Global Change and the World's Mountains

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Global Change and the World's Mountains

Where Are We Coming From, and Where Are We Going To?

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The history of mountain research is most fascinating. Three names for 3 centuries may give an idea of the growing knowledge about the world's mountains: Horace Bénédict de Saussure, who climbed and studied the Mont Blanc in 1787; Alexander von Humboldt, ever investigating the environment during his attempt to ascend the Chimborazo in 1802; and Carl Troll, who founded the International Geographical Union's Commission on High-altitude Geoecology in 1968. Awareness of the growing impact of human activities on the environment led to scientific and political initiatives at the global level, beginning in the 1970s. The Perth conference in 2010 has offered an opportunity to both look back on these developments and explore the future of the world's mountains in a time of rapidly growing "global change" problems and processes.

Keywords: *Mountains; global change; fragile ecosystems; sustainable development; Rio 1992; Rio 2012; science–policy dialogue.*

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Three decisive impulses for the global environment and the world's mountains in the early 1970s

Founded in November 1971, the worldwide program of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) on Man and the Biosphere (MAB) at the time consisted of 14 different projects, covering the world's main ecosystems. Among them, Project 6 was entitled "Impact of Human Activities on Mountain Ecosystems." In 1973, a small group of experts met in Salzburg, Austria, and under the auspices of several outstanding strategic thinkers of UNESCO created a research concept for this mountain project. In the years that followed, the project provided a great stimulus to overcome the large gap between the natural and the social sciences and to develop methods and models for inter- and transdisciplinary approaches and collaborations (UNESCO 1973; Messerli and Messerli 2008).

The United Nations (UN) Conference on the Human Environment held in June 1972 in Stockholm—the first conference of the UN devoted entirely to environmental issues—mentioned and confirmed the MAB program under various headings. Although no specific reference to mountains was made, the recommendations in the final declaration were stimulating for subsequent mountain initiatives and conferences. They stated, for example, that "scientific research and development […], both national and multinational, must be promoted […], especially in developing countries"; "Cooperation through multilateral or bilateral arrangements […] is essential to effectively control, prevent, reduce and eliminate adverse environmental effects"; "the free flow of up-to-date scientific information and transfer of experience must be supported and assisted"; and "the natural resources of the earth […] must be safeguarded for the benefit of present and future generations" (United Nations 1972).

In the same year, the Club of Rome published *The Limits to Growth* (Meadows et al 1972). Provoking both criticisms and endorsements worldwide, this book offered a description of the risks and limits of exponential growth in demography, economy, and technology that was interesting at a time when the idea of sustainability had not yet become common knowledge. A look at global population statistics can serve to illustrate the book's relevance: according to the UN Population Division, the world population increased from about 3.8 billion in 1972 to about 6.1 billion in 2000 (United Nations 2011).

These three global impulses prompted a series of mountain initiatives. In 1974, for example, a conference in Trento, Italy, explored "The Future of the Alps" (Stone 2002), while an international workshop in Munich focused on "The Development of Mountain Environment: An Interdisciplinary Approach for a Future Strategy" (Müller-Hohenstein 1974). This global concept of mountain development envisioned selected pilot projects in the developing world to establish demonstration sites for environmentally sound development. However, both the Trento and the Munich initiatives failed. The visions developed at the Stockholm conference concerning regional and global cooperation had not yet been understood. The only successful global mountain initiatives were UNESCO's MAB mountain project, which began after 1973, and the "Highland–Lowland Interactive System Project" of the United Nations University (UNU), which began in 1978; they owed their

success to the fact that they respected national borders and involved national scientific and political institutions and authorities in their activities.

Beginning in the 1980s: regional cooperation in science and policy

The next decade began with a future-oriented initiative. *Mountain Research and Development*, a quarterly journal founded in 1981 by Jack Ives, with strong support from Pauline Ives, became the most important instrument of communication in the beginning of regional and global cooperation on mountain research and development.

