Biogeographic and Trophic Restructuring of the Biosphere:

The State of the Earth under Human Domination

Calvin B. DeWitt

University of Wisconsin-Madison

and Au Sable Institute

Earth is enveloped by a living fabric of creatures. Their spatial and functional interweavings with each other and their physical environments constitute the remarkable system we call the biosphere. The biosphere is structured dynamically from microscopic through macroscopic levels by inseparable biogeographic spatial relations and trophic transfers of matter and energy. Its organisms produce and consume, multiply and diminish, develop and decompose. Each and every of its species is characterized by particular niches (roles) and all are engaged in fluxes and flows of matter, energy, and information, energized mainly by solar income. Production of photosynthate by green plants, augmented with a minor contribution of chemosynthate by organisms in deep ocean vents, energizes life at all trophic levels, through which the integrity of the biosphere is maintained.

Our species, in contrast with every other, affects these biospheric dynamics on a grand and pervasive scale, and it is this that brings us from time to time to assess our impact on the Earth. In our day, we find, remarkably, that we have become a principal geological force. We find ourselves to have significantly restructured the biosphere both biogeographically and trophically. And unlike the assessment a half-century ago

that examined our role,[1] today's assessment recognizes our domination. During the past half-century Earth has come under human domination and this has propelled us into a new role: stewards of the biosphere.

In a NOVA television program in 1985, a man of the Great Plains was asked why he farmed only 700 acres of land, unlike his neighbors whose farms were in the thousands of acres. He replied, "Seven hundred acres is all that one farmer can care for." He had resisted the dictum, "Get bigger or get out." His neighbors had not. And only he could maintain his proud status as responsible steward.[2]

This assessment finds that we have become like the farmer's neighbors, but on a global scale. We have exceeded our capacity to be responsible stewards and in our over-reach, we have brought to it destruction and degradation as never before, on a grand scale. No doubt, some will take this fact as reason to forsake their stewardship, while anticipating the end of the world. Others will take it as license for grasping even greater domination. But we will have to discipline ourselves in another direction if we are to restore the freedom we have lost through the domination we have imposed. Somehow, we will have to get back, metaphorically, to "700 acres."

This assessment comes, then, as we find the whole Earth under human domination. We are the first to see our planet thus and it is dawning on us that this necessarily makes us its stewards. This assessment is presented under four headings:

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[1]William L. Thomas Jr., ed., *Man's Role in Changing The Face Of The Earth* (Chicago: University of Chicago Press, 1956).

[2]NOVA, *Seeds for Tomorrow* (Northbrook, Illinois: Coronet Film and Video, 1985). Videotape.

(1) planetary energy exchange, (2) land and soils, (3) forests and habitats, and (4) biodiversity. I conclude with consideration of the consequences of this assessment for our stewardship of Earth.

Planetary Energy Exchange

The biosphere relates with the rest of the universe through the filter of the atmosphere, principally by energy transfers among Earth, sun, and outer space. The composition and properties of this filter are being changed by grand-scale burning of the carbon-based deposits that have been sequestered beneath Earth's surface. In distant times past, these great deposits were formed by taking carbon dioxide from the atmosphere by green plants. The result back then was a lowering of Earth's temperatures and greater habitability. Inspired by plants this carbon-based gas was transformed through photosynthesis into carbon-based solids that eventually became sequestered in the great carbon stores of peatlands, coal formations, and coral reefs. Today we are returning this carbon to the atmosphere, at rates orders of magnitude greater than its deposition, as burnt fossil "fuels."[3] Somehow we find it surprising that Earth's capacity to retain heat is again increasing and that global temperatures are rising.

We have known the greenhouse effect since the 1890s,[4] and knew of climate change in response to anthropogenic greenhouse gases since the late 1980s.[5]

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[3]I put "fuels" in quotation marks to remind ourselves that the idea of these as "fuels" may overlook their function as carbon sequestration materials with non-fuel functions.

[4]Arrhenius, S., "On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground," *Philosophical Magazine* 41 (1896): 237-276.

[5]Houghton, Richard A. and George M. Woodwell, "Global Climatic Change," *Scientific*

However, until ice cores were taken in Antarctica, we had little hard data on Earth's earlier temperatures and atmospheric gas composition.[6] Neither did we have sufficient computer capacity to construct models of Earth's climate system, nor sufficient understanding of the coupling of terrestrial climate with the oceans. But over the last few decades, departments of meteorology were transformed into departments of atmospheric and oceanic science, carbon dioxide observatories were created, satellite-based systems for looking at land and sea were invented, high-altitude atmospheric chemistry was developed, and a new generation of scientists was produced that could quantitatively and dynamically couple oceanography with meteorology and climatology. These developments have come sufficiently far now to demonstrate and confirm human inducement of global climate change.

Several atmospheric gases allow the sun's visible radiation to penetrate Earth's atmosphere but restrict its re-radiation of back into space. These "greenhouse gases" are vital for keeping Earth's temperature within a zone conducive to life. Working like windows of automobiles and greenhouses, they transmit sunlight that warms the interior but restrict transmission of infrared "heat" radiation back out.[7] A habitable biosphere is thereby maintained. One of these gases is carbon dioxide. It enters the atmosphere from animal and plant respiration, the burning of forests and forest products, oxidation of exposed soils, and burning of fossil "fuels." And it has been increasing steadily (Fig. 1).

American 260, no. 4 (1989): 36-44.

[6]J. Jouzel et al., "Extending the Vostok Ice-Core Record of Paleoclimate to the Penultimate Glacial Period," *Nature* 364 (1993): 407-412.

