

4D GLOBAL MONTOLGY: TOWARD CONVERGENT AND TRANSDISCIPLINARY MOUNTAIN SCIENCES ACROSS TIME AND SPACE

La Montología Global 4D: Hacia las Ciencias Convergentes y Transdisciplinarias de Montaña a través del Tiempo y el Espacio

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ABSTRACT: With mountain studies we use integrative approaches for geoliteracy about productive socioecological landscapes, and motivate further transdisciplinary research in montology. We conceived this white paper as a confluence of individual expertise and collective reasoning towards forming synergistic research clusters dealing with convergent mountain science, to advance montology to a new level, whereby innovative thinking about sustainability science and regenerative development incorporates alternative propositions for maintenance, improvement, or regeneration of living conditions of mountainscapes. We seek to use this contemporary framing of sustainability and ecological restoration as the impetus to better understand nature-culture relations, framed on lived-in mountains that operate in four dimensions (length, width, depth, and time) oriented at maximizing the cross-cutting of themes around mountains as productive socioecological systems, in a new academic institutionalized convergent unit. We conclude with a call for consilient, sustainable, regenerative development in the world's mountains.

KEYWORDS: Montology; consilience; noetics; geocriticism; sentient mountainscapes; convergent mountain science; transdisciplinary.

RESUMEN: La utilización de los estudios de montaña requiere de narrativas integradoras para la geoalfabetización sobre paisajes socioecológicos productivos y motiva más investigaciones transdisciplinarias en el campo de la montología. Concebimos este artículo como la confluencia de la experiencia individual y el razonamiento colectivo hacia la formación de grupos de investigación sinérgicos que se ocupan de la ciencia de montaña convergente, para hacer avanzar la montología a un nuevo nivel, mediante el cual el pensamiento innovador sobre la ciencia de la sustentabilidad y el desarrollo regenerativo incorpora propuestas alternativas para el mantenimiento, la mejora, o regeneración de las condiciones de vida de los paisajes de montaña. Buscamos utilizar este marco contemporáneo de sustentabilidad y restauración ecológica como el ímpetu para comprender mejor las relaciones de la naturaleza y la cultura, desde una perspectiva transdisciplinar, en montañas habitadas que operan en cuatro dimensiones (largo, ancho, alto y tiempo). El artículo está orientado a potenciar la transversalidad de temáticas en torno a las montañas como sistemas socioecológicos productivos, en una nueva disciplina académica institucionalizada y convergente. Concluimos con un llamado a un desarrollo regenerativo, sustentable y consiliente en las montañas del mundo.

PALABRAS CLAVE: Montología; consiliencia; noética; geocriticismo; paisajes montañosos sensibles; ciencia convergente de montaña; transdisciplinariedad.

1. Introduction

We are experiencing a stage of great acceleration and integration of transdisciplinary knowledge in the vertigo of global environmental change and crisis. Nowhere is this more explicit and imperative than in mountain ecosystems, where the three geospatial dimensions X-Y-Z (width, length and depth) interact by the forcing of verticality (V) of slope and aspect orientation, with another important dimension, time (T) manifested as historicity (H). Unlike the n-dimensional space to create the niche for resource partitioning in ecology (Hutchinson, 1957), the inclusion of temporality in the sequences of events and changes brought by ecological legacies from the past, makes historicity (H) imperative in political and historical ecology (Hartog, 2015; Ellen & Fukui, 2021), particularly when dealing with multidimensional science paradigms (Setiawan & Syamsuddin, 2022).

The importance of the fourth dimension (hence 4D) relies on the flux of scientific narratives leading to landscape transformation in an era of global climate crisis (Balée & Erikson, 2006), the ecological “great acceleration” of the Anthropocene (Eriksen, 2016; Chakraborty, 2021), and with the temporality of “pulses” enduring gradual changes and “pulses” of catastrophic, abrupt, and ephemeral human and environmental impacts. Altogether, all these factors confront the new with the old, the global with the local, and the real with the imaginary in most mountain socioecological systems (MtSES) (Klein *et al.*, 2019). Geographic Information Systems (GIS) enable the visualization of space/time compressions parameterizing how digital “mountains” change on the screen (Bogucka & Jahnke, 2017). This can be done by the repeated acquisition and comparison of raster (e.g., from satellite imagery) or vector (e.g., from LIDAR point clouds) data of the same area of interest—which *per se* offer only 3D. Challenging reconstructions from palaeoecological data help provide modeling for hindcasting the deep past, even in the Pleistocene/Holocene boundaries where humans initiate their impact on mountains (Sarmiento & Koopman, 2019). Going beyond monitoring the recent past and present, modelling approaches can help understanding possible changes of mountainscape in the earlier past—or prepare for probable future scenarios of change due to the interactions of social, cultural, economic, historic, anthropological, and ethnological variables (Sarmiento *et al.*, 2016). Hence, the 4D analysis is achieved when T is incorporated, not only as the passing of time, or T_0 - T_1 - T_2 - T_x , but also with the historicity of the actual framework affecting the type of changes or transformation through time, not only in the middle-mountains (*Mittelgebirge*) but also in the high mountains (*Hochgebirge*) of whitescapes (Pallister-Wilkins, 2022). The scale of these changing variables highly depends on the political decisions taken to manage the MtSES. Only then, the structure and function of the mountain landscape, or mountainscape, can be grasped to its fullest extent.

Currently, the accepted definition of mountain is defined by geologists as a landform that rises at least 300 m

above its surrounding area (Kapos *et al.*, 2000). In areas between 300 m and 2,500 m altitude, a mountain requires a local elevation range of at least 300 m or a certain slope inclination (5° up to 1,500 m altitude or 2° above this limit) within 7 km surrounding area. Their mountain edifice size varies from the smallest islands to nations’ largest on the planet. About 22% of the Earth’s surface is covered by mountains, which provide between 60% and 80% of the world’s freshwater resources, and are home to 25% of the planet’s biodiversity and 28% of the world’s forests. Six of the 20 most important food crops originate from mountain regions, which also attract between 15% and 20% of global tourism (Escobar *et al.*, 2020). However, current global changes such as warming and globalization triggering pollution at global scale threaten the inhabitants and the mountain environment, and, therefore, the planet as a whole (FAO, 2018; Schickhoff *et al.*, 2022; Chakraborty, 2022). With the global environmental changes and impending current climate crisis, a new consilient approach for integrating knowledge about mountains is imperative (Santana *et al.*, 2022).

Mountainscapes, are part of biocultural heritage; they cross political borders, they blend past and present lifescapes, they are water tanks, hotbeds of biological diversity, watchdogs of global change (García Ruiz *et al.*, 2015), and luring places to live and work (Borsdorf & Haller, 2020). In addition, almost one billion people live in mountainous areas, home to a huge variety of languages, ethnic groups, religions, and ideologies (de la Cadena, 2015; Urban, 2020). There are some mountain protected areas (MtPAs) to protect and conserve small samples of biodiversity and geodiversity values. Nowadays, mountains are even sold, grabbed by either monocropping or gated exurbia, either as long-term private properties or as ephemeral spaces that can be experienced by elites, as is the case with mountain tourist destinations (Boscoboinik, 2018; Perlik, 2019; Branca & Haller, 2021).

