Geodiversity. A theoretical and applied concept

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1 Introduction

The assessment and gradually accumulation of understanding of the Earth's richness and natural variety has led to the formulation of new avenues of research. From the fields of biology and the earth sciences, new concepts have been proposed and associated with new terminology, such as «biodiversity», «natural diversity» and «geodiversity», some of which have received broad social diffusion.

The concept of biodiversity was introduced in 1988 as a scientific term to define the variability of the Earth's living organisms, its «biological diversity» (Wilson 1992), and was extended to include «the diversity within species, between species and of ecosystems» (United Nations 1993: 42). Its use became widespread as a result of the Earth Summit held in Río de Janeiro in 1992 which was held to support analysis of conservation of biodiversity and related issues. Its application in the protection and management of the natural environment requires an exhaustive knowledge of the structure and components of the area to be protected, their physical surroundings, including biocenoses and biotopes, and has led to greater awareness of their intimate dependence such that one cannot be conserved without the other.

The management of natural areas has varied in its concepts and activities over the last 130 years. Broadly speaking, the main phases have been:
- Conservationist, with implementation of landscape and monumental concepts involving the most outstanding visible elements of natural areas.
- Biological, with protection of species being placed in the foreground. Over time, activities were extended to include ecosystems.
- Holistic, with extension of understanding of protection of ecosystems to a global level to include habitats and landscapes as visible elements of the multiple relations between living beings, including humankind, and the abiotic environment.

The changes in conservation concepts and the incorporation of biodiversity have led to a greater understanding of the role that the abiotic components of a landscape play in the determination of value, an aspect without which it is not possible to conserve nature. Indeed, protected areas and places of maximum interest (e.g. World Natural Heritage, Reserves of the Biosphere, Places of Interest) are often defined as such because of the abiotic elements that make up these outstanding landscapes. It is within this framework that new terms have been coined and concepts, such as geodiversity, have been born.

Both geodiversity and biodiversity are two structural and dynamic elements of «natural diversity», with multiples links and complex relations between them. Abiotic elements and dynamics are considered important, not only for sustaining life, but also for supporting the smooth functionality of terrestrial and marine systems and the conservation of habitats and landscapes. Consequently, abiotic elements may be seen not only as a supportive vehicle but as an entity in themselves. They are dynamic; they transform, generate and consume energy, become transformed themselves and alter biotopes without the need of biological intervention.

The aim of this article is to present the discussion around the term geodiversity to-date and to propose a broader definition. It also draws attention to recent proposals for measuring and quantifying geodiversity in applied contexts, drawing conclusions for further development in this area.

2 Geodiversity: a theoretical concept

The concept of geodiversity itself appeared as a tool within the management of protected areas, often in contrast to the term biodiversity. Previously, the term «geodiversities», which was coined in the 1940's by the Argentinean geographer, Federico Alberto Daus, was used within the context of cultural geography to differentiate areas of land. Geodiversity referred here to the mosaic of landscapes and cultural diversities of geographical space and the territorial complexities at different scales (locations, districts and regions) related to human habitats. The concept thus really referred to «geographic diversity».

From the 1990's, a naturalist concept of geodiversity prevailed, springing from the concept of biodiversity. In marked contrast to the clear and precise definition of biodiversity, which includes a concept of hierarchical levels (genes, species and ecosystems), geodiversity has shown a conceptual weakness that has left it adrift in various fields. Furthermore, the terms geological heritage, geoconservation and geodiversity are practically inseparable. Although the study of geological heritage has a long history in Europe and the United States, the other terms are more recent.

Duff (1994), for example, argues that natural environments reflect both a biodiversity and a geodiversity, the latter adding a dynamic territorial component to the concept. To Sharples (1995), geodiversity is an expression of the variety of geological, geomorphological and soil characteristics. Eberhard (1997) adds heritage to Sharples' definition and argues for the incorporation of the concept in the management of the natural environment. To Fishman and Nusipov (1999), Erikstad (2000) and Gordon (2004) geodiversity is the support of ecosystems and biodiversity and must be taken into account in management, decision-making, planning and education.