[7]John T. Houghton et al. *Climate Change 2001: The Scientific Basis.* (Cambridge: Cambridge University Press, 2001).

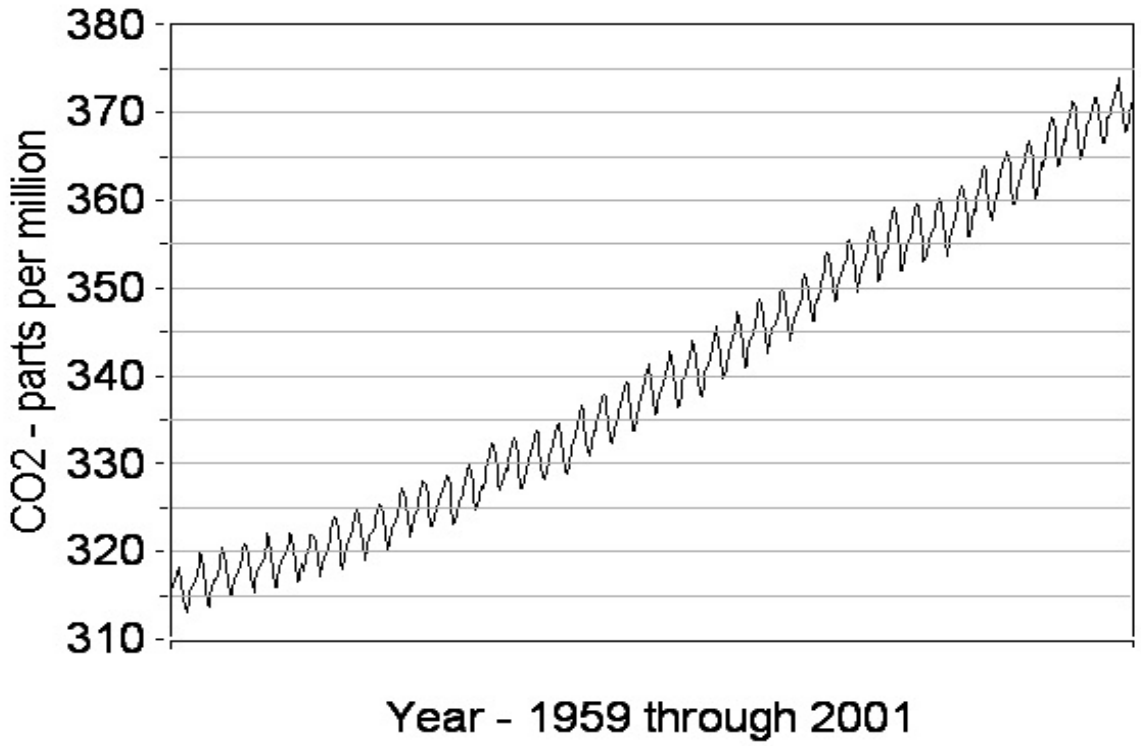

Figure 1. Carbon dioxide concentration from January 1959 through December 2001 at Mauna Loa, Hawaii. Carbon dioxide increases during the northern winter and decreases during the northern summer, with the overall trend being upward. The yearly pulsating downturn shown here represents net removal of carbon dioxide by photosynthesis in the hemisphere that has the largest area of green vegetation.[8]

The increase of this greenhouse gas from about 320 parts per million in 1960 to 270 parts per million in 2001 is largely anthropogenic,[9] an increase that enhances

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[8]Author's plot of data from Keeling, C.D. and T.P. Whorf, "Atmospheric CO_2 records from sites in the SIO air sampling network," in *Trends: A Compendium of Data on Global Change* (Oak Ridge, Tenn., U.S.A., Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, 2002).

[9]This discovery brought the World Meteorological Organization(WMO) and the United

Earth's capacity to retain heat. Some 35 to 40 other gases, many produced by human industry, act similarly[10]. Known consequences include a shifting of the ranges of plant and animal species towards the poles (covered later in this paper) and expected consequences from climate modeling include higher maximum and minimum temperatures, more hot days and fewer cold ones, dryer summers and increased chances of drought and floods in some regions, and some fiercer hurricanes.

Our knowledge of this is summarized in the Oxford Declaration on Climate Change:[11]

● There is now high confidence in the scientific evidence of human influence on climate as detailed by the Intergovernmental Panel on Climate Change (IPCC) and endorsed by 18 of the world's leading Academies of Science.

● Human activities, especially the burning of coal, oil and natural gas (fossil fuels) are rapidly increasing the concentrations of greenhouse gases (especially carbon dioxide) in the global atmosphere. As a result the global climate is warming, with rising

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Nations Environmental Programme UNEP) to establish the Intergovernmental Panel on Climate Change (IPCC) in 1988. In John T. Houghton, et al., the IPCC projects an average global surface temperature increase of 2.5-10.4F during the 21st Century, and an average global sea level rise of 4-36 inches).

[10]See Fig. 2 in Ramanathan, V., "The Greenhouse Theory of Climate Change: a Test of an Inadvertent Global Experiment," *Science* 240 (1988): 293-299.

[11]This statement was prepared by leading climate scientists, policy-makers and Christian leaders at a forum in Oxford, England held by Au Sable Institute and the John Ray Initiative organized by Calvin B. DeWitt and John T. Houghton. (See: www.climateforum2002.org)

sea levels, changes in rainfall patterns, more floods and droughts, and more intense storms. These have serious social, economic and ecological consequences.

