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OBSERVATIONS ON A HUMAN-INDUCED FIRE EVENT AT A HUMID TIMBERLINE IN THE BOLIVIAN ANDES

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The factors determining the present-day position and aspect of the upper timberline in tropical mountains are still poorly understood (Miehe & Miehe 1994, Körner 1998). In the humid tropical Andes, the typical pattern consists of a closed cloud forest timberline at about 3000–3800 m followed by a grassland dotted with isolated patches of forest dominated by *Polylepis* (Rosaceae) which reach up to 4200 m. Frequently, the cloud forest and *Polylepis* forest belts are separated by a zone with very few or no trees (Herzog 1923, Troll 1959, Hueck 1962, Vareschi 1970). The occurrence of trees and forest islands above the current closed timberline has led to a longstanding controversy about the origins of this pattern, the influence of human activities on tropical timberlines, and the natural appearance of this habitat. While some authors believe that the isolated position of the *Polylepis* forest patches is mainly due to locally ameliorated environmental conditions on special habitats such as rock faces, boulder slopes and stream margins, or in places of frequent cloud formation (e.g., Troll 1929, Koepcke 1961, Walter & Medina 1969, Seibert & Menhofer 1991) others (e.g., Ellenberg 1958, Lægaard 1992, Kessler 1995a) consider that this pattern is mainly due to anthropogenic disturbance, mainly in the form of fires and overgrazing, which has restricted forests to these habitats. Despite abundant recent ecological and biogeographical evidence for a strong human impact on Andean timberlines (summarized by Fjeldså & Kessler 1996; see also Kessler 1995a, Ellenberg 1996, Körner 1998), the striking pattern of a closed timberline within locally rather narrow elevational limits and of almost treeless zone between the cloud forest and *Polylepis* forest belts remains unexplained. Although direct connections between cloud forest and *Polylepis* forest habitats have been encountered at scattered locations throughout the Andes (Kessler 1995a), such cases are clearly exceptions in the currently observed timberline patterns. I here present observations on a fire event at a humid timberline in the Bolivian Andes which sheds some light on this problem.

On 28 June 1997 I observed a timberline fire on the Cumbre San Vicente, Carrasco National Park, dpto. Cochabamba, Bolivia, from a vantage point at 3500 m (17°13'S, 65°41'W) along the road from Aguirre to El Palmar. The fire was about 4 km away on the opposite side of the deep valley of the Río San Mateo to the east of the road at 17°14'S, 65°39'W. In this general area, the closed cloud forest timberline, dominated by *Clethra* (Clethraceae), *Clusia* (Clusiaceae), *Hedyosmum* (Chloranthaceae), *Oreopanax* (Araliaceae), and *Weinmannia* (Cunoniaceae), was located at c. 3300–3400 m which roughly corresponds to the regular upper limit of the cloud condensation layer (pers. obs.). Higher up, patches of *Polylepis racemosa* R. & P. forest occurred between 3400 and 3900 m mainly in sheltered microhabitats (ravines, rock faces) but also on "normal" slopes. Isolated groves of *Polylepis pepei* B. Simpson reached

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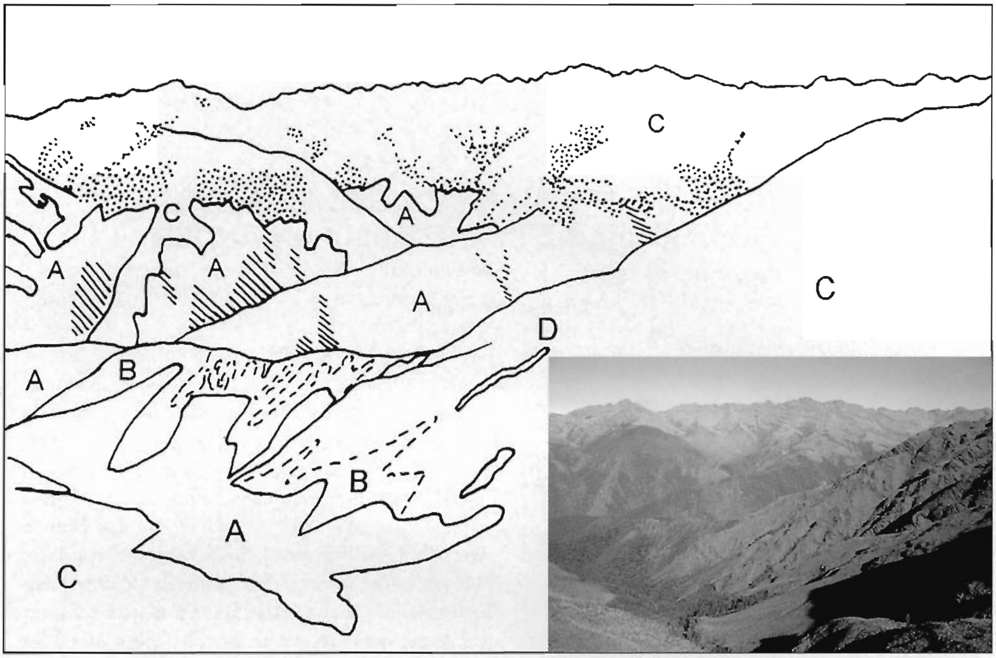

