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A Study of Modern and Geologic Erosion Rates in the Colombian Andes by Low-Temperature Thermochronology, ^{10}Be Analysis, and GIS/RS-based Applied Geomorphology: An Attempt to Adhere to "a New Social Contract for the Sciences"

Sergio A. Restrepo M. Ph.D. Candidate
Department of Geological Sciences, University of Florida, Gainesville, Florida, USA, sergiorm@ufl.edu

Abstract
Whether occurring at its "natural" pace or enhanced by human activities, erosion is an important physical phenomenon. Form a "purely scientific" point of view, erosion deserves to be better understood because it controls many other physical processes across a wide range of spatiotemporal scales. From a more "practical" point of view, erosion deserves even more attention because myriad facets of current environmental degradation are influenced by erosion. Due to human activities, we are experiencing a time of exacerbated erosion rates in Earth's history. A novel approach (involving low-temperature thermochronology, ^{10}Be analysis, and GIS/RS terrain analysis) is used in an attempt to quantify and compare pre- and post-disturbance erosion in the Colombian Andes. This study is also an attempt to adhere to "a new social contract for the sciences". However, the staggering figures about anthropogenic erosion rates (1000X > than geologic rates) derived from sophisticated research techniques cannot solve the actual problem of enhanced soil erosion and depletion of other natural goods and services. Scientific-based information is not enough. Complex social dynamics determine what soils are lost, and even a new social contract for the sciences seems unable to solve the problem. What path should the scientific/academic community take?

Key Words
Anthropogenic-erosion, thermochronology, ^{10}Be, science, society

1. Introduction
Earth's surface processes are those that take place at the interface of the spheres (i.e., geosphere, hydrosphere, atmosphere, and biosphere). Although neglected for some time in geological sciences, it is now recognized that such processes have played a crucial role in the evolution of the Earth, are complex both spatially and temporally, and are characterized by feedbacks and fluxes of matter and energy between the spheres (Phillips, 1999). Erosion by water is one such process and it affects the evolution of landforms and soils (Owens and Slaymaker, 2004), the rate of regolith removal and transfer of sediment to water bodies (Meybeck et al., 2003), the morphotectonic evolution of orogenic belts (Burbank and Anderson, 2001), the composition of the atmosphere and ocean, (Raymo and Ruddiman, 1988), and changes in climate trends (Molnar and England, 1990), etc. Changes in climate, topography, vegetation cover, base level, etc. also influence erosion. In recent years erosion has become a fundamental line of scientific enquiry capturing the attention of scientist working in numerous disciplines such as geomorphology, environmental geology, tectonics, pedology, oceanography, and climatology.

But erosion is more than just an interesting scientific matter. In fact, due to human modification of the natural environment (e.g., deforestation), enhanced-erosion is one of the most pressing, worldwide environmental problems as it affects food security, hydrologic resources, and infrastructure (Goudie, 1995). The majority of human-induced changes in the rate and nature of geomorphic processes are detrimental to the sustainability of the environments that support society. In the tropics, where the majority of ecological “hotspots” are located (Mittermier et al., 2000), the combination of natural factors (e.g., high rainfall, steep terrain, active tectonics, etc.) and human-mediated processes (e.g., deforestation, development of infra-structure, etc.) result in some of the highest erosion rates in the world. Accelerated erosion usually triggers severe environmental degradation.

Relative to the geologic time frame, disruption of natural geomorphic dynamics and the consequent increase in erosion rates are fairly recent phenomena (Page and Trustrum, 2000). The Holocene brought with it the emergence of a new sphere, the technosphere; the realm of the human activities (e.g., agriculture, housing, industry, mining, energy, etc.). Processes within the technosphere have significantly modified the interactions between the spheres. Enhanced erosion is a direct consequence of this late Holocene scenario, and just as we thrive to understand past climate in order to comprehend the degree to which humans have perturbed the climate system, we must also cautiously study past erosion in order to understand the degree of perturbation of natural geomorphic dynamics. And, as is the case for climate, erosion is also a domain of inherently high complexity. Therefore, addressing erosion rates at several spatiotemporal scales requires the use of sophisticated tools ranging from those needed to remotely acquire and analyze terrain data (e.g., DEM, multispectral imagery, etc.) to those utilized in isotopic analysis (e.g., mass spectrometers, scanning electron microscopy, microprobes, etc.). The theoretical developments and research methods used today in quantitative geomorphology are equally sophisticated.

