

cal units, but the losses to the society are 14 hypothetical units. The difference according to ecological economic criterion is $10 - 14 = -4$.

In the second technological variant 10 hypothetical units of benefits will turn out into zero benefits for the society. All the benefits should have been spent to compensate for ecological losses, caused by the production activity of the firm. So the future ecological costs to the society will be equal to the benefits of the firm. The difference according to ecological economic criterion is $10 - 10 = 0$.

In the third technological variant the benefits of the firm will be real, as its activity have not caused ecological losses. The benefits of the firm will not cause any losses to the society, as there will be no ecological losses. The difference according to ecological economic criterion is $10 - 0 = 10$.

The fourth variant is even better, it could be called the "optimal" one, as it satisfies both ecological and economic requirements. However, it is extremely difficult to achieve this variant of technology in the real life. In this variant the benefits cause the equal positive ecological effect. The difference according to ecological economic criterion is $10 + 10 = 20$. This fourth variant satisfies the sustainable development principle announced by Rio-92. This variant of technologies should be a final goal for the individual subjects of national economics (firms), international firms as well as for the countries as it provides for long term sustainable social economic development.

And, finally, the fifth variant – atypical – is theoretically possible. In this case the positive ecological effect exceeds the traditional economic one. The difference according to ecological economic criterion is $10 + 14 = 24$.

Conclusions

The major task of **EED** is to understand organic unity of economic and ecological systems, to explain their interconnection and interdependence, as well as their contradictions and conflicts.

EED is a relatively new educational discipline, which studies the cause-consequence relations and interdependence between economic and ecological systems. It attempts to scientifically explain these relations and the driving forces behind local, regional and global ecological crises. By applying the methods of natural, engineering and social sciences **EED** attempts to find the interconnection between these sciences and the human intellectual ability to ensure sustainable development. Sustainable development could be achieved by stimulating preventive protection of the environment, by "ecologization" of all the spheres of material production as well as meeting ecological imperatives in all spheres of human activity. In order to achieve sustainable development ecological effects should be included in the assessment economic choices. **EED** points out the ways in which an economic incentives system may prevent environmental damage. It also suggests the possibility of compensation for the inevitable ecological damages without the violation of environmental legislation. These damages should be compensated by the responsible industrial and commercial structures. Thus, **EED** provides ways for achieving the goals of sustainable development.

If we truly seek the Sustainable Development called for in the Agenda for the Twenty first Century – we must turn away from the traditional economic thinking of the twentieth century and begin to train the economists of the new era, economist-ecologists enabled to communicate with each other throughout the world.

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David N. Bengston*

NATURAL RESOURCE MANAGEMENT IN AN AGE OF LIMITS: AN ECOLOGICAL ECONOMICS PERSPECTIVE

"A great change in our stewardship of the earth and the life on it is required"

Union of Concerned Scientists, World Scientists' Warning to Humanity, 1993

Adapting to change

Adapting to change has long been the greatest challenge of natural resource management. The history of conservation is a history of responding to changing social, economic, political, technological and environmental conditions. Some examples from conservation history in the United States illustrate this point. The early conservation movement in the U.S. – at the turn of the last century – was in part a response to unregulated, destructive and unsustainable exploitation of forest resources and opposition to that exploitation by a small group of conservation leaders (Hays 1959). One of the results of this movement was the establishment of the U.S. Forest Service and creation of the U.S. National Forest System. Another example is the major U.S. environmental legislation of the 1960s and 70s, including the Wilderness Act of 1964, the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and the National Forest Management Act of 1976. These environmental laws and regulations were responses to growing perceptions of environmental decline and changing environmental attitudes and values.

The rise of ecosystem management as an alternative model of forest management is the most recent example of adaptation to the changing social and environmental context. Ecosystem management has been widely advocated as a "new" approach to natural resource management (Bengston 1994, Bengston and Fan 2001), although many of its core elements can be traced back to the 1920s and 1930s to Aldo Leopold and a few other visionary ecologists (Grumbine 1994, Flader 1994).