- The harmful effects of climate change far outweigh the beneficial ones:
  - –In many arid and semi-arid areas, the quantity and the quality of fresh water will continue to decrease.
  - –Although agricultural productivity may increase in temperate northern latitudes, it will decrease throughout the tropics and sub-tropics.
  - –A greater incidence of diseases, such as malaria, dengue fever and cholera, is expected.
  - –Sea-level rise and increased flooding is already displacing people and will eventually affect tens of millions especially in low income countries. Some island states are likely to disappear altogether.
  - –Important ecosystems, such as coral reefs and forests, will be destroyed or drastically altered, undermining the very foundation of a sustainable world.

On global warming as an moral, ethical and religious issue, the Oxford Declaration concluded:

- God created the Earth, and continues to sustain it. Made in God's image, human beings are to care for people and all creation as God cares for them. The call to "love the Lord your God and love your neighbour" (Matthew 22:37—39) takes on new implications in the face of present and projected climate change. God has demonstrated his commitment to creation in the incarnation and resurrection of Jesus Christ. Christ who "reconciles all things" (Colossians 1:20) calls his followers to the "ministry of reconciliation" (2 Corinthians 5:18,19).

● Human induced climate change poses a great threat to the common good, especially to the poor, the vulnerable and future generations.

● By reducing the Earth's biological diversity, human induced climate change diminishes God's creation.

Impact of Climate Change on the Geographic Ranges of Plants and Animals

These changes in climate bring significant changes to life on Earth. Recent analyses of some 1,700 species show, with very high confidence, that climate change is causing shifts in the ranges of plants and animals that average 3.8 miles per decade (2000 feet per year) towards the poles. With this come earlier springtimes, whose average advance is 2.3 days per decade.[12] Analysis of 143 research publications also shows this shift, with more than 80% of the species showing range changes in the expected direction.[13]

Stewards of the Atmosphere

While in earlier days, Earth's atmosphere and climate were more or less stable "givens" in human life, they are no longer. They have been impacted by human activity and invention that reach to the lower heavens, and so too has our stewardship. Our stewardship of Earth has been pushed upward, by our own accomplishments, to the heights of the stratosphere. We have become stewards of Earth's atmosphere.

Land and Soils

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[12]Camille Parmesan and Gary Yohe, "A Globally Coherent Fingerprint of Climate Change Impacts Across Natural Systems," *Nature* 421 (2 Jan 2003): 37-42.

[13]Terry L. Root et al., "Fingerprints of Global Warming on Wild Animals and Plants," *Nature* 231 (2 January 2003): 57-60.

Land Area Conversions

In the early days of European settlement of North America, pioneering families transformed prairie and forest ecosystems into agricultural lands. At first, their "short grass" wheat fields replaced the tall grass prairies of southern Wisconsin and their dairy farms replaced the maple forests of New England. In time, through responsible stewardship, their land began to image the systems they replaced: cows and "tall grass" corn came to inhabit the tall grass prairie of southern Wisconsin, while New England reverted to forests of Sugar Maple and White Pine.[14] And, wheat came to inhabit the short grass prairies of Nebraska and Kansas.

Household and farming needs were supplied from feed mills, general stores, and churches in rural centers (as in Byron Center, Michigan and Sioux Center, Iowa) mainly in the best agricultural lands. Progressively, labor-saving machinery displaced people from farms, and they moved to these centers. These centers expanded into villages and cities that spread outward into adjacent farmland. Urban spread was augmented by in-migrations from other places, high birth rates, increasing lot sizes, new roads, widened roadways, parking lots, dams, and hydroelectric impoundments. Continuing to the present day, this process converts prime farmland to non-farm uses at rates of two to four times those for less-productive land[15]. Alternatives to prime farmland consumption have been developed and are available, but generally are not being implemented.[16]

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[14]William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York: Hill and Wang, 1983).

[15]*Federal Register*, 67, no. 104 (May 30, 2002): 37756-37760.

[16]The Town of Dunn in Dane County, Wisconsin, is an exception. (See http://town.dunn.wi.us/).

In a five-year period, from 1992 to 1997, slightly more than 1 million acres of active cropland were being converted annually to non-farm uses in the U.S, out of a cropland base of about 410 million acres (Table 1). Another 1.75 million acres were converted from set-aside cropland (CRP land), pastureland, and rangeland for a total loss of 2.75 million acres (about 5 acres per minute). Approximately 2.25 million acres of these annual losses went to development of residential areas and associated infrastructure, including commercial districts, roads, parking areas, and highways (about 4 acres per minute). Over this same 5-year period, 11.2 million acres went to urban development (Table 1.)[17]

Table 1. Five-Year Changes in land cover and land use in the United States between 1992 and 1997, in thousands of acres.

	1992	1997	Losses	Gains	Annual Avg
Cropland	382,315	376,998	5,317	---	(1,063)
CRP land	34,042	32,696	1,346	---	(269)
Pastureland	126,047	119,992	6,056	---	(1,211)
Rangeland	407,380	405,977	1,403	---	(281)
Forest land	405,207	406,955	---	1,748	350
Other rural land	50,626	51,142	---	516	103
Developed land	87,035	98,252	---	11,217	2243
Water areas & federal land	451,478	452,118	---	641	128
Totals	1,944,130	1,944,130	14,122	14,122	0

[17]United States Department of Agriculture, *1997 National Resources Inventory Summary Report, Revised December 2000* (Washington, D.C.: Natural Resources Conservation Service, USDA, 2000).