1.1. Controls on Erosion Rates

Of the variables that control erosion rates (e.g., topography, vegetation, substrate erodibility, and climate/rainfall erosivity) vegetation cover is the one most susceptible to influence by humans (Owens and Slymaker, 2004; Restrepo, 2003, Thornes, 1994; Vis, 1991). We live in a planet heavily impacted by human activities. Massive deforestation has occurred over the last few centuries in the tropics. This activity continues today at a rate of ~30 ha*minute^{-1}, a clear indication that our species is a prominent force within the Earth system.

It has been suggested that humans are now the greatest geomorphic agent (Owens and Slaymaker, 2004; Hook, 2000). In the Tropical Andes of Colombia (TAC), an important ecological “hotspot” (categorized by Mittermeier et al., (2000) as the global epicenter of biodiversity), the combination of natural factors and human-mediated processes cause some of the highest erosion rates in the world (Thomas, 1994; El-Swafy et al., 1982). In the TAC, ~95% of the natural vegetation has been destroyed. Inappropriate agricultural practices render soils even more vulnerable to erosion. Disrupted ecosystems exhibit altered hydrological and erosional dynamics and their long-term integrity is threatened (Mittermeier et al. 2001).

2. Geologic vs. Anthropogenic Erosion: Science with Immediate Social Applications

It has been hypothesized (Restrepo 2003) that average modern erosion rates in the TAC are three to four orders of magnitude higher than long-term, pre-disturbance erosion rates; an increase mainly attributable to anthropogenic activities. To test this hypothesis, a multidisciplinary approach to quantify geologic and recent erosion in the TAC is being implemented.

Despite the general acceptance of the anthropogenic origin of accelerated erosion, it remains difficult to tackle long-term erosion rates based solely on contemporary data. This is mainly due to the pervasive human impact on vegetation cover and slope hydrology. Moreover, estimates of erosion derived from fluvial sediments are spurious as sediment load fluctuates dramatically with time due to variations in discharge and sediment availability (Douglas, 1967). This has led to a dominance of qualitative approaches in studies of long-term erosion dynamics, which precludes reliable estimates of “baseline” erosion rates against which the effects of anthropogenic perturbation can be compared. The research project presented here involves the use of low-temperature thermo-chronology (LTTC), terrestrial cosmogenic nuclide analysis (TCNA), and geographic information systems/remote sensing-based applied geomorphology (GIS/RS-AG) to quantify erosion rates at three different time scales: long- (10^7-10^6 years), mid- (10^6-10^3 years), and short-term (10^2-10^1 years), respectively. This approach permits to overcome the difficulties mentioned above and allows a quantitative evaluation of anthropogenic impact on erosional processes against the estimated background rates of substrate stripping. In addition, results from this study will also shed light on the long-term patterns of landscape evolution and regional exhumation/uplift of an elevated plateau situated in an active mountain chain that is regionally important.

The way in which this investigation has been designed makes it not only scientifically challenging, but also allows making fundamental social contributions. A quantitative comparison of geologic and anthropogenic erosion rates will help raise environmental awareness by highlighting the critical role humans play in accelerating erosion rates and triggering environmental degradation manifested as loss of fertile soil, pollution of water bodies, destruction of terrestrial and aquatic ecosystems, deterioration of infrastructure, and alteration of climate/weather patterns.

3. A Research Strategy that Attempts to Fit Within "a New Social Contract for Science"

"It is time to take stock of the concepts, data and methodologies that can be applied now or in the very short-term to address several troublesome questions". Stone, 1979.

Traditionally, geologists have considered geomorphology more as a branch of physical geography than a geological discipline per se. However, three circumstances have lead to an increased mixture of geology and geomorphology. First, the rising acceptance of the intricate coupling between surface processes (geomorphology) and the morphotectonic evolution of geologic provinces, which resulted in the emergence of "tectonic geomorphology", one of the most interdisciplinary scientific disciplines (Burbank and Anderson, 2001). Moreover, the quantitative study of landscape evolution (at various scales of space and time) has blossomed over the last decade, mostly driven by the prevalent interdisciplinary interest in discovering the nature of potential interactions (at various scales of space and time) between climate, surface processes, tectonics, and, more recently, anthropogenic activities. Second, the recognition that all environmental and human systems are interlinked and that studying complexly interlinked systems in isolation is dysfunctional. And third, the realization that humans are a geologic force, and that, over a rather short time span, anthropogenic activities (i.e., the technosphere) are triggering uncontrollable and unpredictable readjustments of the other spheres (e.g., mass extinction, deforestation, ozone depletion, global warming, sea level rise/glacial melting, etc.).

