Chapter 16
Socioecological Gradients: Contesting Traditional Ecoclines to Explain the High Biocultural Diversity of the Andean Verdant

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16.1 Introduction

There is consensus to advance science with unorthodox narratives generated with new discoveries, different perspectives, or challenging innovation altogether. However, it is also consensual that these mountain narratives, like the waves in fluid

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water or air, move along the time scales with different dynamics and distinctive rhythms, generating a symphony of knowledge, which can only be integrated with the crosscutting ability of montology as a convergent science (Sarmiento 2020). Indeed, applied montology is the appropriate avenue for developing an environmental awareness of the whole mountainscape. With the wise trend of *consilience* (Wilson 1998) and the untested hype of noetic science (Nickell 2010), we contribute this chapter with the objective of increasing our epistemology of mountains to include them as socioecological landscapes and not as mere ecosystems.

To achieve our objective, we need to emphasize on scaling, as scalar considerations – whether in space or in time – are at the crux of our understanding of the mountain environment, hence one of the most important indicators for geographical inquiry. Geographers know that most tangible entities, and particularly the intangible ones, require intervention of design, construction, usage, or neglect due to the political ecology exerted at the research onset (Zimmerer and Bassett 2003). Therefore, along with Sauer (1925) and Head (2017) they agree that mountains are cultural landscapes and that the time scale is not important only for the passing of time –be hours, days, months or years, as phenology would put it– but also, and mainly, for the *historicity* that affected the current state of affairs. We concur and offer cases whereby the cultural heritage is intimately linked with natural heritage in the minds and hearts of mountain communities (Aguirre et al. 2021).

16.1.1 Geographic Inquiry

Geographers also know that the physical characteristics define abiotic conditions that explain the community structure, composition, and change of floral and faunal assemblages (Austin et al. 1994). However, Myster (2018) points out that the two *physicalities* are explicit and can be established with haptic methods, but the third factor is a dynamic two-way errand and could be delimited with thresholds. However, the significance of the declivity, is the difficulty of using indirect gradient analysis for questions on instrumentation, monitoring, and bias offered by the ways in which the biota or co-inhabitants of the mountains (including humans and other than humans) have transformed the mountain space to create a meaningful and protected place. Thus, *placialities* of mountains differ widely depending on the cultural background, scientific affiliation, worldview, and territorial appropriation, in what Haller and Branca (2022) call "cosmophany" and are the culprits for the rich biocultural diversity observed in socioecological production landscapes and seascapes (SEPLS). These are the result of the *natureculture*, "a synthesis of nature and culture that recognizes their inseparability in ecological relationships that are both biophysically and socially formed" (Malone and Ovenden 2016, see also Fuentes 2010; Haraway 2003), something that is particularly important to detect along the Andean crescent and, in general, along the extent of the Andean cordillera (Escobar-Mamani et al. 2020).

In the neotropics, the local *bohios*, or hilltops of equatorial Andes, occupied by elite settlers, are places where you find that "coquito" palms (*Parahubea cocoides),* now survive exclusively in the town boulevards or central plazas of Andean towns – as they cannot be found in the "wilderness." Something similar can be said about the peach palm (*Bactris gasipaes*) that can be found as a testament of abandoned *chacras* of the swidden agriculture practiced in the Andean Amazonian piedmont. Other clear indicators of the socioecological identity of tropandean landscapes are easy to find, when the "tree of Peru," or *molle (Schinus molle),* is found decorating the avenues of Mexico: the reeds of California that are found in the settled Andean lakes with totora, (*Schoenoplectus californicus*) cultivated and harvested for handcrafts, or the pollen grains of corn (*Zea maiz*) that are found in the Amazonian lowlands. In summary, there exists direct paleoecological evidence of an active exchange of plants and animal species between Mesoamerica and the Andes, as well as between Amazonia and the coastal plains; this represents a socioecological gradient that cutcross the altitudinal variation of the mountain chain.

