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The importance of montane regions for biological diversity is well known. We also know that mountains contain a great deal of cultural diversity, despite the relatively small number of people living in mountains compared to other regions. What has been less explored is the interrelationship between mountains, biological diversity, and cultural diversity. The study of biocultural diversity involves a search for patterns across landscapes. As an inherently spatial phenomenon, biocultural diversity can readily be explored through the use of Geographical Information Systems (GIS). Our research has resulted in the development of a global database and map noting the linkage between high linguistic diversity and high plant diversity in montane regions throughout the world. In the present paper we focus mainly on the island of New Guinea to illustrate how important mountains are for biocultural diversity. The implications of this research for identifying areas in need of conservation and development strategies aimed at both biological and cultural diversity are briefly discussed.

Mapping biocultural diversity in mountains: a regional focus

Mapping biocultural diversity presents considerable problems in identifying appropriate proxies for such diversity. For our analyses we have mainly relied on two proxy measures:

1) Distribution of vascular plant species. Vascular plant diversity is an important component of overall biodiversity, and higher vascular plant diversity is closely correlated with higher overall biodiversity in most regions.
2) Distribution of languages. In general, linguistic diversity is a good proxy indicator of cultural diversity because of the interdependent complex relationships between a given language and a specific culture.

For the distribution of vascular plant species we have relied on the work of the team led by Wilhelm Barthlott at the University of Bonn in Germany. Rather than relying on distribution in political units (eg flora of countries) or geographical characteristics (eg flora of the Amazon), they calculate vascular plant diversity based on standardized units of area (10,000 km^2). This allows for comparable diversity categories on a global scale. They use 10 categories of diversity based on the number of vascular plant species, which they call "diversity zones" (Table 1).

The unit of analysis is 10,000 km^2. While some may argue that a smaller unit of analysis would produce different results (eg shifting the areas of highest diversity into the lowland humid tropics), there are good reasons to use 10,000 km^2 units. This has become something of a standard unit of area in ecology for looking at diversity at a global level, because it incorporates geodiversity at this scale and is a more functional unit than 100 km^2. A more pressing reason, though, is that data do not exist for most regions at 100 km^2 units. An additional utility in Barthlott et al's approach is that it moves beyond using political boundaries for denoting areas of high biodiversity and illustrates some important regions of vascular plant diversity, many of which are in montane regions.

For the distribution of languages we used the Ethnologue database produced by the Summer Institute of Linguistics (SIL). Ethnologue is widely regarded as the most comprehensive data source of current languages spoken worldwide. Its major limitation is that it does not indicate the spatial extent of speakers of a given language, only a singular point denoting the most central location of the population. However, on a global scale this is not really problematic, and by using a singular point it allows for graphic depiction of all of the world's languages on a single map. In future editions of Ethnologue, SIL plans to include spatial extent, which will allow for more detailed analyses.

At a global level the predominance of great linguistic diversity in mountainous regions is quite striking (Figure 1). While linguistic diversity tends to increase towards tropical regions, it is also clear that the greatest number of languages is found in mountains.

TABLE 1 The 10 diversity zones defined by Barthlott et al, based on the number of vascular plant species per 10,000 km^2.

Diversity zone	Species number per 10,000 km^2
DZ 1	< 100 spp.
DZ 2	100–200 spp.
DZ 3	200–500 spp.
DZ 4	500–1000 spp.
DZ 5	1000–1500 spp.
DZ 6	1500–2000 spp.
DZ 7	2000–3000 spp.
DZ 8	3000–4000 spp.
DZ 9	4000–5000 spp.
DZ 10	> 5000 spp.

Zooming in: the case of New Guinea

A regional approach allows us to further demonstrate the interrelationship between biological diversity and cultural diversity. The island of New Guinea (which is politically divided between Indonesia and Papua New Guinea) is well known for having great diversity in both these areas. When we look at the distribution of languages in relation to the number of plant species, we can see a clear relationship (Figure 2). Particularly in the highest zones of plant diversity, we find a large clustering of languages. In total, there are 1054 languages spoken in New Guinea. Of these languages, 738 (70%) originate in mountainous regions. However, only 33% of the island is mountainous (Figure 3). Human populations in New Guinea have likely been more isolated over time owing to the island's geography. These data suggest that an ever greater factor, however, is the isolation caused by mountain geography, amplifying the isolating effects of the island and allowing for an extraordinary number of languages and cultures to develop.