As a theoretical concept, geodiversity was initially used in specific contexts, such as pedodiversity or geological diversity (Durán et al. 1998; Ibáñez et al. 1997; Sharples 1995). Johansson et al. (1999), Nieto (2001) and Stanley (2001) define geodiversity according to geological phenomena or environments. Their idea of geodiversity includes an integrative and scale-sensitive element but these are restricted to geological elements and processes. Nieto clearly differentiates between geological heritage (supported by the existence of Points of Geological Interest) and geodiversity, with the latter, at times, being part of the former, depending on what is actually targeted in assessment. Nieto's definition is applied to the conservation of geological heritage and it lacks any intention of integration into the broader term of natural diversity. Therefore, following the integrating visions centring geodiversity on geological processes, but with holistic implications that include physical and human processes and elements (Gordon 2004; Johansson et al. 1999; Nieto 2001), the concept of geodiversity has swayed in the direction of becoming synonymous with «geological diversity».

Alongside these restrictive developments, a broader conceptual vision of geodiversity has also been followed (Alexandrowicz & Kozlowski 1999; Duff 1994; Gray 2004; Kozlowsky 2004; Serrano 2002; Sharples 2002; Zwolinski 2004), leading to agreement on «variety of the abiotic nature» (Gray 2004). This concept includes a plethora of interrelated elements on the land surface, in the seas and oceans. It has also led to attempts to formulate more integrative definitions which try to take into account all the elements involved in the structure and physical processes of the land surface. Alexandrowicz and Kozlowski (1999), for example, limit geodiversity to the land surface and associate the term with the conservation of specific areas, involving geological, hydrological, geomorphological, soil and climatic elements and processes. The landscape is considered to be a synthesis of geodiversity. Sharples (2002), on the other hand, includes not only geological, geomorphological and soil elements, but also the interrelated character of their links, assemblages, properties, systems and processes. The most integrative vision is that of Kozlowski (2004), who defines geodiversity as the

> «natural variety of the Earth's surface, referring to geological and geomorphological aspects, soils and surface waters, as well as to other systems created as a result of both natural (endogenic and exogenic) processes and human activity» (Kozlowski 2004: 834).

According to Gray (2004), the components of geodiversity are the Earth's history, tectonics, minerals, rocks, sediments, fossils, landforms and geomorphological processes and soils. Kozlowski (2004) adds surface waters (springs, swamps, lakes, rivers) and González-Trueba (2007) considers that seas and oceans and the physical elements and processes found within them must be included. Thus, from the discussion above, it would seem that new elements have been added to geodiversity (Tab. 1).

Further, it appears that although geodiversity complements biodiversity, it is clearly different. Biodiversity and geodiversity together reflect «natural diversity». Natural diversity is seen to encompass the components of vegetation, fauna, climate, soils, relief, geology, water and topography. Although its two sub-terms can

Topography	Energy	
	Roughness	
Geology	Earth materials	Minerals
		Lithology (rocks)
		Superficial deposits
		Fossils
	Tectonic	
	Structures	
Geomorphology	Morphostructures	
	Morphogenetic systems	
	Processes	
	Erosion landforms	
	Accumulation landforms	
	Micro-landforms	
Hydrology	Water states	Water
		Snow
		Ice
		Glaciers
	Hydrologic elements	Oceans
		Seas
		Rivers
		Springs
		Wetlands
		Lakes
Soils	Orders	
	Suborders	

Tab. 1: Elements of geodiversity on the Earth
Elemente der Geodiversität auf der Erde
Eléments constituant la géodiversité de la Terre

be analogous in structure and connections, they differ in the characteristic of existence or absence of life.

Natural diversity was introduced in the 1980's as a means of connecting the biotic with the abiotic, leading to the spatial concept of «habitats» (Radford et al. 1981). Today, habitat includes all abiotic components that contribute towards the environment in which biotic elements are to be found. The European Union describes habitats as «terrestrial or aquatic areas differentiated by their geographical, abiotic and biotic characteristics, whether they be wholly natural or semi-natural» (Habitats Directive, 92/43/EEC). Thus, habitats include abiotic and spatial components. The variety of abiotic elements forming habitats can also be referred to as geodiversity. The framing of the concept of geodiversity in this context is of special interest because it reflects an understanding of natural diversity, and links the concept to development of conservation policies and management of natural protected areas and natural heritage in national and supraregional areas, such as in Europe (Natura 2000 network), in the Commonwealth (Wildlife Habitats and Biodiversity Program) and under the supervision of the UNESCO (World Heritage Sites, Geoparks and Biosphere Reserves).