Several initiatives for regional cooperation on mountains followed in various regions of the world. Table 1 shows the main initiatives in the Himalaya, Africa, the Andes, and Europe before and after the so-called "Earth Summit" in Rio de Janeiro in 1992. The dates listed in the first column refer to the official foundation of the various organizations, but the related initiatives began earlier, the majority dating back to the 1980s or 1970s. The International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal, provides an interesting example. Only 3 years after the UN Stockholm conference, the first and conflictual MAB conference on "Integrated Ecological Research and Training Needs in the Southern Asian Mountain Systems, Particularly the Hindu Kush–Himalayas" held in 1975 in Nepal recommended establishing in Kathmandu a "Regional Institute for Integrated Mountain Development" (UNESCO 1975). It would go beyond the scope of this article to discuss all the political difficulties and negotiations that followed until the official inauguration of ICIMOD in Kathmandu 8 years later, in 1983. Similarly, the foundation of the African Mountain Association and the Andean Mountain Association was preceded in both cases by 3 to 4 years of serious scientific fieldwork before it was possible to organize an international conference and offer an instructive field excursion. This shows that most of these regional initiatives were more or less influenced by the significant recommendations and declaration of the 1972 UN Conference on the Human Environment.

A look at the different forms of organization adopted by the various initiatives is most interesting, as they reveal the different scientific and political ideas from which the initiatives emerged. ICIMOD is an intergovernmental organization, proposed by UNESCO and supported by Germany and Switzerland. It was fascinating to see numerous UN and other international organizations represented at the international symposium and inauguration ceremony in 1983: UNESCO, the UN Food and Agriculture Organization (FAO), the United Nations Environment Programme (UNEP), UNU, the United Nations Children's Fund (UNICEF), the International Union for Conservation of Nature (IUCN), the World Bank, and many others had come to send out a positive signal and raise awareness of the world's mountains (ICIMOD 1984). The African and Andean mountain associations were science- and development-oriented organizations that had no permanent secretariat or infrastructure due to a lack of funds. They were the first to produce modern knowledge about mountains in Africa and South America and inspired numerous personal relationships across national borders. However, the lack of a strong organizational structure led to a standstill after 5 or 6 conferences (see Table 1). The Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN) and the African Highlands Initiative (AHI) had a longer-term structure at their host institutions in the framework of the Consultative Group on International Agricultural Research (CGIAR), with different results: CONDESAN has now become a separate organization, whereas the AHI has ceased to exist.

The last two organizations listed in Table 1 are the Alpine and the Carpathian conventions. They are based on political agreement between their member states as a secure base for transboundary and transdisciplinary cooperation in mountain research and development. New movements towards a mountain convention have recently emerged in the Caucasus as well as southeastern Europe, where cooperation began in 2011 based on the so-called "Dinaric Resolution."

How important was the impact of the earlier regional initiatives on the 1992 Rio conference and its Agenda 21? Table 1 gives an indication of how many countries were informed about the upcoming "Earth Summit" and took part in the preparatory conferences, especially the third one held in Geneva in October 1991. It was overwhelming to meet mountain friends there as scientific or political members of different national delegations, from Nepal, Ethiopia, Peru, and many other countries; they were spontaneously willing to intervene for a special mountain chapter in Agenda 21. The first initiatives for regional cooperation on mountains were thus fundamental in achieving a positive decision on a mountain chapter in Agenda 21, and this success in Geneva was by no way an intervention of Switzerland and the UNU alone. Behind it stood a whole community of persons who were willing to prove that the world's mountains with their resources and ecosystem services have a significant role to play in the context of rapidly growing natural and human-induced "global environmental change."

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TABLE 1 The beginning of regional cooperation on mountains in science and policy.

Year	Places	Organizations	Members, main activities
1983	Kathmandu	ICIMOD: International Centre for Integrated Mountain Development	Member countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan
1986	Addis Abeba	African Mountain Association	Conferences: Ethiopia 1986, Morocco 1990, Kenya 1993, Madagascar 1997, Lesotho 2000, Tanzania 2002
1991	Santiago	Andean Mountain Association	Conferences: Chile 1991, Bolivia 1995, Ecuador 1998, Venezuela 2001, Argentina 2004
1992	Lima	CONDESAN: Consortium for the Sustainable Development of the Andean Ecoregion	175 members, including NGOs, universities, international research centers, and others; hosted by the International Potato Center (CIP) until 2009, now independent
1995	Nairobi	AHI: African Highlands Initiative, East Africa Ecoregional Program	Member countries: Kenya, Uganda, Tanzania, Madagascar, Ethiopia; hosted by the International Centre for Research in Agroforestry (ICRAF); AHI has ceased to exist
2000	Bishkek	UCA: University of Central Asia	Member Countries: Tajikistan, Kyrgyz Republic, Kazakhstan (Aga Khan Development Network)
Conventions			
1991	Salzburg	Alpine Convention, entered into force in 1995	Member countries: Austria, France, Germany, Italy, Liechtenstein, Switzerland, and the European Union
			Later: Slovenia 1993 and Monaco 1994
2001	Kiev	Carpathian Convention, entered into force in 2006	Member countries: Czech Republic, Hungary, Poland, Romania, Serbia, Slovak Republic, Ukraine