Acknowledging that articulating strategies for cross-cutting disciplinary silos, such as those of geomorphology, geocology, neotectonics, and landscape ecology, into transdisciplinary science is a major challenge for consilience (Wilson, 1998), this article aims to shape the agenda of montology as an application of transdisciplinarity and convergence in mountain landscapes. This application is required in the era of vertiginous and accelerated change (Steffen *et al.*, 2015) and the disaster risk reduction to obtain the homeorhetic state in transitioning to the culture-nature hybrid of the present from the homeostatic equilibrium-conceived nature pristine of the past (Alcántara-Ayala *et al.*, 2022a). Some authors made it clear that the time-tested local views should be integrated in the historicity of the mountainscape with the humanistic lenses of noetic science (Needleman, 1993) for its ability to explore the mind and intellect of human groups to incorporate earth ethics considerations and to avoid the “interdisciplinary fallacy” (Kramnik, 2017; 2018). Alternatively, convergent propositions are given for defining the sustainability of the planetary lifescape, for all biodiverse stakeholders (Gibbes *et al.*, 2020). We will start by ana-

lyzing transdisciplinarity implications and theoretical developments of the crosscutting trend. Then, we will look into historic disciplinary changes and their major players, the epistemology framing critical literacy of mountains, and some examples of transdisciplinary work. We will end by using cultural terms to illustrate how longing for mountains influence the transgressivity of mountain lore, compounding the referentiality in realizing mountainscapes for sustainable and regenerative development.

This article scrutinizes onomastics to grapple with lexicographic domains that are not directly translated into English, grasping eccentric traditions of sense of place, as a way to dispel the interdisciplinary fallacy with a broader integrative effort. In so doing, we show several challenges to geographic realism with the completed dimensions 4D of sustainable MtSES, as shown in the Andes (Sarmiento *et al.*, 2019a).

1.1 Transdisciplinary Implications and Theoretical Approaches

The uptake of interdisciplinarity within landscape ecology took place by including ecology as a social science (Odum & Sarmiento, 1998) in an effort to better understand neotropical mountains' function and structure. As part of the efforts to make ecology meaningful as a social science for Mountain Complex Adaptive Systems (MtCASs), scholars and educators (Naveh & Liebermann, 1984) alerted about viewing landscape ecology as an educational imperative for the Total Human Ecosystem Science, based on general system theory, cybernetics, and complexity theory (Naveh, 2000). In Europe, planning angles exhibited contrasting premises to the type of landscape ecology practiced in North America, which emphasized Geographic Information Systems (GIS) (Forman & Godron, 1984). A decade later, with the political ecology study of “third world countries”, paradigmatic cross-cutting of academic silos to study nature and culture hybrids from a non-Western, Global South perspective appeared (Forman, 1990; Naveh *et al.*, 2002; Eibach & Haller, 2021; Fúnez-Flores *et al.*, 2022). A critical move to activate consilience of mountain themes further popularized alternative mountain ontologies (Messerli & Ives, 1997; Smith & Mark, 2003; Naveh, 2007; Lang *et al.*, 2012; Pandian, 2014; Gose, 2018; Texeira, 2022).

A plethora of scholars recognized the goal of a new field of montology (Mahat & Boom, 2008; Veteto, 2009; Sarmiento, 2020; Haller & Branca, 2020; Sarmiento *et al.*, 2022). With the realization of cross-cutting, integrative approaches and the convergence of transdisciplinary research in montology (Sarmiento & Frolich, 2020), the nuanced framing of sustainability and regenerative development required understanding 4D human–environmental relations from several angles at the same time (Dunlap & van Liere, 1978; Dunlap *et al.*, 2000; Boil-

lat, 2020) bringing post-phenomenological landscape studies into decolonial scholarship. Grappling with integrative modes to understand MtCASs and with the sustained stewardship MtSESs requires, prompted further inquiry into “montology” (Haslett, 1998; Schirpke *et al.*, 2020). Notwithstanding the changing theoretical and practical framework of critical geography of MtSES from large landscapes to the microbiota scales, the field of mountain studies brings new approaches towards sustainable and regenerative mountainscapes (Hodges, 2006; Müller, 2020; Wang *et al.*, 2022). The bridging of science and humanities with montology is recognized as a best management practice to understand the complex topics and research questions in MtSES (Baer & Singer, 2014; Foggin *et al.*, 2021).

Transdisciplinary approaches became standard academic practice (Hadorn *et al.*, 2008), because they reflected three substantive trends: (1) holistic medicine (Klein, 2008); (2) crosscutting of disparate fields (Veteto, 2009); and (3) the integration trend (Nanshan, 1998). Realizing that mountainscapes were SESs, scholarship of decolonial turn towards explanations for synergies and nexuses of MtCAS's sentient landscapes (Polk, 2014; Xishi & Yuanchang, 1996).

1.2 Historicity: The Route Map to the Construction of Montology

Mountain scholars find themselves navigating a capricious topography, with labyrinths and circuits of positivistic environmental cognition (Gade, 2011; Castree, 2017) and interacting haptic dimensions. The scholarly activity was siloed as either “physical” or “human” geography. Nevertheless, with input from social scientists and science communicators, geography is now seen as the environmental science combined with the study of human society *par excellence* (Wulf, 2015a). With this trend, an increasing number of scientists have, indeed, appropriated notions that navigating MtCASs requires agency cut-crossing the disciplinary poles, engaging with integrative, comprehensive, and critical views of sustainable and regenerative development (Wilcock & Brierley, 2012; Sarmiento *et al.*, 2022a) of current compressions of time and space in 4D (Massey, 1999), counteracting predominantly archaic, morphological-minded past mountain geography (Wulf, 2015b) that highlighted dimensions Z over X or Y, but too often did not include T, much less H. Thus, “cross-disciplinarity” is now widely accepted by sustainability science and landscape ecology scholars (Naveh, 2005; Wu, 2006; Wilson, 2018) with an emphasis on time, to which political ecologists and mountain geographers hone historicity for space/time couplings (Debarbieux & Rudaz, 2010; Pasini, 2022).

Annan-Diab & Molinari (2017), argued that disciplinary nexuses are required when considering priorities of sustainable and regenerative development (Sarmiento *et al.*, 2022a); “montology” advocates for the bridging

of disciplines and nexus of humanities, arts, and sciences, for an improved mountain cognition (Mainali & Sicroff, 2016). Mahat & Boom (2008), problematizing disciplinarity of mountain studies, pointed out that the term has been used orally and in-print several occasions in the last half century. Rhoades (2007) pointed out it was Frank Davidson who first used montology at the Munich Mountain Conference in 1974.

“Just as oceanography has spawned a number of major and minor institutions concerned with the protection and development of ocean resources, so mountainology, once its importance and implications are realized, will lead to a proliferation of institutional responses” (GTZ, 1974: 186). In subsequent discussion between Frank Davidson, Bruno Messerli, and Jack Ives, the term mountainology [sic] was dropped in favor of montology”.

Notwithstanding lexicographic difficulties with this call for montology in 1974, the “Club of Munich” strengthened it with the addition of American scholars such as Ben Orlove, Steve Brush, Paul Baker, and Colin Rosser. The formation of the International Mountain Society (IMS) and the creation of the journal *Mountain Research and Development* formed an active academic home (Ives 2005). This juncture helped the multitude of sources on mountain studies evidenced needed crosscutting integration. The compilation of these findings by Susanne Fairclough (1982) gave specific reference to montology:

At the Cambridge Mountain Conference in 1977, participants discussed the creation of a discipline for the study of mountains, as has been accorded to oceans, and gave it the name of montology, to denote an active, protective emphasis (Allen *et al.*, 1998).