Similar losses of agricultural land to urbanization and other non-agricultural uses are occurring around the world[18]. Cash economies are introduced, opportunities and incentives to make money are created, labor-saving agricultural technology is adopted, food is purchased from the store, people migrate from farms to cities, and cities expand outward into adjoining farmland. With this reduction of agricultural land comes a reduction of agricultural land area per capita. This per capita decline is further decreased by population increases. All of this results in increased pressure on existing agricultural land that is met by intensification of agricultural inputs, such as fertilizers, herbicides, pesticides, higher-producing strains of crops, and new bioengineered varieties.

Land Quality Changes

Intensive agricultural production usually is accompanied by reductions in land fertility, soil quality, and organic matter content. It may also bring land erosion by wind and water, and compaction, salinization, and desertification of soils. These losses may not be noticed, however, since they are masked by introducing new higher-yielding crop varieties developed to that maintain or increase productivity by providing greater fertilizer and herbicide inputs. This in turn generally results in neglect and denial of declining land fertility and soil quality.[19] Masking can go so far that the soil remaining may be used primarily as a rooting medium with chemicals added much like in hydroponic agriculture.

On the world scene, available soil data show that nearly one-third of the arable lands across the globe were lost to erosion during the last half-century and taken out of

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[18]Miller, G. Tyler, Jr., *Environmental Science: Working with the Earth*, 9th ed. (Pacific Grove, Calif.: Brooks/Cole, 2003).

[19]David Pimentel et al., "Environmental and Economic Costs of Soil Erosion and Conservation Benefits," *Science* 267 (1995): 1117-1123.

production. This loss is continuing to the present at more than 25 million acres per year. Much of the remaining land has severe erosion problems, particularly in Asia, Africa, and South America where annual soil loss currently averages 12 to 16 tons per acre[20]. Loss of soil to erosion is less in the United States and Europe which average about 7 tons per acre annually, or about 1 inch of topsoil every 16.5 years. This compares with 0.002 to 0.02 tons (4 to 40 pounds) per acre lost to erosion in undisturbed forests, and with an annual soil formation rate of about 0.4 ton (800 pounds) per acre. Approximately 90% of U.S. cropland currently has losses to erosion above the sustainable rate.[21]

Losses of topsoil translate into reduced water infiltration rates, increased run-off, reduced soil water-holding capacity, thinner topsoil, shortage of organic matter and basic plant nutrients (such as nitrogen, phosphorus, potassium, and calcium), diminished soil biota (earthworms, micro-organisms, etc.), lower productivity, siltation of lakes and streams, and reduced hydroelectric capacity. Wind and water removes mainly the fine soil particles and these generally contains three times more nutrients and 1.3 to 5 times more organic material than the soil left behind.

Quality soil is rich in organic matter and contains, per acre, about 900 pounds of earthworms, 900 pounds of arthropods, 135 pounds of algae, 1500 pounds of bacteria, and 2400 pounds of fungi. These soil biota have the very important role of processing and recycling basic soil nutrients and they create tunnels, burrows, and openings that increase water infiltration and water holding capacity.[22] Much of this is lost under intensified agriculture. Many farms are devoid of significant earthworm populations.

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[20]Pimentel et al.

[21]Pimentel et al.

[22]Pimentel et al.

The world soil situation is summarized in Table 2, showing a total of 4.8 billion acres of land degraded, with about 750 million acres strongly or extremely degraded.

Table 2. Estimates of the global extent (in millions of acres) of land degradation.[23]

Type	Light	Moderate	Strong plus extreme	Total
Water erosion	847	1,302	553	2,702
Wind erosion	664	627	64	1,355
Chemical degradation	230	254	106	590
Physical degradation	109	67	30	206
Total	**1,850**	**2,250**	**753**	**4,853**

Solutions to the problem of loss of agricultural land and decline of soil quality are being implemented successfully in many places, but not at a level adequate to reverse the major trends. To sustain soil with no net soil loss, erosion must be kept below 0.4 ton (800 pounds) per acre per year. This can be achieved by allowing crop residues to remain on the land and replacing the nutrients that are harvested.[24]

Stewards of Soils and Land

Soil and land stewardship has been our acknowledged human task and responsibility since antiquity. As Clarence Glacken indicates however, we have been diverted these last two centuries by an instrumentalist view of the world. Land as promise has become land as investment and commodity. While stewardship generally remains

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[23]Table from Oldeman, L.R., "The global extent of land degradation," in D.J. Greenland and I. Szabolcs, eds., *Land Resilience and Sustainable Land Use* (Oxford: CAB International Publishing, 1994), 99-118. Data converted to English units.

[24]Pimentel et al.

the norm for farmers, external factors push responsible soil stewardship out of first place, and the pleasure of living on the land, the wholesomeness of agrarian culture, and the beauty of the Earth are diminished.

Ironically, we have much greater knowledge of soil stewardship than ever before. Yet, we are continuing to destroy our farms and rural communities, as Tony Ends of the Michael Fields Institute notes:

> I ask you to reflect with me about what I have witnessed in my lifetime... There were 89,000 more farmers on the land in Illinois when I was 4 years old. There were trees and flowering shrubs along many of the roadsides. There were small orchards, berry patches and vegetable gardens in the farmyards. There was livestock visible in the pastures... Almost every vestige of that world has been swept away with those 89,000 farms and with them a rich culture, healthy communities and vibrant rural economies. Most of the barnyards that remain are silent, empty islands in oceans of bare ground, crop residue or stubble, which lap up against the very sides of dilapidated buildings. How can we live our faith in such a setting, knowing what our created world and its nurturing, spiritual qualities looked like such a short time ago?"[25]

These losses of soil and agrarian culture are calling all of us to make soils and land a fundamental and highly significant component of everyone's stewardship. We must do the difficult work necessary to reinstate caring people as stewards of soils and land. Soils and land are a second component of our stewardship.

