Ecosystem Management

Earth's ecosystems are under threat. Twenty per cent of Earth's land cover has been significantly degraded by human activity and 60 per cent of the planet's assessed ecosystems are now damaged or threatened. The irrefutable pattern is one of natural resource overexploitation while simultaneously creating more waste than ecosystems can process.

A rich variety of plants and animals on the Hoang Lien Mountains give way to incredible montane landscapes and managed terrace fields in Sapa district, Lao Cai Province, northwest Vietnam. *Source: Graham Ford*

INTRODUCTION

Ecosystems are, by definition, resilient and adaptable to change—even to abrupt change. This makes the current worldwide collapse of ecosystem function all the more dramatic: Human activities over the last 50 years have accelerated rates of change, and introduced artificial connections and substances, to such an extent that natural systems are losing their ability to adjust. The stresses, including habitat destruction, species loss, pollution, and climate change, combine to make ecological breakdown more widespread, more severe, and more likely (Homer-Dixon 2007). Worse, as multiple stresses unfold simultaneously, major ecosystems are reaching critical thresholds beyond which they will no longer be able to recover from further disturbance.

Science cannot yet predict the precise thresholds for each ecosystem, but our ability to understand cumulative and non-linear change has improved dramatically, offering new insights into how far an ecosystem can be pushed before irreversible changes occur (Willis and others 2007). Crucially, these advances clarify the numerous links between long-term ecosystem health and human wellbeing. It has become clear that ecosystem management, environmental services, and socio-economic development must all be considered together.

In the face of climate change and mounting water vulnerabilities, 2008's unstable energy prices and food price crisis illustrate the global scope and cascading effects of pressures we exert on ecosystems. These events further underscore the vulnerabilities inherent in the global community's current doctrines of perpetual economic growth and demonstrate that conventional, highly compartmentalized ecosystem management methods are not working.

In 2008, voices from all corners of society called for dramatic change. Many endorsed significant long-term measures to incorporate the ecosystem approach for management of agriculture and conservation, with a new focus on integrated management systems, in which the needs of humans and the needs of nature are both taken into account, for the benefit of each.

Box 1: A red hot priority: The world's mammals in crisis

Of the 5487 recognized mammal species in the world, more than half are declining in numbers and more than 20 per cent are threatened with extinction, according to the Red List Index 2008. The Red List, an ongoing global inventory undertaken by the International Union for Conservation of Nature (IUCN), is widely recognized as the best assessment of distribution and conservation status of Earth's plant and animal species.

While the exact threat is hard to quantify, the situation is worst for marine mammal species, with 36 per cent at risk of extinction from pollution, changing climate, and encounters with fishing nets and cargo vessels. Since the last Red List Index assessment on mammal species in 1996, scientists have documented 700 species not covered previously, including 349 new species discovered mostly in Madagascar and the Amazon. Scientists expect that more species have yet to be discovered in regions such as the Congo Basin.

Threatened mammals tend to concentrate in rich ecosystems with high occurrence of endemic species—ecosystems under extreme pressure from human activities. The most vulnerable areas include South and Southeast Asia, the tropical Andes, the Cameroonian Highlands, the Albertine Rift in Africa, and the Western Ghats in India. Deforestation and agricultural expansion have left animals living on increasingly fragmented and smaller patches of land.

Meanwhile, protected areas may no longer offer a safe haven to species: The impact of tourism on local economies tends to attract settlement around conservation areas by people looking for employment. These communities then turn to timber harvesting, bush-meat hunting, and land clearing by fires—all activities that ultimately lead to higher rates of species loss in the protected sectors.

Source: Miller and others 2006, Schipper and others 2008, Wittemyer and others 2008, IUCN 2008

Severe habitat degradation, disease, and reduced water availability have brought the Grevy's zebra to near extinction with 750 adult animals remaining in Kenya and Ethiopia.