But what is ecosystem management? Definitions of ecosystem management have often been so broad and inclusive that they promise to be all things to all people. Ecosystem management is often characterized as emphasizing the following goals and means of implementation: Maintaining social, economic and ecosystem health and sustainability; incorporating social values and human uses; and using adaptive management and a collaborative approach to planning and management (More 1996, Corter and Moote 1999). These characteristics in many ways reflect responsiveness to changing so-

* Ecological Economist North Central Research Station, SDA Forest Service

cial and environmental contexts. But I contend that ecosystem management has fallen short in terms of a sufficient response to the changing context for conservation today. Ecosystem management, as it has been commonly discussed and implemented, is based on an implicit assumption that we can "have our cake and eat it too," i.e., there is little or no recognition of the increasingly apparent biological, physical and social limits to economic growth. The following section briefly describes the changing context for natural resource management today and identifies some of the unprecedented ways in which human economic activities are affecting the earth's life support systems.

The Changing Context for Natural Resource Management

The ecological context for conservation has changed significantly in recent decades due to the growing impact of human activities. Humans have extensively altered the natural landscape locally and regionally throughout human history, sometimes unsustainably and with disastrous effects. But the explosive growth in human population and increased power of technology has greatly magnified our impact on natural systems, including impacts at the global scale. As Lubchenco has observed, "we now live on a human-dominated planet" (1998:491). Some examples of the impacts of economic activities on the global ecosystem make this point abundantly clear:

- Logging and conversion of forests have shrunk the world's forest cover by about one half, and many remaining forests are being fragmented by roads, farms and residences (Bryant et al. 1997).
- We are currently in an era of species extinctions that is unprecedented in human history (Wilson 1992, Reid and Miller 1989).
- An estimated 75 percent of the world's major marine fish stocks are either depleted from overfishing or are being fished at their biological limit (Garcia and Deleiva, 2000).
- Humans now use an estimated 54 percent of accessible surface fresh water (Postel, et al. 1996). It is estimated that the rate of pumping of groundwater by the world's farmers exceeds natural recharge rates by at least 160 billion cubic meters each year (Postel 1999: 255).
- 65 percent of the approximately 1.5 billion ha of cropland worldwide have experienced some degree of soil degradation (Wood et al. 2000).
- Between one-third and one-half of the earth's land surface has been transformed by human economic activity (Vitousek et al. 1986, Daily 1995).
- Humans appropriate 25 percent of potential total global net primary productivity and 40 percent of terrestrial net primary productivity (Vitousek et al. 1986).
- The concentration of carbon dioxide in the atmosphere has increased by about 30 percent since the Industrial Revolution, with almost half of that increase coming since 1959 (Houghton 1997).
- Humans move more earth each year than the traditional forces of nature – rivers, winds and oceans – combined, and the rate is increasing (Hooke 2000).

The list of momentous anthropogenic impacts on the earth and its life support systems could go on and on: stratospheric ozone depletion, growing evidence of global climate change, etc. But it is clear that "The magnitude of human-induced environmental change at the global scale is enormous" (Kates et al. 1990:13).

The social context for natural resource management has also changed dramatically in recent decades, and continues to change at a rapid pace. The social landscape of today would be unrecognizable to conservationists of a few generations ago due to a wide range of economic, political, technological, and social changes. Most important is the fact that the global population has recently surpassed 6 billion people and, according

to United Nations projections, is headed toward between 7.9 to 10.9 billion people by the year 2050 (UN Population Division 2001). With the increase in population and economic growth comes an increase in the demand for natural resources and increased strain on the ecological systems that produce these resources.

These ecological and social changes – unprecedented in human history – imply a new relationship between humans and nature and a new context for natural resource management. The scale of human economic activity has increased dramatically relative to the scale of the earth's life support systems. We have rapidly made the transition from an "empty world" in terms of the human footprint to a "full world" in which the impacts of economic activities are dominant (Daly and Cobb 1989). As a result, the ecological systems upon which all economic activity – and life itself – depends are undergoing changes that threaten social and economic well-being and sustainability.

The Nature of Limits: Eco-Catastrophe or Gradual Unraveling?

