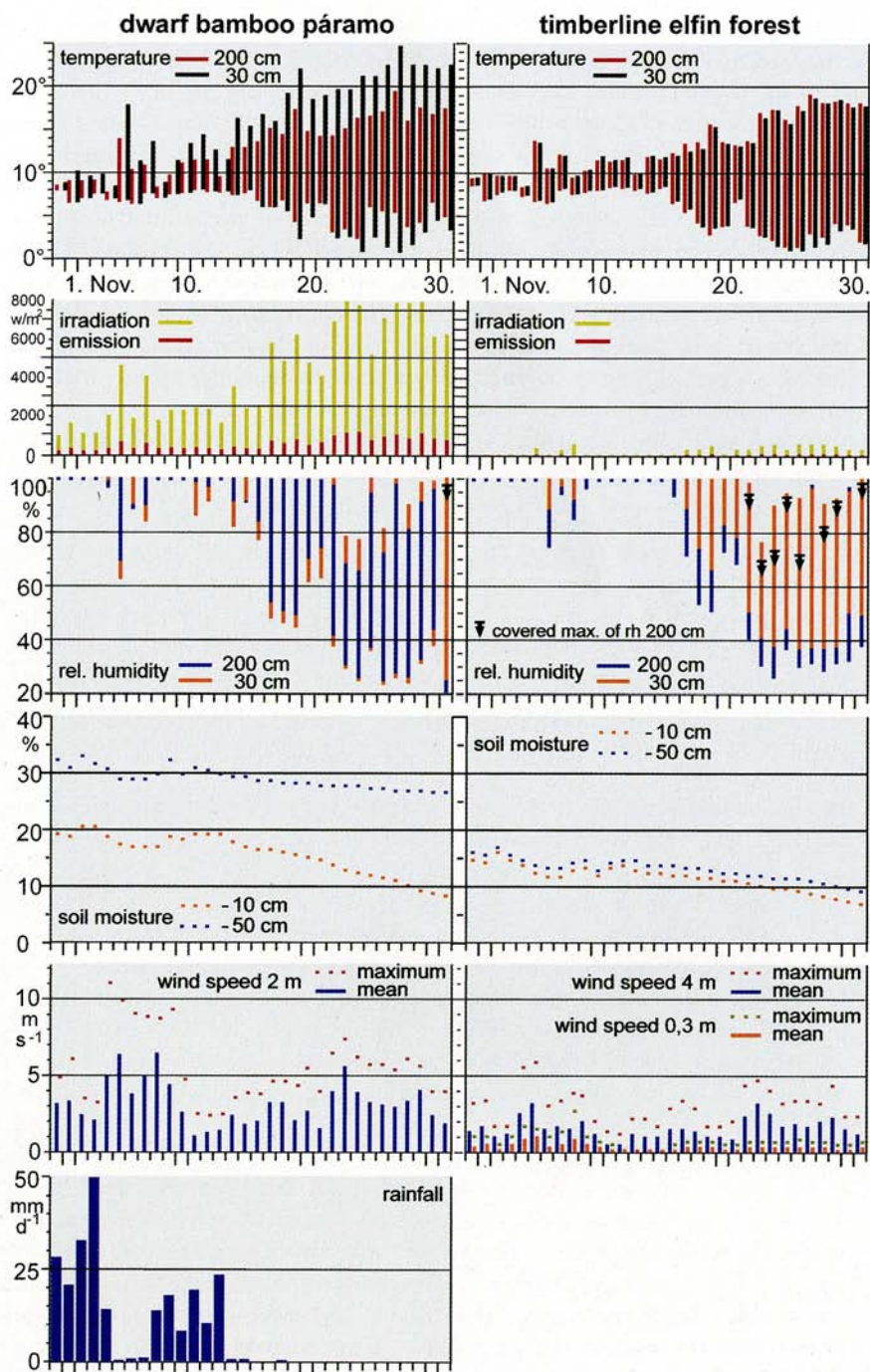
Differences in the distribution of shrubs were obvious. Frequent species only occurring in Cajanuma were *Brachyotum andreanum* and *B. campii*, *Gynoxis cuicochensis*, *Macleania rupestris*, and *Miconia ligustrina*, among others. Restricted to the two lower timberlines were *Brachyotum campanulare* and *B. rotundifolium*, *Cyathea frigida*, *Gaiadendron punctatum*, *Geissanthus andinus*, *Gynoxis fuliginosa*, *Ilex scopulosum*, *Myrsine andina*, *Symplocos canescens*, and *Weinmannia elliptica*. Abundant in all areas were *Freziera minima*, *Gaultheri amoena*, *G. erecta*, *G. reticulata*, *Gynoxis miniphylla*, *Miconia tinifolia*, and *Symplocos clethrifolia*. *Chusquea falcata* and the dwarf species *C. neurophylla* and *Neurolepis elata* were prominent species of all three sites.

