Tending This Fragile Earth, Our Island Home: The Pope's Encyclical in Dialogue with Ecomimesis, a Design Model for Conservation Stewardship

Lillian C. Woo*

In the last fifty years, empirical evidence has shown that climate change and environmental degradation are largely the results of increased world population, economic development, and changes in cultural and social norms. Thus far we have been unable to slow or reverse the practices that continue to produce more air and water pollution, soil and ocean degradation, and ecosystem decline. This paper analyzes the negative anthropogenic impact on the ecosystem and proposes a new design solution: ecomimesis, which uses the natural ecosystem as its template to conserve, restore, and improve existing ecosystems. Through its nonintrusive strategies and designs, and its goal of preserving natural ecosystems and the earth, ecomimesis can become an integral part of stabilizing and rehabilitating our natural world at the same time that it addresses the needs of growing economies and populations around the world.

Introduction

Pope Francis's extraordinarily powerful encyclical *Laudato si'* addresses both the theological aspects of global environmental crisis and a call for remedial action. The dialogue with Anglican theology by John Kater addresses Francis's theological and moral concerns in the first part of this two-part article. The dialogue with conservational stewardship solutions appears here as the second part.

* Lillian Woo is an economist, political consultant, and public policy/legislative advisor. She has authored numerous monographs and journal articles on public policy issues and published five books. She has presented many lectures on the environment in the United States, Europe, and Asia.

Neither the entreaties for moral accountability from religious organizations—such as *Laudato si'*—nor the advocacy by secular national and international organizations has resulted in any substantial slowing or reversal of the culture and practices that produced the present environmental crisis.

During this time period, there have been over five hundred international agreements to stem the deterioration of the land, sea, and air. The most ambitious occurred nine months after Pope Francis issued his *Laudato si'*. The discussions generated by Francis's outspoken, blunt, and urgent call for worldwide conversation and solutions to the environmental crisis gave added importance and interest to the December 2015 United Nations Framework Convention on Climate Change.[1] The agreement was ultimately signed by 195 nations. Like other treaties, however, there are no binding commitments, and there remains a lack of enforcement mechanisms. Unless there are commitments and enforcement, this treaty will be mostly symbolic.

Similarly, the United Nations *15 Year Sustainable Development Goals* adopted on September 25, 2015, established seventeen goals that will be very difficult to achieve. In addition, this plan calls for a $3 trillion annual investment, an amount that will be almost impossible to meet through private and public sources.

Another United Nations sponsored study, *The Millennium Ecosystem Assessment*, conducted by 1,360 experts from ninety-five countries from 2001 to 2005, assessed the condition of ecosystems and human well-being. It concluded, "Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth."[2]

As Francis asserts in his encyclical, the earth is our common home and all humans are bound together by spirit and our commitment for the common good. He accurately describes the environmental crisis in his initial chapter, lambastes the rampant consumer culture, and strongly advocates the need to reuse materials and adopt

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1 The primary goal is to limit global warming to less than 2 degrees C and zero net anthropogenic greenhouse gas emissions by the second half of the twenty-first century.

2 United Nations Environment Programme, *Overview of the Millennium Ecosystem Assessment* (Washington, D.C., 2005), 1.

a circular model (20–23). He urges worldwide efforts and cooperation to change the trajectory of our deteriorating environment and to work for something bigger than ourselves.

However, thirty years before Francis's encyclical drew worldwide attention to climate change, religious groups and leaders in the United States continuously brought moral and ethical dimensions to public discussions and policy about stewardship and social justice.[3] These current religious discourses have given greater depth to the environmental debate by expanding the areas of consideration and changing its focus.

The increased awareness of the damage human action has inflicted on the environment provides opportunities to re-emphasize the values of the natural ecosystems and the benefits they provide. The responses have included innumerable proposals to deal with the environmental crisis. Many address specific aspects of the environment such as energy, carbon, or greenhouse gases. This article focuses on the entire ecosystem—ecomimesis—as an appropriate and important perspective and response to the challenge of *Laudato si'*.

What Is Ecomimesis?

Francis shows great understanding of the symbiotic role that all species play in maintaining equilibrium in a particular ecosystem (34). Francis believes that humans do not have "absolute domination" over the earth (67) but instead links all humans to creation: "We are part of nature, included in it, and thus in constant interactions with it" (139). He minces no words when he describes the serious problems inflicted on nature and climate with human-induced destruction of the ecosystem (24).

Ecomimesis is a design paradigm that uses the earth as a template. Its goal is to design a human community so that its ways of life do not interfere with nature's inherent ability to sustain life in the earth's biosphere and minimize disruptions to nature's ecosystems. Its primary goals are to re-establish ecosystem stability, preserve regional biodiversity and habitats through continuity of functions and connectivity, and conserve, repair, and improve existing ecosystems.

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[3] J. A. Wardekker, A. C. Petersen, and J. P. van der Sluijis, "Ethics and Public Perception of Climate Change: Exploring Christian Voices in the U S Public Debate," *Global Environmental Change* 19 (2009): 512–521.

The idea of ecomimesis is most closely associated with the concept of conservational stewardship, which focuses on preserving the "garden of God" as it was created, and distinguishes it from developmental stewardship and developmental preservation.[4]

Ecomimesis design can be applied to both built and unbuilt environments. In creating a built environment within nature's ecosystem, ecomimetically designed structures, communities, or societies impose minimal disruption of the natural balance of the system. Aspects of the built environment, such as site use, architectural and landscape designs and master planning, product designs, material selection and use, and types of energy systems, are ecomimetically designed to duplicate the properties, structure, functions, and processes of ecosystems in nature. The creation of new eco-sensitive human-made structures can also assist in reclamation efforts to restore cities and environments to a more congenial state with the natural ecosystem.