Most plant ecologists based their findings of gradual changes on measuring the size of leaves, the size of tree trunks, or the amount of rain or temperature that is registered along the ecocline as elevation-dependent gradients (EDGs), often relating to minimum, average, optimum, or maximum values that allow qualifying a threshold, after which the fluid gradient changes into some hard terminus or fixed state. Where concentration of elements diminishes gradually –such as with the adiabatic lapse rate– the presence/absence of "indicators" hints the zoning of hyperabundance of species, or a contrasting lack thereof. This was clearly articulated by Al Gentry (1988) describing a mid-elevational "bulge" in the presence of arboreal taxa in the montane zone when he discussed the geographical gradients that could explain tropandean diversity. We argue that he was right, but incomplete, as the bulge of trees is mimicked by the bulges from other taxa in different elevations, such as the bryophytes' bulge in the high Andean forests, the bulge of shrubs in the Patagonian and Magellan Andes, the bulge of lichens in the upper paramo, the bulge of fords in puna zones, or the pteridophytes' bulge in the Andean flank of the verdant, or even the suspected bulge of underground soil biota, exemplified by the giant earthworm that lives furrowing the mossy surfaces and sandy soils of the talus and scree. A bulge of socioecological factors could be discerned from archaeological evidence of ancient socioecological productive landscapes of the Andean flanks (de la Cadena & Legoas 2012; Sarmiento & Sarmiento 2021). Furthermore, we argue that SEPLS are good examples of biocultural diversity that often survive in isolated microrefugia in the hinterland (Minga et al. 2019), rural fringes occupied by both traditional and indigenous people. These new mixed territories of the "rurban" landscape are the productive zones, economic and otherwise, that are in the tipping point either to lose their identity or to reinforce their sense of microrefugium.

16.1.2 Task at Hand

Notwithstanding the difference between Amazonian or Pacific slopes, these "indicator" species could give the explorer an idea of altitude, precipitation, temperature, and other meteorological climate factors, justly noted in the "Humboldtian" paradigm of altitudinal zonation as elevation increases. Some of the tenets of this "Humboldt law" are still valid to elucidate the "Humnboldt's enigma" (Rahbbek et al. 2019); however, a newer narrative emerged from the highland-lowland dynamics observed across the altitudinal belts affected by economic, religious, military, investment, and other climates experienced in the region (Table 16.1), and the indelible human tracks observable within the slopes of Andean forests (Sarmiento 2000). Increasing scholarly interest is now devoted to clarifying the "Andean-Amazonian divide" (Pearce et al. 2020, see also Cavalcanti-Schiel 2014). Now it is accepted that most places are indeed fusion landscapes, in many cases manufactured landscapes by "bioengineers" of the past, better assessed with transdisciplinary research (TDR) as conduits of mountain transformation and meaning (Harden and Fernández 2022). These SEPLS are now showing the intrinsic relationship of natureculture, whether in the Araucanian slopes (Ibarra et al. 2020), the Mesoamerican mountains (Kremsa and Zigrai 2021), the Japanese satoyamas (Brown et al. 2022), the urban-rural fringe of central- (Haller 2019) and southern -Peru (Branca 2019), and Ecuador (Kingman and Bretón 2017), the páramo mountainscapes (Sarmiento 2012) or the Chocoan or Amazonian junglescapes (Sarmiento et al. 2022).

