

# Mountain biodiversity in Brazil

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(received: June 17, 2007; accepted: October 19, 2007)

**ABSTRACT** – (Mountain biodiversity in Brazil). The high species richness and diversity found in tropical montane habitats are often related to: 1) an effect of climatic and geological history on biotic evolution; 2) the various environmental impacts on species adaptation mechanisms; and 3) the continuous dispersal of fauna and flora in time. However, little is known about how these factors shaped species richness in Brazilian mountains. Official documents on biodiversity in Brazil make no explicit reference to mountains, even though there is a mountain work programme of the Convention on Biological Diversity, which Brazil is a signatory of. This paper discusses the importance of mountain ecosystems in Brazil to show the urgent need to include mountain biodiversity in the national agenda of biodiversity research and conservation.

**Key words** - Brazilian mountains, Convention on Biological Diversity, mountain biodiversity, nomenclature of neotropical mountains

**RESUMO** – (Biodiversidade de montanhas no Brasil). Os altos graus de riqueza e diversidade de espécies encontrados em montanhas tropicais são frequentemente atribuídos a: 1) ao efeito da história climática e geológica sobre a evolução biótica; 2) aos vários impactos ambientais sobre os mecanismos de adaptação biótica; e 3) à contínua dispersão da fauna e flora no tempo. Entretanto, pouco se sabe acerca de como estes fatores afetaram a riqueza de espécies em montanhas brasileiras. Documentos oficiais disponíveis sobre a biodiversidade brasileira não fazem referência explícita à biodiversidade de montanhas no país, muito embora desde 2002 este tema tenha sido considerado ponto focal na Convenção para a Diversidade Biológica, da qual o Brasil é signatário. O objetivo do presente trabalho é caracterizar a importância dos ecossistemas de montanhas do Brasil e mostrar a necessidade de incluir a biodiversidade de montanhas nas agendas nacionais de conservação e pesquisa científica.

**Palavras-chave** - biodiversidade de montanhas, Convenção da Diversidade Biológica, montanhas brasileiras, nomenclatura de montanhas neotropicais

## Introduction

No universal definition of mountains exists; many different terms are in use, reflecting diverse disciplines, traditions and objectives. The one adopted by the Convention on Biological Diversity describes mountains as follows: “Mountains are characterized by distinctive abiotic, biotic, social, cultural, economic and spiritual values. Structurally, these areas tend to have a combination of the following physical and biological characteristics: elevation, high or slope terrain, diverse climates, a relatively high composition of endemic and native species, and degrees of fragility and remoteness. Functionally, these are water towers of the world and can serve as a refuge for many populations. Mountain regions also tend to be inclusive of lowland communities which depend on the provision of goods and services, such as water, energy, food, timber, wildlife, game recreation and spiritual value” (UNEP/CBD/AHTEG-MB 2003).

Mountain ecosystems occur in all climatic zones of the globe and cover approximately 25% of the planet’s surface. Whilst there are some extensive high chains, mountains are often isolated from one another, and some form visually striking islands, emerging from the surrounding lowlands. Mountains are topographically and geologically highly diversified, which is a causal factor in their high biological diversity (Spehn & Körner 2005). About 12% of the world’s population lives in mountains, which results in moderate to high perturbation regimes.

Biodiversity is a good indicator of mountain ecosystem integrity. A functionally diverse plant cover provides soil stability, reduces erosion and the occurrence of landslides, and contributes to maintaining hydrological properties (Körner 2002). Healthy mountain ecosystems provide harvestable products, form the basis for protection of soil, watersheds and water quality, are an increasingly sought after target for tourism and recreation, and have a rich natural and cultural heritage (Körner & Ohsawa 2005). To reflect the importance of mountain biodiversity to mankind the Eighth Conference of the Parties of the Convention on Biological Diversity (CBD) proposed a Mountain Work Programme (MWP) in 2002

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to reduce global, regional and local loss of mountain biodiversity. Some key features of the MWP include: (i) concentration of biodiversity hotspots in mountain areas, ecosystem diversity, species richness and number of endemic and threatened species; (ii) the fragility of mountain ecosystems and species and their vulnerability to man-made and natural disturbances, particularly in relation to land-use and climatic changes; (iii) the interconnectedness between highlands and lowlands, especially as regards water and soil, and (iv) the high level of cultural diversity, including the key role of indigenous and local communities in conservation and management of biological diversity (UNEP/CDB/AHTEG-MB 2003).