Possible factors affecting high biocultural diversity in mountains

Mountains greatly influence both biological and cultural systems in many ways. First, they create limitations on development by requiring larger expenditures of energy by species in order to move through them. For example, a plant species on one side of a mountain range would require much greater inputs of energy (through wind or animal migrations) to disperse itself to the other side of a mountain range than would be required for dispersal over a similar distance in flat terrain. Similarly, two cultures living on opposite sides of a mountain range would require a greater energy investment to exchange goods (Figure 4) and cultural information (represented by greater walking distances around canyons and steeper and more treacherous roads, for example). Under these conditions, both cultures and ecosystems in non-mountainous terrain would require less energy to interact, and therefore be more likely to diffuse language and culture to each other than those in mountainous areas.

Another way in which mountains promote biocultural diversity is by creating an ecological gradient. A good example of this is in certain equatorial parts of the Andes, where all of Holdridge's life zones (a classification system that incorporates both climatic and ecological variables) can be found in a compact area. This allows both different ecosystems and cul-

FIGURE 1 Density of languages in montane regions worldwide. (Map by authors)

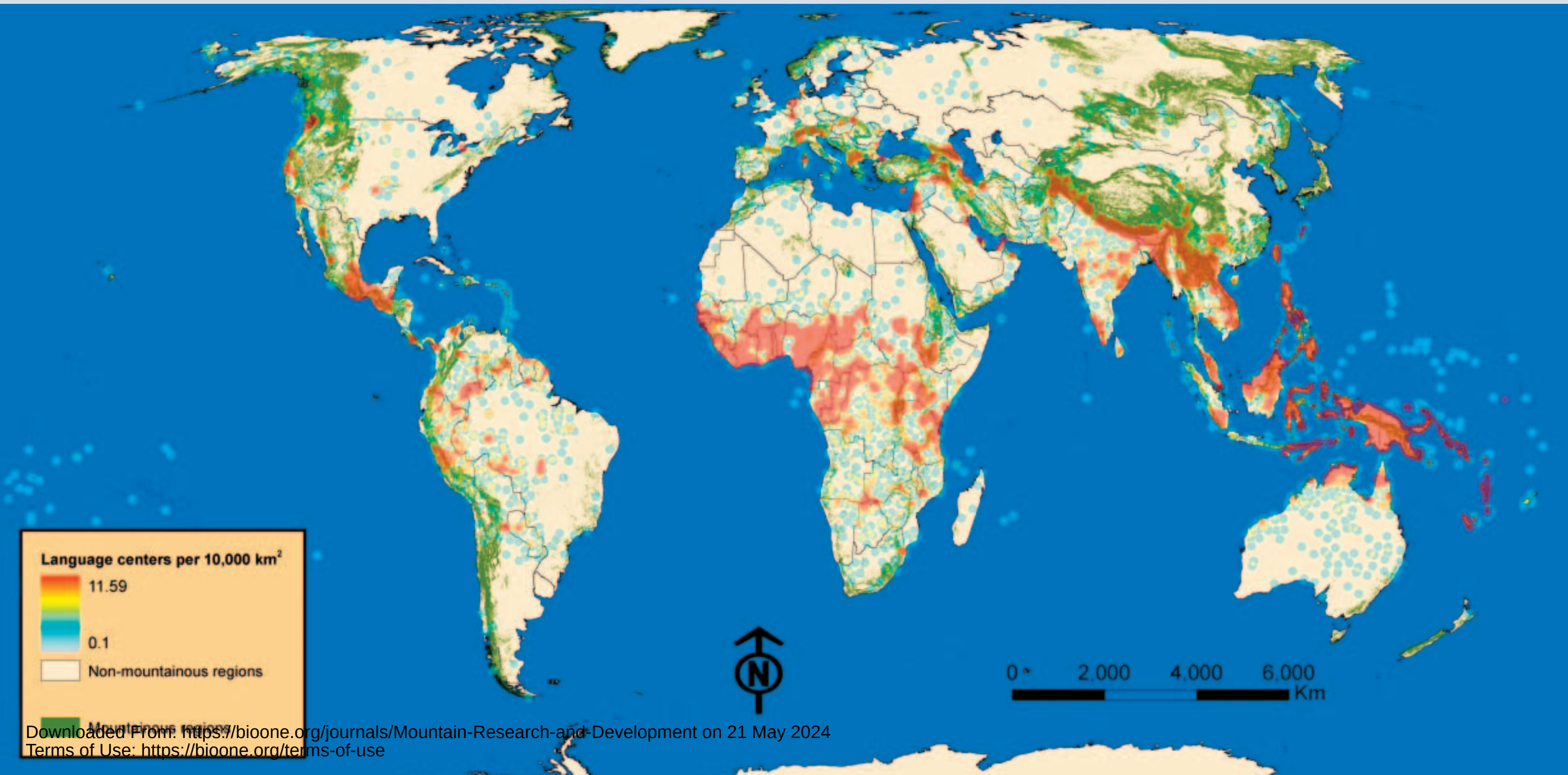
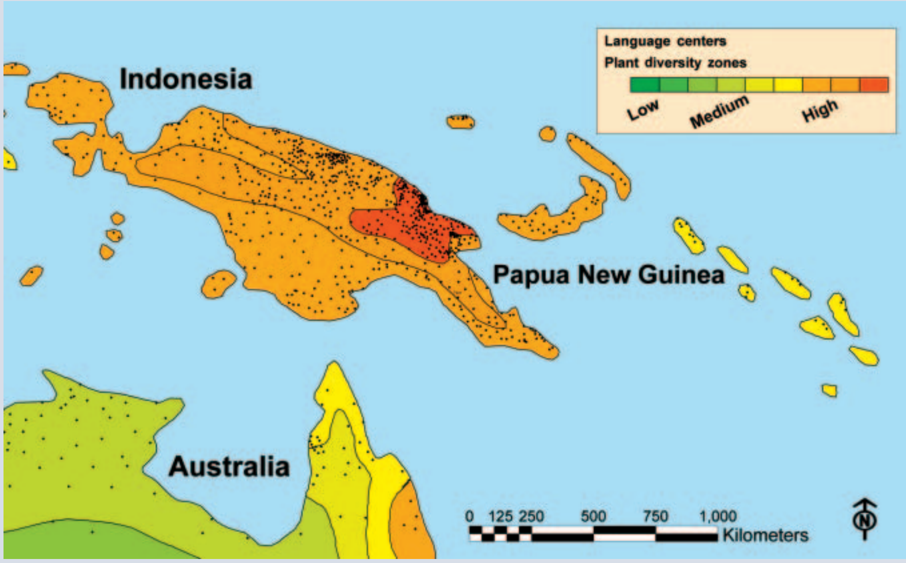