Seen from this point of view, it would seem that geodiversity should be defined by the constituent elements in the physical environment that lead to the richness of biotopes, ecosystems, habitats or landscapes. However, from the package of elements that make up geodiversity, it should be clear that it is more than a complement of biodiversity, but a fundamental part of natural diversity. Indeed, without knowledge of abiotic components, it would not be possible to understand the spatial dimension (location and scale) nor the changes caused by geological, geomorphological, hydrological and human processes on natural system. Further, in recognition of changes over different periods and lengths of time, geodiversity also has a clear temporal dimension that links different natural and human processes at diverse time scales (short: biological and human, medium: historical, and long term: geological).

3 Geodiversity: an applied concept

The term geodiversity was introduced in connection with holistic concepts of nature conservation and the management of natural areas, resulting in a strong practice-oriented touch to the concept. This characteristic could also be due to its regular use in contexts focussing on the study of the natural diversity of specific areas.

As an applied concept, it has been used under the umbrella of «geoconservation» both as a basic tool and as a fundamental principle for the conservation of non-biological elements. According to Gray (2004), geodiversity is a basic principle of geoconservation and protection of places. As a term, it appears easily accessible to managers and politicians, supporting quick recognition of the need to take other aspects of conservation, besides biological ones, into consideration. In particular, it is felt to be useful for the conservation of abiotic heritage and the incorporation thereof in local sustainable development policies, as well as for the assessment of non-biological natural resources. From the point of view of planning, the term can help to integrate nature conservation into sustainable land management. In England, for example, the proposal has been made to incorporate Geodiversity Action Plans into planning processes at the local and regional scale (Gray 2005; Stanley 2001).

The applied use of geodiversity incorporates not only aspects related to geology, geomorphology, soils, hydrology and topography, but allows inclusion of the relations between them and the elements on which life is sustained. As these elements have their own identity at a higher level than the mere biotope, they should be incorporated into geoconservation. The practical manifestation of this applied use of the term may be seen in the management and protection of natural protected spaces with high abiotic and landscape values and clear legal frameworks, such as geoparks, natural heritage sites, geological heritage sites, protected landscapes, natural monuments or geosites.

In association with the management of protected spaces and planning, the term is now in use at the level of supranational institutions. The «European Declaration for Terrestrial Heritage and Geodiversity of 2004», promulgated by the International Geographical Union (IGU), the European Geoparks Network, the European Society for Soil Conservation and the International Union of Geological Sciences (IUGS), can be mentioned in this respect. This development has led to greater attention being given to the issue of scale and, within the context of natural protected areas, raised awareness of the determinant role that abiotic factors play in the selection of sites.

Thus, although geodiversity can be defined as a scientific term, the concept also has a practical role to play in nature conservation, as initial developments in the field of conservation indicate (Eberhard 1997; Sharples 1995, 2002; Stanley 2001). Present-day requirements in land planning, management of conservation and in environmental education call for inclusion of information on geodiversity along two lines. Firstly, the elements that make up a particular geodiversity must be identified at a certain scale and assessed according to value as assets. The geoecological approach to assessment has been put forward as ideal for this purpose (González-Trueba 2007; Gordon et al. 2001; Jonasson et al. 2005) because it permits spatial and dynamic parameters to be taken into account and draws attention to natural processes and their dynamic relations. Secondly, the concept of geodiversity must be integrated into professional action (planning, conservation, protection or education) as a scientific tool to be rigorously applied, together with biodiversity, to territorial understanding and land management. The geodiversity concept thus permits emphasis to be placed on the sensitivity of abiotic elements and dynamics, and on the value of the natural, geological, geomorphological, pedological and hydrological factors in nature conservation and land planning and management of territory and landscapes. However, this does not imply a focus on concrete sites (e.g. geosites, geomorphosites, pedosites), but rather on a set of elements found within a stretch of the land continuum or in a region as a whole. According to Gray (2005), geodiversity is a means for inclusion of natural diversity in conservation, planning and education through different forms (e.g. geotopes, geosites, geomorphosites, geoparks, protected landscapes).