This paper is an overview of mountain research in Brazil – which is often hidden or fragmented – that lists mountain sites and locations that are threatened and/or understudied. Further, I propose the creation of a national programme on mountain biodiversity, so as to protect and produce knowledge about the great biological richness of these habitats.

### Mountain biodiversity

Mountain ecosystems are typically diverse and rich in species, particularly in the tropics (Chaverri-Polini 1998, Sarmiento 2002). This may be attributed to three main factors that have acted at different time scales: biotic evolution in response to climatic and geological history; species adaptations to environmental constraints; and biotic exchanges with the surrounding lowlands (Sarmiento 2002). Thus, both plant migration and *in situ* evolution are essential processes to understand tropical mountain species richness. The high altitude areas of the Itatiaia plateau (Rio de Janeiro, Brazil) provide an interesting example of this combination of causal factors: (1) it became a temperate vegetation island surrounded a tropical rain forest when conditions became warmer after the last glaciation (see Ribeiro *et al.* 2007, in this issue); (2) it has many interesting cases of adaptive histories, such as that of cacti and bromeliads that locally perform C<sub>3</sub> photosynthesis, although they belong to genera that typically display crassulacean acid metabolism (Scarano *et al.* 2001); and (3) some of the species first establish on rocks and subsequently create the necessary substrate for other species to establish, including those originated from the surrounding rain forest (Scarano 2002).

Over the years, there have been various accounts published on the flora and vegetation, and the fauna of several mountain ecosystems (*e.g.*, Hedberg 1969, Weber,

1972, Van Steenis 1974, Löffler 1984, Kitayama 1996). Despite this, there is still a major need for more inventories, particularly in Brazil (but see in this issue Caiafa & Silva 2007, Conceição *et al.* 2007, Felfili *et al.* 2007) and for basic and applied research in view of managing such ecosystems.

Studies on biodiversity in isolated mountains (including high mountain tops) are amenable to applying the theory of island biogeography (MacArthur & Wilson 1967). For instance, Barbará *et al.* (2007) have shown that disjoint distribution patterns and gene flow result in high levels of differentiation for bromeliad populations in inselbergs. Restrictions to gene flow and reduced connectivity between individuals of predominantly out-crossing species suggest that mountain vegetation can indeed be comparable to oceanic islands in this respect.

The isolated nature of many such habitats has also favoured evolutionary studies on endemisms, speciation and adaptation (Chaverri-Polini 1998, Schönswetter *et al.* 2005, Hughes & Eastwood 2006), as well as global-scale comparative studies (Porembski *et al.* 1998, Porembski & Barthlott 2000). Moreover, the biodiversity-ecosystem function paradigm (see overview on this topic in Srivastava & Vellend 2005, Scarano 2007) is highly relevant to mountain biodiversity research (*e.g.*, Quarterman *et al.* 1993, Hopper *et al.* 1997, Shure 1999, Porembski & Barthlott 2000).

Despite the obvious relevance of research on mountain habitats for ecological theory and biodiversity science as a whole, there are still major hurdles to be overcome by mountain research. Habitat heterogeneity and landscape complexity, for instance, remain as challenging features for such studies (Escudero 1996). They often impose methodological difficulties and peculiarities that result in difficulties for comparative studies between sites, or even for the establishment of replicates within a given study site (see Caiafa & Silva 2007 and Ribeiro *et al.* 2007 in this issue).

### Neotropical mountains

Following early explorers in the high mountains of South America (*e.g.*, Humboldt's expedition in 1819, Engler 1910, Mildbraed 1922), the first synthetic works were published on the Andean "páramos" and "punas" by Vuilleumier (1970), Monasterio (1980), and on the Venezuelan "tepui" by Huber & Alarcón (1988), Berry *et al.* (1995), and by Huber (1995). A recent volume covered tropical inselbergs (Porembski & Barthlott 2000). Some of the Neotropical mountains are well known for their high diversity and endemisms, such as some parts of the

Andes (Moraes & Beck 1992, Clark 1995, Gentry 1995, Gradstein 1995, Rangel 1995), some montane forests in Central and South America (Chaverri-Polini 1998) and the “tepui” of the Guiana Shield (see Gröger & Huber 2007, in this issue). However, few comparative studies are available and little is known about ecosystem function and processes in these mountains and their habitats.