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[25]Tony Ends, Unpublished MS, "Tilling and Keeping: Christians Working to Promote Sustainable Agriculture," (East Troy, Wisconsin: Michael Fields Agricultural Institute, 2000).

Forests and Habitats

As we turn from relatively open farmlands to forests, we find remarkable integrated ecosystems whose greater vertical dimensions join with other features that make them remarkably significant across the landscape and around the Earth. Globally, forests with continuous cover of 40% or more occupied about 7.1 billion acres in 1995. Of this area, about 91.6% has no formal protection and is open to deforestation. In 15 countries with the greatest areas of these forests, 88% of the land has low human population density and high potential for ecosystem conservation, including conservation of their human inhabitants.[26] While some efforts are being made to conserve these forests and peoples, measures are far from adequate, and deforestation and cultural decimation continue to be rampant.[27]

Deforestation reduces sustainable production of native forest products and support for indigenous human inhabitants, increases run-off, reduces watershed recharge, increases flood peaks (storm-flows) and diminishes drought flows (low-flows). Deforestation reduces evapotranspiration of water from vegetation to the atmosphere with consequent potential reduction in rainfall, increases exposure of soil surfaces to direct sunlight with resulting higher ground temperatures, and increases atmospheric carbon dioxide levels with consequences for climate change. Deforestation also destroys habitats of a wide diversity of forest-dependent creatures, fragments habitats that

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[26]See Peterson, *Conversations in the Rainforest*, on why native peoples might be included within protected areas, rather than excluded.

[27]UNEP, An Assessment of the Status of the World's Remaining Closed Forests, UNEP/DEWA/TR 01-2, Division of Early Warning and Assessment, UNEP, Nairobi, Kenya: UNEP, 2001).

previously were connected, and increases edge effects by creating and increasing the forest edge. And, increases in forest edge exposure leads to windfall and creates access in many areas of the world to roaming cattle, other non-forest animals, and particularly important for tropical forests, to hunters and poachers. One net result is a large loss of native plant and animals species, including extinction of some.[28]

Losses to deforestation are greatest in the tropical rain forests, with from 20 million to 22 million acres destroyed each year, mostly without approval or support of their inhabitants. Primary tropical forests are long-standing ecosystems that usually include long-standing resident peoples and cultures that sustain and are sustained by them. Losses of tropical forests are summarized in Table 3.[29] The total annual loss of these forests is equivalent to an area intermediate between the areas of Maine and Indiana. Unlike Temperate Zone forests that often return to ecosystems similar to what they had been, cut-over tropical forests do not, but are over-run with weedy tree species and have severely diminished integrity and soil fertility.[30] Although succeeded by woody greenery, the earlier forest system does not return.

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[28]David Skole and Compton Tucker, "Tropical Deforestation and Habitat Fragmentation in the Amazon: Satellite Data from 1978 to 1988," *Science* 260 (1993): 1905-1910.

[29]Ruth S. DeFries et al., "Carbon Emissions from Tropical Deforestation and Regrowth Based on Satellite Observations for the1980s and 1990s," *Proceedings of the National Academy of Sciences* 99, no. 22 (2002):14256–14261.

[30]Unlike temperate soils, most tropical soils are poor retainers of nutrients partly due to low organic content that results from high decomposition rates. Tropical rain forest ecosystems retain most of their nutrients within their own biomass and when the biomass is removed the released nutrients are lost by leaching.

Table 3. Tropical forest area changes (millions of acres per year) in tropical Latin America, Asia, and Africa in the 1980s & 1990s. The "net" figures given here are the sums of lost primary forests and gained secondary forests. Thus the loss of primary forests is greater than the net values given here.[31]

	NASA - DeFries				FAO - Satellite		FAO- Country Reports	
	Deforestation		Net		Net		Net	
	80s	90s	80s	90s	90s	90s	80s	90s
Tropical Latin America	10.94	9.83	8.82	7.85	10.87	10.37	17.64	10.87
Tropical Asia	5.34	6.77	2.96	4.96	6.18	5.68	6.03	5.93
Tropical Africa	3.73	3.29	0.69	0.94	5.68	5.19	9.58	12.84
Pantropics	20.01	19.88	12.47	13.76	22.72	21.24	33.25	29.64
Totals	40.01	39.77	24.95	27.52	45.45	42.48	66.49	59.28

Of particular importance to our assessment are the long-standing cultures that are the principal agents in sustaining and protecting the tropical forests—cultures and peoples who now are threatened by destruction and displacement by outside agents who steal their tress, both legally and illegally.[32] Legal arrangements and individual land ownership have not been a part of the

[31]Satellite data analysis by DeFries, et al. and NOAA are given in left columns, by the Food and Agricultural Organization (FAO) in middle columns and voluntary country reports to the FAO in right columns. All data converted to English units from DeFries, et al. 2002.

[32]See for example: Richard B. Peterson, *Conversations in the Rainforest: Culture,*

heritage of most indigenous peoples and thus only rarely do they hold legal title to the forests they inhabit. They also have limited capacity to counter the new forces they now confront. Lack of legal title often is the pretext for taking their lands from them. Legalism replaces justice, and they, and we, lose their heritage. This presents a great challenge to people everywhere. Again, while some solutions have been developed and implemented, they remain inadequate to halt the destruction that is underway.[33]

Stewards of Forests

Forest stewardship is vital to forest peoples, biodiversity, watersheds and run-off, cloud formation, and climate. However, forest ecosystems are being restructured globally, including displacement of its indigenous peoples and their indigenous stewardship. All of this means that the forests of the world have become an important third component of our stewardship.