Beginning in the 1990s: global cooperation in science and policy

The 1990s began with a high-level scientific conference in Vienna in November 1991, organized by the International Council of Scientific Unions (ICSU). The aim of this conference on "An Agenda of Science for Environment and Development Into the 21st Century" was to prepare the necessary scientific knowledge for the upcoming "Earth Summit" in Rio. Mountains found only a marginal mention, in recommendation 40: "Attention should be paid to integrated regional studies of vulnerability in fragile ecosystems (e.g. in mountains) or where environmental degradation threatens human well-being and capacity to respond" (ICSU 1992: 10).

The 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro was not only a continuation of the 1972 UN Conference on the Human Environment in Stockholm, but—more importantly—also the beginning of a new way of thinking about global problems and global cooperation. A look at when and where the world's mountains featured on the global scientific agenda (Table 2) indicates that UNESCO and UNU understood the significance of mountains and their resources long before the Rio conference. The World Glacier Monitoring Service (WGMS) was also founded years before the Rio conference and independently of it, in cooperation with the World Climate Research Programme (WCRP). By contrast, the four major global programs on the environment—the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the international program on biodiversity science (DIVERSITAS), and the International Human Dimensions Programme on Global Environmental Change (IHDP)—started out with no special attention given to mountains. Indeed, it was only several years after the Rio conference that mountains were given their due place in these research programs.

In the years following Rio, the world's mountains gained a new significance based on Chapter 13 in Agenda 21, entitled "Managing Fragile Ecosystems: Sustainable Mountain Development" (United Nations 1992), but also owing to the strong mountain intervention 5 years later at the 1997 UN Special Session of the General Assembly "to Review and Appraise the Implementation of Agenda 21," backed up by the

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TABLE 2 The world's mountains on the global scientific agenda.

Year	Place	Program	Comments, key references
1991	Vienna	ICSU (International Council of Scientific Unions): Conference in preparation of Rio 1992	*An Agenda of Science for Environment and Development into the 21st Century* (ICSU 1992)
Mountain contributions to global programs			
1971	Paris	MAB: UNESCO Man and the Biosphere program	Project 6: Impact of Human Activities on Mountain Ecosystems (UNESCO 1973)
			Concept of Biosphere Reserves (UNESCO 1974)
1978	Tokyo	UNU: United Nations University	Project on Highland–Lowland Interactive Systems
1980	Geneva	WCRP: World Climate Research Programme	World Meteorological Organization (WMO) , ICSU, Intergovernmental Oceanographic Commission (IOC) of UNESCO
1986	Stockholm	IGBP: International Geosphere-Biosphere Programme	*Global Change and Mountain Regions: The Mountain Research Initiative* (Becker and Bugmann 2001)
1991	Paris	DIVERSITAS: International Programme on Biodiversity Science	UNESCO and International Union of Biological Sciences (IUBS)
1996	Bonn	IHDP: International Human Dimensions Programme on Global Environmental Change	*Global Change and Mountain Regions: The Mountain Research Initiative* (Becker and Bugmann 2001)
2001	Paris	ESSP: Earth System Science Partnership	DIVERSITAS, IGBP, IHDP, WCRP
Specific global programs on mountains			
1974	Paris	MAB: Mountain Biosphere Reserves	More than half of the 580 designated biosphere reserves are in mountains
1986	Zurich	WGMS: World Glacier Monitoring Service	UNEP, UNESCO, ICSU, WCRP
2000	Vienna	GLORIA: Global Observation Research Initiative in Alpine Environments	Today more than 91 target regions on all continents (Grabherr et al 2010; updated according to GLORIA website)
2000	Basel	GMBA: Global Mountain Biodiversity Assessment	Cross-cutting network of DIVERSITAS; *Mountain Biodiversity: A Global Assessment* (Körner and Spehn 2002)
2001	Bern	MRI: Mountain Research Initiative	*Global Change and Mountain Regions: An Overview of Current Knowledge* (Huber et al 2005)

