Geo-indicators in Sustainable Management of Geoparks

Geopark Newsletter 2007-02-20

Ramasamy Jayakumar[1]

Liu Ke[2]

1] Dr. Jayakumar,Program Specialist, Natural Sciences Sector in UENSCO Office Beijing, r.jayakumar@unesco.org

[2] Mr. Liu Ke, Assistant Project Manager, Natural Sciences Sector in,UNESCO Office Beijing k.liu@unesco.org

Introduction: In the present day context, sustainability is primarily defined as the goal of providing economic, social and environmental conditions that meet the current and future needs of people everywhere. In order to achieve sustainability, we need to have the capacity to assess current conditions and trends, so that policies and practices can be tested and revised. Much effort is now being devoted to developing standard economic, social and environmental indicators with which to assess social and environmental conditions (Hammond et al., 1995; Berger, 1998; Moldan et al., 1997). Berger reviewed most of the published state-of-the-art environment reporting and found that most of the published reports appear to ignore key abiotic components of landscapes and ecosystems. For example, in the authoritative *Guide to the Global Environment*, the World Resource Institute (1996), in its review of major problems of rapidly growing urban areas, virtually ignores geo-hazards (McCall et al., 1996), whether they be catastrophic such asearthquakes, volcanic eruptions and landslides, or slower and more persistent, such as surface subsidence, ground-water contamination and depletion, sea-level change, and erosion.

Role of Earth Sciences in Geopark Management: Geology is the major determinant of the topography, the water and soil chemistry, the fertility of soils, the stability of hillsides, and the flow styles of surface and groundwater. These factors, in turn, can determine where and when physical, chemical and biological processes occur.

Despite the importance of the physical environment to park ecosystems, the geosciences traditionally have not been integrated into land management. In this traditional approach, landscape is often perceived as a web of biological processes playing out on an inert geological stage, as opposed to perceiving the landscape as a collection of processes -- biological, geological and social – that are inter-related and inter-dependent. Throughout the last two decades, the focus of land management has slowly been shifting from the former approach to the latter. This changing philosophy brings with it a need to devote increased attention to geosciences, particularly to the interaction between geologic and biological systems.

A challenge in appreciating the relevance of geology is that earth scientists often work with very long relative time scales, whereas life-scientists deal with much shorter time scales.

To overcome these ambiguities, the International Union of Geological Sciences formed a Commission on Geological Sciences for Environmental Planning which suggested standard methods for measuring geochemical, geophysical and geomorphological processes (Berger and Iams, 1996; Gouide et al., 1990). It aims to synthesize all the contemporary geological changes for any particular area that might be significant for environmental assessments. The triangular diagram (Figure 1) illustrates conceptually how the basic sciences of ecosystem studies contribute to our understanding and development of an ecosystem model.

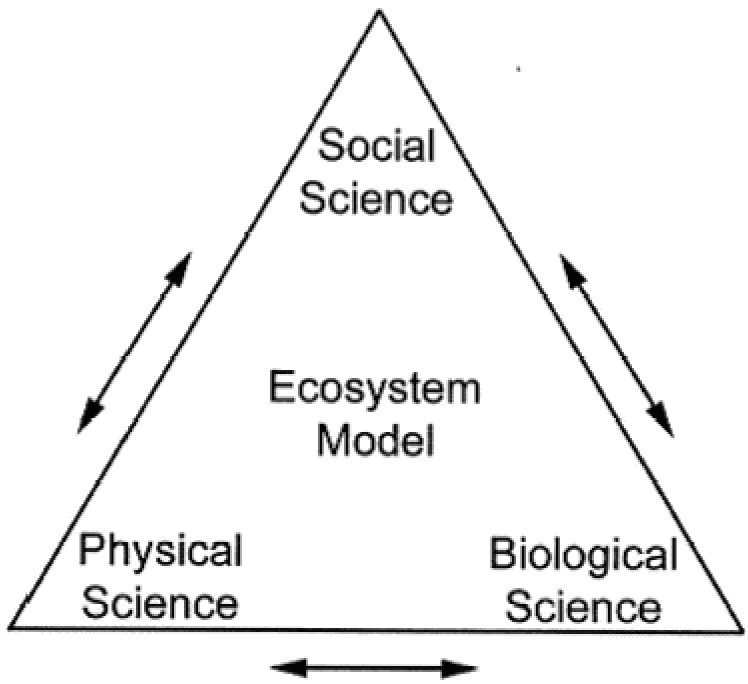

Figure 1. The basis of an ecosystem model.