Table 16.1 Gradual changes associated with differential altitude as registered by field studies and literature reviews of factors affecting the dynamic of Andean flanks based on traditional ecological and alternative socioecological studies

Elevation Dependent Gradients (EDGs)	
Ecological	Socioecological
Temperature	Agriculture output (biomass)
Precipitation	Agrobiodiversity (heirlooms)
Soil humidity	Mining ores (metals)
Acidity	Water capture (hydroenergy)
Photosynthate output	Wind capture (eolic energy)
Evapotranspiration	Sun capture (solar energy)
Luminosity	Human settlements (towns)
Cloudiness	Terracing (slope adaptation)
Sun radiancy	Aqueducts (irrigation)
UVß radiation	Timber harvesting (wood)
Water opacity	Urban expansion (amenity)
Water supply	Transportation network
Root exudate	Animal husbandry (grazing)
Particulate/aerosol	Transhumance (seasonality)
Carbon sequestration	Disturbance (clearing)

Thus, a new narrative must come into play to promote the ontology of Elevation Dependent Gradients (EDGs) based on altitudinal ecoclines to problematize the socioecological reality of mountains (Haller and Branca 2020). We plan to include examples of cases in different latitudes, longitudes, or altitudes, so that the graticule used in our analysis be a good indicator for the important places that SEPLS have in our understanding of ecological legacies, based on anthropic "indicators" that place the mountain slope and aspect, as a focus of significant human intervention. We will end by helping to claim, with Sarmiento and Sarmiento (2021), the need to reclassifying the Andean flanks as an ecoregion on its own right, instead of a mere transitional cline that changes gradually from the highlands to the lowlands. We need to acknowledge that further research on sociobiological and ecological processes is needed, and particularly the TDR study about the cryptic cultural bulge of the verdant.

16.2 Methodologies

Albeit most likely not comprehensive, we tried to incorporate several methodological options to cover different themes, in what is considered a multimethod approach. We based our criteria in several parameters, including participatory research, critical discourse analysis, observational, and survey-based information, contrast-and-compare adaptations, analyses of paleothemes, including pollen fossil, phytoliths, protein separations from excavated samples, chronosequence analysis of repetitive photographs, aerial orthophotography and drone-based estimations, and the old but proven effective "boots on the ground" for ground truthing of both remote and literary observations.

The information generated by the review of socioecological themes published in mountain journals shows that there is a preponderance of sources about EDGs dealing with physical parameters with both direct and indirect gradient analyses. The few sources of related papers are augmented when including other social science outlets not specifically identified as "mountain" research journals, but with comprehensive and areal foci of transformed mountainscapes. The bibliometrics of socioecological gradients is not significantly different from the generally low number of social-science studies about mountains.

16.3 Results

The presence of megalithic constructions associated with places where closed-canopy forests now exist in the Andean flanks gives the paradox of biocultural diversity, while currently, the forest formation seems mature, even old growth and pristine-looking, but, in reality, harbors evidence of heavy human use in the past. Examples abound in recent literature as more and more sites of the caliber of

citadels, fortresses, terraces, temples, open fields, channel-based irrigation, etc. are incorporated in the repertoire of Andean cultural landscapes (Erikson 2020). The communities have created ancestral ways of dealing with the sloppy terrain and in some cases, they have conserved it as traditional ecological knowledge, such as the yearly construction of a suspension bridge over the *Urubamba* river using tussock grasses (*Stipa ichu, Calamagrostis* sp.) to braid a strong interlocked cord that sustain the pedestrian bridge in *Q'eswachaka*, near *Qosqo,* now a UNESCO declared intangible world heritage. In some areas of the wet grasslands of Tucumán, Argentina, the páramo-like formation is maintained by the withered practice of transhumance of cattle. Just as in northern reaches of the cloud forest belt, the effects of trampling and herbivory of grazers are the driver of the maintenance of the upper treeline, blurring the boundaries between the forest and the pastures (Dávalos et al. 2021).