publication of the science-oriented volume *Mountains of the World: A Global Priority* (Messerli and Ives 1997) and the policy-oriented brochure *Mountains of the World: Challenges for the 21st Century* (Mountain Agenda 1997). Astonishingly, only 1 year later, in 1998, the UN General Assembly proclaimed 2002 as the International Year of Mountains (FAO 2000). From 1998 to 2002, policy-oriented brochures were published each year for the annual meetings of the United Nations Commission on Sustainable Development (UNCSD) (Mountain Agenda 1998, 1999, 2000, 2001, 2002), well adapted to the Commission's agenda and continuing the series that had begun in the context of Rio and Agenda 21 (Mountain Agenda 1992, 1997). The so called "Bishkek Mountain Summit," the final conference of the International Year of Mountains in 2002, was an impressive testimony to a strong support for the world's mountains—very often even based on specific

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TABLE 3 The world's mountains on the global political agenda.

Year	Place	Event	Comments, key references
1992	Rio de Janeiro	United Nations Conference on Environment and Development (UNCED)	Agenda 21, Chapter 13, Managing Fragile Ecosystems: Sustainable Mountain Development (United Nations 1992)
			The State of the World's Mountains (Stone 1992)
		United Nations Framework Convention on Climate Change (UNFCCC)	Important role of Intergovernmental Panel on Climate Change (IPCC) founded in 1988
		United Nations Convention on Biological Diversity (UNCBD)	Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) established in 2011
1995	Lima	Founding of the Mountain Forum (MF)	Several host institutions; currently hosted by CONDESAN
1997	New York	United Nations Special Session of the General Assembly to Review and Appraise the Implementation of Agenda 21	*Mountains of the World: A Global Priority* (Messerli and Ives 1997)
1998	New York	United Nations General Assembly 53rd Session, Resolution 53/24 on the International Year of Mountains (IYM) 2002	Inauguration of IYM on 11 December 2001; 11 December officially designated International Mountain Day from 2003 onwards
2000	New York	Millennium Ecosystem Assessment	Volume 1, Chapter 24, "Mountain Systems" (Körner and Ohsawa 2005)
2002	Rome	Watershed Management and Sustainable Mountain Development	Conferences in all continents for policy and science
			Global conference on "Water Resources for the Future" in 2003 (FAO 2006)
2002	Johannesburg	World Summit on Sustainable Development (WSSD)	United Nations Rio+10 conference; founding of the Mountain Partnership
2002	Bishkek	Bishkek Global Mountain Summit (BGMS)	Rio+10 Bishkek Conference (Royal Swedish Academy of Sciences 2002; Price et al 2004)
2002	New York	International Year of Mountains	Engagement of mountain science and policy for and in these 4 UN International Years
2003		International Year of Freshwater	
2010		International Year of Biodiversity	
2011		International Year of Forests	
1998 to 2010	New York	8 Mountain resolutions of the UN General Assembly	"Managing Fragile Ecosystems: Sustainable Mountain Development" (Agenda 21, Chapter 13)

mountain projects—from FAO, UNESCO, UNEP, the United Nations Development Programme (UNDP), UNICEF, the World Bank, and many other international and national governmental and nongovernmental institutions and organizations.

The younger of the global programs specifically devoted to mountains (Table 2)—the Global Observation Research Initiative in Alpine Environments (GLORIA), the Global Mountain Biodiversity Assessment (GMBA), and the Mountain Research Initiative (MRI)—were launched at the turn of the millennium in recognition of this new significance of the world's mountains. A comparison of the appearance of mountains on the scientific (Table 2) and the political (Table 3) agendas reveals a strong connection between the two. Several global political initiatives depended on science for their success. For example, "the Millennium Ecosystem Assessment was called for by UN Secretary-General Kofi Annan in 2000 in his report to the UN General Assembly" (Watson 2005: xiii), leading to the commissioning of a specific assessment of mountain ecosystems (Körner and Ohsawa 2005). FAO's