Biotic Species and Biodiversity

Biodiversity—the sum total of all biological species on Earth, including subspecies and varieties—is sustained by an array of dynamic ecosystems (lakes, marshes, tidepools, forests, prairies, etc.) and is the source of all of our cultivated plants and domesticated animals, animal pollinators, biological agents for pest and disease control, and thousands of pharmaceuticals. It also is responsible for a wide range of "ecological services" provided by the biosphere, including soil formation and fertility renewal, reducing flood peaks and increasing drought flows of streams,

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Values, and the Environment in Central Africa (Boulder, Colorado: Westview Press, 2000).

[33]Ghillean T. Prance, "Economic Prospects from Tropical Rainforest Ethnobotany," in John O. Browder, ed., *Fragile lands of Latin America: Strategies for sustainable development.* (Boulder, Colorado: Westview Press, 1989), 61-74, and Nigel J. H. Smith et al., *Amazonia - Resiliency and Dynamism of the Land and its People* (Tokyo: United Nations University Press, 1995).

processing oxygen and carbon dioxide, moderating local climates, and maintaining a wide array of biogeochemical cycles (e.g., phosphorus cycle and nitrogen cycle)[34]. Despite our knowledge of its critical importance to the health and integrity of the biosphere, biodiversity is seriously threatened and is being reduced through habitat destruction, clearing of land and forests, putting toxic materials into global circulations, introducing exotic species, and changing climate.

Global Biodiversity

Assessment of biodiversity is complicated by the fact that we have only begun to identify the biological species of the world. A century ago taxonomists had expected the biodiversity of the tropics to be similar to that of the North Temperate Zone. However, the tropics are much more diverse. To illustrate, Michigan has about 100 tree species[35] while a study of 25 sites in humid tropical rainforests, found the number of tree species per hectare (about 2 ½ acres) to be: 168 (upper flood plain, Peru); 283 (old flood plain, Peru); 246 and153 (clay upland, Ecuador); 83 (sandy upland, Venezuela); 56 (sandy-clay upland, Uganda); and 240 (sandy humult upland, Sarawak). For these sites, tree species per 500 individuals range from 50 to 235[36]. The taxonomy of some groups of plants and animals is so incomplete that many tropical species go extinct before they have been classified.

The more conspicuous and charismatic organisms are better known. As an example, for bird species we are beginning to understand how deforestation leads to extinction, and we expect 314 species in the southeast Asian islands to go extinct if deforestation continues (Table 4).

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[34]In biblical terms these are rightly identified with God's provisions for creation.

[35]Burton V. Barnes and Warren H. Wagner, Jr., *Michigan Trees: A Guide to the Trees of Michigan and the Great Lakes Region* (Ann Arbor: University of Michigan Press, 1981).

[36]O. L. Phillips, et al. Dynamics and Species Richness of Tropical Rain Forests. *Proceedings of the National Academy of Sciences USA* 91 (1994): 2805-2809.

Table 4. Numbers of endemic and threatened endemic bird species and predictions of bird extinctions due to deforestation for the southeast Asian islands.[37]

	Endemic Birds	Threatened Endemics	Predicted Extinctions
Phillipines	184	73	55
Java & Bali	27	5	12
Borneo	38	3	4
Sumatra	15	7	3
Lesser Sundas	86	12	32
Greater Sundas	110	17	15
Sulawesi & Sulas	87	5	10
Total Southesast Asian Islands	585	121	83

Areas that currently have relatively low threats of extinction constitute about 47% of Earth's land surface. While this includes the Sahara Desert and Antarctica, it also includes areas of rich biodiversity. Within these lesser threatened areas, five have less than one person per square kilometer and 1,500 or more endemic species of vascular plants (Amazonia, Congo Forests of Central Africa, New Guinea, North American Deserts and Miombo-Mopane Woodlands and Grasslands of Southern Africa). These areas also include the habitats of many of Earth's remaining indigenous peoples.[38] However, very few of these areas have any form of protection.

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[37]Data for this table were extracted from Table 1 of Thomas M. Brooks, Stuart L. Pimm, and Nigel J. Collar, "Deforestation Predicts the Number of Threatened Birds in Insular Southeast Asia," *Conservation Biology* 11, no. 2 (1997): 382-294.

[38]Russell Mittermeier, et al., *Wilderness: Earth's Last Wild Places*, (Chicago: University of Chicago Press, 2003).

To deal with the problem of protecting the biodiversity of the Earth, the Council for Agricultural Science and Technology (CAST) has urged significant action:[39]

- Substantially increase the worldwide network of biodiversity reserves, including properly managed forests and grasslands, national and regional parks, wilderness areas, and privately held lands, in order to prevent massive, human-caused extinction of species and loss of genetic diversity.
- Preserve large blocks of land in native ecosystems to preserve terrestrial diversity.
- Prevent habitat destruction worldwide because it causes large irreplaceable losses of genetic diversity of direct long-term value to crop and livestock production.
- Increase the capacity of rural landscapes to sustain biodiversity and ecosystem services by maintaining hedgerows/windbreaks; leaving tracts of land in native habitat; planting a diversity of crops; decreasing the amount of tillage; encouraging pastoral activities and mixed-species forestry; using diverse, native grasslands; matching livestock to the production environment; and using integrated pest management techniques.
- Educate policy makers and the public about the many ecosystem services that are provided by biodiversity in natural ecosystems.

