Study proposes refinement of models to project ecosystem services in montane forests

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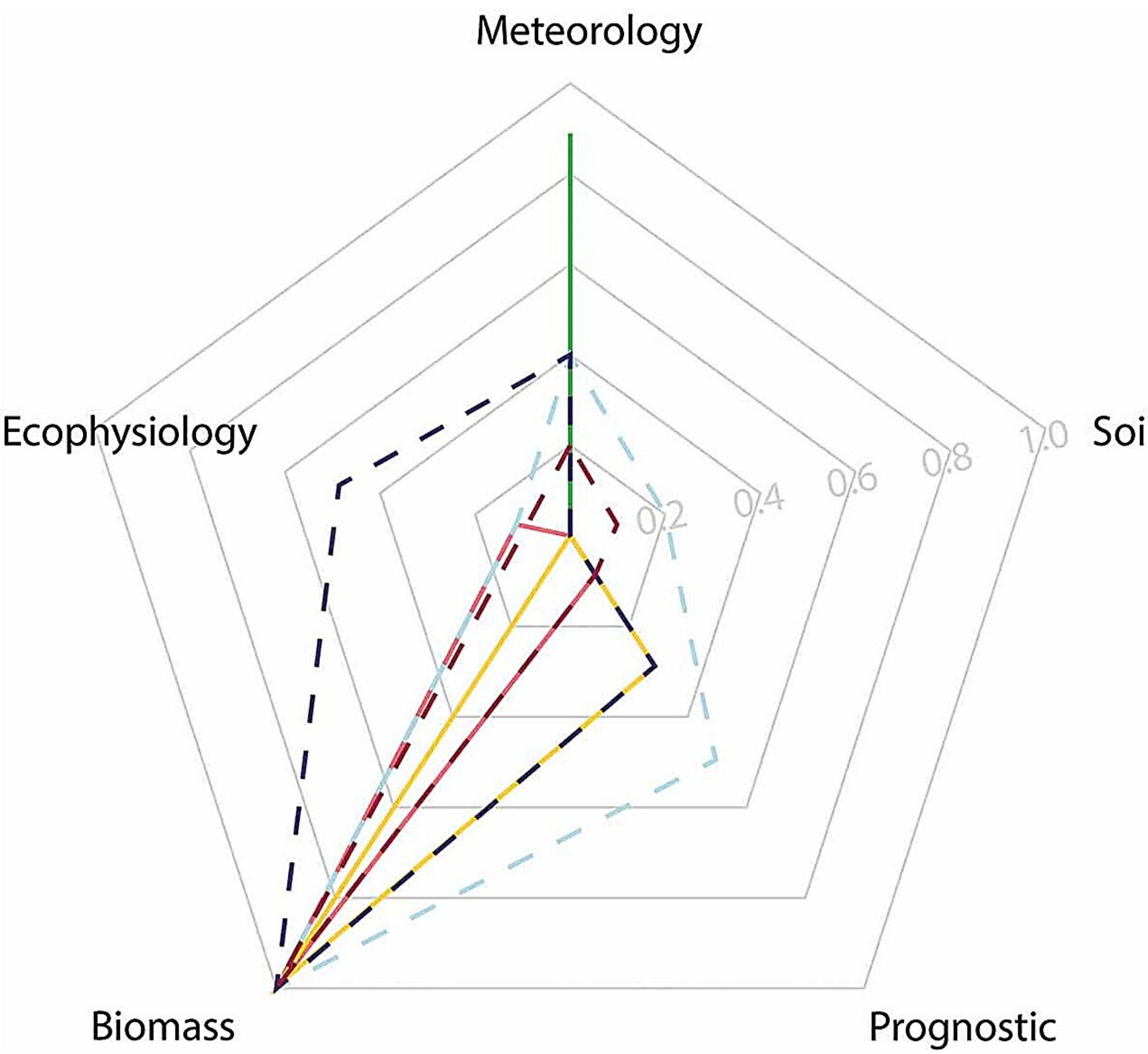

The classification of research sites based on their data availability for process-based modeling to contribute to Earth System modeling in the Andes and in the south-eastern Brazilian mountain ranges. The list of variables was compiled from Best et al. (2011 Best MJ, Pryor M, Clark DB, Rooney GG, Essery RLH, Ménard CB, Edwards JM, Hendry MA, Porson A, Gedney N, et al. 2011. The Joint UK Land Environment Simulator (JULES), model description – Part 1: energy and water fluxes. Geosci Model Dev. 4(3):677–699. doi:10.5194/gmd-4-677-2011.[Crossref], [Web of Science ®] , [Google Scholar]) and Clark et al. (2011 Clark D, Mercado L, Sitch S, Jones C, Gedney N, Best M, Pryor M, Rooney G, Essery R, Blyth E, et al. 2011. The Joint UK Land Environment Simulator (JULES), model description – part 2: carbon fluxes and vegetation dynamics. GeosciModel Dev. 4(3):701–722. doi:10.5194/gmd-4-701-2011.[Crossref], [Web of Science ®] , [Google Scholar]) and each variable per site was scored on a scale 0–1 (0, no data; 1, data available). Scores represent the proportion of data that for each of the four groups of variables (meteorology, soil, ecophysiology, and prognostic) plus biomass were available. Solid lines: green, Chile; ochre, Peru; salmon, Ecuador; Dashed lines: light blue Campos do Jordão, Brazil; dark blue, Venezuela; deep red, Argentina; Colombia has biomass and ecophysiology data which are masked by the ochre line of Peru and the salmon line of Ecuador; the Serra do Cipó, Brazil site has some meteorology data which are masked by other sites. Credit: *Plant Ecology & Diversity* (2023). DOI: 10.1080/17550874.2023.2196966