10.4.3.2 Climate and Soil Properties as Driving Forces

The two weather stations of the Cajanuma area are located at 3240m a.s.l. within the timberline ecotone. One provides data from a mixed elfin forest located on a slope with coarse debris, the other from a 120m nearby dwarf bamboo páramo on a flat ridge with loamy soil above solid rock. Long-term climate data are available for temperature and relative humidity (200cm, 30cm), wind speed and direction (400cm, 30cm at the forest site, 250cm at the páramo stand), global irradiation and emission (30cm within the forest, 200cm at the páramo), and soil moisture (-10cm, -50cm).

Fig. 10.4.4 gives an idea of two ecologically decisive weather types, i.e. the rainfall situation (by far predominant) and the fog situation, both derived from the quasi-permanent easterlies, and the short radiation periods during October and November originating from western airflows (so-called "veranillo"). Both situations are highlighted by taking November 2005 as an ideal example. The first half of this month presents rainy weather and the second sunny weather. Rainy weather is typical for a season of at least 10 months between December and October; and even during the short "dry" period fogs and rain prevail. The precipitation type is marked by a rather constant but not strong input whereas thunderstorms with downpours are rare in the crest area, which is mostly enveloped in shallow cloud caps.

Fig. 10.4.4 Comparison of air temperature (amplitude at 200cm and 30cm above ground), irradiance and emission (daily sum w h m^{-2} at 200cm above ground), relative humidity (amplitude at 200cm and 30cm above ground), soil moisture in vol% at -10cm and -50cm (values at 4:00 p.m.), maximum and mean wind speed per day (based on hourly means; at 200, 400, 30cm above ground) over an open dwarf bamboo stand on an exposed side ridge and in a slope forest (120m nearby) within the timberline ecotone at Cajanuma at 3240m and 3230m a.s.l., respectively. Precipitation measurements were taken on the side ridge at 100cm above ground



A comparative interpretation of both weather situations leads to an explanation of the main microclimatic triggers. They are characterized by long-time equal conditions of narrow temperature and humidity amplitudes during fog and rainfall and extraordinarily high irradiation inputs during sunshine. In the latter context record values were recorded: up to 1.832 w m^{-2} at the nearby Páramo climate station (3400 m a.s.l.; March 2000) and up to 1.756 w m^{-2} at Cajanuma-Mirador (2960 m a.s.l.; December 1999). Such occasions of a very high excess of global irradiance above potential irradiance were measured and explained by Emck (unpublished data) as "white-screen" effects of reflection by transparent and opaque clouds. They give a reason for the temperature maxima on plant surfaces exceeding 50°C – just contrary to the equally cool thermal conditions during most of the year. Thus, plants at the timberline are best adapted to long-time wet surroundings but must endure short-time stress by overheating, extreme or "super-irradiance", and desiccation too.

Although microclimatic features at the timberline ecotone within the Cordillera Real do not differ considerably from general principles, some noteworthy characterizations are given in Fig. 10.4.4 by comparing the two sites.

1. Temperature. Minima at 30 cm are nearly the same as at 200 cm above ground during and some few days after rainfall. After drying of the upper soil layers slight freezing at soil surfaces is found on bare ground. No significant differences are seen between the stand temperature at 30 cm and 200 cm within the forest and also not between forest and open páramo at 200 cm. Temporary heat stress is restricted to the uppermost part of the canopies and to open herbaceous strata where it explains xeric structures such as pubescent, scleromorphic, or waxy leaf surfaces.
2. Irradiation and emission. It is hard to imagine that plants at the Cajanuma timberline might suffer from "super-irradiance" although 84% of the daytime during a year are rainy or foggy (calculated by sunshine rates; Emck, unpublished data). However, many vascular plant species show reddish colors on fresh leaves and hence, hint to carotene protecting against excessive UV-B rates. Not only global "super-irradiance" is responsible for any of the protective features. Since UV radiation is scattered more than total shortwave radiation, maximum absolute UV intensities are observed just below the upper boundary of clouds by diffuse fluxes (Barry 1992). Since the Cajanuma mountain ridge is mostly wrapped by shallow cloud caps the timberline area consequently underlies such conditions.
3. Relative humidity. According to the thermal and solar circumstances for the exceptional dry period during the last part of the time-scale presented in Fig. 10.4.4, relative humidity is also marked by a special situation of dryness with minimum values below 30%. This is even true for the stand climate at 200 cm within the elfin forest, where once again similar amplitudes like that in the open environment become obvious. Only the near-ground air and thus the undergrowth does not suffer in the same way by water vapor deficits.
4. Soil moisture: Soil water contents differ considerably between the two sites. Soils of the open páramo on the ridge develop on solid rocky layers, which on