FIGURE 2 Vascular plant and linguistic diversity in New Guinea. (Map by authors)



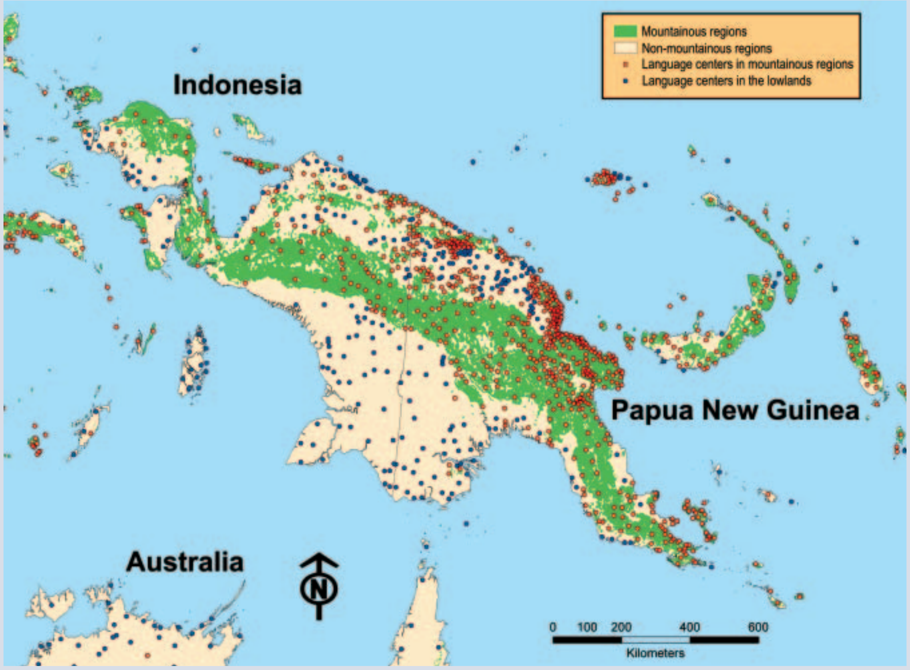


FIGURE 3 Distribution of languages in montane regions in New Guinea. (Map by authors)