Academic programs on geomorphology at the graduate level are now offered by geology and geography departments alike, providing unparalleled opportunities to establishing multidisciplinary research and to approximate sophisticated geological and geographic technologies (isotope geology, GIS/remote sensing, etc.) useful in studying both geologic and environmental matters. Courses of environmental geology, now spread across campuses, have resulted in large part from the hybridization of geology and geography. A further positive outcome is the emergence of a more interdisciplinary academic community that, through a more open dialogue, strives to comprehend the complexities of Earth's systems in order to plan a more judicious manner to operate the technosphere. In this investigation, the bridging nature of geomorphology and the proximity between geology and geography are exploited to address relevant geologic (landscape evolution, active orogenic belt exhumation, plateau development, etc.) and environmental problems (anthropogenically enhanced erosion rates, land use effects on geomorphic processes, etc.).

The evident nature of the adverse environmental effects of erosion on soils, biota (terrestrial and aquatic), and water resources make it a crucial environmental issue. Richter and Markewitz (2001) made the point that "humans are increasingly living in urban and suburban environments, away from the land and apart from the soil, yet the quality of human life and the Earth's environment has never depended more on soil management than it does today. Soil deserves a much greater share of human attention and affection…

Soil is the central processing unit of the Earth's environment". The costs associated with worldwide soil erosion are estimated to be ~$500 billion*$y^{-1}$ as a result of direct damage to agricultural lands and 'indirect' damage to waterways, infrastructure, and health (Pimentel et al., 1995). Undoubtedly these values would increase if other deleterious effects on the environment were considered (e.g., destruction of fisheries, desert expansion, etc. Restrepo, personal communication).

Within the framework just presented for this investigation it seems feasible to satisfy one's passion for science while simultaneously providing something useful to society. In other words, it becomes relatively simple to adhere to a new social contract for science as postulated by Lubchenco (1998): "Urgent and unprecedented environmental and social changes challenge scientists to define a new social contract. This contract represents a commitment on the part of all scientists to devote their energies and talents to the most pressing problems of the day, in proportion to their importance, in exchange for public funding".

3.1. The Research Strategy: A blend of Geology, Geomorphology, and Geography.

Although there is general agreement about the great intensity of modern erosion in the TAC, quantitative data on pre-disturbance rates are still scant. Understanding the degree to which humans have exacerbated erosion rates is crucial to raise the awareness in relation to soil and water depletion, a pressing environmental problem. However, a thorough understanding of erosion rates has often been limited by a lack of quantitative data, making it virtually impossible to understand the role of humans as a geomorphic agent or to discern patterns of landscape evolution.

Reconstructing long-term erosion histories by extrapolating current trends in erosion derived either from river sediment loads or experimental plots is spurious due to both the extent of human perturbation of natural geomorphic systems and the stochastic nature of sediment removal and transport (Trimbley, 1977). Measurements of erosion rates derived from AG studies (e.g., erosion pins, sediment load, sediment traps, experimental plots, etc.) carried out over short temporal scales (e.g., 10^0-10^1 years) are strongly influenced by anthropogenic perturbation of natural geomorphic dynamics (Douglas, 1967).

To the contrary, quantitative data for erosion rates generated for geologic temporal scales (i.e., 10^3 – 10^8 years) by using LTTC and TCNA provide reliable information about erosion rates free of anthropogenic signals (Burbank and Anderson, 2001; Gosse and Phillips, 2001; Farley, 2002). Such an approach permits defining a base-line of erosion so that pre-Holocene (i.e., geologic) and modern (i.e., anthropogenic) erosion rates can be quantified and compared, which allows us to increase our understanding about the impact of humans on natural geomorphic systems. For this investigation, erosion rates are quantified for three different time scales: long- (LT), mid- (MT) and short-term (ST), that is to say, from tens of millions to tens of years. The geologic (i.e., 'natural') rate of erosion will be measured and compared to modern (i.e., anthropogenically-enhanced) erosion rates.

