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Distinguished Ecologist Commentary

Humanity will sustain tropical forests

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I reject gloom and doom scenarios that predict a bleak future for tropical forests. Instead, I believe that humanity will find ways for conserving tropical forests and their biodiversity. To do so will not be easy as it requires proactive management of all tropical lands (Lugo 1995, 1999) and increased levels of scientific understanding of natural systems. This effort will benefit from, but cannot exceed, the enormous resilience of tropical ecosystems (Lugo *et al.* 2000a). In this vision of the future, humans will use ingenuity, knowledge, technology, and resources to address and resolve natural resource issues. Active management is the key to a prosperous future, even as fossil fuels decline (Odum & Odum 2001). I arrive at this position after 40 years of study and learning about tropical forests. Interestingly, I was a gloom and doom ecologist during the first half of my career. What changed?

A lot has changed in the field of tropical ecology since I began my career in the early 1960's. At the time, it mattered if you were an ecosystem or a population ecologist. You belonged to one school of thought or the other, and there was little integration. Technologically, we had no computers (I used a mechanical Monroe calculator with a built-in constant to accelerate calculations), no GIS (we colored maps by hand), no portable LICOR photosynthetic apparatus (my bulky Beckman infrared IRGA required that I carry a gasoline generator to the field along with a lot of other equipment to measure gas exchange). More important, however, was our view of ecosystems. At a time when ecologists were establishing the basis of ecosystem structure and function, our attention was focused on natural mature ecosystems. Mature systems are closer to steady state, which facilitates comparisons of structure and function across broad ecological gradients. The classic paper by E.P. Odum (1969) crystallized the dichotomy between mature unspoiled natural ecosystems and young successional ones recovering from human impact. Tropical ecologists were very selective in choosing mature stages of succession and these ecological systems became the standard of scientific study and conservation.

Today, the dichotomy between ecosystem and population ecologists has faded somewhat as it is clear that both views are important for ecological understanding. We also have a different understanding of the levels of biotic organization or hierarchies of structure and function in the world. However, we have not overcome our focus on mature natural systems at the expense of secondary, degraded, or human designed ecosystems. I am not saying that these types of ecosystems don't get any attention, but the level of attention they get is much less than that given to natural mature ecosystems.

Regardless of what tropical ecologists do, tropical landscapes are changing very fast because of the high level of human activity. A measure of this change is the loss of forest area to deforestation (15.2 million ha per year between 1990 and 2000; FAO 2001). The area of degraded lands in the tropics is also increasing, which justifies the need for rehabilitation actions (Brown & Lugo 1994). However, the current popularity of restoration ecology is but one aspect of how humans are beginning to address the plight of tropical forests.

To understand the role that humans will play in the conservation of tropical forests, it is necessary to understand the major trends in events affecting the global forestry sector. According to Global Trends, a non-governmental organization established to sustain forests by creating and cap-

turing their market value, these major trends include:

1. Major threats not clearly perceived a few decades ago (global change, alien species).

2. Dramatic increases in indigenous and other community ownership of forests and management (443 million ha of forests in 24 of the top 30 forest countries are owned by these groups; White & Martin 2002).

3. Market changes including the emergence of tree plantations as a main source of wood (tropical tree plantation area increased over 6-fold since the 1980's to 68 million ha in 2000; FAO 2001).

4. Increased influence of global markets on forest management.

5. Emerging demand for environmental services of forests.

6. Greater attention to governance and the growing role of independent certification.

7. Increased assertiveness of the 'South' and reduced assistance from the 'North' with a proliferation of global issues fostering disjoined and confused responses by both sides.

How should tropical ecologists react to these trends? What is our role in promoting tropical forest sustainability? Obviously, we must continue to do the work in progress with the cataloging of biodiversity, developing understanding of ecosystem structure and functioning, promoting the conservation of rare and endemic organisms, supporting increases in the area of protected wild lands, supporting the protection of remaining wilderness wherever we find it, and so on. This traditional ecological approach to tropical forest conservation needs to be set in the context of long-term study with attention to large and infrequent disturbances (Dale *et al.* 1998). These events, even if of short duration, have enormous influence over long-term ecosystem response. In Puerto Rico, for example, a four-hour hurricane event triggers responses that are measurable beyond the next 60 years (Lugo *et al.* 2000b). If we fail to identify the disturbances responsible for ecosystem response, we are in danger of misinterpreting the causes of ecosystem changes.