16.3.1 Cultural Bulge in Andean Flanks

One of the most significant socioecological gradients of the EDGs is the differential resource use preference that increase in the mid-elevation mountains as a result of terracing, building of irrigation channels, and other transportation networks. In fact, most of the successional dynamics of the cloud forest is a direct consequence of road construction and talud breakage, hence providing for landslides (e.g., Myster and Sarmiento 1998), rockslides, or the feared "*waiku*"or destructive mudflow that washes downstream-bound catastrophes. Huge floods of the piedmont are directly related to the changes in forest cover and resource use of the headwaters. The socioecological hybridity is manifested mainly in the concentration of terraced geoforms distributed along the incline, but concentrated in the mid-elevation bulge observed in the plotting of the number of findings at different elevations. Certainly, incomplete archaeological studies are showing now the occupancy of the mid-elevation montane zone with the dry terraces and stone terraces built in the Andean arc (Fig. 16.1), such as in *Wuapaula*, by the *Upano* river, in the shadow of the *Sangay* volcano in Ecuador.

Sites distributed in the isolated slopes of the *Sierra Nevada* de Santa Marta, and throughout the *Quindío* in Colombia, provide evidence that human occupation abounds in this mid-elevation cultural bulge. Recent findings on the *Quijos* Andean flank, even within the most pristine of National Park in Ecuador, *Llanganati* the stone walled terraces are an evident signal of past occupations. Northern Peru also boasts a significant number of archaeological sites that confirm the rich variety of human occupation in the mid-elevation bulge with impressive fortresses (or *pukarakuna)* and even whole citadels, such as *Kuelap* in Chachapoyas, or *Chuquiquiraru* in *Sabancay* towards *Cuscu* in southern Peru. The majority of the Andean flank in Bolivia is peppered with archaeological sites with either mounds, channels, or walls (or *pirkakuna*) that tell about ancient heavy usage of the verdant. The best known example of this cultural bulge is Bingham's "discovery" in 1911 of what is now the

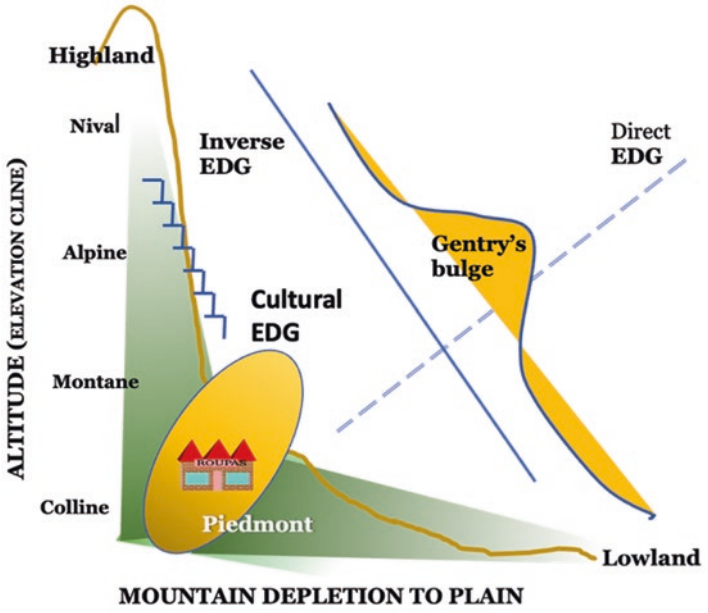

Fig. 16.1 Representation of the interaction of Elevation Dependent Gradients (EDGs) in the ecological and socioecological consideration. Notice that the presence of elements at a certain altitude is no longer correlated to the gradual change and most cultural EDGs show erratic socioecological gradients

National Sanctuary of *Machu Picchu*, when the area looked like a pristine mountain forest with continuous canopy, just to show a masterful architecture when the excavation and restoration practices finished, ancient stoneworks that helped to appreciate it as one of the "modern wonder of the world."

Many other sites throughout the Andean Arc – sometimes called "Andean Crescent" tell of previous civilizations and indigenous groups lost in history, such as the *Quixus*, the *Bracamoros*, the *Awaruna*, or the *Ashwar*. With the use of the new LIDAR technology, the discovery of the oldest human settlement in the whole of the Amazon has been located in *Wuapula*, near the *Sangay* volcano in the mid-elevation areas of tropandean landscapes, making the point of considering a cultural bulge in the EDGs much stronger than before.