The work of Ives, Messerli, Rhoades, and other montologists allowed the inclusion of the term in the Oxford English Dictionary (2002) and several other sources in the web. It stirred counter voices of those who saw it as unnecessary jargon; however, others reiterated the imperative of professional prowl with this moniker, uniquely suited. Contention about the term montology among scientists ensued, and a call for moving “mountains” to higher global priorities with a term of their own was formalized (Bandyopadhyay & Perveen, 2004). Mountain scholars and practitioners required then to grapple with the “listening to the mountains” aphorism (Rhoades, 2007; Pandian, 2014).

Mountainscapes face multiple challenges, not only for their propensity to disaster risk and increased rate of geological hazards occurring in the mountain en-

vironment—i.e., mass wasting, snow avalanche, flash flooding-induced glacial ablation, rock fall, 0 °C isotherm rise to high altitude, fires, volcanic eruptions, and forest dieback (Alcántara-Ayala *et al.*, 2022b) but also for their intrinsic contentious community’s dynamics (Debarbieux & Rudaz, 2010).

The challenges include the increasingly serious impact of climate crisis and environmental change, the impact that socio-economic and cultural globalization has on mountain populations and the ecosystems they inhabit (Haller & Branca, 2020). An example from Europe, the Feldafing Accord of 2010, prompting creation of institutions for mountain research among countries of Asia and Europe, depicts the globalization turn in the planetary acceleration. These trends are delineated in Sarmiento (2020), claiming for action to transgress silos, welcoming non-traditional institutions, non-governmental organizations (NGOs), charitable foundations, and community-driven mountain work, artistic and humanitarian groups, as well as in established research institutes of the ever more urbanized mountainscape (Branca & Haller, 2021).

2. Conceptualization and framing

2.1. Onomastics, Conceptual, and Institutional Approaches

Current tendency shifts away from *orology* (Greek for mountain and knowledge) to *montology* (mixed Greek and Latin for mountain discourse), positing to incorporate biotic elements and spiritual dimensions (Descola, 2013) in understanding mountains through historicity to achieve 4D. Annotated bibliographies on mountain geography (*c.f.*, Resler & Sarmiento, 2016) include now multifunctional approaches for MtCASs with holism and post-structuralism methods for mountain ontology (Sarmiento *et al.*, 2017; Fabian, 2014). Former pundits signaled against the etymological mingling, such as glaciology, mineralogy, sociology, etc. (Yuanchang, 1986; Haller & Branca, 2020), and that a plethora of mountain names borrows from either Greek or Latin indistinctively.

To prevent that language affiliation could engage to a biased understanding of mountain lexicography, a genealogy of scholars from several origins who actively worked in montology was attempted by Axel Borsdorf, in his teaching the subject matter at Innsbruck, about stages of development and the group leaders of these effort. Other seasoned scholars also incorporated Ives’s vision of montology, namely: Yuri Badenkov, Robert Rhoades, Gregory Knapp, Christoph Stadel, Daniel Gade, Larry Hamilton, and Alton Byers (Ives *et al.*, 2016). Borsdorf’s term likened informal monikers of “mountain mafias,” popularized by Messerli & Ives (1997), was used to advocate convergent and transdisciplinary mountain science (Table1).

Table 1. Decadal progression of montological thought as contributions from academics from Global North and Global South converge in the development of decolonial scholarship in montology; the list is taken as a sample of successes through teaching and research, reflected in publications on montology. Differential shading tone indicates more active years. Note the reduced participation of women scholars and the lack of reference from non-academic knowledge holders of the Global South. Source: Sarmiento et al. (2023).

Tabla 1. Progresión decadal del pensamiento montológico a medida que la convergencia de los académicos del Norte Global y del Sur Global contribuyó en el desarrollo de la escolaridad decolonial en montología; la lista es dada como una muestra de los éxitos de investigación y enseñanza reflejados en publicaciones sobre montología. El tono diferencial de la sombra indica los años más activos. Note la participación reducida de mujeres y la falta de referencias de los sabios no académicos del Sur Global. Fuente: Sarmiento et al. (2023).

MAJOR PLAYERS	DECADAL ADVANCE OF MONTOLOGY						
	60s	70s	80s	90s	00s	10s	20s
GLOBAL NORTH							
Carl Troll (DE)	Light Green	Light Green					
Jack D. Ives (CA)		Light Green	Dark Green	Dark Green	Dark Green	Dark Green	
Eugene P. Odum		Light Green	Light Green	Light Green	Dark Green		
Bruno Messerli (CH)			Dark Green	Dark Green	Dark Green		
Maurice Strong (UNEP)				Light Green	Light Green		
Carol Harden (US)				Dark Green	Light Green	Light Green	
Lawrence Hamilton (US)		Light Green	Light Green	Light Green	Light Green	Dark Green	
Axel Borsdorf (AT)			Light Green	Light Green	Dark Green	Dark Green	
Robert Rhoades (US)		Light Green	Dark Green	Dark Green			
Bernard Debarbieux (FR)			Dark Green	Light Green	Light Green	Light Green	Light Green
Teiji Watanabe (JP)			Light Green	Light Green	Light Green		
Jörg Balsinger (CH)		Light Green	Light Green	Light Green			
Zev Naveh (IL)		Light Green	Light Green	Light Green			
Nigel Allan (US)			Light Green	Light Green	Light Green	Light Green	
Edwin Bernbaum (US)			Light Green	Light Green	Dark Green	Dark Green	Dark Green
Hermann Kreutzmann (DE)		Light Green	Light Green	Light Green	Light Green		
Christoph Stadel (CA-AT)			Light Green	Dark Green	Dark Green	Light Green	
Martin Price (UK)			Light Green	Light Green	Light Green	Light Green	
Monique Fort (FR)				Light Green	Light Green		
José María García Ruiz (ES)			Dark Green	Light Green	Light Green		
Alton Byers (US)				Light Green	Light Green	Dark Green	Dark Green
Thomas Schaaf (DE)		Light Green	Light Green	Dark Green	Dark Green	Dark Green	Light Green
Hans Hurni (CH)				Light Green	Light Green	Light Green	
Yuri Badenkov (RU)		Light Green	Dark Green	Dark Green	Dark Green		
Donald Friend (US)			Light Green	Light Green	Light Green	Light Green	
Thomas Kohler (CH)			Light Green	Dark Green	Light Green		
Alexey Gunya (RU)				Light Green	Light Green	Dark Green	Dark Green
GLOBAL SOUTH							
Gerardo Budowski (CR-VE)	Light Green	Light Green	Dark Green				
Misael Acosta-Solís (EC)	Light Green	Light Green	Light Green				
Trilok Singh Papola (IN)		Light Green	Light Green	Light Green	Light Green		

MAJOR PLAYERS	DECADAL ADVANCE OF MONTOLGY						
GLOBAL SOUTH							
Fausto Sarmiento (US-EC)							
Víctor Toledo (MX)							
Hugo Romero (CL)							
Mesfin Woldemariam (ET)							
Radu Rey (RO)							
J. Gabriel Campbell (NP)							
Guangyu Huang (CN)							
Irasema Alcántara-Ayala (MX)							
Esther Njiro (ZA)							
Constanza Ceruti (AR)							
Gustavo Martinelli (BR)							
Virginia Nazarea (PH)							
Eliás Mujica (PE)							
Arturo Eichler (VE-DE)							
Eduardo Gudynas (UR)							
Ricardo Rozzi (CL-US)							

Initial attempts to popularize Mountain Geography were promoted by the journal *Geographical Review*, crowning the effort of more than 100 years with the special issue on mountains in 2010. The establishment of the “Man and the Biosphere” (MAB) Program of UNESCO (<https://en.unesco.org/mab>). has been greatly augmented by the Mountain Biosphere Reserves Program, and the World Heritage Center’s Natural and Cultural Sites that have prioritized mountain protected areas as World Heritage Sites. Montology research institutions now comprise not only multidisciplinary and interdisciplinary teams, but also transdisciplinary 4D interpolations, links, and nexuses.