Physiographic characteristics of the Altiplano Antioqueño (elevated plateau incised by the Medellín/Porce fluvial system, granodioritic batholith, anthropogenic perturbation of natural ecosystems via deforestation, etc.) offer an excellent scenario to reconstruct and compare geologic and modern erosion rates by using LTTC, TCNA, and GIS/RS-AG. This part of the study demonstrates the usefulness of helium dating to quantify long-term erosion rates and exhumation of the Altiplano Antioqueño. An integrated application of LTTC, TCNA and GIS/RS-AG can not only revolutionize our understanding of erosion, but also provide a quantitative basis to support our models of morphotectonic evolution in diverse geologic provinces. Because TCNA and GIS/RS-AG are still in a very early stage of implementation for this research, only preliminary results of apatite helium dating are presented.

3.1.1. Low Temperature Thermochronology

LT data (10^6-10^7 years) are derived from high-resolution LTTC, specifically the systems (U-Th)/He (partial retention zone-PRZ ~ 40-80°C), and fission tracks in apatite (partial annealing zone-PAZ ~110-

60°C). Helium analysis is based on measurements ^{4}He (emitted and retained α particles) resulting from the radioactive decay of ^{235}U, ^{238}U y ^{232}Th. Thermokinetics of helium diffusion and α-particle stopping distances in apatite (~20μm) are well constrained. Thus, measurements of U, Th and He by mass spectrometry allow calculating the closing time of the system. The equation that defines the accumulation of ^{4}He through time is (Farley, 2002):

$$^{4}He = 8*[^{238}U(\exp(\lambda_{238}\, t) -1)] + [7/137.88]*[^{238}U(\exp(\lambda_{235} t) -1)] + 6*[^{232}Th(\exp(\lambda_{232} t) -1)]$$

Where ^{4}He, ^{238}U, and ^{232}Th represent the amounts of such isotopes as measured in the sample by mass spectrometry, t is the accumulation time (retention) or radiometric age, and λs are the radioactive decay constants for each isotope.

Apatite fission-track analysis relies on the measurable amount and length of lattice defects (tracks) induced by spontaneous nuclear fission of ^{238}U (Gallagher et al., 1998). These two thermochronometers possess the lowest closure temperatures known. LTTC-derived apparent ages obtained from samples collected along vertical profiles (e.g., canyon walls/scarps) and analyzed against elevation provide a measure of long-term erosion rates because both systems record the time at which a rock cools through the last 3 km of the crust (~ 60-90°C), a domain strongly influenced by surficial processes such as erosion (Burbank and Anderson, 2001).

A Preliminary examination of the data derived from helium analysis for Matasanos and La Garcia profiles shows a very well behaved data set with excellent reproducibility of helium ages and very little dispersion in the apparent age vs. elevation plots. Helium ages decrease systematically with profile depth for all of the samples collected along the Medellín-Porce scarps from 48.9 ± 2.4 Ma to 22.84 ± 1.14 Ma. Such behavior is in agreement with theoretical profiles and apparent age vs. elevation diagrams. Exhumation curves clearly display the inflection points, and the characteristic shape of the exhumed PRZ-helium. The first segment of the cooling curves for both profiles indicates a typical rapid-exhumation period starting at about 25 Ma. The similarity in the age versus elevation distribution is a sign of very good internal consistency of both data sets and can be interpreted as the exhumation of the entire plateau as a continuous, discrete unit. Even though the samples analyzed represent the full extent of the crustal section exposed along the northern scarps of the Medellín/Porce fluvial system, fission-track data is required in order to reconstruct the paleo-geothermal gradient, which will permit a more accurate estimation of erosion rates. The period of quiescence represented by the "shallow" segment of the profiles gives an average erosion rate of about ~0.037 mm*y^{-1} that prevailed from ca. 45 to ca. 25 Ma (~ 20 Ma). Such rates are well below estimated modern rates ~80 mm*y^{-1}.

3.1.2. Terrestrial Cosmogenic Nuclide Analysis (^{10}Be)

Quantification of MT erosion rates (10^{6}-10^{3} years) will be based on TCNA of ^{10}Be. Terrestrial cosmogenic nuclides (e.g., ^{10}Be, ^{26}Al) are produced by the interaction of cosmic rays (mainly neutrons) with a variety of target atoms, e.g., Si and O in quartz. Neutrons are rapidly attenuated with depth in the uppermost crust, and hence, can be employed to monitor near surface processes (e.g., erosion, geomorphic exposure). Nuclide activities of a sample, as measured by accelerator mass spectrometry, are greater for materials collected on geomorphic surfaces with low erosion rates/long exposure times (Goose and Phillips 2002). For this investigation, ten site-specific samples of rock, soil and regolith obtained on erosional surfaces will yield erosion rates at discrete points on the landscape. In addition, twelve samples of active sediment from small fluvial systems will be used to determine spatially averaged erosion data at the basin scale.