In planning and creating an unbuilt environment, the same ecomimetic principles apply. It is critical to protect the unbuilt environment and its ecosystems by designing and developing a green infrastructure to protect against natural disasters, reclaim damaged ecosystems, maintain biodiverse habitats, and create natural carbon stores and sinks. Some of the benefits include purifying water and bodies of water, reducing polluting emissions, reducing waste, stabilizing biogeochemical cycles and the nutrients in the soil, restoring damage to ecosystems, limiting human-made ecological footprints, and strengthening biodiversity.[5]

Ecosystem

As an interacting system of a biological community and its nonliving environmental surroundings, every ecosystem is composed of two components: biotic, which includes plants, animals, and microorganisms; and abiotic, which includes climatic, edaphic (soil and its chemical and physical properties), and inorganic (water, carbon, sulfur, nitrogen, phosphorous, and others) factors. Abiotic

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[4] Wardekker et al., "Ethics and Public Perception," 512–521. Developmental stewardship focuses on the human mission to use creation's resources to develop the world, with humankind placed above nature (516). Developmental preservation stresses human ingenuity, technology, and entrepreneurial capacity to prevent conflicts between development and preservation (517).

[5] Ken Yeang, *Ecodesign: A Manual for Ecological Design* (London: Wiley-Academy, 2006), 45–58.

and biotic elements form a complex integrated unit that is controlled by external factors (climate, temperature, rainfall, geological material, mineral nutrients, topography, water sources and retention) and internal factors, including processes (photosynthesis, energy flow, decomposition and nutrient cycling), disturbances, and changes that affect the composition and stability of the ecosystem.

Francis acknowledged the "unprecedented destruction of ecosystems, with serious consequences for all of us," produced by the environmental crisis. He conceded that the church does not "presume to settle scientific questions" but accepts the "best scientific research available today" (24).

Changes in existing biotic and abiotic elements and additions of new or foreign ones change the composition and stability of an ecosystem. When the symbiotic balance of interconnection and interdependence among ecosystem components becomes disordered and unbalanced, ecosystem succession results in a change in species composition and community structure.[6]

The size of an ecosystem, known as its carrying capacity, is determined by food availability, water, rates of biogeochemical recycling, resource supply, climate, functional groups of organisms, energy flow, land, and intrinsic and extrinsic disturbances.[7] The time it takes for a system's return to ecosystem equilibrium depends entirely on the length and severity of the interruptions of the ecosystem, such as floods and hurricanes, land erosion, desertification caused by heat and drought, and degradation of the soil. When an ecosystem is in equilibrium, it is self-sufficient and self-regulating.[8] For example, the biotic information network on the semiannual great migrations in Africa depends on grazing, population density, attack avoidance, prey abundance, natural selection, overcrowding, and nutrient cycling, which can provide information (feedback) about overshoots and destructive oscillations. These conditions regulate the health and stability of an ecosystem community and determine its stability.[9]

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6 W. H. Drudy and I. C. T. Nisbet, "Succession," *Journal of the Arnold Arboretum* 54 (1973): 331–368.

7 Bernard C. Patten and Eugene P. Odum, "The Cybernetic Nature of Ecosystems," *American Naturalist* 118, no. 6 (December 1981): 886–895.

8 Robert L. Smith, *Ecology and Field Biology* (New York: Harper & Row, 1980), 613, 619, 627.

9 A. G. Volkov and D. R. A. Ranatunga, "Plants as Environmental Biosensors," *Plant Signaling & Behavior* 1, no. 3 (June 2006): 105–115.

Although ecosystems have a strong ability to resist limited changes resulting from human activities, the extent of these activities can overwhelm the recuperative capacity of natural systems. Decades of research from the U.N. Environment Programme, U. S. Environmental Agency, and other environmental organizations have shown that the human impact on abiotic components has increased toxicity, global warming, increased ozone, increased carbon dioxide, increased greenhouse gases (GHG), and fragmentation and degradation of biogeochemical cycles in the soil, water, and hydrologic cycles. In other words, human activities have been largely responsible for changes in climate, environmental pollution, and interference with normal cycling and flows of energy in ecosystems.

The fundamental structures and functions of ecosystems include biodiversity, spatial efficiency, ecological cybernetics, homeostasis, succession, energy, and biogeochemical cycles. Each element is necessary for the continuity and balance of an ecosystem. If any part is disrupted from its natural ability to adapt and adjust, other parts will also be affected.

Researchers estimate that approximately 40–50% of the land surface of the earth has been degraded by anthropogenic activities, 66% of marine fisheries have been overfished, carbon dioxide in the atmosphere has increased more than 30% since the beginning of industrialization, and almost 25% of the earth's bird population is now extinct.[10]

The following discussion of the damage to biodiversity summarizes the degradation caused by human activities. The proposed ecomimetic solutions are examples of what can be done without further harming the natural ecosystems, and hopefully illustrates the potential of ecomimesis to repair degraded environments and return ecosystems to their natural equilibrium.

Biodiversity

Biodiversity is the basis and foundation of all ecosystems. The biodiversity of a specific area is controlled by the same two major factors that influence an ecosystem, abiotic and biotic components. The resources, food webs, and energy cycles establish the number

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[10] P. M. Vitousek, J. Lubchenko, H. A. Mooney, and J. M. Mellilo, "Human Domination of Earth's Ecosystems," *Science* 277, no. 5325 (July 25, 1997): 494–499.

of species that can symbiotically survive within a specific ecosystem. Changes to any of these factors can affect the ecobalance and ultimately the existing biodiversity of a given ecosystem. If one population within the ecosystem becomes too large, the cybernetic and feedback loops create adaptive responses that keep correcting the imbalance until a new equilibrium is reached. This self-correction and regulation allows each ecosystem to maintain its limits and continue to function as an entity.