2.2. *Transgressivity: The Montological Route*

The integration imperative is a skilled methodology, as mountain Geographies and neotectonics engage with convergent science, consilient trends, and simplified synoptic processes (Roberts & Smyth, 2022). Price *et al.* (2013) incentivized intersections of the physical with the human mountain geographies (Sarmiento, 2015). The trust here relies on a multimethod approach with statistical and mathematical equations conditioning the biophysical component of the experimental research; yet meristic and qualitative assertions affect the socioecological component of the observational system intertwined as the MtCAS settles in trajectory. Traditionally, the use of probability analysis and Bayesian modeling allow for understanding the likelihood

of a null hypothesis to be falsified only if ‘all other things being ‘equal,’ and that the process is reliable and replicable. The functioning of MtSESs challenges the *caeteres paribus* since all processes continue their homeorhetic flow while scientists study a still-shot, a frozen-in-time portion of it, which is the basis for fluvial discontent in the riverine geocriticism of mountains (Pasini, 2022). The conditions for generalization with replicability and reliability are questioned by situational oddities that make mountain specificities in different parts of the world unique; therefore, requiring a selective multimethod approach. Experimental studies often play with the parameters of X and Y in direct Cartesian relation, while elevation (Z) is often assigned positive or negative values for vertical exaggeration (V). We challenge the idea of using T as an indirect Spinozan relation with H framing the inverse explanatory etiology of change.

$$f_{t_0}^{t^{n-1}} X_1 \cdot Y_1 \cdot [Z \cdot V]_1^{-1} \quad f_{t_0}^{t^{n-1}} \frac{X_{(1-n-1)} \cdot Y_{(1-n-1)} \cdot [Z \cdot V_{(1-n-1)}]^{-1}}{H \cdot T_{(1-n-1)}}$$

We use Jodha’s (2003) specificities to describe the transgression and referentiality of mountain studies (Westphal, 2011; Tally & Battista, 2016) by inverse definition methodology approach, with binomials that might be oxymora and hard to define, unless using their contrary meaning (Table 2).

Table 2. Example of the inverse definition method when applied to common terms of difficult meaning, that become very clear when explained in the absence of it. The inverse definition approach requires a series of iterations to obtain the pedagogical aim. Source: Elaborated by Fausto Sarmiento. *Tabla 2. Ejemplo del método de definición inversa aplicada a términos comunes de difícil significado, que se aclaran cuando se los explica en su ausencia. La aproximación de la definición inversa requiere una serie de iteraciones para obtener su objetivo pedagógico. Fuente: Elaborada por Fausto Sarmiento.*

MONOMIAL	BINOMIAL	INVERSE DEFINITION	SOURCE
<i>Sustainability</i>	Sustainable development	Easily explained when unsustainable practices affect the mountain slope	Hamilton & Hurni (2003)
<i>Health</i>	Environmental health	Easily explained when sickness and disease are apparent in the environment	Dovjak & Kucek (2019)
<i>Harmony</i>	Natural harmony	Easily explained when disruption in the balance break the equilibrium in the system	Botkin (1990)
Peace	Pax Romana	Easily explained when criminality pervades neighborhoods in the Roman empire	Kirkpatrick (2007)
Happiness	Satisfactory wellbeing	Easily explained when the malfunction of welfare affects largely on the emotional basis	Maddison <i>et al.</i> (2020)

It can also be done with single terms (i.e., monomial) lacking direct translation into English (Figure 1) of the triad needed to problematize mountainscapes by rethinking the interacting spheres in the episteme of mountain cognition (Tadaki, 2017):

Critical in or *geoliterate*, in the physical biogeographic mountain setting, encompassing descriptive, meristic variables; e.g., ontology of the space.

Critical of or *ecoliterate*, in the socioecological mountain production system, including analytical, non-meristic variables; e.g., ontology of the place.

Critical through or *sopholiterate*, in the mental mountain imaginaries, encircling spiritual, ethical and morality variables; e.g., ontology of the soul.

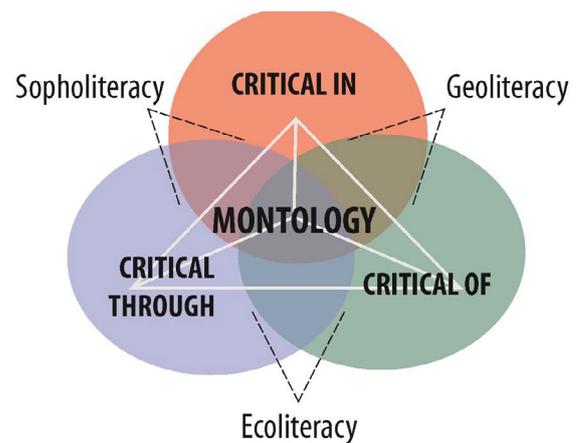


Figure 1. Interacting vectors of transgressivity and referentiality among the spheres of critical thinking applied to mountain cognition and etiology of mountainscapes. Elaboration: F. Sarmiento and I. Alcántara. (Modified from Sarmiento, 2020). *Figura 1. Vectores de transgresividad y referencialidad interactuando entre las esferas del pensamiento crítico aplicado al conocimiento sobre montañas y la etiología de los paisajes montañosos. Elaboración: F. Sarmiento e I. Alcántara (Modificado de Sarmiento, 2020).*

This approach seeks to radicalize geocology and landscape ecology of mountains with linguistic artifacts conveying ideas without direct translation (Castree, 2017; Lomas, 2018). Therefore, readers are compelled into using whole sentences in lieu of a simple term, to integrate ideas to execute transgression in mountain cognition (e.g., Prieto, 2011) toward sustainable and regenerative development. This jump from monomials to the phrasal lexicon of binomials or trinomials, often implies a much higher level of place attachment, which has been geovisualized from crowdsourcing social media and data mining in an Ecuadorian mountain setting (Kong & Sarmiento, 2022). Some of these terms include Arabic (*barzakh*), French (*terroir*), German (*Gemütlichkeit*), Portuguese (*saudade*), Sanskrit (*kharma*), and Spanish (*arraigo*). With this artifact, we prompt geo-literacy to be more relevant than eco-literacy when dealing with hybrids of humanities, art, and science, because eco-literacy emphasizes “nature only” judgement of the biophysical landscape, whilst geo-literacy stresses “nature-culture linkages” of the biocultural mountainscapes immersed in the sopho-literacy of their vernacular cultures (Prieto, 2016; Franco, 2022).