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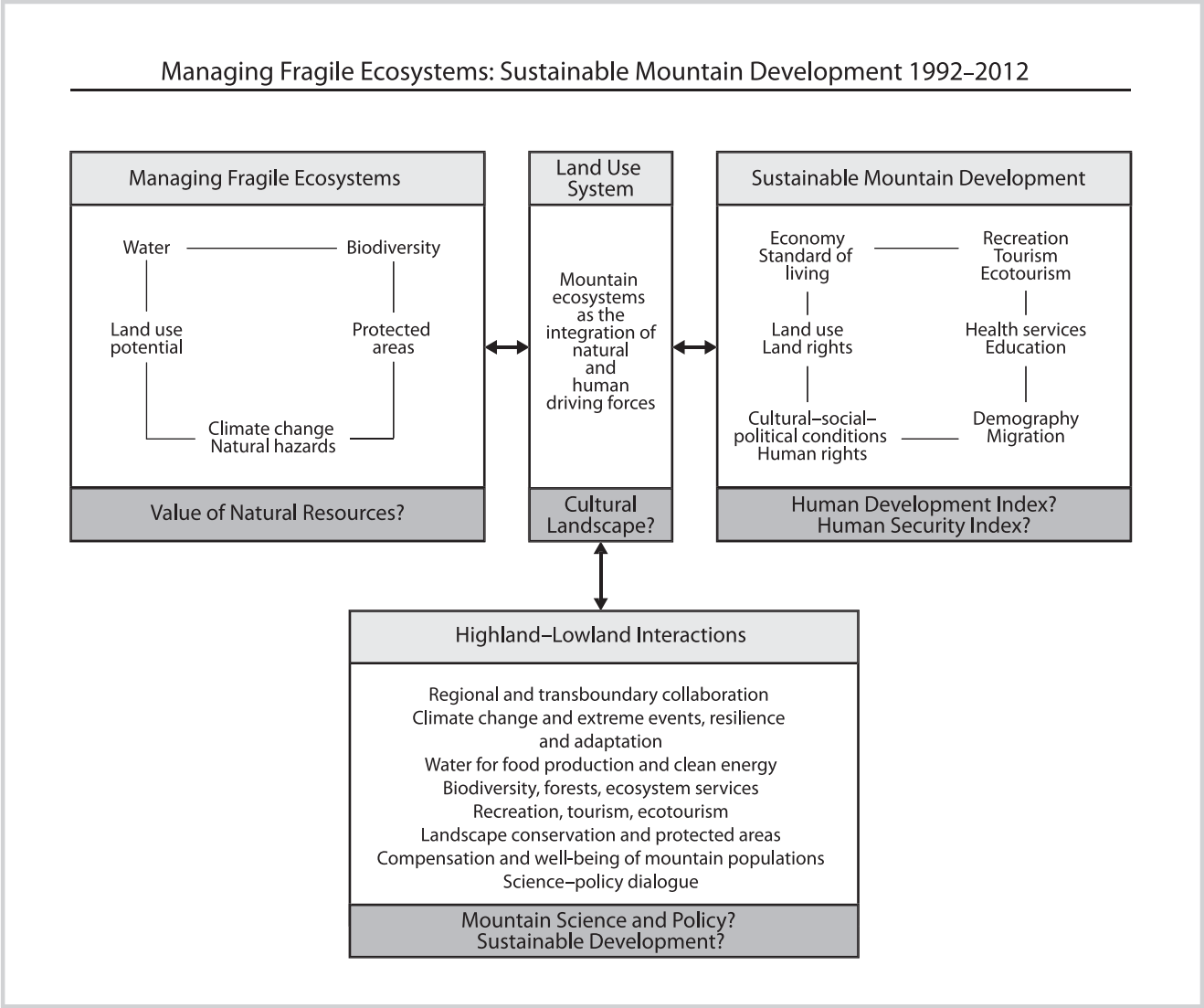
FIGURE 1 Positioning sustainable mountain development (1992–2012) within a conceptual framework for discussing management of fragile ecosystems.



program on Watershed Management and Sustainable Mountain Development was a similar case; it was launched in the International Year of Mountains 2002 to assess existing knowledge and future trends in watershed management under the headline of "Preparing for the next generation of watershed management programmes and projects: Water resources for the future," and involved political authorities and competent scientific institutions in all continents (FAO 2006).

The list of political mountain initiatives in Table 3 begins with the Rio conference and Agenda 21. A decade after Rio, however, the two UN conventions on climate change and on biodiversity became much more important to the advancement of mountain issues than the original text of the mountain chapter in Agenda 21, because of the growing significance of "climate change" for mountain water resources and of "biodiversity" and "ecosystem services" for both mountain and lowland populations (see also Figure 1).