4 Proposals for a definition of geodiversity

Geodiversity can be defined by its constituent elements in the physical environment. As these elements are bound to a place, possess certain dimensions and a location, they contribute towards a spatial dimension of the term. Depending on how the components of the physical environment are interrelated in a geographic dimension, be this at a micro, meso or macroscale, the characteristics of an area (local, district, regional) will change. Consequently, geodiversity cannot be understood without taking scale into consideration. Different authors have referred to the problematic issue of scale with regards to geodiversity assessment (Jonasson et al. 2005; Kozlowski 2004; Nieto 2001; Stanley 2001). For pedodiversity, for example, four levels of reference have been proposed: microhabitat (or polipedon), habitat, landscape and region (Ibáñez et al. 1997).

Thus, it appears that research into geodiversity should begin with the definition of scale. Depending on whether discrete points (geotopes, geosites), an area, a region or territory (natural protected area, province, country) are targeted, the approach to assessment may change even if the set of elements to be considered remains the same (see Tab. 1). Furthermore, the diversity of elements on the Earth's surface and the difference in complexity of their structural and dynamic relationships implies a need to also take hierarchy of scale into account.

A proposal is made here for the ranking of abiotic diversity to reflect four levels of complexity, ranging from a simple particle to a complex landscape:

- «Particles» of geodiversity are understood to be simple abiotic elements or processes that lack a spatial dimension (atoms and molecules, minerals, sediment particles, energy processes). They form the first layer in the hierarchy of geodiversity. As these so-called particles lack a spatial dimension, they are difficult to asses in the field, making their value within the hierarchy more theoretical than practical.
- «Elements», such as topography, geology, geomorphology, hydrology and soils (Tab. 1) form the next level and can be targeted by geodiversity assessment at any spatial scale. For such assessment, this level is particularly interesting as elements can be mapped and relationship between elements established. Indeed, the elements listed here have been the main focus of territorial management and conservation policies in the past. They have also, for example, been used for estimation of geodiversity values in Natural Protected Areas (Serrano et al.).
- Geodiversity of «places» focuses on groups of different elements with a high degree of organization, spatial dimension and moderate extension (e.g. geotopes, geosystems, units). Due to the greater complexity of systems, this level is less suitable for practical application. However, geodiversity of places can be a useful synthesis tool for mapping, assessment of assets or definition of units in large territories.
- The final scale rank is given to landscape geodiversity. This rank includes biotic and abiotic factors – natural diversity – and takes the influence of human activity of an area into consideration. Although geodiversity may be seen as a basic aspect of landscape diversity, it becomes clear here that landscape geodiversity should be related to *geographical* diversity and not simply be seen as a part of geodiversity.

The scale discussion is an important issue in geodiversity assessment of defined areas and, as may be seen in research to natural diversity, both the scale of research and of the objects targeted for assessment, will affect the final results. As much as biodiversity focuses on species, rather than on genes or ecosystems, at different spatial scales, be these natural (geomorphic, habitats, landscapes) or anthropogenic units (landscapes, natural protected areas, countries), geodiversity is also in need of an agreement on targeted scale. More unity in this matter would allow geodiversity to strengthen its role in conservation, as well as in environmental analysis, management and education.

Thus, in acknowledgement of the elements targeted by the concept and, in particular, in recognition of the integrative character of the abiotic elements of a natural system, it is put forward here that geodiversity be defined from a theoretical point of view as the variability of abiotic nature, including lithological, tectonic, geomorphological, soil, hydrological, topographical elements and physical processes on the land surface and in the seas and oceans, together with systems generated by natural, endogenous and exogenous, and human processes, which cover the diversity of particles, elements and places.