Geoindicators: Geoindicators represent geologic environmental indicators recently developed to assess rapid change in the environment and provide some measures of an ecosystem.

Geoindicators measure environmental changes in ways that can be regarded as significant within the time span considered. They do not apply to important earth processes that generally take place in terms of geological time scale, such as diagenesis, metamorphism and deformation and plate tectonics.

Geoindicators express environmental parameters and the processes which are capable of changing with or without human intervention. Nature is dynamic; it always changes in space and time whether there is human intervention or not, even though humans are an integral part of nature.

Geology, geochemistry, geophysics, geomorphology, hydrology and other related earth sciences have been used to develop the geoindicators, as have the detailed expertise and technology needed to measure them (Gouide et al., 1990; Berger, 1997; Berger and Hodge 1998; Berger and Iams 1996). Some indicators are complex and costly to measure, but many are relatively simple and inexpensive. Table 1 indicates the geoindicators, changes, relative influences of human and natural (non-anthropogenic) stresses on geoindicators.

Table-1 Geoindicators and selected environmental changes they reflect, impact of natural and human influences and utilities for reconstructing past environment.H – Highly influenced by; M – Moderately influenced by; L – Low

influence

Geoindicator	Change	Natural Influence	Human Influence	Paleo reconstruction
1.Coral chemistry and growth patterns	Surface water temperature, salinity	H	H	H
2.Desert surface crusts and fissures	Aridity	H	M	L
3.Dune formation and reactivation	Wind speed and direction, moisture, aridity, sediment availability	H	M	M
4.Dust storm magnitude, duration, and frequency	Dust transportation, aridification, land use	H	M	M
5.Frozen ground activity	Hydrology, downslope movement, especially in active layer	H	M	H
6.Glacier fluctuation	Precipitation, insolation, melt run-off	H	L	H
7.Groundwater chemistry in the unsaturated zone	Weathering, land use	H	H	H
8.Groundwater level	Abstraction, recharge	M	H	L
9.Groundwater quality	Industrial, agricultural and urban pollution, rock and soil weathering, land use, acid precipitation, radioactivity	M	H	L
10.Karst activity	Groundwater chemistry and flow, vegetation cover, fluvial processes	H	M	H
11.Lake levels and salinity	Land use streamflow, groundwater flow	H	H	M
12.Relative sea level	Coastal subsidence and uplift, fluid withdrawal, sediment transport, and deposition	H	M	H
13.Sediment sequence and composition	Land use, erosion and deposition	H	H	H
14.Seismicity	Natural and human induced release of earth stresses	H	M	L
15.Shoreline position	Coastal erosion, land use, sea levels, sediment transport and deposition	H	H	H
16.Slope failure-landslide	Slope stability, mass movement, land use	H	H	M
17.Soil and sediment erosion	Surface runoff, wind, land use	H	H	M
18.Soil quality	Land use, chemical, biological and physical soil process	M	H	H
19.Stream flow	Precipitation, basin discharge, land use	H	H	L
20.Stream channel morphology	Sediment load, flow rates, climate, land use, surface displacement	H	H	L
21.Stream sediment storage and load	Sediment load, flow rates, climate, land use, basin discharge	H	H	M
22.Subsurface temperature regime	Heat flow, land use, vegetation cover	H	M	H
23.Surface displacement	Land uplift and subsidence, faulting, fluid extraction	H	M	M
24.Surface water quality	Land use, water-soil-rock interactions, flow	H	H	L

	rates			
25.Volcanic unrest	Near-surface movement of magma, heat flow, magmatic degassing	H	L	H
26.Wetland extent, structure and hydrology	Land use, biological productivity, stream flow	H	H	H
27.Wind erosion	Land use, vegetation cover	H	M	M

Criteria to evaluate geoindicators: The geoindicators provide sufficient information to assess each indicator based on ten separate criteria. With these tools, we can easily determine the significance of each indicator for specific *Biosphere Reserve* (BR) ecosystems. In addition, these criteria help to define parameters for monitoring each indicator.

1.Significance – Why is it important to monitor this indicator?

2.Human or natural cause – Can this geoindicator be used to distinguish natural from human caused change, and if so, how?

3.Environment where applicable – In what general landscape setting would this geoindicator be used?

4.Spatial scale – At what scale would this geoindicator normally be monitored in the field?

5.Types of monitoring sites – Where specifically should the geoindicators be measured?