The biological characteristics of neotropical mountains are very much influenced by past geological events (*e.g.*, Pleistocene glaciations), as well as present day climatic and edaphic factors (Chaverri-Polini 1998). The occurrence of a cold, temperate climate within a tropical zone is often the basis for the very insular nature of vegetation in such areas, as well as that of the fauna. Air humidity and soil conditions are largely variable among mountains. For instance, in dry, arid mountains, soils are often highly saline, whereas in humid mountains soil acidity and aluminum content tend to be higher (Chaverri-Polini 1998). Therefore, it is not surprising that diverse vegetation types and plant communities occur (table 1, Udvardy 1975, Chaverri-Polini 1998). Thus, the suggestion of Huber & Riina (1997) that an effort should be made to

achieve a single classification system for the neotropics is still in order.

Climate, geomorphology and soil characteristics turn mountain habitats into particularly sensitive environments to human use. The time required for natural regeneration and susceptibility to soil erosion are some of the major constraints (Chaverri-Polini 1998). Human activities may take place over large areas, and include agriculture, foraging by domestic animals, introduction and cultivation of exotic species (*e.g.*, *Pinus*, *Eucalyptus*, *Cupressus*, *Brachiaria*, *Mellinis*), deforestation, burning, illegal extraction of plant species, mining and predatory tourism (*e.g.*, Cavelier & Etter 1995, Chaverri-Polini & Herrera 1996).

### Brazilian mountains

The official documents on biodiversity in Brazil make no reference to mountain biodiversity, although the theme has been considered a focal point of the Convention on Biological Diversity (of which Brazil is a signatory) since 2002. For instance, many of the

Table 1. Regional names of the main vegetation types and plant community physiognomies in Latin American mountains. Altitudes are informed, but precision is difficult due to the immense variation from country to country. Modified from Chaverri-Polini (1998), by adding information from the following sources: Graf (1981), Giuliotti *et al.* (1987), Dezzio & Huber (1995), Doumenge *et al.* (1995), Kapelle (1996), Martinelli (1996), Chaverri-Polini & Herrera (1996), Almeida-Leñero (1997), Chaverri-Polini & Cleef (1997), Huber & Riina (1997), Muñoz & Bonacic (2006), Altmann (2006).

| Vegetation type                        | Description  | Countries (biomes)                                      |
|--|--|---|
| “Páramo”                               | Top of mountains (3,000-4,500 m a.s.l.); canopy height up to 2m; typical plant groups: Poaceae, Cyperaceae, Asteraceae, Rosaceae, Ericaceae, Apiaceae, <i>Swallenochloa</i> , <i>Espeletia</i> . | Costa Rica, Panama, Colombia, Venezuela, Ecuador, Peru. |
| “Puna”                                 | High part of the Andes (above 3,400 m a.s.l.); herbs (Poaceae, Cyperaceae) and some shrubs; climate cold and relatively dry.   | Peru, Bolivia, Chile, Argentina.                        |
| “Campos Alpinos (zacatonal)”           | Vegetação das montanhas vulcânicas (> 3,800 m.a.s.l.)  | Mexico, Guatemala                                       |
| “Campos de Altitude da Mata Atlântica” | Mountains of the Atlantic Forest (1,200-2,900 m a.s.l.); shrubs and herbs: Asteraceae, Melastomataceae, Orchidaceae Bromeliaceae, <i>Trilepsis</i>   | Brazil (Atlantic forest)                                |
| “Campos Rupestres”                     | Cerrado mountains (1,000-2,000 m a.s.l.); shrubs and herbs: Asteraceae, Xyridaceae, Velloziaceae, Cyperaceae, Melastomataceae  | Brazil (“Cerrado”)                                      |
| “Campos de Altitude da Amazônia”       | Amazonian mountains (1,600-2,900 m a.s.l.); shrubs and herbs: Melastomataceae, Poaceae, Bromeliaceae (in northern Amazon it resembles the Venezuelan “tepui”)                                    | Brazil (“Amazonia”)                                     |