However, continuing the work we have done for decades, even if we incorporate new approaches such as disturbance and landscape ecology with all the fascinating technologies that accompany such fields, is not sufficient to reverse the degradation of resources now in progress throughout the tropics. We are still missing the human component of the resource management equation. Incorporating the human component has been one of the most important transformations in the field of tropical ecology since I started my career.

In college, I learned that scientific activity was justified by the contributions it made for improving the welfare of people. In the 70's and 80's, ecologists viewed humans as agents of disturbance, polluters of nature, and a factor that operated outside of the natural realm. These views were not universal among tropical ecologists. My mentor, Howard T. Odum (1962) was always seeking ways of designing new ecosystems where humans and nature functioned in harmony. He was in the minority. In fact, tropical ecologists are usually ambivalent when operating at the interface between humans and natural ecosystems. I vividly remember a graduate student discussion in Chapel Hill, NC in the 1960's between my two closest friends Peter Murphy and Jack Ewel. One was arguing that you could not find a single hectare in the tropics that had escaped human influence. The other was arguing for the existence of such a hectare covered with undisturbed forest. My mind was racing, unable to take sides and to my friend's chagrin, 1 played my minority "I don't speak English" card and kept silent.

Today, there is no question in anyone's mind (I hope), that human effects on the biosphere are global. Just by changing the gas composition of the atmosphere, we impact most ecosystems of the world. Some use the global level of the human impact on the biota as an argument to continue to exclude humans from natural systems. However, such exclusion is impractical. It is impossible to separate humans from the biota because we are part of the biota. Moreover, the ecological systems of the Earth have always adjusted to the conditions facing them and are doing so today in response to our influences as a dominant species. The mechanisms of adjustment include species remixing and self-organization guided by natural selection. The process leads to new ecosystems that maintain function and services, and which are adjusted to emerging environmental conditions.

Humans have always had enormous influence on the species composition of tropical forests. Arturo Gómez-Pompa & Brainbridge (1995) described how the Maya altered the species composition of large forest areas in support of their food

and fiber requirements. The Maya were tropical forest managers. Today, the flora of these forests maintains the human imprint (Rico Gray *et al.* 1985). Even the giant mahoganies that are the subject of today's conservation debates, originated in Mayan agroforestry fields (Lamb 1966). What appears to be pristine nature turns out to be human-designed.

Research in the Luquillo Experimental Forest uncovered the importance of the human footprint on forest structure and composition. Jill Thompson *et al.* (2002) found that sites deforested, farmed, and abandoned many decades ago maintained the human imprint through altered species composition and that even the passage of several hurricanes could not erase the human imprint of these forests. We now know that to better understand forest structure and composition we need to understand the history of human use of the site. We ignore past human activities at our own peril.

Suppose we didn't know that the Maya forest was a human construct or that, the secondary forests of Puerto Rico and elsewhere have a human imprint in them; does that make these forests less valuable or less ecologically functional? I remember a discussion with a professor, who wanted to protect tropical biodiversity by eliminating human influence from the landscape. He was particularly proud of the re-discovery of a wild race of corn, thought to have been extinct. He and his assistants found the wildling in a deforested tropical pasture. I always wondered if he ever understood the irony of the situation. We found four endemic tree species in the Metropolitan area of San Juan (Lugo & Brandeis, 2005) to the chagrin of some botanists. I interpreted the finding as a celebration of life. These endemic species grew in the urban forest because what are important are the conditions of growth and not the label of the site as "urban". Even in urban environments, you can find beautiful and diverse forests with endemic species.