Source: Jason Jabbour/ UNEP

CHANGING ECOSYSTEMS

The 2005 Millennium Ecosystem Assessment reported a substantial and largely irreversible loss in the diversity of life on Earth, along with the deterioration of more than 60 per cent of all ecosystem services assessed (MA 2005) (**Box 1**). The sobering reality inspired a surge in scientific research and ideas. It prompted calls for a serious rethinking of our management approaches, seeking methods that better deal with the mounting risks and challenges to ecosystems. The stakes are high. If humans are to survive on this planet with a minimally acceptable, universal quality of life, we must manage and utilize our ecological assets in far more efficient and creative ways (Steiner 2008).

Irrefutable evidence of degradation

All ecosystems are undergoing change, but some transitions are more dramatic than others. Certainly one of the most visible and significant ecosystem changes is the widespread degradation and conversion of tropical and sub-tropical ecosystems (**Figure 1**). Increasing demands for food and other agricultural products has led to the intensification of agricultural production and the drastic expansion of land under cultivation (Yadvinder and others 2008). Today, farmland covers nearly a quarter of the planet's surface. Entire forest systems have effectively disappeared in at least 25 countries and have declined by 90 per cent in another 29 countries (Dietz and Henry 2008). This destruction continues at staggering rates. Such abrupt and comprehensive changes to ecosystems result in significant stress on ecological processes and biogeochemical cycles, with further adverse implications for both regional and global ecosystem services that derive directly from the health of basic ecological functions. This knock-on effect through conversion of tropical and sub-tropical ecosystems leads to critical losses in watershed protection, diminished soil integrity, increased erosion, disappearance of biodiversity, decrease in carbon sequestration capacity, and deterioration of regional and local air quality (Scherr and McNeely 2008, Hazell and Wood 2008).

Less visible but just as significant human-induced changes are underway in marine and coastal ecosystems. Coral reefs, intertidal zones, estuaries, coastal aquaculture operations, and seagrass beds have all experienced intense pollution, degradation, destruction, and overexploitation. The resulting decline of aquatic ecosystems has essentially forced the world's marine fisheries into a state of stagnation for nearly a decade (World Bank and FAO 2008). Since the onset of industrial fishing in the 1960s, the total biomass of large, commercially-targeted marine fish species has declined by a staggering 90 per cent (Halpern and others 2008, MA 2005).

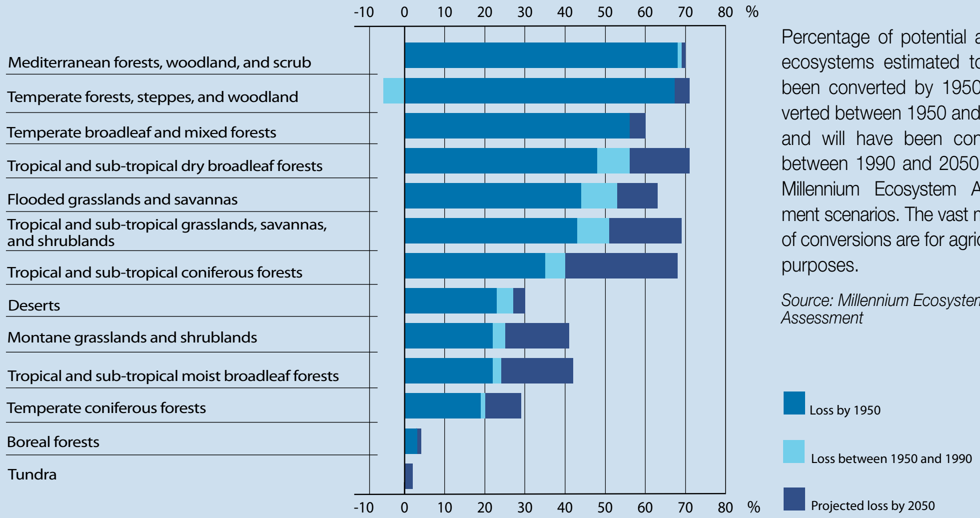
The need for action on fisheries is urgent. Over one billion people, many among the world's most vulnerable, depend on fish as their primary source of protein. According to a 2008 study commissioned by the World Bank and the UN Food and Agriculture Organization (FAO), the exploitation and near depletion of the ocean's most valuable fish stocks have caused an annual net loss in the value of global marine fisheries in the order of US$50 billion. The excessive build-up of redundant fishing fleet capacity, the deployment and mismanagement of increasingly powerful fishing technologies, and increasing pollution and habitat loss are to blame (World Bank and FAO 2008).