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| Vegetation type   | Description   | Countries (biomes)   |
|---|---|--|
| “Tepuis”  | Mountain (1,400-3,000 m a.s.l.) vegetation complex: forests, shrubby, herbaceous and savannic forms; Poaceae and Bromeliaceae   | Venezuela and Brazil   |
| Peat Bog (no regional name; it is a variation of “Bofedal”) | Azonal vegetation (3,500-4,900 m a.s.l.) in flooded and poorly drained areas (peat bog): Cyperaceae, Juncaceae, Ericaceae, <i>Sphagnum</i>  | Costa Rica, Colombia, Peru, Bolivia, Chile, Argentina, Venezuela                           |
| “Bofedal”   | Azonal vegetation (3,000-5,500 m a.s.l.) in flooded areas (marshland), characterized by the presence of hard cushion plants; <i>Plantago</i> , <i>Distichia</i> , Cyperaceae                    | Bolivia, Chile, Peru   |
| “Arrayan”   | Ecotone between the “páramos” and the Andean forests (various altitudes) characterized by Ericaceae shrubs.   | Costa Rica, Colombia, Chile  |
| “Queñoa”  | Dwarf upper montane forest, with small trees and treelets with distorted trunks. Altitude: from 4,000 m a.s.l.; abundance of epiphytes on <i>Polylepis</i> .                                    | Bolivia, Colombia, Peru, Chile   |
| Andean Montane Forest                                       | Lower montane, evergreen forest; very humid; many epiphytes; common plants: <i>Weinmannia</i> , <i>Podocarpus</i> , <i>Polylepis</i> , Ericaceae and Araliaceae. Altitudinal range is variable. | Colombia, Ecuador, Peru, Bolivia, and other countries of the Andean range                  |
| Andean fringe Forest (chaparral)                            | Highland vegetation between the “páramos” and the Andean forests, characterized by coriaceous leaves and heavily thorned dwarf shrubs. Altitudinal range is variable.                           | Ecuador and other countries of Andean range)   |
| “Yungas”  | Xeromorphic, shrubby, latifoliate (400-3,000 m a.s.l.). Sub-tropical montane deciduous and evergreen forests which flank the eastern slopes and valleys of the Andes                            | Peru, Bolivia, Argentina.  |
| Cloud forest  | Various forests, occurring along several altitude ranges. Humid and cloudy throughout the year. Lauraceae, Myrtaceae, Melastomataceae, Ericaceae and many epiphytes.                            | Porto Rico (low altitudes), El Salvador, Costa Rica, Colombia, Venezuela, Bolivia, Brazil. |
| Montane forest  | Forest-type vegetation, which varies according to the region where it is located.   | All countries  |
| Shady Montane Forest  | Altitudinal forest with intermediate height; (1,800-2,800 m a.s.l.) humid; many epiphytes, Podocarpaceae, Araliaceae, <i>Alnus</i> , <i>Brunellia</i> and <i>Weinmannia</i> .                   | Venezuela  |
| Conifer forest  | Intermediate altitude (1,000-3,000 m a.s.l.): <i>Pinus</i> , <i>Juniper</i> , <i>Abies</i> and <i>Cupressus</i> .   | Mexico, Guatemala, Honduras, El Salvador, Nicaragua, Chile, Venezuela                      |
| <i>Pinus</i> and oak forest                                 | Intermediate altitude (900-1,600 m a.s.l.): <i>Quercus</i> and <i>Pinus</i> .   | Mexico, Guatemala, Honduras (in low altitudes), Nicaragua.                                 |
| Oak forest  | Forest with predominance of trees of the genus <i>Quercus</i> , <i>Chletra</i> , <i>Ilex</i> , <i>Styrax</i> , Lauraceae, Araliaceae and many epiphytes (1,600-2,800 m a.s.l.)                  | Mexico, Guatemala, Honduras, Nicaragua, Colombia.  |

priority areas for biological inventories and creation of conservation units for various Brazilian biomes, designated by using general criteria mostly related to their forest remnants and/or scenic beauty status (MMA 2002), are montane sites. The importance and ecological singularity of mountains by itself has not been considered.

Existing mountain areas are treated as part of other biomes or biogeographic regions (*e.g.*, MMA 1998, 2000, 2004, 2006; table 2). This is perhaps the legacy of past focus on other biomes and conservation priorities in lowland ecosystems, where large-scale land use has been concentrated. However, it is important to realize the importance of mountain systems, both ecologically and economically and allocate resources for their study and management for long-term provision of ecosystem services.