3.1.3. GIS/RS-Based Applied Geomorphology

Reconstruction of ST erosion rates (10^{6}-10^{3} years) is in progress. A GIS/RS-AG model of spatial patterns of erosion that incorporates the variables that exert the greatest control on erosion is being constructed. The potential of GIS/RS data and digital terrain analysis in geomorphologic studies has been stressed elsewhere (Wilson and Gallant, 2000). Data being employed include multispectral Landsat 7ETM+ scenes, digitized lithological and pedological information, high-resolution relief data from NASA's SRTM-DEMs, and meteorology/basin hydrology data by HIDRO-SIG-National University of Colombia. The analysis will also involve existing sediment load data for the Cauca and Magdalena rivers.

3.1.4. Bridging the Gap between Research and Education at the Basis of Society.

> *"Despite the emergence of a worldwide environmental movement, capitalism and consumerism are virtually everywhere triumphant. The great scam called the global economy is reshaping the world for more consumption, not less. And not the least, mass advertising aims to reshape the minds of young people to believe that consumption is their natural right." Orr, 1998*

More than a decade ago, several authors (e.g., Lubchenco, 1998; Meffe, 1998) pointed out that establishing proper mechanisms of exchange between science and society was the most critical endeavor the scientific community could pursue, as a way to facilitate the use of scientific knowledge in shaping a more sensible relationships with the natural world as well as with other fellow citizens. Such mechanisms of exchange must of course work in both directions and should foster easier access and better understanding of science by society in general. Years continue to pass by and it seems that scientific knowledge has a strong tendency to staying sequestered in journals (written by elites and for elites), which ultimately accumulate dust on library shelves rather than becoming a useful tool for society to enact some change (e.g., stop environmental degradation).

As discussed above, this investigation had a double aim. On the one hand the importance of erosion as a geologic phenomenon had to be addressed in a region where quantitative studies of this matter are scant. Of equal importance was the need to compare geologic and anthropogenically enhanced erosion rates so that the role of humans as a strong geomorphic agent would be a good excuse to start exploring, in a systematic manner, erosion as a crucial environmental problem. The reasons to consider erosion as a major environmental threat are many but let us just summarize those who concern only soils themselves.

Appropriately managed, soil circulates water, chemical elements, and energy, thus providing an incommensurable suite of ecologic goods and services, without which, it becomes virtually impossible to visualize an optimistic future for human society and for life in general (Richter and Markewitz, 2001). Soils represent one of the fundamental supporting structures for life. Soils both result from and respond to geologic and geomorphic processes, biota (including human activity), and climate. Because soils are the ultimate source of food for humans as well as for other organisms, erosion is also central to the well-being of society in general. The TAC constitute one of the most heavily populated mountainous regions in the world. The Magdalena river basin for instance, ranks 3rd in population density. That implies high levels of stress on the base of resources present in the area, in particular soil and water. Both the Magdalena and Cauca rivers exhibit sediment loads comparable to those of the Ganges. Such high sediment loads are an indication of the velocity with which soils are being eroded away as a consequence of changes in land use that have taken place since colonial times.

After addressing the technical aspects of erosion in tropical mountainous systems it was necessary to find a way back to the community so that the knowledge gathered through expensive and sophisticated research methods could transcend the usually enclosing realm of higher academe (i.e., inaccessible journals, meetings, summits, etc.) and reach the base of society, thus completing the task of reverting useful information to humanity. For this investigation the path was an expeditious one. Within the study region targeted in this research The Corporation for Investigation and Regional Ecodevelopment (CIER, NGO), operates a vast project for education among economically depressed rural communities. The project directly serves more than 9,000 people and has two accredited academic programs, both with emphasis on alternative management practices for sustainability, one at the high school level and another one at the college level. Indirectly, about 120 rural villages benefit from the project.

