GEODIVERSITY: CONCEPT, ASSESSMENT AND TERRITORIAL APLICATION. THE CASE OF TIERMES-CARACENA (SORIA)

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The current concept of Geodiversity was born like a applied tool to the management of Natural Protected Areas. It is a opponent term to the Biodiversity one, used since middle the ninety years of twenty century. The origin and diffusion of term geodiversity began at the last years of the ninety decade in works on Natural protected areas management. At this time it is necessary a term to include the abiotic elements of natural environment. The use in public policies and territory management of the concept biodiversity and their exhaustive study have showed that it is also necessary to study the abiotic elements for the management, protection and conservation of Nature. There are very much Natural Protected Areas where their abiotic elements have a high value and they are protected by geological, geomorphological, hydrological or landscape values. In this framework the geodiversity is considerate as settling of the biodiversity. So, the sum of both concepts (Biodiversity and Geodiversity) constitutes the Natural Diversity. But while the biodiversity has a clear and precise definition, geodiversity has a important conceptual weakness.

The first uses of the term Geodiversity appear in applied work and they are a answer to holistic conceptions of nature conservation. These works give more importance to the geological elements but other elements of physical and human environment are incorporated (Duff, 1994; Sharples, 1995; Eberhard, 1997). The initial conceptions pass quickly to a considerations of Geodiversity like geological diversity. This conception persists today and a lot of conceptual problems have been derived.

Together with these restrictive considerations, a broader conceptual vision of geodiversity has developed (Duff, 1994; Alexandrowicz and Kozlowski, 1999; Serrano, 2002; Sharples, 2002; Kozlowsky, 2004; Zwolinski, 2004; Gray, 2004), which has led to define its as «*variety of the abiotic nature*» (Gray, 2004). From this point of view the Geodiversity includes all constituent elements of physical environments, not only geological ones (Alexandrowicz y Kozlowski, 1999; Sharples, 2002; Gray, 2004; Kozlowski, 2004). The most integrating vision in the component elements is that of Kozlowski (2004), who defines it 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».

From the elements considered, and with an integrating vision of the abiotic elements of the natural system, we can define geodiversity 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 sites»*.

Geodiversity is, moreover, a useful concept for geoconservation and management of abiotic heritage. It is a necessity the incorporation of abiotic elements to the local policies of sustainable development and the assets of natural resources. Also this concept have been considerate suitable for a geoecological management of Natural Protected Areas. Geodiversity is today related to concept as Geoconservation, Natural Heritage, Geological Heritage, or legal figures like Geoparks, Protected Landscapes, Natural Monuments or Geomorphosites.

In Spain, the term geological heritage, geoconservation and geodiversity are practically inseparable. While the studies of Geological Heritage have a history of almost 30 years in Spain, the use of the term geodiversity came much later. The earliest references to this term in Spain appear linked to publications dealing with the identification of regional geological resources or scientific meetings dedicated to the conservation of geological heritage, which has led to some confusions in terminology between the two concepts (Arribas y Durán, 1998; Durán Valsero, 1999; Palacio, 1999 y 2000; Nieto, 2001; Moreira, 2001).

Although the term have been broadly used, the efforts made in a methodological development for assessment are still very little. In this work we present a procedure used to estimate the geodiversity and the application of a index. The next steps are given:

— Analysis of abiotic elements: Study of geological, geomorphological, hydrological, pedological elements of the study area and elaboration of a detailed geomorphological map.

— Units set up: The geomorphological units are the base for the assess of geodiversity and it are delimited from the geomorphological map, remote sensing and field work. A inventory of the main physical characters of units is made and it is synthesized in cards.

— Assessment of units: We have establish a index to relate to the variety of physical elements with roughness and surface of the units. We have considerate that if there are more elements, the geodiversity is bigger, and for higher roughness the micro and topo-climate complexity is also bigger. Thus, the elements and roughness incise on the increase of geodiversity. In agree of this sentences the next formula is applied:

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

Gd = Geodiversity index. Eg = Number of differents physical elements (geological, geomorphologic, hydrological and pedological) of the units; R = Coefficient of roughness of the unit; S = Surface area of the unit (km^2).

The parameter Eg is calculated from the recount of physical elements contents in the next table and obtain from the cards.