Ecologists estimate that there are approximately 1.7 million species that have been described and probably another 10–30 million species that exist but have not yet been described. Most of the world's 1.7 million described species are concentrated near the equator, particularly in tropical rain forests and coral reefs. Only 10–15 percent of the world's species live in North America and Europe. As expected, plant species thrive in the Neotropics, with over two hundred thousand species, while the Malaysian Peninsula has eight thousand species, and Britain 1,400 species.[11]

The general view among biologists and ecologists is that ecosystems with greater numbers of different species are stronger than those with fewer species, because more species strengthen an ecosystem's resiliency and ability to adapt to changes.[12] In some ecosystems, the diversity helps create a stronger homoeostasis by providing greater numbers of species that can assist in processing food through their complex webs. In other ecosystems diversity can result in wide population swings for individual species, and in some cases, these species become extinct.[13]

Francis devotes section III (32–42) of chapter 1 to the loss of biodiversity, castigating the "plundering of the Earth's resources because of shortsighted approaches to the economy, commerce, and production" (32). He precisely points to the carbon cycle and the loss of resources and its polluting and environmentally warming effects that have threatened the planet's ability to maintain biodiversity (24), and bemoans the loss of thousands of species each year because of human activity (33).

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[11] W. P. Cunningham and M. P. Cunningham, *Principles of Environmental Science* (New York: McGraw-Hill, 2006), 108.

[12] Anne S. Moffatt, "Biodiversity Is a Boon to Ecosystems, Not Species," *Science* 271, no. 5255 (March 15, 1996): 1497.

[13] Mark B. Bush, *Ecology of a Changing Planet* (Upper Saddle River, N.J.: Prentice-Hall, 2000), 169.

Francis is correct in his assessment. The loss of biodiversity is caused by human alteration of natural ecosystems that stem from human overpopulation, industrialization, resource depletion, economic development, urbanization, the Green Revolution, and permissive government policies.

These anthropogenic actions disrupt ecosystem balances by altering or destroying natural habitats and threaten biodiversity through overfishing, floods, eutrophication, disease, deforestation, decrease in the quality and stability of land, introduction of new species and genetically modified organisms, pollution, and climate change.[14] World Wildlife Global has estimated that the rapid loss of species is somewhere between one thousand and ten thousand times higher than it would have been from natural extinction.[15] Globally, it has been estimated that expanded agriculture negatively affects 76 percent of species.[16]

In 2014 World Wildlife Fund issued its biennial *Living Planet Report,* which measures trends in three areas: populations of more than ten thousand vertebrate species, the human ecological footprint, and biocapacity. The data compiled by WWF indicates that between 1970 and 2010 populations of mammals, birds, reptiles, amphibians, and fish around the world decreased by 52%. Specifically, in that forty-year span, 39% of terrestrial wildlife, 30% of marine wildlife, and 76% of freshwater wildlife became extinct. While high-income countries showed a 10% increase in biodiversity, middle-income countries showed an 18% decline, and low-income countries showed the biggest decline in biodiversity, 83%.[17]

Researchers indicate that fresh water and coral reef ecosystems are currently the most threatened. With the destruction of natural barriers, there has been a rampant spread of invasive species, destroying native ones.[18] Scientific data models predict that many marine

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[14] T. Newbold, L. N. Hudson, S. L. L. Hill, et al., "Global Effects of Land Use on Local Terrestrial Biodiversity," *Nature* 520 (April 2015): 45–50.

[15] Eric McLamb, "Continuing Ecological Impact of the Industrial Revolution," *Ecology Global Network*, November 11, 2013, 1.

[16] Alejandro Estrada et al., "Impending Extinction Crisis of the World's Primates," *Science Advances* 3, e1600946 (January 18, 2017): 1–16.

[17] Carter Roberts, Keya Chatterjee, and Jon Hockstra, "Half of Global Wildlife Lost," *World Wildlife Fund: The Living Planet Report*, September 30, 2014, 8–10.

[18] C. Vogler, J. Benzie, H. Lessios, P. Barber, and G. Worheide, "A Threat to Coral Reefs Multiplied? Four Species of Crown-of-Thorns Starfish," *Biology Letters* 4, no. 6 (2008): 696–699.

species will "run out of ocean" in the mid- to higher latitude ranges as they encounter continental margins. The result could be a massive migration of species toward the polar regions.[19]

Data from the International Union for Conservation of Nature (IUCN) further verifies the threats to biodiversity. Data indicates that 76% of primate species are in jeopardy from agriculture, 60% from logging and forest harvesting, 31% from livestock farming and ranching, and 60% from direct loss from hunting and trapping.[20]

Humans are the only species whose population keeps growing beyond an ecosystem's ability to support it. With all other species, overpopulation results in dying out until the environment can accommodate it. Human beings have overcome this natural limitation by changing their physical environment. As a consequence, the ever-increasing human population has resulted in greater and greater demands for food, shelter, and settlements, and products that steadily consume more than their share of resources.

In a closed ecosystem there is no waste. Everything is used by some member of an ecosystem, and there is a circular pattern of using resources. Humans, on the other hand, practice a linear pattern of resource use: extract a resource, convert it for use, consume it, and throw it away after it is no longer wanted or useful. This practice has resulted in an accumulation of waste and depletion of nonrenewable resources. Many human-made products are another source of waste; they are discarded when their usefulness is completed but their residual material do not decompose quickly or easily.