FIG. 1. General location of the fire event on the Cumbre San Vicente, Carrasco National Park, dpto. Cochabamba, Bolivia, showing the mosaic of closed humid montane forest (A), fire-influenced scrub near timberline (B), fire-influenced grassland above the current timberline (C), and open *Polylepis* stands reaching to 4000 m (dotted). More open vegetation in the cloud forest belt (cross-hatched) corresponds to successional vegetation on natural landslides. Note the fairly even localization of the closed upper cloud forest limit at about 3300–3400 m, the abrupt transition from forest to grassland, and the relict lines of trees in deep ravines which are protected from fire (D). Photo M. Kessler.

up to 4200 m (Fig. 1). This general region is among the most humid in Bolivia, with c. 5700 mm mean annual precipitation registered in the foothill zone at Villa Tunari (460 m), 38 km northeast of the study site (Morales 1990).

The fire apparently started in grassland at about 3500 m and spread downward along the slope to an elevation of c. 3350 m (Fig. 2). As no thunderstorm was observed prior to the fire event, it was presumably started by one of the peasants occasionally travelling through this otherwise uninhabited area. Nearby, I have repeatedly witnessed local people deliberately setting grassland slopes on fire. On its way downhill, the fire burnt the understory of an open *Polylepis racemosa* forest, humid shrubby timberline vegetation and the edge of the closed humid timberline. Interestingly, the fire was able to spread through the open *Polylepis* forest and the scrub but not through the humid cloud forest. Elsewhere in the general region all open *Polylepis racemosa* forests that I visited showed evidence of understory fires (charred bunchgrasses and trunk bases) but I never observed such signs inside humid cloud forests.

These observations suggest that humid cloud forests and *Polylepis* forests are differentially affected by fires. Mature *Polylepis* trees frequently survive groundfires because of their multilayered bark, while seedlings and young trees are often killed (Kessler & Driesch 1993, Kessler 1995a, b). The destruction of *Polylepis* forests thus occurs as a gradual process by a supression of regeneration in the event of regular fires. Whether the multilayered bark of *Polylepis* evolved as an adaptation to fires, as a protection against low temperatures (Hensen 1995) or against being overgrown by epipyhtes (Ellenberg 1958) remains open to debate. In any case, it clearly permits the persistence of *Polylepis* populations over extended periods in areas with occasional fires.

Epiphyte-laden cloud forests, on the other hand, appear to be completely destroyed when they are reached by a fire (Lægaard 1992). In the study area, and elsewhere in the Bolivian and Peruvian Andes, I have repeatedly seen cloud forests in which all the trees had been killed by a single fire event. In most cases, as shown by the fire reported here, fires only affected the outermost 5–10 m of the forest belt, presumably lacking the heat to dry out and burn the abundant water-storing moss layers typically covering the branches and trunks of trees in this habitat (cf. Young 1993). On occasion, however, especially after prolonged periods without rain, fires may spread well into cloud forests, killing hectares of forest at a time. These burnt forests are quickly invaded by aggressive shrubs, mainly *Chusquea* (Poaceae - Bambusoideae), *Sticherus* (Gleicheniaceae), and *Pteridium* (Dennstaedtiaceae). The resulting thickets are much more susceptible to burning than the original forests and may eventually be converted to grasslands if subject to repeated fires. The regular distribution of the upper limit of the present-day closed cloud forest timberline at c. 3300 m is probably caused by a noticeable increase in humidity due to regular cloud condensation. Higher elevations, albeit still very humid, are more exposed to dessicating cloudless periods and thus more susceptible to fires. I have, however, also found burnt forest areas at lower elevations in the study area (at 2000 and 2700–2800 m) within the cloud condensation belt, but these were clearly not burnt frequently enough to lead to the development of scrub or grassland vegetation.