5 Geodiversity assessment

The possibility of measuring and quantifying geodiversity has been discussed since the very first references to it. It is accepted that the effectiveness of the incorporation of geodiversity in land management depends on the capacity to understand and evaluate it. Nevertheless, the applications of the term and the theoretical reflections thereof have not been accompanied by systematic evaluation of geodiversity assessment methods.

One of the first attempts to assess geological diversity was made by Cendrero (1996), who proposed that diversity of elements of geological interest, and their intrinsic value in particular, be one of the criteria to be taken into account when cataloguing and classifying geological heritage. Geological diversity was ranked here on a scale from one to five according to the number of different elements present in the study area. Durán et al. (1998) argued that space and time should be taken into consideration in geodiversity assessment and Gray (2004) pointed out the possibility of using specific values of spatial geodiversity and geoindicators for assessment. However, the latter authors offered no practical guide as to how these should be achieved and to this day very little has been explored in this direction. Nevertheless, three approaches do appear to be particularly promising:

- Kozlowski (2004) worked with five levels of geodiversity (very high, high, moderate, low and very low) in order to make a quantitative assessment of given areas. The approach was applied at a regional scale in Poland. In a different context, Jonasson et al. (2005) established the relation between geodiversity (mainly landform diversity) and habitat diversity for three different spatial scales: large, intermediate and small. Quantitative assessment thus appears suitable for implementation at local, district, regional, continental or global scale. This approach was implemented in order to further the understanding of protected territories and to allow a comparison between them as a basis for land intervention or conservation policies, be this at a local or global level.
- Nieto (2001) considered the number and variability of geological elements to be the basic parameters on which the quantitative and qualitative assessment of geodiversity should be founded. Thus, whereas number was seen as an estimate of the different elements (structures and materials) in the targeted area, variability allowed different geological contexts (past and present) to be taken into account. Consequently, geodiversity increases with the number of elements and the representativeness of the geological environments. Nieto (2006) points out the need to include the size of the area in the assessment of geodiversity by making use of mathematical criteria and he suggests the use of diversity and density models. These models allow a combination of a number of geological categories with objects and relate them to the surface of the study area. Nieto proposes the use of indices (like the Shannon vegetation index, which permits establishment of the relationship between the number of species and their abundance), or distribution models (such as Hollow's model, which relates categories with frequency).
- The proposal forwarded by Serrano et al. for geodiversity assessment appears to be the most specific. The authors suggest a geodiversity index, which relates the variety of physical elements (geomorphological, hydrological, soils) with the roughness and surface of the previously established geomorphological units according to the following formula:

  $$Gd = Eg\ R\ /\ Ln\ S$$

  where Gd = Geodiversity Index; Eg = Number of different physical elements in the unit; R = Coefficient of roughness of the unit; S = Surface of the unit (km^2); Ln = neperian logarithm.

The parameter Eg is obtained by counting the different geomorphological, geological, hydrological and pedological elements (Tab. 1). The coefficient of roughness is an attempt to include the variety of orientations, slopes and radiation affecting soil, hydrological and geomorphological processes. The final result is a semi-quantitative scale that permits the establishment of five values of geodiversity, from very low to very high for each homogeneous unit. It is argued that use of this geodiversity index would allow easier comparison of units and aid suitable management of protected areas, be these districts, regions or areas. Further, it would seem a practical tool for compilation of geodiversity maps, an example of which is given in Fig. 1.

6 Conclusions

Geodiversity has developed into a term with multiple meanings depending on the view point, be this theoretical or applied. This development coincides with the need to put the concept into practice and to define it with precision rather than to simply use the term in a