The highest mountain ranges in Brazil are found in the Amazon (states of Amapá, Amazonas, Pará and Roraima) and the Atlantic forest biomes (“Serra da Mantiqueira”; *e.g.* Benites *et al.* 2007, Ribeiro *et al.* 2007). However, most mountain biodiversity research in Brazil is concentrated in elevations within the “cerrado” biome (“campos rupestres”; *e.g.*, Coelho *et al.* 2007, Figueira & Del Sarto 2007, Medina & Fernandes 2007, Velten

& Garcia 2007), and in the “campos de altitude” of the Atlantic Rainforest biome (Martinelli 1996, Porembski *et al.* 1998, Safford 1999, Safford & Martinelli 2000, Caiafa & Silva 2007, Ribeiro *et al.* 2007). This pattern repeats itself in the present special issue: none of the studies published here are set in the Brazilian Amazon, and most concentrate within the “cerrado” and the Atlantic forest biomes. This must be urgently reversed, given the high number of rock outcrops and/or high altitude areas within the Amazon and the “caatinga” biomes (table 2).

### Conservation needs of mountainous areas in Brazil

Although most Brazilian mountain chains and inselbergs are at least partly covered by conservation units (MMA 2002, Machado *et al.* 2004, Rylands & Brandon 2005), most such protected areas still lack specific conservation and management plans that would take into account the peculiarities of mountain environments. Thus, various mountain regions, particularly those within the biomes Atlantic forest, “cerrado” and “caatinga”, are largely degraded or threatened. The main threats are common to other mountain habitats in the neotropics:

Table 2. Brazilian mountains with partial or total absence of biological information in each major biome: (\*) areas selected based on the document “Biodiversidade Brasileira: Avaliação e Identificação de Áreas e Ações Prioritárias para a Conservação, Utilização Sustentável e Repartição de Benefícios da Biodiversidade Brasileira – Vegetação” (MMA 2002); (\*\*) author’s personal observations. States: PA = Pará; AP = Amapá; AM = Amazonas; RR = Roraima; AC = Acre; PI = Piauí; CE = Ceará; RN = Rio Grande do Norte; PE = Pernambuco; PB = Paraíba; BA = Bahia; ES = Espírito Santo; MG = Minas Gerais; RJ = Rio de Janeiro; MT = Mato Grosso; TO = Tocantins; GO = Goiás; SC = Santa Catarina; RS = Rio Grande do Sul. (CU = conservation unit; H = highly important; E = extremely important; 0 = no information available. Regional terminology has been maintained. Equivalents in English to Portuguese terminology are: “serra” = mountain range; “alto” = high elevation; “pico” = peak; “monte” = mount; “morro” = mountain; “rio” = river; “pedra” or “rochedo” = stone or rock, “chapada” = mountain plain.)

| Biome/site/location                       | State | Priority actions                       | Importance |
|---|-------|--|------------|
| <b>Amazon</b>                             |       |  |            |
| “Serra do Divisor”**                      | AC    | Inventory                              | H          |
| “Alto Rio Juruá”*                         | AC    | Restoration, inventory, management     | E          |
| “Tepui Surucucu”*                         | RR    | Inventory, creation of CU, management  | H          |
| “Tepui Serra da Ufaranda”*                | RR    | Inventory, creation of CU              | H          |
| “Monte Roraima”*                          | RR    | Restoration, inventory, creation of CU | E          |
| “Pico da Neblina and adjacent mountains”* | AM    | Restoration, inventory, management     | E          |
| “Rio Içana”*                              | AM    | Restoration, inventory, management     | E          |
| “Serra Igarapé-Pégua”*                    | AM    | Restoration, inventory, management     | E          |
| “Tepui Serra do Araçá”*                   | AM    | Inventory                              | E          |
| “Pico 31 de Março”**                      | AM    | Inventory                              | E          |
| “Morro dos Seis Lagos”*                   | AM    | Inventory                              | E          |
| “Inselbergs Rio Curicuriare”**            | AM    | Inventory, creation of CU              | E          |
| “Serra Imeri”*                            | AM    | Inventory, creation of CU              | E          |