their part cause long-lasting water stagnation. Consequently, especially for the lower soil strata directly above the rock surface, moisture content is considerably higher than in the coarse porous debris layer beyond the forests. In contrast, thick humus layers in elfin forests guarantee that the soils there never dry up strongly. Thus elfin forests create their own water regime by a mighty uppermost organic stratum that conserves moisture also during the (rarely more than two weeks long) dry periods of Veranillo del Niño. Furthermore, the immense water storage capacities of thick epiphytic bryophyte packages on tree branches are verified as a general feature of elfin forests (Müller and Frahm 1998; Kürschner and Parolly 2004b).

5. Wind: Diurnal means of wind velocity as well as maximum gust speeds of the páramo stand (2 m above ground) are around twice as high as above the forests (0.5 m above canopy surface or 4 m above ground, respectively). Within the forest the air-flow is once again much weaker, sometimes reaching only one-fifth of the above-canopy wind speed. Interestingly, the wind direction in open stand differs considerably from the direction above the forest canopy. While the open stand was prevalently marked by air flows from the south-west (39%) and from the north-west (34%) the forest site only 60 m off showed a clear dominance of the north-west (63%, only 9% from the south-west). A weather station on the crest-line at 3400 m a.s.l. measured the easterly airflow with an input of 45% from the north-east, while 31% from the north-west traces back to the special October–November phenomenon of sunny weather during the last two weeks of observation. An interpretation of the different directions hints at turbulence effects at the lee side where easterlies are often turned into western winds that are weaker than on the crest side. However, the wind velocities vary considerably on the lee side depending on the orographic position. During the observation time shown in Fig. 10.4.4, the mean wind speeds were: on the main crest 14.5 km h⁻¹ (max. gust 49.7 km h⁻¹), at 160 m lower down on the side ridge with the páramo site still 11.3 km h⁻¹ (max. gust 40.3 km h⁻¹), and over the forest site only 5.8 km h⁻¹ (max. gust 20.9 km h⁻¹). Apart of an effect of friction caused by an irregular canopy surface, the location of the forest on a less exposed slope between two side ridges provides a more effective screen.

Wind as a decisive force for the position of timberline is proved by measurements on Paso El Tiro at around 2810 m a.s.l. (Fig. 10.4.5). Of course, mean wind and gust speeds are highest on the crest itself. Only 8 m beyond the ridge, mean velocity is reduced to 58% on the leeward side. Interestingly, wind speed is still lower on the windward side at 8 m and 13 m east of the crest. This phenomenon traces back to a rather plain topography in front of the ridge but beyond a steeper slope, which lifts up the upwind from the east. The consequence is a patchy structure of isolated but dense tree stands in flat hollows or on wind-protected flats on the windward escarpment below the crestline. In contrast, dense forest cohorts climb just up to the rim of the same crest, forming a sharp timberline on the leeward side.