tures adapted to them to exist in these relatively small areas. In this way cultures adapted to the rainforest on one side of the Andes could exist within miles of cultures adapted to premontane and montane forests, as well as others adapted to alpine highlands. The abrupt difference in ecological conditions created by the presence of mountains fosters the existence of plants and animals with different survival strategies for each system. Learning to use the different biological resources provided by this ecological gradient is one source of variation in cultural and linguistic diversity. The steep gradient of ecosystems generated by the altitudinal gradient creates conditions of great biocultural diversity. These conditions allow different cultures and ecosystems to exist in close quarters and at the same time serve as obstacles that limit their interaction, preserving great diversity throughout time (Figure 5).

Clearly, the processes of globalization are taking their toll on montane biocultural diversity. Through modern technology, and its increased energy availability, contact among cultures becomes relatively less costly and more frequent. This accessibility also endangers biological diversity in many cases. Easier logging and introduction of invasive species, for example, are results of this. In addition, modern means of communication eliminate the need for physical travel to exchange cultural information. Cultural information (often one way) can now be spread from dominant, high-technology cultures to the traditional, eco-specific cultures of mountainous areas. This uniformity and increase in cultural exchange brought on by modern technology is probably responsible for the loss of cultural diversity in many regions. Even with these technologies present, mountains continue to represent significant barriers (to radio waves, or through higher cost in roads) that promote and preserve biocultural richness.

Future directions

As we continue this research, our major goals are to 1) conclusively demonstrate on a global scale the interrelationships between mountains and biocultural diversity and 2) explore reasons why this relationship occurs, and analyze the factors involved in both change and persistence of biocultural diversity. We have begun work on additional regional projects in mountainous areas, mainly in Mesoamerica and the Greater Himalayan region. Such a regional approach allows for more refined hypotheses and the incorporation of more detailed data. Especially with the regional level projects, we plan to identify patterns using a range of data from biodi-

FIGURE 4 Tobacco merchant in New Guinea. Interestingly, exchange of goods in mountainous areas of the island of New Guinea has not led to loss of linguistic diversity. (Photo courtesy of the authors)

versity inventories to socioeconomic analyses in order to formulate and begin to answer refined hypotheses regarding biocultural diversity. We will explore the role of globalization, population growth, and land use/land cover change in biocultural diversity.

Apart from the theoretical aspects of this project, there are important applied aspects as well. We hope to identify particular regions and cultures where appropriate conservation and development activities can help mitigate the loss of biocultural diversity. For example, throughout the Maya Forest of Belize, Guatemala, and Mexico, researchers from the University of Florida are engaged in collaborative and applied projects that are meaningful to the communities in which the work is being done. The challenges of conservation and development in areas of great cultural diversity are significant because of the need to work in local languages and collaborate across cultures. Complex phenomena such as biocultural diversity can be made more accessible to a broad audience by the development of well-designed and easily understood visual representations such as maps: biocultural diversity maps can serve as invaluable tools for stakeholders, educators and policymakers.

By exploring the relationship between language and biological diversity and investigating potential factors that promote or inhibit biocultural diversity, we hope to enable decision-makers to adopt appropriate policies that will protect and conserve the diverse montane biocultural landscapes throughout the

FIGURE 5 Huli tribesman. New Guinean tribes are a well-known example of extreme cultural diversity in a biologically very diverse environment. (Photo courtesy of the authors)

FIGURE 6 Firewood vendor in New Guinea; sustainable use of resources is a characteristic of mountain communities in this area of the world. (Photo courtesy of the authors)

world, along with assessing their potential for appropriate and sustainable development.

Protection and conservation of biocultural diversity need not imply a static view of culture and landscape, but it is important that communities in areas of rich biocultural diversity can engage in self-determination of their future without undue external cultural impositions (Figure 6).

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