Urban sprawl has resulted in increased population density, increased paved surfaces, and increased heat island effects. Urban sprawl in the developed world has created unlimited outward extension, low-density development, and leapfrog development. This changes land use from farmland and natural areas and forests to commercial and residential development and extensive human-made infrastructure, including widespread strip malls and big-box shopping centers, decaying city centers, congestion, heat island effect, excess use of nonrenewable energy sources, water runoff, and atmospheric

[19] W. W. L. Cheung et al., "Projections of Global Marine Biodiversity Impacts under Climate Change Scenarios," *Fish and Fisheries* 10 (2009): 235–251.

[20] Estrada et al., "Impending Extinction," 2.

warming.[21] At the same time, there are fewer open fields, forests, marshlands, and other natural habitats.

The Green Revolution, which was designed to increase crop production in underdeveloped countries, unwittingly contributed to the negative effects of monoculture and severe soil damage.[22] In addition to new crop hybrids suited for various climates, heavy use of chemical fertilizers, herbicides, and insecticides in both developed and underdeveloped countries has disrupted the soil's biogeochemical cycles (carbon, oxygen, nitrogen, sulfur, and water) and edaphic factors.[23] Among the most serious changes have been (1) increased susceptibility to diseases, (2) low tolerance to stresses of drought or temperature, (3) reduced resistance to insects, (4) famines resulting from crop failures, (5) decreased soil fertility and increased soil erosion, 6) increased habitat for pest species and reduced habitat for beneficial species, (7) elimination of indigenous vegetation and extant species, (8) destruction of wetlands, (9) eutrophication, and (10) alteration of water quality. The same monoculture that disturbs homeostasis also has a negative impact on an ecosystem that leads to succession.[24]

A 2016 study found that climate change is making it more difficult to grow staple crops in sub-Saharan Africa, with maize, beans, and bananas most at risk. CGIAR Research Program on Climate Change, Agriculture, and Food Security scientists found that 40 percent of the maize-growing areas will need to be transformed with either new types of crops or abandonment of crop farming. The heat and drought conditions in this region of Africa make it necessary to replace the threatened crops with more heat-tolerant crops within the next ten years. Adaptation to climate change has become urgent in high-risk countries like Guinea, Zambia, Senegal, Burkina Faso, Niger, Ghana, Namibia, Botswana, Zimbabwe, and Tanzania. The current situation

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21 Cunningham and Cunningham, *Principles,* 344–346.

22 Justin Gillis, "Norman Borlaug, Plant Scientist Who Fought Famine," *New York Times*, September 19, 2009, A-1. Borlaug, father of the Green Revolution and winner of the 1970 Nobel Peace Prize, acknowledged late in his life the validity of some environmental concerns and embraced more judicious use of fertilizers and pesticides.

23 National Science Foundation, "Earth's Biogeochemical Cycles, Once in Concert, Falling Out of Sync," *Science Daily*, August 4, 2009, www.sciencedaily.com/releases/2009/08/090804071400.htm.

24 H. T. Odum, "Working Circuits and Systems Stress," in H. E. Young, ed., *Symposium on Primary Productivity and Mineral Cycling in Natural Ecosystems* (Orono, Maine: University of Maine Press, 1967), 81–95.

affects not only the food supplies for these countries but also their economic markets and social changes.[25]

Abiotic components have been adversely affected by human activities. They include increased toxicity, global warming, increased ozone, increased carbon dioxide, increased greenhouse gases, fragmentation and degradation of biogeochemical cycles in the soil, water, and hydrologic cycles, air and their impacts on climate change and environmental pollution, and interference with normal cycling and flows of energy in ecosystems. Polluting factors like agricultural runoff, sewage, paper and textile mills, and food processing have stimulated oxygen consumption in water by decomposers, like aerobic bacteria and algae. As biochemical oxygen demand (BOD) in bodies of water increases through the oxygen consumed in the decomposition process, other aquatic organisms are robbed of the oxygen they need to live. The resulting eutrophication increases algal blooms and produces reduced water clarity, periods of hypoxia, loss of sea grass beds and coral reefs, decrease in the health of fish and shellfish, and ecological changes in food webs.

Indisputably, by burning coal, oil, and natural gas, carbon dioxide is added to the atmosphere much faster than the atmosphere can absorb it. Burning forests to create agricultural land also converts organic carbon to carbon dioxide gas. While oceans and land plants absorb part of the carbon dioxide, the rest is added to the atmosphere.

Degradation of natural habitats and the environment results directly from overuse, natural resource depletion, and land use changes. For example, tropical forests are being cut at a rate of 0.6% to 2% per year, and it has been estimated by the United Nations Environment Programme that half of remaining forests will be lost or degraded in twenty-five to eighty-three years. The number of extinctions caused by human domination of ecosystems has been steadily increasing since the start of the Industrial Revolution. Current research indicates that about 50% to 84% of the earth's surface (excluding Antarctica and Greenland) has been lost by filling in wetlands, and converting grassland and forests to crop fields and urban areas.[26]

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[25] Megan Rowling, "Climate Change: Scientists Say Time Is Running Out to Protect Africa's Food Supply," *The AfricaReport.com*, March 7, 2016, http://www.theafricareport.com/North-Africa/climate-change-scientists-say-time-is-running-out-to-protect-africas-food-supply.html.

[26] U.N. Environment Programme, *Global Diversity Outlook 4: 2011–2020,* 2009, 11–13.