Nowhere is the challenge of incorporating humans into the tropical forest experience more daunting than with the issue of alien species. This issue raises legitimate differences among tropical ecologists on how these species are viewed and assessed in relation to native species (Ewel *et al.* 1999). However, the resolution of differences is clouded by the introduction of value-laden terminology and by extrapolation of observations beyond reasonable limits (Lugo & Brandies, 2005). Terms such as "weeds" and "pests" are examples of value-laden terminology that suggest that the species so designated have either no intrinsic ecological role or are somehow unworthy of consideration. Yet, we have known for some time that weeds and pests are associated with particular ecological conditions, usually created by human activity. Crosby (1986) said it best in his book (p. 170): "...weeds were crucially important to the prosperity of .. Europeans. The weeds ... aided in healing the raw wounds that the invaders tore in the earth. The exotic plants saved newly bared topsoil from water and wind erosion and from baking in the sun. And the weed often became essential feed for exotic livestock, as these in turn were for their masters. The colonizing Europeans who cursed their colonizing plants were wretched ingrates." Do these principles apply to the current expansion of aliens in the world?

Our experience in Puerto Rico suggests they do. Most groups of taxa in Puerto Rico have increased in number of species since humans set foot on the island several millennia ago. In terms of trees for example, 27 percent of the tree flora is alien. These species include not only ornamental trees but also naturalized species that are now among the most common ones on the island. These aliens are mixing with native and endemic species, colonizing abandoned agricultural fields, and forming diverse forests that are new on the landscape because they have species composition and mix of species not seen in the island before (Lugo & Helmer 2004).

I see these new forests as nature's response to the changes that human activity is introducing on the environment. Upon reflection, it seems obvious that a natural response to disturbance regimes introduced by human activity on the landscape is a change in species composition. A change in species composition maintains ecosystem functioning under the novel environmental conditions. Very often, humans create conditions that preclude the establishment and growth of native species. Given the large species pool in the world, it is likely that an alien species will be capable of growing and reproducing in these novel environments. We should not be surprised by the changes in the rates of ecological processes in alien-dominated forests. Many times these species either have to overcome site degradation, in which case their metabolic rates are slower than those of native species, while in

other situations they exploit untapped resources that favor explosive growth. The surprising event would be a static response of natural ecosystems in the face of dramatic changes of environmental conditions introduced by humans. Our tendency is to assign value to any documented change in ecological processes and assume that if we somehow eradicate a particular species, the ecosystem will be as it once was. Unfortunately, global change is not reversible and the wide spread of alien species might be a blessing in disguise because their presence adds to the genetic diversity of locations and increases the opportunities of vegetation cover in the face of intensive human pressure on the land.

So how will human intervention help conserve the tropical forest? The global trends impacting the forestry sector (listed above) all reflect the power people have when they dedicate resources and effort to a particular cause. Planting trees, providing incentives for conservation, active management, better governance, local empowerment, and improved understanding of nature to avoid inaction and fear of ourselves are a few examples of how humans will reverse the degradation of tropical forest lands. A particularly promising approach is the building of financial value into forests.

The market system has proven unreliable in the valuation of natural products from ecosystems. Witness the negative effects of markets on the exploitation of wood and fisheries. However, by marketing ecosystem services and functions, it might be possible to use market forces for conserving forests because if the forest is lost, the market loses its profit from the investment on products and services. This is already happening all over the world (Unasylva 54 (212): 2003). It turns out that green infrastructure is a much cheaper way of solving many environmental problems than gray infrastructure. In New York City, for example, it was cheaper to purchase and manage a whole watershed to supply the city with clean water than it was to treat the water with filtration plants (1.5 billion dollars vs. 5 billion dollars). The choice is clear and telling.

As positive as these developments are, they are no panacea because the market will never absorb or value all of the biodiversity of the world. A significant sector of the biota will always be outside the market and it is up to our sense of ethics and understanding to preserve the intrinsic values that are at the core of naturalness. I will feel positive about the prospects of humanity's relationship with nature if we learn to deal objectively with the biota and understand that species and ecosystems follow natural laws and are outside of human control. As long as there is life, there will be change and formation of new ecosystems. Understanding and coping with continuous change is the ultimate challenge to humanity.

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