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| Biome/site/location  | State | Priority actions                      | Importance |
|--|-------|---------------------------------------|------------|
| “Serra de Tapirapecó”*   | AM    | Inventory                             | E          |
| “Alto Jari e Amapari”*   | PA/AP | Inventory, creation of CU, management | E          |
| “Inselbergs da Serra do Tumucumaque”**   | PA/AP | Inventory                             | E          |
| “Serra dos Carajás”*   | PA    | Inventory, creation of CU, management | E          |
| “Serra de Maicuru”*  | PA    | Inventory, creation of CU, management | H          |
| “Inselbergs Rio Parú Doeste”*  | PA    | Inventory, creation of CU             | E          |
| “Granitoides do Rio Mapuera”*  | PA    | Inventory, creation of CU             | H          |
| <b>“Caatinga”</b>  |       |                                       |            |
| “Serra do Estevão”*  | PI    | Inventory                             | E          |
| “Serra das Confusões”**  | PI    | Inventory                             | E          |
| “Serra Vermelha”**   | PI    | Inventory                             | E          |
| “Serra das Almas”**  | PI/CE | Inventory                             | H          |
| “Serra das Flores”**   | CE    | Inventory                             | E          |
| “Pico do Cabugi”*  | CE    | Inventory                             | 0          |
| “Serra de Santana”*  | CE    | Inventory                             | 0          |
| “Rochedo de Serra Caiada”**  | CE    | Inventory                             | 0          |
| “Serra de Porto Alegre”**  | CE    | Inventory                             | 0          |
| “Serra de Santa Catarina”*   | RN    | Inventory                             | H          |
| “Monte Horebe”*  | PB/CE | Inventory                             | H          |
| “Buique”**   | PE    | Inventory                             | H          |
| “Chapada do Araripe”*  | PE    | Inventory                             | E          |
| “Serra do Ororubá”**   | PE    | Inventory                             | E          |
| “Inselbergs of Triunfo”**  | PE    | Inventory                             | E          |
| “Inselbergs of Vale de Ipojuca”**  | PE    | Inventory, creation of CU             | E          |
| “Inselbergs of Quipapá”**  | PE    | Inventory, creation of CU             | E          |
| “Inselbergs of Brejo da Madre de Deus”**   | PE    | Inventory, creation of CU             | E          |
| “Serra Talhada”*   | PE    | Inventory                             | E          |
| “Serra do Açuruá”**  | BA    | Inventory                             | E          |
| “Chapada Diamantina”*  | BA    | Finalize inventory                    | E          |
| “Calcarium outcrops at the margin of Rio São Francisco in the vicinities of Januária”* | MG    | Inventory                             | E          |
| <b>“Cerrado”</b>   |       |                                       |            |
| “Serra do Cachimbo”**  | MT    | Finalize inventory                    | E          |
| “Serra da Petrovina”**   | MT    | Inventory, creation of CU             | E          |
| “Afloramentos Sitio Santa Felina”**  | MT    | Inventory                             | H          |
| “Serra dos Caiabis”**  | MT    | Inventory                             | E          |
| “Serra das Araras e Serra Azul”**  | MT    | Inventory                             | E          |
| “Chapada dos Guimarães”*   | MT    | Inventory                             | E          |
| “Serra Ricardo Franco”**   | MT    | Inventory                             | E          |
| “Lageados de arenito de Rondonópolis”**  | MT    | Inventory, creation of CU             | E          |
| “Serra em Miracema do Tocantins”**   | TO    | Inventory                             | H          |
| “Serra do Lajeado”**   | TO    | Inventory, creation of CU             | E          |
| “Alto do Araguainha”**   | GO/MT | Inventory, creation of CU             | E          |
| “Serra Geral de Goiás”**   | GO/BA | Inventory                             | E          |
| “Serra da Mesa”**  | GO    | Inventory                             | E          |
| “Serra do Pirineus”**  | GO    | Inventory, creation of CU             | E          |
| “Chapada dos Veadeiros”**  | GO    | Finalize inventory                    | H          |
| “Pedra Menina”**   | MG    | Finalize inventory                    | E          |
| “Serra da Bodoquena”**   | MS    | Inventory                             | E          |