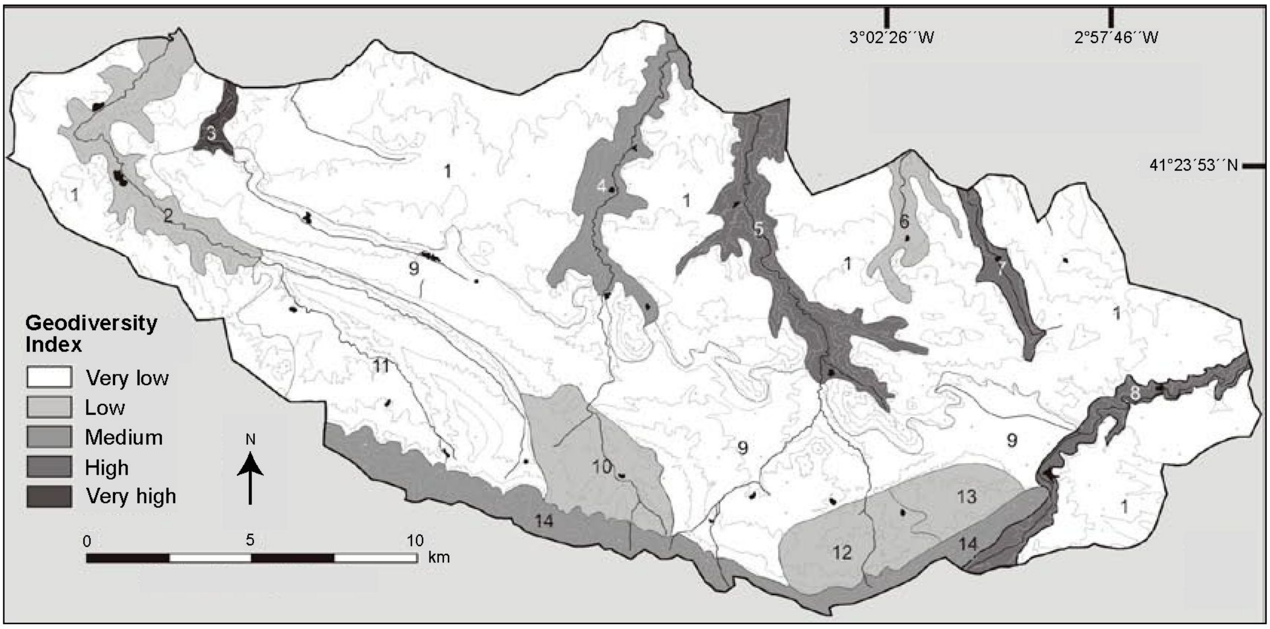

Fig. 1: An example of a geodiversity map compiled from geomorphological units. Tiermes Caracena area (Castilla and León, Central Spain)
Beispiel einer Geodiversitätskarte, die anhand geomorphologischer Einheiten erarbeitet wurde. Region von Tiermes Caracena (Kastilien und León, Zentralspanien)
Exemple de carte de géodiversité élaborée à partir d'unités géomorphologiques dans la région de Tiermes-Caracena, Castille et León, Espagne centrale
Source: Life03/ENV/000161 Project; cartography: E. Serrano, P. Ruiz-Flaño, P. Arroyo

general sort of way. This general use of the term is widespread in academic, educational and conservationist fields. The article argues for a turn to greater reflection and increased specific conceptualisation of its theoretical and applied use. In this light, the full range of abiotic elements in the natural system must be attended to, and not only certain factors, such as geology. Further, scale should be given due consideration. However, despite the differences in understanding of the term, it is recognised that geodiversity as a concept has been usefully applied in the assessment of geodiversity, in geoconservation and in environmental education.

The application of the concept necessarily involves the quantification of geodiversity and its integration, together with biodiversity, in the consideration and estimation of «natural diversity». Although a few approaches have been forwarded, their differences in target scale and their level of development make direct comparison or evaluation difficult. It is thus argued herein that geodiversity assessment should take all of the abiotic elements into account at an appropriate scale, and not only at the level of geosites or geotopes. Further, it appears important to consider the surface of the study area, as its current inclusion only permits comparison of assessments at the same scale. In a similar light, for the assessment of different elements, the use of spatial units should be taken as a reference. For example, geomorphological or landscape units seem suitable for assessment of geodiversity at a local or regional scale.