2010 data verifying the biodiversity crisis for primates shows that 48% of hardwood extraction comes from the Neotropics, 23% from South East Asia, 16% from sub-Sahara, and 13% from South Asia.[27] Deforestation has resulted in fragmentation of 58% of subtropical and 46% of tropical forests, resulting in isolated forest habitats, decreasing primate numbers, and loss of genetic diversity.[28] The loss of canopy covers, reduction of forest undergrowth, and decline of large tree species as sources of food and shelter for primates has also created a growing threat to ecosystems and their primates.

Many designed solutions to integrate human-constructed ecosystems with natural processes of succession have actually been harmful to natural ecosystems. In dealing with rural and urban ecosystems, for example, designers have ignored the natural process of ecological succession, preferring their own intensive inputs—built structures and infrastructures, intense use of artificial fertilizer—to maintain farmlands and cities and to develop urban sprawl haphazardly. These practices, in essence, are examples of human environmental succession in industrialized countries.

Conversely, in economically underdeveloped countries with long-standing traditional societies, there remain many centuries-old practices that take advantage of ecological succession in ways that allow them to use fewer inputs. However, the resources of many of these nations have been extracted and depleted by industrialized countries for their own economic and commercial purposes. Francis mentions the effect of this depletion and environmental change on the poor in almost every section of his encyclical and gives specific examples of the dangers and impacts on nations unable to protect themselves.

Maintaining and Restabilizing Diversity: The Human Role

In order to maintain and ensure that ecosystems are healthy and balanced, designs for the human-constructed ecosystem should include space efficiency and continuity, connectivity, and biogeochemical

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[27] S. L. Lewis, D. P. Edwards, and D. Galbraith, "Increasing Human Dominance of Tropical Forests," *Science* 349 (2015): 827–832.

[28] N. M. Haddad et al., "Habitat Fragmentation and Its Lasting Impact on Earth's Ecosystems," *Science Advances* 1, no. 2 el500052 (March 2015); doi:10.1126/sciadv.1500052.

balances in soil and water. Below are a few of the hundreds of new approaches and designs to maintain and preserve biodiversity.

1. Conserve existing continuities and linkages of ecosystems by minimizing fragmentation of ecosystems through the creation of new ecological corridors, eco-bridges, eco-undercrofts, land bridges, hedgerows, enhanced horizontal integration, and interconnectivity over terrain.
2. Maintain the balance of abiotic and biotic components in an ecosystem buildings through incorporated greenwall systems (see figure 1). Greenwall systems, also known as breathing walls, are totally vegetated building facades. Instead of a horizontal green roof, the greenwall system is vertical greening, which develops a stable plant and microbial community using hydroponic growing media that improves internal air quality.
3. Ensure that energy sources are renewable, and materials can be reused. Design for efficient use of materials by (l) designing to minimize amount of material used, resource depletion, and waste; (2) designing for adaptive use of buildings; (3) designing for disassembly—recycle, reintegrate, reuse, conserve nonrenewable materials, and use renewable materials; (4) using materials with a low ecological impact. This includes low toxic materials, nonchemical materials, natural biodegradable alternatives, such as plastics from corn.
4. Utilize deep plan, double envelope, double layered façade, ecocell, green roof, light pipes, and light-shelf designs for new structures to conserve energy.
5. Ecomasterplan with a blue infrastructure—a sustainable drainage system to manage surface water runoffs so that it stays on site. Create water management and conservation within the built environment.[29]
6. Design wastewater and sewage treatment and recycling systems to treat waste at its source. This can be done by controlling and integrating human waste and other emissions, capturing storm runoffs, and reusing municipal wastewater for irrigation. Design wetlands for wastewater treatment, irrigation leach fields, aerobic wastewater treatment.[30]

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29 Ken Yeang, *Ecomasterplanning* (London: Wiley & Sons. 2009), 24–26.
30 Yeang, *Ecodesign*, 266–269.

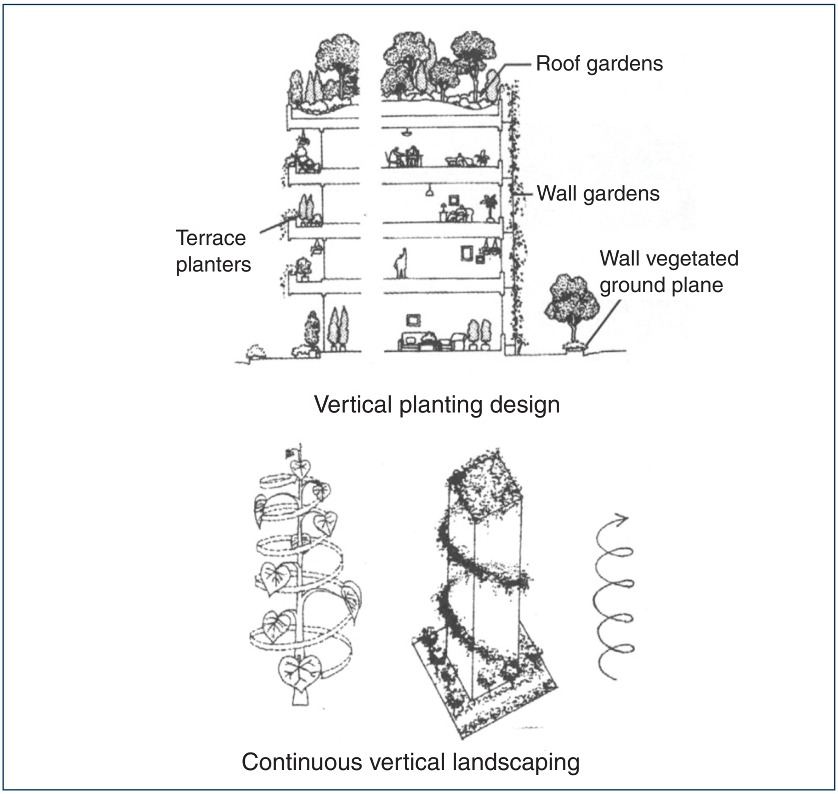

Figure 1. Illustration of greenwall system.
Reproduced with permission from Ken Yeang and Lillian Woo, *Dictionary of Ecodesign: An Illustrated Reference* (London: Routledge, 2010), 39.