There are, therefore, limits to the growth of economic activity on a finite planet. A point is reached at which economic growth becomes "uneconomic," and the costs of aggregate economic activity begin to outweigh the benefits (Daly and Cobb 1989). The Union of Concerned Scientists issued a "World Scientists' Warning to Humanity" in 1993 that was signed by 1,670 of the world's most prominent scientists, including 104 Nobel laureates. This declaration is a strong and clear statement of the need to recognize the limits to economic activities and the need for a changed relationship between society and nature:

"The earth is finite. Its ability to absorb wastes and destructive effluent is finite. Its ability to provide food and energy is finite. Its ability to provide for growing numbers of people is finite. And we are fast approaching many of the earth's limits. Current economic practices which damage the environment, in both developed and underdeveloped nations, cannot be continued without the risk that vital global systems will be damaged beyond repair." (Union of Concerned Scientists 1993).

What is less clear is the *nature* of the limits to economic growth. As we approach limits to material and energy resources, waste absorption, entropy or thermodynamic limits, etc., are we likely to experience catastrophic ecological collapse (Meadows, et al. 1992, Tainter 1988)? Or, as Davidson (2000) has argued, is environmental degradation more likely to be continuous and gradual rather than catastrophic? Certainly, there are many examples of localized ecological collapse, such as the collapse of a fishery, and the possibility exists of catastrophic thresholds at larger spatial scales. An example is the possibility of large-scale changes in ocean circulation patterns due to global warming that could cause significant and rapid changes in world climate (Broecker 1997). But in general, most environmental degradation is more like a gradual fraying of the web of life, which slowly but inexorably reduces our options and erodes the possibilities of future generations.

Davidson suggests that the metaphor of a tapestry representing the earth's biophysical systems is a useful way to view the relationship between economic activity and the environment:

"Tapestries have long been used as metaphors for the richness and complexity of biological systems (e.g., the tapestry of life). As a metaphor for environmental degradation, each small act of destruction ... is like pulling a thread from the tapestry. At first, the results are almost imperceptible. The function and beauty of the tapestry is slightly diminished with the removal of each thread. If too many threads are pulled – especially if they are pulled from the same area – the

tapestry will begin to look worn and may tear locally. There is no way to know ahead of time whether pulling a thread will cause a tear of not. (Davidson 2000: 434).

Concluding Comment

The growing impact of human economic activities on earth's life support systems demand new ways of conceiving of the relationship between economic systems and ecological systems. The worldwide debate on sustainable development is evidence of growing recognition of this new reality. The sustainable development debate has spurred a search for new approaches to economics, economic and environmental policy, and natural resource management strategies that can help define and move society toward sustainability.

Ecological economics is a major result of this search. Following the principles of this emerging field, we must view the world's economies as being embedded within and wholly dependent on ecological systems, in contrast to the traditional economic view of the environment as a source of raw materials and "amenity values" and a sink for wastes. We must view sustainability as a higher value than narrowly defined economic efficiency. We must expand our notion of efficiency to include the efficiency with which capital, both natural and manufactured, is used to provide life-support and life-enhancing services. We must carefully analyze the scale of the human economy relative to the global ecosystem that sustains it. Finally, decisions about how to use resources over time must not discount the life-supporting ecological functions and services that all economic activity – and life itself – depend on.

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Dennis P. Bradley, George Xu, Bernard J. Lewis¹

FORESTS AS NATURAL CAPITAL: PARALLELS, PROBLEMS AND IMPLICATIONS

Introduction

Forests are simultaneously part of the biosphere, ecosystems on their own account, the source of materials essential to human survival, and not least, the origin of deep human symbols and meanings. While these insights may not be new, as the scale of our impacts on ecosystems has grown to global proportions, the always difficult task of integrating the multi-faceted character of forests into management actions has assumed a new-found importance. Further, new knowledge about the complexities of ecosystem and social system interactions suggest an even greater need for more realistic views of these systems and, as a result, how we may best use them to survive. In other words, at the root of many current difficulties is a fundamental incoherence between our thoughts and actions vis-a-vis Nature and Society.

This incoherence is evident in our difficulty defining, for example, what we mean by *sustainability* or *ecosystem health* in recent debates whether modern economies seeking mass and large-scale consumption threaten the long-term productivity of forests and other ecosystems. A key to understanding these difficulties is that such meanings are inescapably confounded by positivist and normative mixtures of *fact* and *value*. That is, while our efforts to survive must be guided by the best science we can

¹ Forest Economist, North Central Research Station, USDA Forest Service, St. Paul, Minnesota; Environmental Economist, Washington State Department of Transportation, Olympia, Washington; and Visiting Assistant Professor, Forestry Department, University of Missouri, Columbia, Missouri.