Table 3 showcases an impressive series of UN conferences, resolutions, international years, and conventions, all more or less related to the world's mountains. In this connection it must be acknowledged that the Swiss Agency for Development and Cooperation (SDC), and partly also the Swiss National Science Foundation (SNSF), advised and supported all mountain interventions and initiatives shown in Tables 2 and 3, from the foundation of ICIMOD in 1983 to that of the African and Andean mountain associations in 1986 and 1991, to the international conferences in Geneva in 1991, Rio in 1992, New York in 1997, and Johannesburg and Bishkek in

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2002, the International Year of Mountains 2002, but also the foundation of the Mountain Forum in 1995 and the Mountain Partnership in 2002 at the Johannesburg conference. As two thirds of Switzerland's territory consist of mountains, mountains and mountain people have always played a fundamental role in Swiss policy and science. Mountains have historically become an important source of identity for the Swiss population. It is understandable, therefore, that early Swiss foreign aid to the developing world went to mountain countries such as Nepal, Peru, Rwanda, and others. This engagement led to a fascinating policy of international scientific dialogue, which determined the successful way to Rio 1992 and beyond.

The year 2012 and its significance for the world's mountains

The global UN conferences in Stockholm in 1972, Rio in 1992, and Johannesburg in 2002 had enormous impacts, not only on the development of scientific and political "global change programs," but also on a wide range of mountain initiatives at the regional, national, and local levels. This indicates that 2012, with two important global events, might again have a fundamental effect on the entire decade and beyond.

The first of the two major events is the "Planet under Pressure" scientific conference, scheduled for 26–29 March 2012 in London. Unlike the 1991 Vienna conference, it is organized not by ICSU alone, but jointly with the four global research programs on global change. The 4-day conference will cover the following topics: "State of the planet," "Options and opportunities," "Challenges to progress," and "Ways ahead: A vision for 2050 and beyond." One session will be devoted specifically to mountains: "Mountains as arenas for adaptation to global change," chaired by representatives of UNESCO, the MRI, the Centre for Mountain Studies in Perth, Scotland, the Centre for Development and Environment of the University of Bern, Switzerland, and Makerere University, Uganda; several other sessions will be addressing mountain issues as well. Overall, the conference is intended to explore new partnerships and pathways towards global sustainability. Special attention will also be paid to the inclusion of the social sciences, as well as to regional environmental change as a major issue requiring regional and decadal prediction and advanced observation systems (ICSU 2010).

The second major event scheduled for 2012 is the United Nations Conference on Sustainable Development (UNCSD), also known as "Rio+20," to be held—once again—in Rio de Janeiro, on 20–22 June 2012. It will focus on two themes: "Green economy in the context of sustainable development and poverty eradication" and "Institutional framework for sustainable development." The second theme is a continuation of the 2002 Rio+10 conference in Johannesburg, also known as the "World Summit on Sustainable Development" (WSSD). The first theme focuses on a new development, which makes it harder to grasp. Among the numerous draft papers one finds explanations that underline the following aspects: a green economy and economic growth, clean technology, renewable energy, and conservation, but also water resources, food production, forests, tourism, transport, building, and others. The detailed conference program is not yet available, but there will certainly be ample possibilities for strategic interventions concerning mountain research and development (see the box on highland–lowland interactions in Figure 1).

Regional cooperation and a solid knowledge base for sustainable development

Figure 1 positions sustainable mountain development within a conceptual framework for discussing management of fragile ecosystems; it has been given the same title as the mountain chapter in Agenda 21. The three boxes in the upper part of the figure show the traditional conceptual framework for research and development in mountain areas. They are connected to the box representing highland–lowland interactions in the lower part of the figure, which lists several important strategic topics for the upcoming London and Rio conferences and beyond. The three boxes in the upper part represent natural (left) and human (right) driving forces, connected by mountain ecosystems (middle) as a reflection of natural and human impacts. The components of these boxes represent the possible combinations of natural and human-induced environmental changes on local, national, and regional scales, stimulating inter- and transdisciplinary research, although disciplinary studies will remain highly significant. All these natural and human components must be adapted to the special situation of each mountain system. Two things, however, are of overriding interest: well-functioning regional cooperation and a solid knowledge base in times of global change. Every mountain system needs one or several knowledge centers to ensure continuous exchange of data and observations from the regional to the global and from the global to the regional levels (Messerli 2006). Upscaling and downscaling of scientific knowledge and development experiences is most important, and this requires a well-functioning communication system.