Agricultural Biodiversity

Beyond loss of native species, there is serious loss of diversity for traditional varieties of plants used for food, fiber, and medicines. This comes through displacing local varieties by a relatively small number of commercially produced plants, many of which are bioengineered for characteristics that achieve product uniformity and intensify food production. Similar displacement

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[39]Tilman, G. David et al. *Benefits of Biodiversity.* Task Force Report no.133 (Ames, Iowa: Council for Agricultural Science and Technology, 1999).

is occurring for traditional farm animal breeds. With this comes the demise of kitchen gardens, farms, and agrarian culture whose biodiversity was developed and adapted by indigenous peoples to local soil types, microclimates and other conditions.[40]

If brought to completion, replacement of local agriculture and agrarian culture by aggressive monocultural industrial crop production no doubt will elevate some plant and animal to pest status, as explained by entomologist B. Uvarov in his classic work on pest generation[41]. And, natural and artificial selection of crop plants in time will be replaced with selection by the global market.

In recognizing this, CAST presented the following to the U. S. Congress and others:[42]

- Genetic diversity of crop plants and of breeds of livestock animals is being lost forever, as farmers around the world change farming practices in response to changing demands for food and fiber, and as native habitats of the wild relatives of agricultural species are destroyed.
- The diverse on-farm germplasm must be collected and stored in long-term storage depositories or in monitored farm and field preserves or it will be lost. If it is lost, sources of genetic diversity for future plant and animal breeding will be dangerously or even fatally constricted.

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[40]See for example Michael K. Steinberg, "Neotropical Kitchen Gardens as a Potential Research Landscape for Conservation Biologists," *Conservation Biology* 12, no. 5 (1998): 1150-1152.

[41]B. P. Uvarov, "Problems of Insect Ecology in Developing Countries, *Journal of Applied Entomology* 1 (1964):159-168.

[42]Tilman, et al. 1999.

CAST urges the following actions:

- Ensure that genetic diversity now found in agricultural plants is preserved in seed banks and plant collections *(ex sit*u) or as growing crops *(in sit*u).
- Ensure that wild crop and livestock relatives are conserved in carefully identified natural systems.
- Increase the effective use of diversity in agriculture, recognizing that production agriculture is one component of the complex and highly interdependent ecosystem that encompasses all aspects of nature: urban, agricultural, and "natural." Biodiversity performs vital functions at all levels of this system.
- Develop and spread understanding of the "whole ecosystem" concept, which treats production agriculture as one component in a complex and highly interdependent ecosystem encompassing all aspects of nature.
- Broaden the use of genetic diversity to protect crops against pest and weather problems by introducing multiple genetic systems for coping with biotic and abiotic stress.

As we now turn from the land to the sea and coastal regions, we not only find that habitats and populations of marine organisms are being seriously degraded, but also that the major world fisheries are collapsing. The latest fishery to come to the verge of collapse is that of the European Union, a cod fishery that extends from Western Norway to the Atlantic shores of Scotland.[43] This fishery has dropped in catch from 270,000 tons in 1977 to 38,000 tons in 2002 and now has less than half of what is needed to sustain it. This follows the earlier collapse of the Atlantic coast cod fishery, closed by Canada in July 1992, where there are now too few mature cod remaining for

[43]Robin Cook, "Cod Stocks in Trouble," *Fishing News* 6 (December, 2002).

egg production.[44] Sadly, most other ocean fisheries have collapsed or are in serious trouble because of overexploitation. Degradation of fisheries by overexploitation is joined with coastal development that is destroying productive wetlands and bottom trawling that is degrading and destroying cold water and warm water reefs.

Of great ecological interest in all of this are the affects of overfishing on the trophic structure of ecosystems. Steve Carpenter of the Wisconsin-Madison's Limnology Laboratory found that large carnivorous fishes, through their cascading effects on aquatic herbivores, limit blue-green algal blooms.[45] By reintroducing large Northern Pike and increasing size limits into Lake Mendota, he and his colleagues brought about a reduction in algae populations in a fish-driven trophic cascade. Interesting as Carpenter's work is for lakes, it is almost overwhelming when applied to ocean fisheries. Jeremy Jackson of the Scripps Institution of Oceanography constructed a long history of ocean fisheries with his colleagues that shows overfishing removes large creatures from the top trophic level of the food web, which next is occupied by un-fished species that next take over the top consumer role (such Orange Roughy). As these in turn are over-fished or succumb to disease from overcrowding, the next lower trophic level takes the top place, moving the system downward toward "microbialization."[46]

On the positive side of this unfolding discovery of trophic cascades is that progress made in understanding ocean biotic communities and fishery collapse that can inform coastal and

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[44]Sonya Maldonado, Unpublished MS (Department of Animal Ecology, Iowa State University Ames, Iowa).

[45]Carpenter, S.R., "Temporal Variance in Lake Communities: Blue-Green Algae and the Trophic Cascade," *Landscape Ecology* 3 (1989): 175-184.

[46]Jeremy B. C. Jackson et al., "Historical Overfishing and the Recent Collapse of Coastal Ecosystems," *Science* 293 (2001): 629-637.

oceanic stewardship. On the negative side, we are discovering that prospects for restoration of the trophic structure of the oceans is daunting.

Stewards of the Creatures and Trophic Structures

Since the time of Noah we have known our responsibility as stewards of the creatures. In the setting of Eden, human beings were asked to name the animals, as God watched with interest to see what each would be called. This required awareness and appreciation of each species, including their biogeographical and trophic characteristics. This was a prerequisite not only for selecting appropriate names, but also for stewardship. As our task of naming the creatures remains incomplete so too our stewardship. As change agents of the trophic structure of oceans and other systems, who now bring about both commercial extinction and biological extinction of species, we necessarily have extended our stewardship. We have extended it to the creatures and their trophic relations across land and sea and throughout the entire biosphere. Biodiversity and trophic relationships have become a fourth important component of our stewardship.