16.4 Conclusions and Discussion

Our conclusion is that the SEPLS conditions are evidence often perceived as indicators of elevational gradients with ecoclines that confirm the well-known physical estimates of clinal variation. However, we claim the need of reclassifying the Andean flanks as a proper ecoregion, instead a mere transitional cline that changes

gradually from the highlands to the lowlands. This prompts an urgent change in textbooks, maps, magazines, and even in scientific circles, to move urban montology and critical biogeography into a new height, literally! (Sartori and Moreira-Muñoz 2022). Also, we claim the imperative to study more about the cryptic cultural bulge of the verdant to identify the true natureculture hybridity of these heritagescapes (Sarmiento et al., 2023).

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References

Aguirre CP, Córdova JD, Piqué R (2021) Agriculturización: la alquimia de un paisaje precolombino Kañari en la cuenca alta del río Chanchán, Andes del Ecuador. Estud Atacameños 67:1–11

Austin MP, Nicholls AO, Doherty MD, Meyers JA (1994) Determining species response functions to an environmental gradient by means of a β-function. J Veg Sci 5:215–228

Branca D (2019) The urban and the rural in Puno, highland Peru. Anthropol Today 35(6):18–20

Brown J, Yoshida M, Inaba N (2022) Mountain landscapes as "lifescapes": sustaining traditional biocultural heritage and supporting resilience in Asia-Pacific region. In: Sarmiento FO (ed) Montology palimpsest: a primer of mountain geographies. Springer-Nature/Switzerland

Cavalcanti-Schiel R (2014) Cómo construir y sobrepasar fronteras etnográficas. Entre Andes y Amazonía, por ejemplo. Chungara Rev Antrop Chil 46(3):453–465

de la Cadena M, Legoas PJ (2012) Introduction: Cosmopolitiques dans les Andes et en Amazonie comment l'autochtone politique influence-t-il la Politique? Researches amerindiennes au Québec 42(2–3):5

Dávalos LM, Dávalos E, Holmes J, Tucker C, Armenteras D (2021) Bosques, coca y conflicto: la dinámica de la frontera de pasturas y deforestación en la Amazonía andina. JIED 3(1):74–98

Erikson CL (2020) The domesticated landscapes of the Andes. In: Seligman LJ, Fine-Dare KS (eds) The Andean world. Routledge, London/New York

Escobar-Mamani F, Branca D, Haller A (2020) Investigación de montaña sobre y para la región andina. Rev Investig Altoandin 22(4):1–3

Fuentes A (2010) Naturalcultural encounters in Bali: monkeys, temples, tourists, and ethnoprimatology. Cult Anthropol 25:600–624

Gentry AH (1988) Changes in plant community diversity and floristic composition on environmental and geographical gradients. Ann Mo Bot Gard 75(1):1–34

Haller A (2019) Impacts of urban growth on Andean smallholders. A study of perception in the rural-urban zone of Huancayo, Peru. Espac Desarro 29:37–56

Haller A, Branca D (2022) More than landscape: towards cosmophanic diversity in environmental planning and governance. Soc Nat Resour 35(10):1123–1133

Haller A, Branca D (2020) Montología: Una perspectiva de montaña hacia la investigación transdisciplinaria y el desarrollo sustentable. Rev Invest Altoandin 22(4):313–322

Haraway DJ (2003) The companion species manifesto: dogs, people, and significant otherness, vol 1. Prickly Paradigm Press, Chicago

Harden C, Fernández A (2022) Mountain waterscapes: geographies of interactions, transformations and meanings. In: Sarmiento FO (ed) Montology palimpsest: a primer of mountain geographies. Springer-Nature/Switzerland