An efficient regional and global communication system is fundamental

Over the last decade, the flood of mountain information has increased to a level that is no longer manageable. Mountain Forum, Mountain

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Partnership, regional mountain centers, and specific mountain programs (Tables 2 and 3) are producing newsletters, newsflashes, press releases, reviews, announcements, and other communications with no coordination between them. One global voice and many regional and thematic voices are urgently needed. Messages of global significance from regional centers or specific mountain programs should be carefully selected and disseminated by one single global voice, even if overlaps cannot always be avoided. FAO, as the lead agency for mountain issues within the United Nations that prepares General Assembly mountain resolutions based on biennial reports to the Secretary-General, should also coordinate global communication on mountain issues. At the same time, however, every region, every scientific program, and every mountain organization must have the freedom to create its own communication system. The biennial FAO reports could function as a summary of processes and progress in science and policy related to ecology and economy, adaptation to climate change, and natural resources in the different mountain regions, as a basis for rethinking the long-term strategy for research and sustainable development in the world's mountains.

Some strategic ideas for Rio+20 and beyond

In Figure 1, each box ends with one or two keywords followed by question marks. These keywords indicate some strategic ideas for Rio+20 and beyond. For example, "Value of natural resources?" points to the need for more research on the value of mountain resources, especially to the adjacent lowland populations and their land use, and in the context of urbanization and industrialization processes. This could be of special interest for the three strategic issues of "Water for a growing population, for food production, and for renewable energy," "Biodiversity and ecosystem services," and "Recreation, conservation, and protected areas." In line with recent recommendations by the IHDP, it would be fascinating if some results could be expressed as monetary values (IHDP 2011). This would have an enormous effect on political authorities in particular and on mountain policy in general.

For example, it would be interesting to calculate the value of agricultural production by irrigation in different lowland areas around the Himalaya. Combining these results with precipitation and discharge data, we could calculate the specific mountain contribution compared to precipitation and discharge in the lowlands. If mountain resources made it possible to enlarge irrigation areas and increase production in the lowlands, what would the monetary value of the additional production be, and what would this mean for food security? Another interesting question is that of the additional value contributed by mountain areas in terms of clean energy production and its significance for urbanization and industrialization. Focusing on these questions also raises the issue of compensation: careful management of mountain ecosystems, clean water, sufficient forest cover, high biodiversity, protection against extreme events, and similar services can no longer remain the sole responsibility of poor mountain populations. A dialogue between science and policy is the necessary basis for a changing mountain policy and for a new understanding of mountain resources. Let us not forget the UN Population Office's projection that the combined populations of China and India will reach about 3 billion people by 2050—the same number that constituted the entire world population in 1965. What does this imply with regard to the significance of mountain resources for lowland populations in the second half of the 21st century?

The top middle box in Figure 1 raises the question of long-term preservation of mountain cultural landscapes as a treasure for future generations. Today, many of these landscapes are endangered—by poverty, emigration, and overuse of natural resources in the developing world, and by urbanization and tourism with its winter and summer activities in the developed world. The top right box representing the human components raises not only the many difficult questions related to long-term sustainable development but also issues of security in connection with poverty, food shortages, conflicts, and even warfare.

All these reflections come together in the bottom box representing highland–lowland interactions. The strategic focus issues listed here cannot be discussed in detail in the context of this article, but it is important to emphasize once more the significance of regional and transboundary cooperation at the interface of science and policy (see also IHDP 2011), especially in a time of climate change and potentially increasing frequency of extreme events. The scientific knowledge about climate change in the monsoon belt in particular and in the tropical-subtropical zone in general is not yet satisfactory, and the existing knowledge gaps harbor many uncertainties for sustainable mountain development. Understanding resilience is not easy, and the definition of adaptation and mitigation measures is demanding (Figure 1). Finally, taking into account mountain resources such as "water towers," biodiversity treasures, unique places for recreation and conservation, and many others, we are confronted with the problem of compensation and well-being of mountain populations. Highland–lowland interactions cannot be a one-way process in favor of lowland populations (UNECE and Water Convention 2007), and lowland–highland compensation needs to be considered as an important topic in mountain policy. Without such a

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compensation mechanism, it will not be possible to achieve sustainable mountain development and the well-being of mountain people.

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