Tropical mountain ecosystems, including montane forests, are relatively little studied, yet they are home to significant biodiversity and provide important ecosystem services, such as water supply and participation in regulation of temperature and regional and global climate. The data available on mountain vegetation and its dynamics falls far short of what is needed to simulate with confidence its interaction with the atmosphere in response to climate change.

A new study published in the journal *Plant Ecology & Diversity* by a group of scientists affiliated with universities in Brazil and several other South American countries, as well as the United Kingdom, casts light on these questions.

An effective way to bridge this gap, the authors of the article argue, would be to create "a transdisciplinary network" capable of studying the natural dynamics of mountain ecosystems and their responses to global change drivers locally, regionally and across the continent, within the framework of a socio-ecological system.

"The results of our research show that very little information of the kind needed to model mountain clusters in South America is available. We need more specific data to do this modeling, especially if we want to include socio-ecological diversity. We advocate the creation of a network of sites representing the heterogeneity of social and ecological conditions in mountain ecosystems with the aim of quantifying the hitherto neglected role of these ecosystems in carbon and water cycling, as well as other ecosystem services," Laszlo Karoly Nagy, first author of the article, explained.

Tropical montane ecosystems in South America

Tropical forests in mountainous areas more than 1,000 meters above sea level vary from wet, like Serra do Mar in Brazil, for example, or parts of the Andes adjacent to the western Amazon Basin, to seasonally dry, like the Atlantic Rainforest biome or the Andean inter-ridge valleys.

Mountain vegetation comprises both forest and non-forest. Tree growth is limited at high altitudes and low temperatures, but climate change will alter the structure and functioning of these ecosystems. The Andes has many montane forest areas, for example, but current rates of warming there are three times higher than in other parts of South America, and temperatures in the region are expected to rise as much as 6 °C by the end of this century.

South America's mountains also have large non-forest areas where land use has changed to agriculture and pasture. In this context, the subtropical and tropical mountains of South America are a high priority for projecting the impact of future climate on the structure and functioning of these ecosystems in terms of climate feedback and potential use of ecosystem services.

In the study, which was based on a workshop held in Campinas, the researchers analyzed a network of mountain ecosystem sites in South America, cataloging and synthesizing existing knowledge for use in future modeling of these sites' contribution to regional and global carbon/water cycles.

"Selection of the areas has to be stratified on the basis of climate and biogeography, taking into consideration the historical and cultural context for land use," Nagy said. "All this shows the diversity of situations to be analyzed in socio-ecological terms so that the available knowledge can be synthesized and a pathway found for the construction of a wide-ranging project."

Methodology

The study covered eight sites in the Andes and Southeast Brazil: the Venezuelan, Colombian and west Ecuadorean Andes; the Amazon-Andes transect in Peru; the mountains of northwest Argentina; Cape Horn in Chile; and Serra da Mantiqueira and Serra do Cipó in Brazil.

Only two of these (one in Venezuela and the other in Brazil) had climate, ecological and ecophysiological data that could be used as parameters for dynamic global vegetation models (DGVMs), computer programs that simulate shifts in vegetation and the associated biological and hydrological cycles in response to climate change for decades ahead.

Tree biomass data was available for six sites. The scientists performed a preliminary assessment using a DGVM known as JULES (Joint UK

Land Environment Simulator) to look for gaps in available data and their impact on model parameterization and calibration. This analysis identified a temperature-related decrease in montane forest net primary production, respiration, and allocation to above-ground biomass, as well as an increase in soil carbon stocks with elevation.

One of the difficulties for researchers on these regions is obtaining data to identify the transition between montane forest and non-arboreal alpine vegetation. "If we combine modelers and field researchers who know the forest, we can decide what works for each participant, identify the peculiarities, and see how they can talk to each other. It's most important for the two communities to interact so that the results produced by modeling can be checked against empirical data," Nagy said.

Next steps will include continuing the development of models with Ibero-American colleagues, including Brazilians, and three European groups of modelers. All these groups work at different scales, including the global scale adjusted for mountains and landscape, which can encompass land use.

"Mountain characteristics require a specific approach," he said. "For example, you should analyze how tree growth is limited in terms of plant tissue production versus limitation by photosynthesis."

Right now, he added, the work entails bringing together the various actors, including a network of socio-ecological observatories for the Andes (ROSA), under construction, and definition of the sites to be studied in the next stage of the project.

More information: Laszlo Nagy et al, South American mountain ecosystems and global change—a case study for integrating theory and field observations for land surface modelling and ecosystem management, *Plant Ecology & Diversity* (2023). DOI:

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