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| Biome/site/location                             | State | Priority actions            | Importance |
|---|-------|-----------------------------|------------|
| <b>Atlantic forest</b>                          |       |                             |            |
| “Pico do Jabre”***                              | PB    | Inventory, creation of CU   | H          |
| “Inselbergs of Jaqueira”***                     | PE    | Inventory, creation of CU   | E          |
| “Inselbergs of Serra da Naceia”***              | AL    | Inventory, creation of CU   | E          |
| “Serra Lisa”***                                 | AL    | Inventory, creation of CU   | E          |
| “Ipirá / Serra do Orobó”***                     | BA    | Inventory                   | E          |
| “Pico do Barbado”***                            | BA    | Inventory (transition area) | H          |
| “Inselbergs de Itamaraju”***                    | BA    | Inventory, creation of CU   | E          |
| “Serra da Lontra”***                            | BA    | Inventory                   | E          |
| “Serra da Panelinha”***                         | BA    | Inventory                   | E          |
| “Serra da Jibóia”***                            | BA    | Inventory                   | E          |
| “Serra do Ramalho”***                           | BA    | Inventory                   | H          |
| “Pedra Azul”*                                   | MG/BA | Inventory                   | E          |
| “Inselbergs Teófilo Otoni”***                   | MG/BA | Inventory, creation of CU   | E          |
| “Serra do Brigadeiro”***                        | MG    | Inventory                   | E          |
| “Pedra Dourada”***                              | MG    | Inventory                   | H          |
| “Serra de Ibitipoca”***                         | MG    | Inventory                   | E          |
| “Serra de Aiuruoca”***                          | MG    | Inventory                   | E          |
| “Inselbergs de Pancas”***                       | ES    | Inventory, creation of CU   | E          |
| “Inselbergs Santa Teresa”***                    | ES    | Inventory                   | H          |
| “Inselbergs da Região Serrana ES”***            | ES    | Inventory                   | H          |
| “Inselbergs Cariacica-Vitória”***               | ES    | Inventory                   | E          |
| “Inselbergs Cachoeiro do Itapemirim-Alegre”***  | ES    | Inventory, creation of CU   | E          |
| “Inselbergs Forno Grande”***                    | ES    | Inventory                   | E          |
| “Serra das Torres”***                           | ES    | Inventory                   | E          |
| “Pico do Frade de Angra”***                     | RJ    | Inventory                   | E          |
| “Pedra do Desengano”*                           | RJ    | Inventory                   | E          |
| “Inselbergs do NE do RJ”***                     | RJ    | Inventory                   | E          |
| “Serra dos Três Picos”***                       | RJ    | Inventory                   | E          |
| “Inselbergs de Morro do Coco”***                | RJ    | Inventory                   | E          |
| “Inselbergs de Bom Jardim”***                   | RJ    | Inventory                   | E          |
| “Serra da Bocaina”*                             | SP/RJ | Inventory                   | E          |
| “Pico do Corcovado”***                          | SP    | Inventory                   | 0          |
| “Pedra da Mina, Cupim de Boi e Três Estados”*** | SP    | Inventory                   | 0          |
| “Pico Itaguaré e Marins”***                     | SP    | Inventory                   | E          |
| “Maciço da Pedra do Baú”***                     | SP    | Inventory                   | E          |
| “Conjunto de Serras Marumbi”***                 | PR    | Inventory                   | E          |
| “Serra Capivari Grande”***                      | PR    | Inventory                   | E          |
| “Serra Ibitiraquire”***                         | PR    | Inventory                   | E          |
| “Serra da Graciosa”***                          | PR    | Inventory                   | E          |
| “Serra da Farinha Seca”***                      | PR    | Inventory                   | E          |
| “Serra do Iquererim”***                         | PR    | Inventory                   | E          |
| “Serra do Leão”*                                | PR    | Inventory                   | E          |
| “Serra dos Castelhanos”***                      | PR    | Inventory                   | E          |
| “Serra de Araçatuba”***                         | PR    | Inventory                   | E          |
| “Serra de São Luiz do Purunã”***                | PR    | Inventory                   | E          |
| “Serra da Anta Gorda”*                          | SC    | Inventory                   | E          |
| “Serra do Rio do Rastro”***                     | SC    | Inventory                   | E          |
| “Serra Furada”*                                 | SC    | Inventory                   | E          |
| “Serra do Tabuleiro”***                         | SC    | Inventory                   | E          |
| “Serra Geral”***                                | SC/RS | Inventory                   | H          |
| “Campos de Cima da Serra”***                    | RS    | Inventory                   | E          |
| “Aparados da Serra”*                            | RS    | Inventory                   |            |

sensitivity of soils to anthropogenic activities, promoting erosion and instability; removal of buffer vegetation in surrounding areas facilitating invasibility; low competitive capacity of the local flora *versus* invaders; fire and burning; intense extraction of attractive species of the flora that are often endemic or rare; mining (granite, gneiss, sandstone); urban expansion; high altitude agriculture (*e.g.*, coffee cultivation in some parts of the state of Espírito Santo may reach up to 1,200 m a.s.l., at the foot of the rock outcrops); installation of energy transmission and communication facilities; difficulties regarding law enforcement and protection, monitoring, restoration, and *ex-situ* conservation; high susceptibility to climate change.