2.3. Collective efforts for convergent montology

This crosscutting collective effort to understand Mt-SESSs, such as in farmscape transformation (Sarmiento *et al.*, 2022), food sovereignty, and agrobiodiversity (Zimmerer *et al.*, 2017; Sarmiento *et al.*, 2019b), crop vulnerability (Conzo, 2022), or glacier retreat and climate change in mountain communities’ disaster risk (Carey, 2010), ex-

plains the strengthening of montology, as important networks for mountain research operate, led by Swiss-funded Mountain Research Initiative (MRI) for a global reach (<https://www.mountainresearchinitiative.org>). Another network operates out of the Austrian Academy of Sciences' Institute for Interdisciplinary Mountain Research (IGF) (<https://www.oeaw.ac.at/igf>). Also of note is the Institute of Mountain Hazards and Environment (IMHE) (<http://english.imde.cas.cn>) that operates out of the Chinese Academy of Sciences. The synergy of montology is manifested recently with the creation of an Interdisciplinary Centre for Mountain Research (ICMR) at the University of Lausanne (UNIL) in Switzerland (<https://www.unil.ch/centre-montagne>).

Lately, funding agencies of the Global North prioritized transdisciplinary teams for grants given in coordinated and shared fashion, as the creation of the Belmont Forum (<https://www.belmontforum.org>) to fund climate change research on mountains. Also, federal funding in the USA awarded TARN (Transdisciplinary Andean Research Network) as a Collaborative Research Network (Polk *et al.*, 2017); SENTINELS for mountain observatories (<https://mountainsentinel.org/>); MtnSEON (Mountain Social Ecological Observatory Network (<https://webpages.uidaho.edu/mtnseon/>); GEO Mountains (<http://geomountains.org/>); and, the Neotropical Montology Collaboratory (<https://montology.franklinresearch.uga.edu>).

In addition, the Belmont Forum's project VULPES (Vulnerability of Populations Under Extreme Scenarios) that looked into microrefugia conservation research into mountain forests worldwide (<https://vulpesproject.wix-site.com/vulpes>) (Cheddadi *et al.*, 2017). Implementation by the German International Cooperation for Development (GIZ) of its policy to exclusively fund projects observing transdisciplinary tenets shows the wherewithal in favor of montology.

The United Nations University's (UNU) Institute of Advanced Studies in Sustainability (IAS) invigorates this effort by hosting a successful International Program called "Satoyama Initiative" (IPSI) (<http://satoyama-initiative.org/>), working globally with headquarters in Tokyo. In addition, sustainability science researchers, who have identified transdisciplinarity in mountain basins (Lang *et al.*, 2012), and the work of the Mountain Partnership of FAO (<https://www.fao.org/mountain-partnership/>), with its recent incorporation of the Latin American and Caribbean Mountain Research and Innovation Network (LACMONT) in Brazil (<https://www.fao.org/mountain-partnership/events/event-detail/tr/c/1381033/>) contribute to montological strengthening. This can be seen in case studies from across the globe, including the Satoyama landscapes of *Soteapan* community in Mexican Yucatan, of *Cauca* valley headwaters in Colombia, of *Imbakucha* watershed in highland Ecuador, of the vicuña herders of *Pushka Warmi* in the Argentinean puna, and of the *Galtür* and *Ischgl* municipalities in Austrian Tyrol.

In the 'city of science' near Tokyo, a UNESCO chair of cultural heritage ([ESCO-Chair/\) keeps scholars at the University of Tsukuba grappling with Biocultural Heritage and Nature–Culture Linkages. This chair contributes to updating practitioners from around the world with capacity building, and to training students in a Master's program on mountains through an impressive Center for Mountain Research, with many field sites in Japan. However, some initiatives in the Global South are starting to bring the transdisciplinary approach to their work, such as the group Lab Natural ANDES del Sur, Austral University of Chile.](http://nc.heritage.tsukuba.ac.jp/UN-</p>
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Mountain Research and Development adopted a guide for inclusion of Traditional Ecological Knowledge (TEK) to understand the Global North–Global South dynamics of mountain sustainability. The journal promotes sharing of applied research and knowledge generation with hard and soft sciences. Founded by Jack D. Ives and published by the IMS until 2000, MRD became an open journal, edited by Hans Hurni at Bern. At present, editors-in-chief Thomas Breu (CDE), Pema Gyamtsho (ICIMOD) and Yanfen Wang (UCAS) work with associated editors Sarah-Lan Mathez-Stiefel, Brigitte Portner, and Susanne Wyman von Dach, at the Center for Development and Environment at the University of Bern. Coincidentally, another journal also created by Jack Ives, covering *Arctic, Antarctic, and Alpine Research* (AAAR) interdisciplinary perspectives, that initiated his tenure as director of INSTAAR founded at the University of Colorado, Boulder, is very active in the United States. Bibliometrics of mountain research output is now enhanced by the collaboration of Springer and the Academia Sinica producing the *Journal of Mountain Science* (JMS), with an active international editorial board, coordinated by Professors Peng Cui and Dunlian Qiu of the IMHE in the Institute for Mountain Hazards located in Chengdu, China.

Pirineos Journal of Mountain Ecology underwritten by the National Council of Science and Technology of Spain, is published by the Pyrenean Institute of Ecology in Jaca; the publication of open access online promoted by editors Teodoro Lasanta-Martínez and Estela Nadal-Romero led an innovative production, emphasizing European and Iberoamerican authorship. In addition, the *Journal of Alpine Research* (JAR)/ *Revue de Géographie Alpine* (RGA) produced by the Institute of Alpine Research at University of Grenoble, France, continues editorial leadership on mountain research as the oldest mountain journal running uninterruptedly since creation in 1913. Lastly, *eco.mont*, the *Journal on Protected Mountain Areas Research and Management*, edited at the Austrian Academy of Sciences, includes montological research and conservation in MtPAs worldwide.

3. Results and discussion

3.1. Mountains as Ontological Subject Matter

The advent of critical social theory with decolonial scholarship pushes to incorporate dialectics, meristic

metrics, and trialectics, which not only requires a new conviction for 4D, but also different protocols, such as critical biogeography, biocultural heritage paradigms, onomastics and term causation, and political ecology explanatory tropes (Sarmiento, 2016a). Delving mountain theory, grasping it from both sides of the Cartesian or Spinozan divide (i.e., single trajectory or multiple tracks), the consilient imperative is obvious (Painter, 2008; Hansson, 2012). This “cartographic anxiety” created by the nature-culture hybridity (Gregory, 1994), pleads the trifacta of critical in–, critical of–, and critical through– of the literacy about the mountain environment (i.e., *geoliteracy*, *ecoliteracy*, *sopholiteracy*) (Figure 1). Therefore, montology became a staple in novel thinking about mountain research, particularly in the less developed countries, where most humans speak languages other than English and practice non-Western thought.

Al-barzahk in Arabic, could be equivalent to “purgatory” in Christian thought. Nevertheless, it goes deeper in describing the fuzziness binding neighboring fields that are hard to discriminate. This *Al-barzahk* lemma or monomial connotes the boundary line that bounds death and life, or the moving crepuscular line of darkness and light, or the *tempusculus* of past and present tenses, or the fuzzy realm of the imagined and the seen; sometimes it mediates what constitutes the domain of humans and gods. Montology binds this trifacta of mountains, by forming a complete picture of mountainscapes. For instance, the trinomial dimension in the Andes, given by the trilemma of identity can be (in)ducted from the meaning of what is planned, conceived, and calculated –or *Andeaness*, can be (de)ducted from the appearance of what can be touched and measured –or *Andeanity*, or can be (sub)ducted from the imaginary of revelations and dreams –or *Andeanitude*. The Andean identity of this trilemma interplays affecting effective MtPAs conservation (Sarmiento, 2016b) in reference to the fluid process (or ducted) of reciprocity (or *ayni*) of Andean mountainscapes. In tropandean landscapes, the Sarmiento’s trilemma explains sentience from toponymy and onomastics of ancient descriptors that genderize mountains (e.g., *Mama Tungurawa* and *Tayta Chimburasu*) without specific bodily metaphors. Sentient mountainscapes elsewhere find their essence in other latitudes, with consideration of landscape dynamics in their deep ecology graticule. In this vein, you may think of *Alpinity*, *Himalayaness*, and *Appalachitude*, when exploring the physical features of the Alps, or hidden mental constructs of the Himalayas, or spiritual and sacred confines of the Appalachians.