Head L (2017) Cultural landscapes and environmental change. Routledge
Ibarra JT, Barreau A, Marchant C, González JA, Oliva M, Donoso-Correa ME, Sarmiento FO (2020) Montology: an integrative understanding of mountain foodscapes for strengthening sovereignty in the Andes. In: Sarmiento FO, Frolich LA (eds) The Elgar companion to geography, transdisciplinarity and sustainability. Edward Elgar Publisher, London
Kingman E, Bretón V (2017) Las fronteras arbitrarias y difusas entre lo urbano-moderno y lo rural-tradicional en los Andes. J Lat Am Caribb Anthropol 22(2):235–253
Kremsa V, Zigrai F (2021) Landscape ecology in Mexico: evolution, research, education and future (selected theoretical and meta-scientific aspects). J Landsc Ecol 14(2):82–114
Malone N, Ovenden K (2016) Natureculture. In: The international encyclopedia of primatology. Wiley, Hoboken, NJ
Minga D, Cordero P, Donoso M, Montesinos K, Jimenez M, Antaki B, Sarmiento F (2019) The *Uchucay* microrefugium: an Interandean forest relict with an important arboreal richness in Southern Ecuador. Pirineos J Mt Ecol 174:1–16
Myster RW (2018) The nine classes of plant-plant replacement. Ideas Ecol Evol 11:29–34
Myster RW, Sarmiento FO (1998) Seed inputs to microsite patch recovery on two Tropandean landslides in Ecuador. Restor Ecol 6(1):1–10
Nickell J (2010) 'Noetic science' in the lost symbol. Skept Inq 34(1):60–61
Pearce AJ, Beresford-Jones AG, Heggarty P (eds) (2020) Rethinking the Andean-Amazonian divide: a cross-disciplinary exploration. UCL Press
Rahbbek C, Borregaard MK, Colwell RK, Dalsgaard BO, Holt BG, Moreuela-Holme N, Nogues-Bravo D, Whittaker RJ, Fjeldså J (2019) Homboldt's enigma: what causes global patterns of mountain biodiversity? Science 13–365(6458):1108–1113
Sauer CO (1925) The morphology of landscape. Foundation Papers in Landscape Ecology (2007). Pp. 36–70
Sarmiento FO (2020) Montology manifesto: echoes towards a transdisciplinary science of mountains. J Mt Sci 17(10):2512–2527
Sarmiento FO (2012) Contesting Paramo: critical biogeography of the Northern Andean Highlands. Kona Publishing, Higher Education Division, Charlotte
Sarmiento FO (2000) Breaking mountain paradigms: ecological effects on human impacts in managed tropandean landscapes. AMBIO J Hum Environ 29(7):423–431
Sarmiento FO, Inaba N, Iida Y, Yoshida M. (2023). Mountain Graticules: Bridging Latitude, Longitude, Altitude, and Historicity to Biocultural Heritage. Geographies 3(1):19–39
Sarmiento FO, Sarmiento EV (2021) Flancos Andinos: Paleoecología, Biogeografía Crítica y Ecología Política en los Climas Cambiantes de los Bosques Neotropicales de Montaña. Editorial INDES_CES/UNTRM. Universidad Nacional Toribio Rodríguez de Mendoza, Amazonas. Chachapoyas
Sarmiento FO, Rodríguez J, Yépez A (2022) Forest transformation in the wake of colonization: the Quijos Andean-Amazonian Flank, past and present. Forests 13(11):1–19
Sartori M, Moreira-Muñoz A (2022) Biogeography of knowledges in the mountain anthropocene: hybrid conceptual and practical spaces within the GeoHumanities. In: Sarmiento FO (ed) Montology palimpsest: a primer of mountain geographies. Springer-Nature/Switzerland
Wilson EO (1998) Consilience: the unity of knowledge. Vintage Books, Random House Inc, New York
Zimmerer KS, Bassett TJ (eds) (2003) Political ecology: an integrative approach to geography and environment-development studies. Guilford Press, New York