Conservation planning should account for the distinct communities and life zones within the mountain range, particularly in regard to altitude. Regional and national borders might require bilateral partnerships for entire ecosystem conservation and integrity, since mountains are often used as geopolitical limits between countries, states and municipalities (World Bank 2002). Other official priorities are sustainable use of the biodiversity, establishment of biological corridors, reforestation of deforested mountains (CCAD/CCAB-AP/FAO 1997) and promotion of natural regeneration in areas used for pasture (World Bank 2002).

In order to include mountain ecosystems in the Brazilian agenda of conservation of biological diversity and to promote the necessary actions for preserving mountain regions, I have suggested ten actions in a report to the Secretary to Forestry and Biodiversity of the Brazilian Ministry for Environment – SBF/MMA (Martinelli 2003): (1) to establish a National Programme for Mountain Research and Conservation, in a partnership between the Brazilian Ministry for Environment and Ministry for Science and Technology (see table 3 for a list of ongoing international programmes); (2) to promote the articulation of multidisciplinary work groups to integrate scientific knowledge available on Brazilian mountains, organizing a database with open access; (3) to promote biological inventories in unknown or under-explored areas (see table 2); (4) to explicitly include mountain ecosystems in the national policy for biodiversity; (5) to create a research and conservation fund for mountain biodiversity, with emphasis in biological inventories; (6) to prepare an action plan for mountain conservation and sustainable development; (7) to set as a priority the restoration of degraded buffer areas, with particular emphasis in the Atlantic forest biome; (8) to foster an integrated management plan to reconcile integrity of hydrographic basins, urban

Table 3. Examples of ongoing international programs concerned with a global evaluation of richness of mountain biota its causes and its changes in time. Note that most such initiatives focus on mountain ecosystems of Europe, North America and Asia.

| Programs and Agencies   | Host country  |
|---|---|
| Alpine Convention   | Innsbruck, Austria  |
| Centre for Mountain Studies   | Perth, United Kingdom   |
| “Consortio para el Desarrollo de la Ecoregion Andina” (CONDESAN)  | Peru (including over 85 institutions and organization of the Andean countries of Argentina, Bolivia, Colombia, Chile and Ecuador) |
| Food and Agriculture Organization (FAO)   | Rome, Italy   |
| Global Mountain Biodiversity Assessment (GMBA), which is part of “Diversitas” (an international agency for the development of biodiversity research on mountains) | Basel, Switzerland  |
| International Centre for Integrated Mountain Development (ICIMOD)   | Kathmandu, Nepal  |
| International Partnership for Sustainable Development in Mountain Regions   | Hosted by FAO (Rome, Italy)   |
| International Mountain Society  | Berne, Switzerland  |
| International Union of Forest Research Organizations (IUFRO)  | Vienna, Austria   |
| Mountain Research Initiative (MRI)  | Zurich, Switzerland   |
| Mountain Forum  | Kathmandu, Nepal  |
| Mountain Partnership  | Rome, Italy   |
| World Conservation Monitoring Centre (WCMC)   | Cambridge, United Kingdom   |



expansion and agriculture in mountain, identifying the best practices to avoid degradation and to guarantee stability and maintenance of ecological services; (9) to revise and analyse the network of protected areas in mountain regions; and finally (10) to promote training and formation of personnel involved with mountain habitats.

Considering both the evidences of human impacts on Brazilian mountain and the insufficiency of current knowledge available of ecological systems, it seems necessary and urgent to establish a national program aiming to understand and protect their complexity and functioning. This issue is directly related to at least two other topics already included in the Brazilian biodiversity agenda: sustainable forestry and water resources. A national mountain biodiversity program might integrate and further incentive ongoing efforts of institutions and scientists, such as those reported in this special issue.

Acknowledgements – I thank Laszlo Nagy and Masresha Fetene who revised and made substantial contributions to this paper; Fabio R. Scarano for encouragement and linguistic advice; Miguel d'Ávila de Moraes for assistance with data and vivid discussions about the topic; and Bráulio F. S. Dias and Paulo Y. Kageyama for debates about the idea of creating a national program on mountain biodiversity.

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