Rising food prices, the impending energy crisis, and increasing impacts of climate change all have the potential to put further pressure on marine ecosystems. The immediate and paramount need is to improve the resilience of those ecosystems, through a series of institutional and regulatory reforms. Recommendations for concerted national and international reforms are designed to increase investment in and to empower poor small-scale fishing communities. These would include the elimination of counterproductive subsidies and perverse incentives, as well as supporting initiatives to certify sustainable fisheries and new measures to eliminate illegal fishing (World Bank and FAO 2008).

Shifting ecosystems

Recent studies have revealed migration and some expansion of certain ecosystem types as they respond to changing climatic and biogeochemical conditions (Silva and others 2008). The conversion of Arctic tundra to shrubland has been observed as temperatures rise during recent years. The process involves warmer winter temperatures when a few shrubs can stabilize a snow layer, the snow layer insulates the soil, and the local soil

Figure 1: Per cent of available area converted by 2050



Percentage of potential area of ecosystems estimated to have been converted by 1950, converted between 1950 and 1990, and will have been converted between 1990 and 2050 under Millennium Ecosystem Assessment scenarios. The vast majority of conversions are for agricultural purposes.

Source: Millennium Ecosystem Assessment

microbes that remain active for longer periods under the warmer conditions produce the nutrients the shrubs need to thrive. This process fosters the colonization of tundra by more shrubs (Strum and others 2005). The resulting ecosystem shift has forced caribou populations out of traditional grazing areas in search of the lichens and grasses normally found on tundra (Tape and others 2006). In 2008 new evidence showed that while warmer Arctic temperatures encourage earlier availability of caribou grazing resources, caribou reproductive cycles are not advancing with resource availability. This has significant repercussions on caribou reproductive success (Post and others 2008).

In the northern Ural Mountains of Russia, the warming summer climate and the doubling of winter precipitation have altered the composition, structure, and growth forms of Siberian larch (Devi and others 2008). As mature forests, these 10-20 metre conifers typically grow in a mix of single- and multi-stemmed tree clusters. But a recent study found that 90 per cent of trees emerging after 1950 were single-stemmed, a characteristic of less mature forests. The researchers concluded that this tree generation largely reflects the expansion in both space and time of a new forest. This forest-tundra ecosystem may already have advanced as far as 20 to 60 metres up the mountains in the past century (Devi and others 2008).

Scientists had long thought that the boundaries between savannas and gallery forests, two distinct and separate ecosystems, were effectively fixed due to sharp contrasts in soil properties such as water content, nutrients, aeration, and acidity (Furley 1992, Beerling and Osborne 2006). In 2008, new evidence from central Brazil revealed a surprising migration of gallery forests into surrounding savanna regions. It appears that climatic changes can initiate such ecosystem migration and that subsequent feedback mechanisms including nutrient accumulation and fire suppression may push the expansion process further still (**Figure 2**) (Silva and others 2008).

Figure 2: Vegetative regions and ecological transitions in Brazil

Map of Brazil showing major vegetative regions and areas of ecological transition. Complex factors associated with changing climate and subsequent soil, moisture, and nutrient conditions have given to an increase in these ecological transition regions and the expansion of certain vegetative biomes including gallery forests into savannas.