3.2. Longing for Critical Montology

In spite of having mountains in large urban scenarios, such as Tokyo, Mexico City, Shimla, Gangtok, Quito, Valdivia, or Innsbruck, the diminution of the appeal of the mountain livelihood conflates the urbanite modalities afforded by city infrastructure and municipal facilities, allowing for fast connections, diminished travel times, unobstructed terrain, or industrial parks for factories

and harbors to export globally, generally located in the lowlands and by the river deltas (Messerli & Ives, 1997; Wu & Hobbs, 2002). Mountain civilizations of the past, nevertheless constructed their centers in forgotten valleys, isolated from others, remaining in the hinterland, on peripheral areas where to build hegemony, even in challenging topography (Sarmiento & Sarmiento, 2021). The endemicity generated by this spatial isolation produced different creeds and languages, with distinct use in the creation of mountain myths and landscapes’ identity markers in different continents (Lewis & Wigen, 1997; Skutnabb-Kangas *et al.*, 2003; Zimmerer *et al.*, 2017).

Saudade, in Portuguese, describes something good that has been lost, that is longed for at present, but with a great potential to recur due to the past opulence. Most citizens, including the amenity migrants, exurbanites and suburbanites of cityscapes or farmscapes, tend to incorporate “specificity” to secure survival in those urbanized places, stress-riddled megalopolises, and harbors. The Portuguese monomial *saudade* is expressed in the longing experienced by people who want to be closer to MtPAs for their high quality of cultural ecosystem services (CES). Moss (2006) pointed out that one of the manifestations of expats and retirees around the world is the development of second home residential areas or summer cottages and retreats that evidence this longing for mountain lifescapes. The archetype of the “American dream” that moves many migrants into developed areas is given the moniker of “Home on the Range” as one of the aspirations of its citizens (Johnson *et al.*, 2016), making it an envisioned investment of urbanites for fulfillment of ambitious goals by the mountainside.

Padoan (2021) reminds us that mountains’ metageography is an important part of “the Self” identity, which easily converts a mountaineer in “the Other” (Fabian, 2014), as an archetype found from *Aconcagua* to *Atlas*, and from *Ausangate* shrine to *Atna* peaks. An old anonymous Irish aphorism puts it better:

“You can never take the mountains out of the boy,
but you can take the boy out of the mountains”

Deeply established notions of lifescape and livelihood, exerted in the mountains by problematized political ecologies (Sarmiento, 1987; Ives & Messerli, 1989; Debarbieux, 2008), often puts personalized perspectives. Mountains supply a respite in the acceleration of current globalization space-time schemes; not only to defy a plain’s monotony, but also to improve quality of urban life with ecosystem services, including fresh air, ample vistas, resource extraction potential, fresh water, wildlife refuge, and CES (i.e., sanctuaries for ancient rites of spiritual fulfillment, theophanies and epiphanies, cosmophany, historical memory, national pride, recreation and tourism (Schirpke *et al.*, 2020) and more intangibles of biocultural diversity (Termorshuizen & Opdam, 2009; Hommes *et al.*, 2019) for regenerative and sustainable mountain futures. Furthermore, mountains provided

refuge for survival from global epidemics (Cheddadi *et al.*, 2017). Therefore, it is in publishing various texts *de novo* as palimpsests, and their diffusion through today's mass media and online browsers, that montology grips on this transdisciplinary geoliteracy (Tally & Battista, 2016; Sarmiento, 2022).

3.3. *Crosscutting Mountain Lore*

Crosscutting of humanities and sciences has flourished with the fusing of geopoetics, archaeology, religion, history, ecological criticism, geocritical epistemology, and other disciplines as proxies to understand fluxes towards sustainability. This recognition fuels the training of scientists as part of STEAM (science, technology, engineering, arts and medicine) education, complementing old STEM (science, technology, engineering and mathematics) education. Current multiversities are now replacing the individualistic universities in the Global South in their search for urgent multiethnic and pluricultural solutions to the climate crisis in local communities. Hybrid multifunctional teams are becoming popular across the world's mountains.

Transgressivity took down borders meshing sciences and humanities (Westphal, 2011). Conversely, the transdisciplinary spatial turn to incorporate the fourth dimension (4D) is underscored in the edge of urban complexes (Soja, 1996) and mainly in the use of multimethodologies to study shifting mosaics in mountain environments (Zimmerer, 1994; Henderson & Wang, 2005) operating in *n*-dimensional space and time. Moreover, to integrate mountain knowledge, the sequence of events requires a *Gestalt Systems'* thinking (Naveh *et al.*, 2002). In *Gestaltism*, different factors work to auto-generate order out-of-chaos. The integration of scientific methods and traditional wisdom follows *Gestalt* principles of spatial arrangement (*sensu* Bradley, 2014), including past experiences towards landscape memory, aids in the popularization of montology.

The monomial Sanskrit *Kharma*, denotes an ancestral practice of Hindus River civilizations, a framework to Buddhists and Hinduists everywhere, for the accumulative deeds of the Self propels the individual towards complex levels of integration to aid retributive justice in the mind while attaining the ultimate reality. The karmic idea of spiritual account for improving soul and body, as well as the environment of the Himalayas, was presented by Ives (2013). This flow reinforces achieving higher organization and complexity, and prompts to better understand sustainable and regenerative MtSESs at the spiritual level in the new convergence of montology (Sarmiento & Hitchner, 2017; Bernbaum, 2022a).

3.4. *Referentiality of Mountainous Environments*

Mountains are heterotopic spaces. They follow imprints marked by ancestral effects that anthropogenic

pressures left in what we consider literary palimpsests, often with iterative modifications that have been sustained by conviction, rituals, or force. This engages us to learn our own rendering of the mountainscape with renewed optics, apart from paradigmatic narratives. We agree that historicity and political maneuvers of the 4D have created the idealized mountain entity (Debarbieux & Rudaz, 2015). When tabulating mountain diversity of either polar regions or neotropical forests that "look" pristine (*fundamental* mountainscape), it is hard to imagine that they have been "manufactured" as hidden MtSESs and MtCASs (*re-alized* mountainscape). Since millennia, paleoecological dynamics of these built anthromes, respected and cared for by mountain dwellers, have interventions creating actuoecological manufactured landscape structure, function, and change (Scheiber & Zedeño, 2015) perpetuated as ancient ecological legacies.

Arraigo in Spanish, is the lemma that describes love and respect to the motherland, not only in the construction of their territoriality, but also in their customary practices and national identity. Borsdorf & Stadel (2015) showed that highland people exhibit a trait of deep *arraigo*. Yet, the notion is more than rootedness of a person in the place of residence; it is inherently tied to the MtSES. This nexus requires recognizing that social belonging to a place is made with intimate linkages with various characters of the mountainscape. The term *Pachamama* in *Kichwa* or '*Runashimi*', not only refers to the ground's agricultural production, but also to the collective communal effort of 4D; reciprocity is viewed as central to time-tested (T) cohesion and agency of historicity (H) of the diverse mountain social groups, or *ayllu* in ranges (X), valleys (Y) and ridges (Z). Offerings, or *pagapu*, to mother Earth links ritualized elements in X-Y-Z-T space, with the three commandments for *Inka* cosmology wellbeing, or *sumak kawsay*, when they are balanced timely within the trilemma: Do not steal (*ama shua*), do not lie (*ama llulla*), and do not be lazy (*ama killa*) (Sarmiento *et al.*, 2023).