6.Method of measurement – How is this indicator measured in the field?

7.Frequency of measurement – How often should this geoindicator be measured so as to establish a time series and baseline trend?

8.Limitations of data and monitoring – What significant difficulties are there in acquiring field and laboratory data?

9.Application to past and future – How can this geoindicator be applied to paleo-environmental analysis?

10.Possible thresholds – What thresholds and limits can not be exceeded without drastic environmental changes or threats to human health and biodiversity?

Human Influences in Indicators:

Most of the indictors were grouped under generic themes of Land use, Consumptive use, Tourism use and Developmental (administrative) use in order to determine their impacts in the BR ecosystems.

Land use changes (most commonly occurring adjacent to BR sites):

Agriculture – Intense agricultural activity can cause a loss of soil, erosion and dust storms; intense use of fertilisers and pesticides can affect both surface and subsurface water quality.

Grazing – Overgrazing aggravates soil erosion and create conditions conducive to fire.

Forestry – Intensive logging creates favourable conditions for increased erosion and lodging of sediments in streams that could affect fluvial habitat.

Water impound – By changing the stream morphology and flow patterns of the river, it controls sediment load and sedimentation process which has a direct impact on the habitat that are dependent on a fluvial system.

Urbanization – Urban activities have many negative environmental impacts, the most important of which are changes in natural drainage patterns, increased erosion, changes in surface and subsurface water quantity and quality and the release of toxins into the atmosphere which alter the climate of the region.

Consumptive uses:

Groundwater extraction – When excessive groundwater extraction affects the groundwater's equilibrium, it also affects groundwater-dependent ecosystems; continued exploitation may also cause ground subsidence.

Oil and gas extraction -- This activity may cause ground subsidence and contaminate surface and subsurface water.

Mining - Mining activity reconfigures the entire landscape permanently, and mining waste and its leaching may pollute soil and water bodies. Its ramifications to the environment are not yet fully understood.

Tourism use:

Trampling and compacting of soil – Overuse by too many people in a small area can compact the soil and diminish its capability to function and maintain itself as a viable part of the ecosystem.

Social trails – Depending on the fragile nature of the environment, walking off-trail can seriously damage fragile resources.

Boating – Recreational boating over a period of time can affect the water quality through fuel contamination.

Developmental (administrative) use:

Roads & bridges – Often these structures are constructed with little or no consideration for natural processes, and they can disrupt drainage, cause erosion and create hill slope instability. The abutments for bridges can change the flow and morphology of streams and rivers.

Water consumption -- BR sites located in arid and semi-arid lands need to be planned in such a way to require less water for its management.

The Role of Geoindicators in Geopark Management

By preserving unique geological resources, the contribution of geoparks towards tourism development has been well appreciated. Specifically, geoparks have also turned into a vehicle not only for the preservation of geological resources but also for creating employment, and enriching local inhabitants. For instance, in Yunnan China, the Shi Lin Geopark now attracts one million tourists per year, and the park has grown into a substantial stimulus for the local economy and a source of income for those living in the area.

Nevertheless, while appreciating the positive economic impact.

For example, the use of Geoindicators for geopark management may be seen in two ways. The first could be the use of indicators for setting geopark borders. For instance, in a report of IUCNon the Stone Forest Geopark (IUCN, 2002), it was noted that the “border of the park is not clearly defined, nor is it in high relation with local geological features,” and a “setting of the existent borders seems more dependent on tourism rather than geological values.”Apparently, if the border of the Stone Forest Geopark is not clearly defined, the geological resources preserved within represented by the Karst landscape, could be subjected to negative impacts of a larger scale. From this perspective, Geoindicators may help scientifically set the borders through investigating different Karst activities of the landscape, and this may subsequently serve to balance the preservation of geological resources and economic development.

Another potential use of Geoindicators for geopark management is an Environmental Impacts Assessment (EIA). Through measuring such indicators as groundwater level, stream flow and surface water quality, can geological condition -- which is a crucial aspect of natural environment within geoparks -- be understood. Moreover, these measurements may also indicate the sources of impacts on the environment (such as those from land use, consumptive use, tourism use, and developmental use), which would guide the application of the corresponding management strategies implemented thereafter. Nevertheless, it is still useful to notice that uses of Geoindicators for geopark management would not be limited to these two types. In addition, given the role of geoindicators for geopark management, they would not be the only indicators used to manage the parks; those from biological as well as anthropological perspectives may also be considered.