The fire event reported here exemplifies the different effects of fires on Andean high-elevation forest types and their resulting development. Regular fires will eventually depress the humid cloud forest timberline, usually only a few meters at a time but occasionally affecting larger forest areas. *Polylepis* forests, on the other hand, will persist over prolonged periods of time. The resulting pattern is that of remnant *Polylepis* patches in a zone dominated by fire-maintained grasslands and of a closed humid timberline at lower elevations. If the fires occur with high enough frequency, or over long enough periods of time, they may depress the closed timberline to elevations well below the natural lower limit of *Polylepis* forests. Since neither cloud forest nor *Polylepis* trees are able to recolonize regularly burnt grasslands (Kessler 1995a), the result is a completely forest-free zone separating the cloud forest from the *Polylepis* forest belt, resulting in the so far unexplained pattern described above.

Clearly, the development of timberline habitats in the humid tropical Andes is determined by the frequency of fires. Occasional fires, occurring at long enough intervals to allow the growth of trees, may not significantly affect the distribution of timberline forests. Regular fires, however, especially on a long-term basis, will eventually lower the timberline and restrict forest to sheltered microhabitats which are not usually reached by fires, i.e., ravines, rock faces, boulder slopes. It is not known whether humid timberlines in the Andes are affected by natural lightning-induced fires, even though this has been observed in semihumid *Polylepis besseri* Hieron. forests near Cochabamba city, dpto. Cochabamba, Bolivia (R. Bode, pers. comm.). A photograph of a natural timberline situation in the Cordillera Vilcabamba, Peru, by Baekeland (1964: 282–283) also shows a forest-scrub-grassland mosaic which may partly be caused by natural fires, even though abrupt edaphic changes cannot be excluded.

The current high fire rate, however, is undoubtely caused by deliberate burning by local inhabitants.

FIG. 2. A fire affecting open *Polylepis racemosa* forest (scattered trees) and dense very humid cloud forest (detail from Fig. 1). Note how the downslope-spreading fires extended through the *Polylepis* forest (upper left) and shrubby vegetation but only damaged the outer limit of the humid cloud forest. The abrupt transition of the cloud forest to grassland and shrubby vegetation is the result of previous fires. Photo M. Kessler.

FIG. 3. Natural grassland-forest mosaic at timberline elevation in the very wet Cordillera Colán, dpto. Amazonas, northern Peru. Forest typically occurs on well-drained, deep-soiled slopes, whereas grassland occupies regularly waterlogged flat areas and shallow-soiled sites near rock faces. The gradual transition from forest to grassland involves scrub communities of varying height. Photo T.S. Schulenberg, September 1978.

The reasons for this burning are varied, involving the creation and maintenance of pastures, the destruction of forests serving as shelter for carnivores and crop-raiding birds, and religious beliefs (Seibert 1983, Kessler & Driesch 1993, Hensen 1995, Kessler 1995a, b). In the case of Parque Nacional Carrasco it seems likely that the fires do not serve any practical purpose, since grazing animals are limited to more accessible pastures of lower stature at higher elevations and in drier regions. Fire has presumably played a crucial role in the destruction of Andean high-elevation forests for several millenia (Chepstov-Lusty *et al.* 1998).

Assuming a much lower natural fire frequency in the study area, it seems likely that most of the present-day grassland up to elevations of 4000–4200 m would naturally be forested, with a gradual transition from cloud forest to *Polylepis* forests at about 3400 m. In humid regions such as this, grasslands would naturally be limited to edaphically determined microsites, particularly fairly flat, regularly waterlogged valley bottoms and ridges, as well as to very steep slopes with shallow soils. As a result, natural grasslands may extend well into the forest zone, resulting in a forest-grassland mosaic extending over several hundred meters elevation. Such mosaics have been documented at the few undisturbed humid timberlines known to exist in Peru (Fig. 3; see also photos in Baekeland 1964 and Kessler 1995a). Typically, such mosaics show a gradual transition of forest to grassland through shrub belts, whereas burnt timberlines are characterized by an abrupt shift from forest to grassland (Lægaard 1992, Young 1993, Miehe & Miehe 1994).

If such extensive forest-grassland mosaics were the natural situation along humid timberlines in the central Andes, then the Andean timberline must rank among the most severly modified and threatened ecosystems in the Neotropics. It is certainly no coincidence that the bird communities inhabiting *Polylepis* forests and timberline habitats contain a large proportion of globally threatened species (Fjeldså & Kessler 1996, Kessler & Herzog 1998). Accordingly, the currently dominating grassland vegetation should probably be considered as largely artificial. Whether these conclusions also apply to the climatically and physiognomically fairly similar páramo vegetation of the northern Andes (northern Ecuador to Venzuela) remains open to debate because of marked biogeographical differences between the northern and central Andes, i.e., few *Polylepis* species but an abundance of distinctive páramo plant species such as *Espeletia* in the north.