They are intricate in time, as they train youngsters in land labor, and in the respect to the elderly by providing them a hierarchical place of power. Heightening the T dimension in their mountain communities, elders exert political will in narrow citadels, or *llakta*, or in ancestrally protected sacred sites. The temporal link (T) tracks the historicity of several generations (H), because of the practice of burial of the ancestors, or an unborn child, under their homes, recalling the practice of mummification in antiquity. This intimate relationship with the land makes "*arraigo*" a cherished value (Sarmiento, 2012). Consequently, the worst punishment in the region is to extirpate them from their homeland. Banished expats and prisoners of war, or *mitima*, were obliged to colonize faraway areas for *Inka* territorial expansion, so far as achieving the largest-known mountain empire: *Tawantinsuyu*. This trend is manifested in the Andean communities' foremost political platforms of struggle: ownership of property, official ethnic territorial titling, and plural rights for water of their motherland, or *manta*.

3.5. Impacts on Mountain Ecosystem Services

Montology, posed as a consilient vogue to convergent mountain science, was first attempted in the 1800s by Alexander von Humboldt, the “father of ecology” (Eibach & Haller, 2021). He was stimulated by pragmatic romanticism to characterize the landscape of mountains to re-assess natural history, the so-called Humboldtian method. Instead of understanding mountains from a mechanistic perspective, as if they were machine-like beings assembled from individual parts, Humboldt conceptualized mountains as a web of life, where all things depended on each other, being more than the sum of all the individual parts (Haller & Branca, 2020). This method improved his *naturgemälde*, using Humboldtian views of his visit to *Apu Chimborazo*, Mt. *Cotopaxi*, Mt. *Pichincha*, and Mt. *Antisana* in 1802 (Wulf, 2015b); the *Tableau Physique* populated with species names, elevation, temperature, and atmospheric pressure, confirmed his views of the human impact on tropical mountains, which has not only guided scholarly inquiry of geographers, but also of anthropologists, volcanologists, ecologists, and other researchers of ‘geoecology’ (e.g., Troll, 1968), that was later called ‘landscape ecology’ (Naveh *et al.*, 2002), now termed ‘montology’ (Sarmiento *et al.*, 2020).

Mountains represent diverse ecosystems due to their elevational gradient, different climatic zones in a small area, and summits acting as islands in the sky (Körner, 2004; Sneath *et al.*, 2022; Myster, in press). The high level of endemism in mountainous environments is hefty, especially on the tall isolated prominent edifices (Steinbauer *et al.*, 2016; Noroozi *et al.*, 2018) and hard to climb cornices. The highest *alpha*-diversity index of bryophytes in the nival zone, of forbs in the alpine zone, of epiphytes in the montane zone, and of angiosperms in the colline zone (Gradstein & Homeier, 2010) exemplify rich mountain biodiversity. As such, mountains are the acute crucible of deep evolutionary processes and are critical repositories for species maintenance and conservation efforts (Rahbeck *et al.*, 2019). In addition, the mountain’s ‘ecological geographies’ were swayed by island biogeography theories of isolation, colonization, and extinction (MacArthur & Wilson, 2001). Thus, mountain’s ‘geographical ecologies’ were highlighted as apolitical spaces, interesting only to natural scientists (Ives, 1980). The realization of conflictive power struggles with the agency of mountain peasant communities was made evident not only for mining and agroindustries of countries in the Global South (Zimmerer, 1994), but also for inclusion of their perspectives of self-governance and endogenous cosmophany (Sarmiento, 2000), and for the endurance of anarchists leaving within *Zomia* (Scott, 2009).

Far from emphasizing ecosystem services and biodiversity, montology is claimed an environmental education toolkit for the cognition of benefits of mountains to people (Sarmiento *et al.*, 2022b). With 4D dimensions, mountains are also anchored in the emotional geographies of biocultural heritage of ancestral lineage, and in the trope

of sustainable, regenerative development (Zhong, 2000; Bernstein, 2015). Furthermore, the horizontally segmented slopes (so-called Humboldtian paradigm) have been aided with new vertical integration, with ecotonal borders in lowland/highland dynamics, comprising the anthropic landscape change and social gradients (Sarmiento, 2002). A bronze plaque rests at a Chimborazo’s snowline cairn (Figure 2), immortalizing Alexander von Humboldt in the monument, including the words ‘montology’ and ‘geoecology’, written in *kichwa* for the Andean world, in *castellano* for Latin America, and in English for the Global North (Sarmiento, 1999).

3.6. Modifying the Mood of Mountain Minds

The inclusion of non-linearity of mountain *Gestalt* systems, transitioning to sustainable mountain communities gets fuzzy, as farmscape transformation affects the MtCASs. In this sense, ‘mountain’ is a heterotopic space extremely fragile. Lima (2013) stated the imperative to accept another mountainscape health metaphor: we now require a new approximation of rhizomic interactions, in lieu of dendritic or arborescent descriptions, allowing horizontal synergies and bottom-up approaches instead of a cascading hierarchy and rigid top-down decisions. Whereas humans cohabit slopelands with upward adaptations, they also inhabit the inverse verticality of canyonlands or the modified relief of former hills now transformed into deep holes, such as in the Appalachian’s mountaintop removal fields in Kentucky or the gold mining digs of *Serra Pelada* in Brazil.

Terroir, in French, is the monomial that defines unifying multisensorial inputs to recall a fulfilling emotional reality of landscape memory. *Terroir* is not only the aroma or flavor integrated into the wine, but also those intangible site conditions of cherished moments, all in a tasted memory sentient landscape. Like *terroir*, montology integrates heritagescapes, both tangible and intangible, with a *Gestalt* behavior that is non-linear, decentralized, interconnected, interdependent, abiding cartographic anxiety in a 4D scenario, where the integration of vectors X, Y, Z, and T define the graticule heavily determined by interaction of T and H of the heritagescape (Sarmiento *et al.*, 2023). To solve the mathematical function that these interactions define, the simple linear regression of physical conditions gives way to a quadratic equation that relativizes T in favor of H for the sentiment created to feel appropriated conditions in the MtCASs. This place attachment informs sacred geographies to partake in MtSESS’ route towards sustainability (Sarmiento, 2016a) with a twist for the regeneration and rewilding of sentient mountainscapes (Taylor, 2010). Mountain responses to climate change have often been considered the manifestation of an intangible sentiment or a salient demonstration of sentient more-than-human entities that conform the mountain community’s memoryscape (Grover *et al.*, 2014; Gade, 2015; Rozzi *et al.*, 2015).

ALEXANDER VON HUMBOLDT – 23 JUNE 1802

The Andean Mountains, especially Chimborazo, stirred the imagination of scientific labor of this great man. In addition to his many other publications, it was in this tropandean landscape, beneath the eternal snows of our majestic volcano, where he laid the foundations of “mountain geocology,” or “montology,” that continues to mold world society. The Rio de Janeiro Earth Summit of 1992 ensured international recognition of the importance of our mountains, in part from United Nations University research, and created awareness that is finally transcending into action. This advance culminated in November 1998, when the General Assembly of the United Nations declared AD 2002 as the International Year of the Mountains.