The strategy for incorporating this investigation into CIER's educational project includes the modification of the actual curriculum to include earth and environmental sciences with focus on erosion. The process is now in its initial phase of implementation but the strategy will be helpful not only in giving continuity to the research project undertaken and disseminating the findings of the investigation per se, but also in transferring to the local communities all cognitive and technological capacities to monitor erosion rates by: 1) Establishment of experimental plots, meteorological stations, and instrumentation for small catchments in order to collect modern data on rates of sediment production and transfer efficiency to waterways; 2) enhancement of the GIS/RS-based study of modern patterns of erosion; and 3) experimentation with alternative land-use practices while monitoring changes in sediment yield from watersheds.

This last portion of the research project should bring about the essence of "a new contract for science".

4. Erosion and the Disjunction between Science, Education, and Society

"How can we as a scientific society become more effective and influential in using science to inform policy? I invite a dialogue… on how we can make such a transition and thus improve the chances for a sane and livable world for humanity and biodiversity". Meffe, 1998.

In spite of decided and unparalleled efforts to understand erosion past and present, erosion by water continues to be one of the most pressing environmental problems (see special publications Global and Planetary Change, 2003, Vol. 39; PAGES, 2000, Vol. 8; and UNEP, 2002). Sediments derived from enhanced erosion are the number-one pollutant of water in the USA (UNEP, 2002). In Colombia, fumigation, deforestation and expansion of the agricultural lands resulting from an absurd war on drugs, as well as inadequate environmental policies, are causing erosion to increase rather than diminish. And then one is obligated to ask: What are the actual benefits of understanding erosion by undertaking costly and sophisticated scientific studies? It has been suggested that through dedicated efforts in education and science it will be possible to construct an alternative societal paradigm: one that must envision society's progress with minimal detrimental effects on the environment, as the latter is the ultimate and finite base of resources we can count on (Lubchenco, 1998). But what educational and scientific frameworks are in operation out there to support this statement, when the whole purpose of higher education is being challenged (Long 1992, Illich, 1968)?

Erosion in the tropics is not a recent environmental problem. In fact, erosion has been the focus of major attention for more than half a century and several studies have attempted to alert both the public and policy makers about the disastrous consequences that can come with enhanced erosion. Restoring "normal" geomorphic dynamics is a rather difficult enterprise. The reasons are many and include increased population, increased pressure on soils, erosion of natural and cultural capital, and prevalence of certain political and economic models. No sensible research strategy, not even a new contract for the sciences seems to be having a noticeable effect on current trends of environmental deterioration. Perhaps with soil erosion (and environmental degradation in general) we are (as in the case of overpopulation, war, infectious diseases, etc.) confronting a problem that has no technical solution (Hardin, 1968). From that perspective, if we continue to look for solutions in the realm of science and technology only, the most likely result will be a worsening of the situation.

However, the academic enterprise, particularly in science and technology (aided by the media and the political class), is increasingly propagating the idea that most societal problems have a technological solution. This misconception has rapidly colonized the minds of the constituents (who are now expecting technology to be a panacea) while suppressing actions in other orders such as human values and morality (Hardin, 1998), when, in fact, major alterations of the ecosphere have been attributed to rapid technological development (Slaymaker, 2000).

It is also unlikely that the problem of environmental pauperization, as suggested by some authors (e.g., Dos Santos, 2002), is strictly related to lack of knowledge, or ineffective dispersion of that knowledge. Implantation of civilized, western knowledge in countries such as China have already proven catastrophic morally and environmentally (see special issues of State of the World 2006; Nature, 2004, Vol. 435; and Global Change News Letter, 2005, No. 62). Furthermore, China's example invalidates one of Lubchenco's (1998) central propositions: planning will no longer lack the essential scientific knowledge to accomplish its goal of protecting our base of resources. Who would be even tempted to suggest that "planners", either in China or the US, have caused major environmental chaos on the basis of lack of scientific knowledge? What knowledge do we want to spread? How can we regain access to indigenous knowledge in a scientific/academic environment founded on Euro-centric curricula? Would the dissemination of scientific knowledge and associated technologies help solve the problem? Perhaps not! Fagin and Lavelle (2001) provided several examples of obscure alliances between research groups, corporations, media, and policy makers aimed at fabricating and disseminating erroneous scientific facts to mislead the public. It is also known that corporations not only have hordes of scientists working directly for them, but also have many others in academia working "indirectly" through studies that they subsidize. For Meffe (1998), at high political instances scientific reasoning and potentially impartial scientific findings "hold minor importance in a world driven by voter satisfaction, campaign dollars, demands of constituents, the power of special interests, and political relationships". He further defines the task of trying to inject science in policy making as "a daunting task". It is difficult to understand, however, how the author concludes that science is held in high regard by most political leaders and that "they are quite receptive to our messages".