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REFERENCES

Baekeland, G.B. 1964. By parachute into Peru's lost world. Nat. Geogr. Mag. 126: 268–296.

Chepstov-Lusty, A.J., Bennett, K.D., Fjeldså, J., Kendall, A., Galiano, W., & A. Tupayachi H. 1998. Tracing 4,000 years of environmental history in the Cuzco area, Peru, from the pollen record. Mountain Research and Development 18: 159–172.

Ellenberg, H. 1958. Wald oder Steppe? Die natürliche Pflanzendecke der Anden Perus. Umschau 1958: 645–681.

Ellenberg, H. 1996. Páramos und Punas der Hochanden Südamerikas heute großenteils als potentielle Wälder anerkannt. Verhandlungen der Gesellschaft für Ökologie 25: 17–23.

Fjeldså, J., & M. Kessler. 1996. Conserving the Biological Diversity of *Polylepis* Woodlands of the Highlands of Peru and Bolivia – A Contribution to Sustainable Natural Ressource Management. NORDECO, Copenhagen, Denmark.

Hensen, I. 1995. Die Vegetation von *Polylepis*-Wäldern der Ostkordillere Boliviens. Phytocoenologia 25: 235–277.

Herzog, T. 1923. Die Pflanzenwelt der bolivianischen Anden und ihres östlichen Vorlandes. Die Vegetation der Erde XV. Leipzig.

Hueck, K. 1962. Der *Polylepis*-Wald in den venezolanischen Anden, eine Parallele zum mitteleuropäischen Latschenwald. Angewandte Pflanzensoziologie 17: 57–76.

Kessler, M. 1995a. *Polylepis*-Wälder Boliviens: Taxa, Ökologie, Verbreitung und Geschichte. Dissertationes Botanicae 246. Berlin.

Kessler, M. 1995b. Present and Potential Distribution of *Polylepis* (Rosaceae) Forests in Bolivia. Pp. 281–294 *in* Churchill, S.P., Balslev, H., Forero, E., & J.L. Luteyn (eds.). Biodiversity and conservation of Neotropical montane forests. The New York Botanical Garden, Bronx.

Kessler, M., & P. Driesch. 1993. Causas e historia de la destrucción de bosques altoandinos en Bolivia. Ecología en Bolivia 21: 1–18.

Kessler, M., & S.K. Herzog. 1998. Conservation status in Bolivia of timberline habitats, elfin forest and their birds. Cotinga 10: 50–54.

Koepcke, H.-W. 1961. Synökologische Studien and der Westseite der peruanischen Anden. Bonner Geograph. Abhandl. 29. Bonn.

Körner, C. 1998. A re-assessment of high-elevation treeline positions and their explanation. Oecologia 115: 445–459.

Lægaard, S. 1992. Influence of fire in the grass paramo vegetation of Ecuador. Pp. 151–170 *in* Balslev, H., & J.L. Luteyn (eds.). Páramo. An Andean ecosystem under human influence. London.

Miehe, G., & S. Miehe. 1994. Zur oberen Waldgrenze in tropischen Gebirgen. Phytocoenologia 24: 53–110.

Morales, C. de (1990) Bolivia. Medio ambiente y ecología aplicada. Instituto de Ecología, UMSA, La Paz.

Seibert, P. 1983. Human impact on landscape and vegetation in the Central High Andes. Pp. 55–65 *in* Holzner, W., Wegner, M.J.A., & I. Ikurima (eds.) Man's impact on vegetation. Hague.

Seibert, P., & X. Menhofer. 1991. Die Vegetation des Wohngebietes der Kallawaya und des Hochlandes von Ulla-Ulla in den bolivianischen Anden. I. Phytocoenologia 20: 145–276.

Troll, C. 1929. Die Cordillera Real. Zeitschrift der Gesellschaft für Erdkunde Berlin 7/8: 279–312.

Troll, C. 1959. Die tropischen Gebirge – ihre dreidimensionale klimatische und pflanzengeographische Zonierung. Bonner Geograph. Abhandl. 25: 1–93.

Vareschi, V. 1970. Flora de los Páramos. Universidad de los Andes, Mérida.

Walter, H., & E. Medina. 1969. La temperatura del suelo como factor determinante para la caracterización de de los pisos subalpino y alpino de los Andes de Venezuela. Boletín de la Sociedad Venezolana de Ciencias Naturales 28(115/116): 201–210.

Young, K. 1993. Tropical timberlines: changes in forest structure and regeneration between two Peruvian timberline margins. Arctic and Alpine Research 25: 167–174.

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