The Stewardship Consequences of Our Domination of the Biosphere

Our assessment of (1) planetary energy exchange, (2) land and soils, (3) forests and habitats, and (4) biodiversity each concluded with stewardship consequences. To summarize: Human stewardship extends to all systems we have chosen to affect and the pervasive human domination of the biosphere that now includes the atmosphere, Earth's soils and land, the forests of the biosphere, and biodiversity and trophic relations, has brought us a new status. In short, for the first time in history, *we have become stewards of the biosphere.*

Our emerging role as stewards of the biosphere has not gone unnoticed. A key paper in *BioScience* in 2002 recognized that "The global extent of the human footprint suggests that humans are stewards of nature, whether we like it or not."[47] And a major article in *Science* magazine

[47]Eric A. Sanderson, et al., "The Human Footprint and the Last of the Wild," *BioScience*

in 1997, concluded: "...humanity's dominance of Earth means that we cannot escape responsibility for managing the planet."[48] In short, we are left with no recourse but to act on the threatening consequences of our pervasive impacts and disruptions.

We know, however, the difficulty and have counted the cost of managing but a few small space stations. And we also know of our failure to sustain Biosphere II. However, even if we had the knowledge and capacity and resolve to manage the planet, we might well choose to do otherwise. The reasons are (1) that our knowledge is now sufficient to inform us that the biosphere, if properly and respectfully treated, will take care of itself, including ourselves and (2) that the immense cost of even trying to manage the planet would cost us the freedom we enjoy from its self-regulation. The dictum of physiologist, Claude Bernard, derived from his extensive research into physiological control and regulatory systems also applies to the biosphere: "La fixité de la milieu intérieur est la condition de la vie libre."[49] Respecting Bernard's principle applied to the biosphere, we would need to respect and preserve the systems that sustain us and all life. And for whatever aspects of biospheric operations we have adversely affected, we would need to restore the conditions that allow them to work. By so doing, we would be applying the first principal of biospheric stewardship: *The better part of the steward's art is to give back to the*

52, no. 10 (2002): 891-904.

[48]P.M. Vitousek, et al., "Human Domination of Earth's Ecosystems," *Science* 277 (1997): 494-499.

[49]"Regulation of the internal environment is the necessary condition for a free life." This concept of regulation was developed by Claude Bernard as a central tenet of physiology and is central to his *Leçons sur les Phénoménes de la Vie Communs aux Animaux et aux Végétaux* (Paris: Baillière, 1878-1879). It was further developed by Walter B. Cannon, "Organization for Physiological Homeostasis," Physiological Reviews 9 (1929): 399–431.

biosphere what it already had been doing quite well.[50]

In seeking to proceed in this time of domination we will need to transform our management into stewardship. And in our stewardship we must incorporate (1) preservation of biospheric systems that are working quite well, (2) application of the physician's art and science at setting the conditions for restoration and healing of whatever we have abused and degraded, and (3) making peace with creation and its creatures in deliberate and determined reconciliation.

In working to achieve responsible stewardship, every person needs to identify responsible stewardship paradigms (examples) already in place, and amplify and replicate these across every field of work and endeavor; we must create and invent new and effective stewardship responses to the conditions and problems we have created at all levels of biospheric operations. In pursuing this work of biospheric stewardship, ecologists and environmental scientists must continue their progression in research from reservation ecology and restoration ecology on to reconciliation ecology.[51] Scholars and practitioners must make significant contributions to biospheric stewardship by publishing not only in journals and web pages, but also in lives and landscapes. And, readers of journals such as this need to conduct periodic self examinations in the context of our knowledge of ourselves and the biosphere, taking perhaps as a model the resolve of the founders of the journal, *Conservation Biology*, whose founders...

> ...knew we could no longer simply follow the traditional academic model—placing bricks in the wall of knowledge and claiming them to be available to whomever

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[50]A restatement of the principle from Calvin B. DeWitt, "Let It Be: A Wetland Scientist and Restorationist Reflects on the Value of Waiting," *Restoration and Management Notes 7, no. 2 (1989): 80-81.*

[51]Michael L. Rosenzweig, *How the Earth's Species Can Survive in the Midst of Human Enterprise* (New York: Oxford University Press, 2003).

> wants to use them—and still have much hope of altering the course of world events. They saw that changes in the way the world operates would not come about through passive building of that wall... Like it or not, conservation science operates in a world increasingly defined by dishonesty, blatant self-interest, blasé acceptance of the loss of nature, increased tolerance for ugliness, global corporate control, growing fascination with an artificial cyberworld, and anti-intellectualism. To shy away from such realities and pretend they do not exist would consign us to irrelevancy. We must face these issues head on and begin new—and perhaps uncomfortable—conversations if this field is to be more than an odd historical curiosity to be cast upon the rubbish heap of indifference in future decades.[52]

Many professions, trades, businesses, governments, denominations, congregations, and individuals already are establishing new priorities for addressing the great issues we have brought into play through our domination of Earth. Our challenge, within the academy and the wider world, is dealing with ourselves, professionally and personally, corporately and individually. Ultimately we all must face the question in every aspect of our life and work, Will we "bring ***good news*** to *every* creature?"[53]

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[52]Gary K. Meffe, "The Context of Conservation Biology," *Conservation Biology* 15, no. 4 (2001): 815-816.

[53]Cf. Mark 16:15.