Albeit some isolated efforts by independent groups of researchers in trying to blend social and physical sciences in alternative ways to tackle complicated problems such as conservation and development in the tropics (e.g., Kainer et al., 2006; whose success in resolving the problem they address is still a matter of debate), it seems that universities are hardly trying to reverse the multi-decadal trend of training "the pieces" that will perpetuate an even more technocratic society. Furthermore, an academic community that reflects very little on the transcendental definition of purpose for higher education (Long, 1992) favors the maintenance of a technocratic society, one that sees only in technological "advancement" the solution of all crucial problems, one where there is even less opportunity for reflection or for consideration of moral values as an alternative means to overcome the actual crisis. If that appreciation is correct, then the dispersal of academia-manufactured knowledge can be more deleterious than beneficial.

The academic realm also seems to be overwhelmingly contributing to perpetuate just one type of knowledge. And then, as suggested by Dos Santos (2002), knowledge can become an instrument of acceleration of the already present process of social division (and environmental chaos), instead of becoming a mechanism for humanistic and sustainable development. From that perspective the university will be playing against society. One good example of such "deleterious knowledge" gestated in the university domain and rapidly absorbed by society (through several mechanisms) is provided by the assertion that "It is simply wrong to believe that nature sets physical limits to economic growth" (Sagoff, 1997). Even though Sagoff is a proclaimed enemy of cost-benefit analysis as a means to create environmental policy (because the approach usually fails to use a full-cost type of assessing, see Constanza et al. 1997), such an imprecise approach to a crucial societal problem contributes to the dissemination of misconceptions (e.g., the idea that our base of resources is an infinite one, or that problems of food security in the near future are improbable). On the other hand, it is true that the university allows for the germination of alternative knowledge. However, that alternative knowledge is produced in very small amounts and, due to reasons still hard to determine, is very hard to disseminate.

Finally, there is the problem of an egocentric academe rather inflated in its technological aspects, in which each individual is in pursue of academic prestige by compulsively following three destructive dogmas: "Publish or perish", "expensive science is good science", and "more technology is best". Co-option of these dogmas in modern research environments creates an avalanche of redundant and notmeditated-enough scientific information, while fostering the illusion that most environmental problems have a technological fix. Yes, technology can extend our view into the distant universe and into the intricacies of the subatomic world, but at the expense of diminishing our ability to see (and inquire about) what is before our very eyes.

The risks inherent to envisioning technology as panacea and/or religion are many. For instance, adherents to the religion of technology would easily fail to understand a simple argument such as this: “Once we fully industrialize our food production systems, society will have lost much of the cultural information required to farm more efficiently (again, full-cost put into the equation) and feed the community in less precarious and more desirable ways” (Restrepo, personal communication). Adherents to the dogma of technology will not accept either that technological solutions are not neutral and that, in fact, they skew power and resources in one way or another (Orr, 1998).

5. Epilogue: Where is Hope to be Found?

Teenagers in the US can recognize about 1000 corporate logos but know less than 10 plants and animals native to the places in which they live. From Hawken, 1993.

There are esthetic matters about environmental issues on which people will disagree, e.g., whether a desert is a more desirable landscape than fertile grounds or forested land. What cannot be disputed is the importance of both productive agricultural lands and forested ecosystems in granting the sustainability of life in the planet. The economic cost of obliterating the planetary base of ecological goods and services (Constanza,1997) in order to convert land into deserts or urban centers does not admit controversy either. Ehrlich et al., (1997) indicated that Sagoff (1997) not only oversimplified the problem of scarcity of natural resources but also had “done a disservice to the public by promoting once again the dangerous idea that technological fixes will solve the human predicament”. Ehrlich et al., (1997) fervent response to Sagoff’s (1997) erroneous appreciations illustrates an important matter: there are members within the academic environment that are very competent, not only intellectually and cognitively but also morally, who are working to transform academe and society, and who are willing to eradicate all manifestations of pomposity and frivolity from the academic endeavor in order to establish the necessary link with the base of society. In that link, and assuming that researchers in all disciplines will maintain a profound appreciation for indigenous knowledge, remain great hopes for society.

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