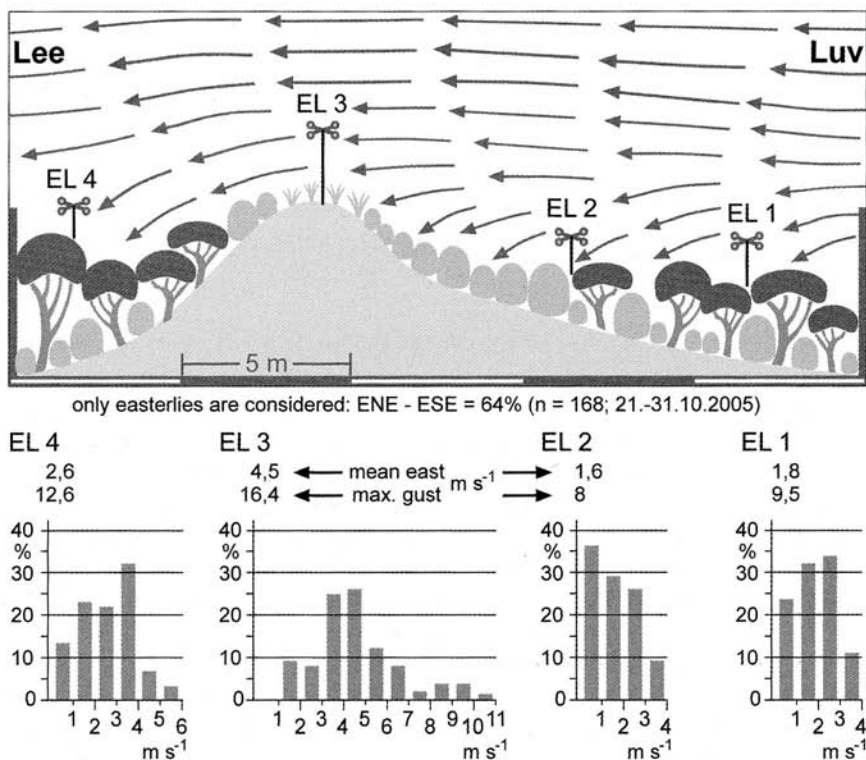


Fig. 10.4.5 Wind speed classes on Paso El Tiro during an easterly period (21–31 October 2005). The evaluation is restricted to the prevailing wind direction (sector ENE–ESE = 64% of the observation period). Air-stream lines give an idealized interpretation of friction effects caused by the local topography and the vegetation type; an overview of the surrounding profile is given in the *bottom sketch*. The two sketches (*top*, *bottom*) give an impression of the sharp timberline at the leeside of the El Tiro crest and a nearby wind-protected isolated tree stand on the windward side

10.4.4 Conclusion: Too Much Wind and Too Much Water

One of the most surprising results is the high species number of trees at the timberline ecotones of the Cordillera Real. This is all the more astonishing under the aspect of climatic conditions (researchers active in the area sometimes raise the question why any of all those organisms might like to live under such

circumstances...). This taxonomic richness is not only an attribute of the input from the humid tropical lowlands but also results from the dizzying kaleidoscope of semi-arid to perhumid environments in the neighborhood (Young et al. 2002; Richter and Moreira-Muñoz 2005).

Soil temperature is not a decisive factor for the delimitation of tree growth in this region of tropical timberline. It shows rather high average values without decisive variations around 11 °C at 2930 m a.s.l. in Cerro del Consuelo and around 8.8 °C at 3400 m a.s.l. on the main ridge above Cajanuma. Further long-time comparative measurements of soil temperatures at -50 cm at 2650 m a.s.l. in RBSF hint to an average mean reduction of 2 K in a dense forest as against to open stands. Taking this value of diminution in forest habitats as well as a vertical thermal gradient of 0.58 K per 100 m into account, mean soil temperatures of 7 °C under forests should be reached at about 3650 m to 3750 m a.s.l. This corresponds to an elevation between 400 m and more than 800 m above the highest position of existent timberlines in the Cordillera Real. This study indicates that the postulated cooling impact as a main trigger for tropical timberlines is questionable and obsolete.

Instead, wind has to be considered as a much more important factor to explain the absence of trees on exposed ridges, as shown for the El Tiro area. However, this is not the case at the Consuelo site where wind is of lesser importance, while rainfall and fog show an exuberant impact underlined by dense *Sphagnum* cushions or by the presence of a not yet identified *Drosera* spec. Consequently, "low timberlines" (or "local timberlines", in analogy to the expressions "climatic" and "local snowline") are caused by strong wind and/or soil moisture impact. In the case of the Cordillera Real this observation also holds true for some elevated U-shaped valleys such as the upper Sabanilla Valley where an ensemble of cold-air drainage and water-logging results in *Sphagnum*-rich bogs. In the same region many ridge sites also suffer from water-saturated soils that inhibit tree growth, which creates local timberlines expanding along both sides of crests. In some areas, this symptom starts above 2600 m a.s.l. On lower elevations the same ridges disappear under a coherent forest cover as they become steeper and thus water drainage is more efficient apart from lower precipitation and higher evaporation rates towards inferior parts of V-shaped valleys.

To a minor extent, temperature might play an additional part. It explains for example that the two "low local timberlines" have floristically more in common than either of them have with the comparatively more isolated flora of the "high local timberline" at Cajanuma. Most apparently the latter traces back to each of the mentioned factors, i.e. wind and soil-logging on the ridge sites combined with a quasi-permanent cooling effect, which however cannot explain the lack of trees alone. Consequently, the presence or absence of tree stands and forests within all timberline ecotones in the Cordillera Real depends on a complicated synergetic bundle of driving factors. These are given by strong wind and/or high soil-water content, in some areas to a limited degree supported by cool climate.

Acknowledgement We gratefully acknowledge the help of Bolívar Merino at Herbario Loja for assistance with the identification of the collected plant material.