Geology	Litho logy	Structure	
Geomorphology	Morphostructures	Morphogenetic systems	Processes
	Erosional landforms	Accumulation landforms	Micro-landforms
Hydrology	Water states	Hydrologic elements	
Soils	Orders	Suborders	

Only are tabulate the different elements and the reiterations are not take account. In the same way, only are considerate the processes that they are not included in any landform.

The topography, micro and topo-climate variations are represented by the roughness coefficient. His incorporation is supported by the important role of both parameters on the energy and material fluxes at the slopes, and so, on the diversity and distribution of landforms, soils and processes. It is a integrative parameter introduced for take account the smaller variations and the complex relations between the elements and processes of the abiotic natural system. The roughness value is establish from the dominant slopes in each unit. We have made a slopes maps using five intervals. The roughness coefficient of each unit corresponds to the dominant interval in the unit.

Once the algorithm is applied the geodiversity of the unit is get. The next threshold have been establish:

Geodiversity	Very Low	Low	Medium	High	Very high
Values	<15	15-25	25-35	35-45	>45

This procedure have been applied to the Tiermes-Caracena Area, a rural environment located to the South of the Soria Province. The area has 381 km^2 of surface and a relief characterised by broad valleys and uplands crossing by narrow fluvial gorges. The territory has strong abandonments rates of agrarian activity and a aged population.

In the study site have been defined 14 geomorphological units with different sizes and properties. Seven units are fluvial valleys and several of them, Caracena and Talegones Gorges for example, are sharply incised on highlands. In this units the roughness reaches values equals or higher than 3. The Sierra de Pela has a roughness coefficient value of 3,3 and the smallest roughness values are located on the planation surface and the orthocline valleys, and in second place the valleys formed in the pericline fold, with roughness coefficient value of 1. The soils represented in the study area are inceptisols and entisols.

The results obtain are showed in the next table:

Unit	Number of elements	Surface (km²)	Roughness	Geodiversity Index	Geodiversity value
Highlands	23	184	1	4.4	Muy baja
Pedro Gorge	22	12	2.5	22.1	Baja
Pozo Moreno Gorge	18	1	2.7	48.6	Muy alta
Tielmes Gorge	24	9	2.7	29.5	Media
Caracena Gorge	30	15	3.2	35.4	Alta
Madruédano Valley	8	4	2.6	15	Baja
Modamio Valley	14	3	2.5	31.8	Media
Talegones Gorge	18	7	3	27.7	Media
Liceras-Retortillo valley	30	73	1.2	8.4	Muy baja
Manzanares pericline fold	24	11	2	20	Baja
Pedro-Noviales Valley	26	32	1.7	12.7	Muy baja
Tejera Valley	20	8	1.8	17.3	Baja
Carramonte Valley	20	5	1.5	18.6	Baja
Pela Range	24	18	3.3	27.4	Media

In general terms the geodiversity is low. In the 75% of the surface (three units) the geodiversity is very low, related to the low values of slopes, wide surface and few constituents elements. Five units (10,4% of the surface) have low values, related to medium roughness and lesser surfaces with few constituents elements. The medium values are located in four units (9,7% of the surface). They are related to high roughness of fluvial valleys and the range Sierra de Pela. Only one unit has a high value, the Caracena Gorge, where the diversity of constituent elements and roughness is higher. The same character has the Talegones unit, with high values due more to the small surface (less than 0,3% of surface area) than by his abiotic constituents.

The index is easy to apply and it permit compare, at the same scale, between different territories. But the method must be confirmed in areas with more internal differences and, until it can be made, the method must be used with precaution. Some improvements must be included in the next applications. We can point up the necessity of improve the calculation of roughness by units and the relationships between surface and slopes. Now, the index is not applicable to small size units. Finally, it is necessary to improve the incorporation of other elements that increase the geodiversity, like palaeontology or micro-landforms. About the last one, in this work only his presence or absence have been considerate, with a collective value, but in the future and on other areas or scales, it could be considerate with individual values.

It is a quantitative approach to assess the Geodiversity. The objective is to be used, joint to cultural, ethnographic and biological assessments by planner and manager for use and conservation of abiotic and geomorphologic values of the territory. The map of geodiversity, together the indexes are useful tool for management.