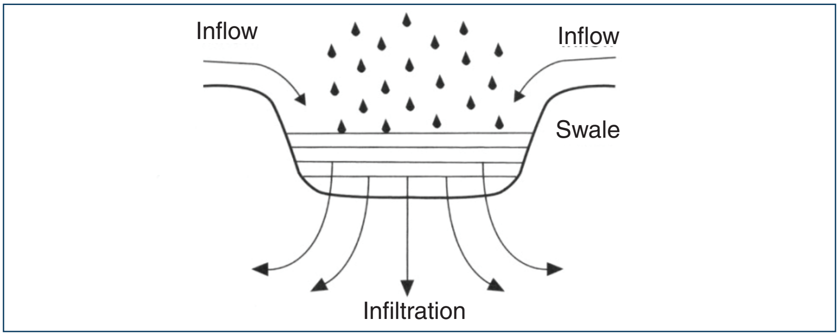

Figure 2. Bioswale.
Reproduced with permission from Ken Yeang and Lillian Woo, *Dictionary of Ecodesign: An Illustrated Reference* (London: Routledge, 2010), 37.

7. Treat waste ecomimetically with the design and use of living machines. Living machines are living organisms of all types that are housed in a casing or structure made up of lightweight materials. Living machines can be designed to produce food or fuels, treat wastes, purify air, regulate climates or perform a combination of these tasks at the same time.[31]
8. Design and construction of bioswales, filtration strips, retention ponds, sustainable drainage (SUDS), and lagoons. Return of water to its source will decrease runoff and pollution of bodies of water (see figure 2). A bioswale is a drainage course with sloped sides filled with vegetation, compost, or riprap. It is designed to maximize the time water spends in the swale as it moves along in the wide and shallow ditch. The swale traps pollutants and silt from the surface runoff water. Bioswales are most commonly used around parking lots to trap and treat runoff before releasing it to a watershed or storm sewer.
9. Design shallow mound (see figure 3) or shallow trench gray water systems. A shallow mound trench reuses gray water for irrigation and uses an elevated absorption field for disposal of wastewater. To use it for irrigation, a shallow layer of sand fill and top soil are placed over existing soil, and a pumping system is installed. Pipes are placed near the root zone to provide irrigation. Gray water flows from the house through pretreatment and is piped into shallow trenches. These pipes are placed close enough to the surface to feed the plant roots.

Restabilizing and Maintaining Biodiversity:
Unbuilt Econometric Solution

Too often, we have concentrated on urban and developed areas and have not given enough attention to unbuilt natural areas. We have been preoccupied with the ever-increasing human population, economic growth, and consumption and have failed to protect the unbuilt environment and its ecosystems.

Planning and management of unbuilt (nonstructural) ecomimetic designs, commonly known as "green infrastructure," serve the dual goals of preserving ecosystems and protecting vulnerable areas and

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[31] N. J. Todd and John Todd, *From Eco-Cities to Living Machines* (Berkeley, Calif.: North Atlantic Books, 1993), 165–176.

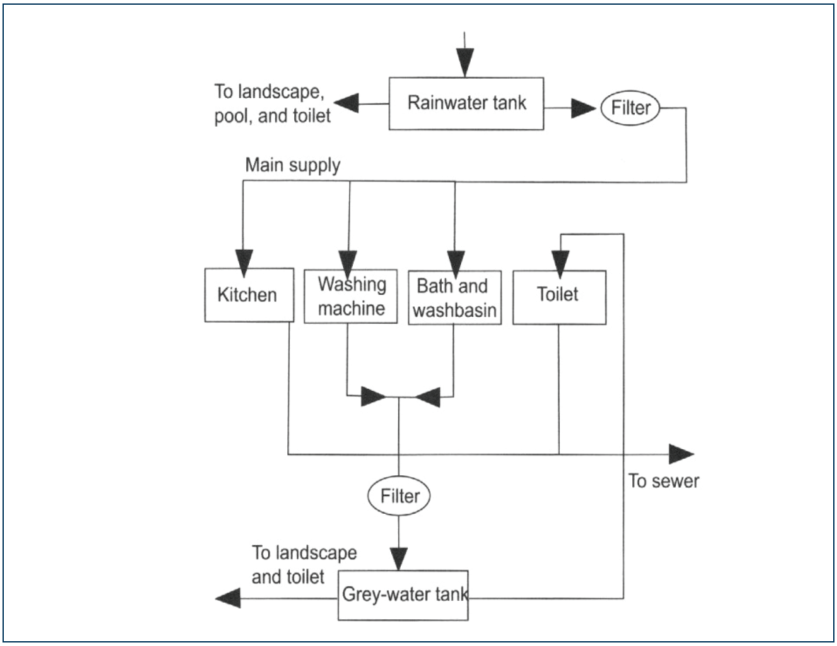

Figure 3. Integrated gray-water reuse system.
Reproduced with permission from Ken Yeang and Lillian Woo, *Dictionary of Ecodesign: An Illustrated Reference* (London: Routledge, 2010), 113.