“FOR A BETTER BALANCE BETWEEN MOUNTAIN ENVIRONMENT, DEVELOPMENT OF RESOURCES, AND THE WELL-BEING OF MOUNTAIN PEOPLES”

*Chimborazo, the birthplace of Mountain Geocology
December 15, 1998*

Indigenous Committees of Chimborazo

*Jack D. Ives (IMS/UNU) International Mountain Society
Fausto O. Sarmiento (AMA) Andean Mountains Association
Lawrence S. Hamilton (WCPA-IUCN) World Conservation
Union, Commission of Protected Areas: Mountains*

*Bruno Messerli (IGU) International Geographical Union
Juan Hidalgo (CEPEIGE) Pan American Center for
Geographical Studies and Research
Patricio Hermida (INEFAN) Chimborazo Reserve Manager*



Figure 2a. The cairn honoring von Humboldt and montology at the Chimborazo snowline. Monument installed in 1998. Figure 2b. Trilingual plaque, recognizing the “International Year of Mountains”. Pictured are the superintendent of the Chimborazo Faunal Reserve, park rangers, and signage company workers. Source: Sarmiento (1999).

Figura 2a. El hito de piedra en honor a von Humboldt y montología en la línea de nieve del Chimborazo. El monumento fue instalado en 1998. Figura 2b. Placa trilingüe en reconocimiento del “Año Internacional de Montañas”. En la foto se encuentran el superintendente de la Reserva Faunística Chimborazo, guardaparques y trabajador de la compañía de señalización. Fuente: Sarmiento (1999).

3.7. The Route Map: Using the Altimeter to Look for Paradise?

One of the most important learning objectives for instruction to promote youngsters’ understanding is ge-

ographic literacy. In the United States, the National Geographic Society (NGS) suggested “Geoliteracy” as primary target (Edelson, 2011). The International Geographical Union (IGU) welcomed the *Three-I’s* slant into the headquarters of geographical academies worldwide, including

Italy's "Home of Geography". This Three-I's approach (Interconnectedness, Interdependence, and Implications) in mountain studies, posits that montology merits highlight as *de facto* method to promote geoliteracy about the world's mountains. By using convergent montology, we are including new content material that affects the objective and subjective mountainscape (Avriel-Avni & Dick, 2019).

Gemütlichkeit, in German, is a lemma that defines a feeling of prosperity perceived peacefully only in the place you love, or hominess. This term does not refer to the house's physical settings (*Umwelt*) in the hilly terrain, neither to the felt agreement of the home environment with the domestic imaginary (*Lebenswelt*) of the mountain place. Rather, it evokes social constructs of the shared, built-environment, real or imagined (*Mitwelt*) of the MtSES (Westphal, 2011).

In summary, montology allows for spatiotemporal identities—or *tempusculus*—in transgressing disciplines (Tadaki, 2017) in space and time. This 4-D approach would help with transgressed factors as the parsimonious explanation to comprehend holistic mountain landscapes, juggling myths of the "heavenly bliss", the "dark green religion" or the "axial age", as drivers of sustainable futures (Provan, 2013). "As ageless quests for finding paradise require, many ethnic groups have often imagined paradise onwards and upwards, somewhere nice upslope, in the nursery of apical summits, pleasant mountaintops, or hanging valleys" (Bernbaum, 2022b), described in the myths and languages of their arcane cultures (e.g., *Shambhala, Shangri-La, Xiguanmu, Tian Shan, Meru, Burkhan Khaldun, Hlidskjál, Odin Valhöll, Janaidar, Gokuraku mine, Okuyama, Takamagahara, Maya-san, Kahiki, Maunapohuatu Havai'i, Sumanakuta Sri Pada, Sídh Munsalvaesche, Avalon, Eden, Teengir-Too, Xanadu, Kari Kö Ruwa, Arcadia, Hallélūyāh Edinu, Sumak Wak'a, Urku Apu, Tepuy, Zomia*, etc.). Using montology to frame sustainable and regenerative development makes mountains' heterotopia of space/place/landscape/inscape ontologically viable and universally alluring.

4. Conclusion

The continuous but also renewed interest in mountains has been mirrored by the new-flanged cross-chapter on mountains in the IPCC reports (Adler *et al.*, 2022). Mountains are a geo-socio-ecological system that have taken on great importance worldwide, particularly for humanity and, in general, for biocultural diversity, by becoming priority areas for intervention of microrefugia, being the subject of numerous scientific and empirical studies.

Framing montology within mountain geography informs critical, decolonial scholarship towards sustainable futures. Mountain onomastics translate frameworks and concepts illustrating the need for consilience and of transdisciplinarity, to guide effective teachings about mountains. The cultural terms obviate the competency of montology transgressing disciplines, and offering the

referentiality of a new panoptic corpus, with a mountain lexicon of updated terminology. The use of foreign words, without direct English translation, bridges reductionism that separates pieces of knowledge in discrete academic silos, favoring holistic translational ecologies of development, with an eye on the sustainability and renewability of mountain communities in the era of climate crisis. Historicity, as the H dimension of MtSES, helps branding of "Mountain Studies" instead of a separate new field, as an alternative for mountain epistemology. Montologists should integrate applied as well as basic research with the new approach, generating a stronger body of evidence in support of montology. The argument exhibited in mountain geoliteracy, ecoliteracy and sopholiteracy of newer panoptic and synoptic epistemologies, evidences the new mountain ontology.

Because of the immanent nature of sentient mountainscapes, the co-production of knowledge is imperative. Multi-methodological approaches are needed to converge in the character and value of transdisciplinarity (Sarmiento & Frolich, 2020). Mountain scholars and their students of the greater South shall contribute with reinforcing the development of montology for a sustainable mountain life-cape. Mountain geography necessitates a new approximation in the study of MtSEs, not only in intradisciplinary specialization, or in multidisciplinary or interdisciplinary works, but also transdisciplinary convergent science, as a paradigmatic shift of scalar significance of the decolonial turn (Frolich *at al.*, 2020). Those crosscutting collective efforts are imperative for a better understanding of the ontology of mountainscapes. It is essential to create new collaborating networks, research alliances, and learning clusters, or to enliven those already formed, translating hard science into practice. While soft science delves into power relations to shift in favor of equitable development policies that are meaningful for studying mountain phenomena, hard science keeps at work with innovation and technical solutions. By permitting consilience of all research done about mountains—whether from the physical or social sciences, the humanities, or the traditional and indigenous ecological knowledge—and its concomitant reification of mountain arts, politics, and management, the affirmation of convergent, transdisciplinary intervention will acquire the luring road leading to a sustainable and regenerative future of mountainscapes.

Supplementary Materials

The following supporting information can be found on the Commission of Mountain Studies website of the International Geographical Union.

Author contributions

Conceptualization, F.S., I.A., A.G., A.H. and C.M.; methodology, F.S., M.P., A.Y. and M.Y.; investigation, F.S., D.L., D.P., K.W., K.G., E.K., A.K., J.C., J.R., and

R.C.; writing original draft preparation, F.S., I.A., R.C., A.Y., M.P., A.H. and A.K.; Review and editing, all authors listed; visualization, R.C., I.A., F.S. and A.Y.; Project administration, F.S.; Funding acquisition, FS, A.K., J.C., K.W., D.L., D.P., E.K., and S.L. All authors have read and agreed to the published version of the manuscript.

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