Geodiversity should also take the needs of land planning and management into consideration since the conservation of geodiversity, be this at the level of particles, elements or places, is important for upholding biodiversity or biological diversity, as well as natural diversity. For this reason, the definition given here for geodiversity proposes inclusion at different scales of all abiotic elements in nature, their related physical processes and their relationship to human activity. Geodiversity assessment is argued to be a potentially effective tool for supporting decision-making processes with regards management and conservation of natural areas or regions at different scales, be these local or supraregional. Further, geodiversity is seen to be a complementary resource to natural heritage and as such can be an asset of environmental, scientific, educational, cultural or economic interest in need of effective management. In short, abiotic elements should be given due attention in assessment procedures and be of priority concern in land management, nature conservation, sustainability programmes and education.

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Abstract: Geodiversity. A theoretical and applied concept

The concept of geodiversity appears to have grown out of the discussions around biodiversity, and has evolved over time to become both a tool and a theoretical concept. The paper presents an overview of this conceptual evolution, leading to formulation of the argument that geodiversity is a broader term than geological diversity. Consequently, it is proposed that the concept should take into account all abiotic elements, processes and relations to the natural system and human activity. The overview serves as a basis for focussing on the constituent elements of geodiversity that lead to the richness of variety in biotopes, ecosystems or landscapes and that influence its use in theoretical, educative and geoconservation terms. The suggestion is made to include four levels in a hierarchy of abiotic diversity (particles, elements, places and landscapes). Several approaches to measuring and quantifying geodiversity are discussed, pointing to a need for a geodiversity index which links the different physical elements with processes in the soil, hydrology and geomorphology, as well as with topographical factors (orientation, slope and radiation).

Zusammenfassung: Geodiversität. Ein theoretisches und angewandtes Konzept

Der Begriff der Geodiversität wurde vom Konzept der Biodiversität abgeleitet und dient sowohl als Instrument zur Anwendung wie auch als theoretisches Konzept. Der Artikel präsentiert einen Überblick über die Entwicklung des Konzepts Geodiversität. Darauf aufbauend erstellen die Autoren eine Liste jener Elemente, welche das Konzept der Geodiversität ausmachen, und die dessen Einsatz im theoretischen, bildungstechnischen und geokonservatorischen Bereich beeinflussen. Das Konzept der Geodiverstiät umfasst mehr als bloss die geologische Diversität. Es ist durch die Grundelemente der physischen Umwelt definiert, welche in der Vielfalt von Biotopen, Ökosystemen oder Landschaften vorhanden sind. Vier Ebenen werden für die Hierarchie der abiotischen Diversität vorgeschlagen (Partikel, Elemente, Orte und Landschaften). Es wird eine breit gefasste Definition vorgestellt, die alle abiotischen Elemente, Prozesse und Verbindungen des natürlichen Systems wie auch die menschlichen Prozesse beinhaltet. Anschliessend werden verschiedene Möglichkeiten zur Messung und Quantifizierung von Geodiversität diskutiert, die die Notwendigkeit eines Geodiversitätsindexes verdeutlichen, welcher die Verschiedenheit der physikalischen Elemente, des Bodens, der hydrologischen und geomorphologischen Prozesse wie auch der topographischen Faktoren (Ausrichtung, Hangneigung und Strahlung) repräsentiert.

Résumé: Géodiversité: un concept théorique et un instrument d'application

Le terme Géodiversité, dérivé du concept de Biodiversité, constitue autant un concept théorique qu'un instrument d'application. L'article propose une discussion de l'évolution des différentes définitions au cours du temps, ce qui permet d'établir une liste d'éléments compris dans le concept de géodiversité, ainsi que ses usages en termes théoriques, éducatifs et de géoconservation. La géodiversité couvre un champ plus vaste que la simple diversité géologique et peut être définie par l'ensemble des éléments constituant l'environnement physique et influençant la diversité des biotopes, des écosystèmes et des paysages. Quatre niveaux d'échelles sont proposés pour hiérarchiser la diversité abiotique: particules, éléments, objets et paysages. Une définition générale de la géodiversité, incluant l'ensemble des éléments abiotiques, des processus et des relations avec le système naturel et humain, est proposée. Différentes possibilités de mesure et d'évaluation de la géodiversité sont également discutées et permettent de conclure à la nécessité d'établir des indices de géodiversité permettant de représenter la variété des éléments physiques, des sols, des processus hydrologiques et géomorphologiques, ainsi que des facteurs topographiques (orientation, pente, insolation).

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