developing nations from natural disasters. Researchers believe that green infrastructures are more cost effective in reducing disaster risks like tsunamis, hurricanes, landslides, tidal events, and floods than construction of hard barriers.[32] While green infrastructure and protected ecosystems cannot stop all natural hazards, there is increasing evidence that healthy ecosystems are more resistant to their impacts and reduce humanitarian disasters.[33]

Green infrastructure and its protection of the unbuilt environment are particularly important because Third World emerging nations have limited resources and technology to deal with increased

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[32] S. Stolton, N. Dudley, and J. Randall, *Natural Security: Protected Areas and Hazard Mitigation* (Gland, Switzerland: WWF International, 2008), 36–38.
[33] N. Dudley et al., eds., *Natural Solutions: Protected Areas Helping People to Cope with Climate Change* (Gland, Switzerland: IUCN-WCPA, UNDP, World Bank, WWR, 2010), 87–93.

natural disaster risks created by unstable land and unprotected coastlines, rivers, and lake banks. For this reason, the following examples of ecomimetic solutions are more extensive and detailed than those for the built environment.

1. Establish protected areas in a defined geographical space that is dedicated and managed for long-term conservation. Sites may range from being strictly protected with limited human access, to protected landscapes and seascapes with settled human communities.[34] Through the creation of both green infrastructure and sustainable land management, these protected areas become natural buffers against tidal surges, flash floods, and landslides, and provide systems for natural restoration of degraded and lost habitats and flood plains.[35] They protect humans against disasters at the same time that habitats can be rehabilitated from overexploitation of resources and over human use.
2. Expand natural habitats to mitigate climate change by storing and sequestering carbon in vegetation and soil.[36] It has been shown that terrestrial (forests), freshwater, and marine (salt marshes, mangroves, kelp and sea grass) ecosystems are important in the carbon cycle as major carbon stores and sinks, mitigating and reducing GHG emissions from energy production, transport, and land use change.[37] Without eco-planning and management these habitats could become large sources of carbon and habitat losses.[38]
3. Rather than constructing seawalls, groins, jetties, breakwaters, and other hard barriers that cause erosion and riptides, maintain natural ecosystems as buffers of tidal surge

[34] N. Lopoukhine, N. Crawhall, N. Dudley, et al., "Protected Areas: Providing Natural Solutions to 21st Century Challenges," *Surveys and Perspective Integrating Environment and Society (SAPIENS)* 5, no. 2 (2012): 20–23.

[35] Stolton et al., *Natural Security,* 23, 34–36; A. P. Dobson, A. D. Bradshaw, and A. J. M. Baker, "Hopes for the Future: Restoration Ecology and Conservation Biology," *Science* 277 (1997): 515–522.

[36] World Bank, *Convenient Solutions to an Inconvenient Truth: Ecosystem-Based Approaches to Climate Change* (Washington, D.C.: World Bank 2010), 25–36.

[37] F. Parish et al., eds., *Assessment on Peatlands, Biodiversity, and Climate Change: Main Report* (Kuala Lumpur, Malaysia: Wetlands International 2008), 99–104.

[38] H. Gitay et al., eds., *Climate Change and Biodiversity, Technical Paper V* (Geneva: IPCC 2002), 37–42.

and important carbon sinks (mangroves, salt marshes, kelp, sea grass beds, and coral reefs) along shorelines, inlets, and rivers and streams. Structures are static, but water bodies are dynamic, constantly changing course and shape. Changing the course of natural water flow has been shown to have a negative impact on intertidal habitat and diversity.

4. Conserve and maintain wetlands and marshes rather than dredging them. These natural bodies are habitats for birds and marine life as well as macroinvertebrate diversity, and provide water storage capacity to prevent flooding during storms. They also filter pollutants from the water. Wetlands, along with rivers and lakes, are essential water recharge areas and important sources of water for irrigation and domestic and industrial use. Inland wetlands, particularly peat, are large carbon sinks. It has been estimated that 10–30 percent of global soil carbon is sequestered by wetlands.[39] Coastal and freshwater wetlands are natural productive fisheries in many Third World countries.[40]
5. Plan, establish, and manage agroforestry systems with systematic maintenance of native trees, vegetation, and soil. The tree and plant root systems provide protection from landslides, and traditional crops are usually more drought resistant than imported ones. Forests cover 30 percent of the earth's land surface, but store 50 percent of terrestrial carbon, including soil carbon and serve as a sink for atmospheric carbon.[41] This plan would include restoration of degraded ecosystems, such as reforesting on steep slopes.
6. Protect water supplies: (a) Identify, establish management plans, and actively eradicate invasive alien plants that consume large quantities of water annually, which results in polluting water supplies, impeding farming and irrigation, intensifying floods and fires, causing erosion, increasing siltation of estuaries, and destroying rivers. Agriculture is the biggest consumer of fresh water. It has been estimated to use 50% of fresh water in many countries and as much as 95% in developing countries. The World Bank predicts that

39 Parish et al., *Assessment on Peatlands*, viii–ix.
40 Stolton et al., *National Security*, 39.
41 Parish et al., *Assessment on Peatlands*, 99–102.

by 2030 irrigated crop production will increase by 80% from 2010 levels in order to meet global food demand. It is, therefore, critical to protect fresh water supplies for both agricultural production and human consumption.[42] (b) Create watersheds and conserve catchments. (c) Protect headwaters and source of rivers.

7. Design alternatives to traditional farming to stabilize, rehabilitate, and decrease pressures on the soil. Some examples are alley cropping, hydroponic agriculture, aquaponic agriculture, permaculture, and building integrated food production. Promote urban agriculture and permaculture; this would include warehouse farms for cities and suburbs, rooftop gardens, street orchards, bus stop aquaculture.[43]
8. Use nonchemical, natural alternatives to chemical pesticides. This would include natural predators and development of new plants that resist pests.
9. Restore and maintain the biogeochemical cycles: (a) Stabilize the oxygen cycle by decreasing runoff from agriculture, sewage, paper and textile mills, and food processing, which increase carbon dioxide and ozone at the ground level. (b) Stabilize nitrogen cycle and decrease eutrophication by decreasing the use of chemical fertilizers and emissions of greenhouse gases. (c) Stabilize phosphorous cycle and decrease algal blooms and eutrophication by decreasing the use of detergents with a high phosphorous content. (d) Stabilize sulfur cycle by decreasing the use of fossil fuels. (e) Stabilize hydrologic cycle by designing systems that ensure that water remains in the ecosystem of its origin, maintain wetlands, prevent flooding, prevent soil erosion.
10. Establish and protect natural dry lands as biodiversity sites for native food crops, such as barley sorghum, cereals, nut forests, pollinators, and pest control. Cultivation of native crops will decrease land degradation.

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[42] World Bank, *Convenient Solutions*, 10, 62–64; UN Environment Programme, “Proposed Actions in the Area of Freshwater Ecosystem Management,” *Freshwater Ecosystems and Water Quality Annex II*, January 1998, sections 63–66.

[43] Todd and Todd, *From Eco-Cities,* 118–125.

11. Create marine protected areas for biodiversity conservation and sustainable fisheries.[44] Maintain nursery, feeding, and breeding for fisheries. This practice will also prevent and control invasive species and protect water supplies.[45]
12. Create local, regional, state, and national planning policies that regulate development and manage lands on the basis of the ecosystem concept. Ecosystem management would include the integration of ecological, economic, and social principles to manage biological and physical systems that protect long-term ecological sustainability, natural diversity, biogeochemical cycles, and the productivity of the land. This approach would recognize that there is no dichotomy between humanity and the environment.[46]
13. Create public policy soil conservation regulations for not only agricultural land but also urban-rural landscapes: (a) Strengthen existing regulations and laws, such as required environmental impact statements that precede project approval; clean air and water laws; pesticide control laws; toxic substances control acts; and conservation, forest, coastal, and endangered species laws, among others. (b) New public regulations to correct current imbalances that are detrimental to ecosystem functions, such as gas exchange, water purification, and nutrient cycling. (c) Enact public laws and treaties, and increase the number of protected areas in the world from the present number of two hundred thousand. (d) Limit city size, or organize cities in modules, encourage city self-sustainability with locally grown food, waste and water recycling, and promote natural areas and greenbelts.[47]

Conclusion

The findings cited show that human activities have had seriously negative effects on biodiversity. The findings underscore the combined

[44] B. S. Halpern, "Impact of Marine Reserves: Do Reserves Work and Does Reserve Size Matter?," *Ecological Applications* 13 (2003): 117–147.
[45] World Bank, *Convenient Solutions*, 10, 49–52.
[46] James P. Barker, "Archeological Contributions to Ecosystem Management," *Society for American Archeology Bulletin* 14, no. 2 (March 1996): 16.
[47] Cunningham and Cunningham, *Principles,* 347.

impact of human activities on ecosystems and their future ability to support an ever-growing population without a dramatic change in the way that we design and use our human-made ecosystem.

The discussion of the various aspects of an ecosystem, the effects of anthropogenic activities, and proposed solutions through ecomimesis lead to a simple conclusion: ecomimetic designs, both built and unbuilt, can slow the rate at which humans are altering nature for their own purposes. Ecomimesis can also help stem the despoilation of ecosystems and assist in repairing them by adopting natural circular processes rather than linear ones in creating anthropogenic structures and communities.

Ecomimesis and its inclusion of the entire ecosystem and the impact human activities have on the natural ecosystem represent a design paradigm that utilizes both new scientific solutions and respect for the stability of the natural ecosystem. Rather than resolving problems of individual segments of the ecosystem, ecomimesis is a design approach for the built and unbuilt environments that demonstrates the feasibility of restoring the natural balance in the whole environment.

While the Industrial Revolution was made possible and flourished with advances in technology, Francis correctly states that present-day scientific and technological developments can make major contributions to minimizing climate change and rehabilitating nature that have been harmed by the centuries of industrial development, lack of conservation of resources, and population growth. Creative ecomimetic solutions, such as artificial photosynthesis, nontoxic batteries, and Solar Sewage Walls and living machines to treat waste, are being continually developed and refined by researchers, scientists, and inventors worldwide.[48] Green infrastructures and sustainable land management can also benefit from technology to preserve and maintain environments, minimize natural disasters, and protect populations in less developed nations.

Through its nonintrusive strategies and designs and goal of preserving natural ecosystems and the earth, our common home, ecomimesis can become an integral part of stabilizing and rehabilitating our natural world at the same time that it addresses the needs of growing economies and populations around the world. In its vision of the earth

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48 Lynn Savage, "Artificial Photosynthesis: Saving Solar Energy for a Rainy Day," *Optics and Photonics News* 24, no. 2 (February 2013): 20–25.

as a living organism in which seemingly disparate elements turn out to be interdependent, ecomimesis reflects Pope Francis's vision of creation as a spiritual unity. In its deeply practical approach to the challenges created by humankind, it offers a complex but concrete avenue to the healing for which we pray and to which he calls us.