Vegetation class

- Other vegetation
- Amazon / Atlantic forest
- Ecological transitions
- Woodland savanna (Cerrado)
- Shrubland (Caatinga)
- Water

Source: Màrton Bàlint and Jason Jabbour/ UNEP; adapted from Heckenberger and others 2008, Silva and others 2008

Non-linear changes and emerging ecosystems

The occurence frequency and accelerated rates at which environmental conditions are transforming vegetated landscapes—and the unexpected manner in which existing natural systems are responding—raise important questions about our understanding of ecosystem thresholds. What we are learning about accelerated, abrupt, unexpected, and potentially irreversible ecosystem changes leads to serious uncertainties about the future of those ecosystems, the consequences of our interventions, and the implications for human wellbeing.

Such evidence has prompted a renewed investment in monitoring and early warning systems, and highlights the value of alternative management options. Already these investigations have expanded our ability to explain and predict some of the drivers and positive feedback mechanisms that influence non-linear ecosystem change (Dakos and others 2008, Scheffer and others 2006, Lenton and others 2008, Tallis and others 2008).

Observations of non-linear changes and expectation of their increasing occurrence have encouraged concepts of emerging ecosystems. These are assemblages of species within a given ecosystem that are documented in previously unrecognized combinations and abundances under new ecological conditions (Milton 2003, Seastedt and others 2008, Silva and others 2008). The emerging ecosystems concept borrows from the idea that as ecosystems pass through various states of vulnerability and resilience, they evolve—adapting to disturbances differently, and restructuring themselves as a function of both the state of the system and the spatial scale at which the disturbance occurs. Accelerated rates of change from human-induced forces have pushed some ecosystems towards extinction. But these forces have also propelled some ecosystems past their historical range of variability into states that are relatively stable despite being new (Sax and Gains 2008). As emerging ecosystems and their enabling conditions evolve, management approaches must be able to analyse the costs incurred and benefits offered. Study of the current state of ecosystem functioning is essential, but management of dynamic systems must also focus on likely trajectories or predictions of future changes to anticipate opportunities for disaster prevention. Emerging ecosystems require novel management approaches, including a more deliberate collaboration between scientists and managers in developing methods and measures for achieving short- and long-term objectives (Seastedt and others 2008).

In the United States of America's Yellowstone National Park, new insights on the cascading ecological changes occurring in a warmer park have prompted managers and scientists to rethink traditional assumptions and strategies. An invasive thistle species, long established in North America, was initially thought to be thriving in the park because of changing climate. Researchers recently discovered the thistle's success is part of a larger feedback loop in which a simultaneous expansion of pocket gophers has helped the plant spread. The gophers create ideal growing conditions for their thistle food source by churning surface soil as they tunnel. More thistles feed more gophers and, at the same time, grizzly bear populations have stabilized due to an ample supply of both (Robbins 2008). Consequently, park efforts to control the thistle have been significantly reduced.

Should an emerging ecosystem persist, it could offer new valuable ecosystem products and services. The extent that these new systems can contribute to future diversity, renewal, and resilience will require careful research. A key goal for the future of ecosystem management is to maximize beneficial changes and reduce less advantageous elements, while tracking the processes and persistence of both benefits and costs (Hobbs and others 2008).

A shrimp farmer in Apalachicola, Florida, USA, describes the drastic decline of fisheries in the Gulf of Mexico and the increasing challenges that fishers face. *Source: Tara Thompson*

ECOSYSTEMS AND HUMAN WELLBEING

Healthy ecosystems, and the goods and services they provide, are the foundations of survival for all societies. Given current consumption levels in the industrialized world and the rapidly accelerating material aspirations in developing countries, those foundations are threatened. The problems associated with environmental degradation and agricultural growth alone will incur substantial costs to future generations in the form of threats to human and ecosystem health (Hazell and Wood 2008, Levin and others 2008, RRI 2008). Externalities of climate change and economic globalization are accelerating the approach of critical thresholds for already threatened ecosystem health at local and global scales. The potential for catastrophic mistakes grows.

The prospects for biofuels

It is difficult to think of an environmental issue that attracted more controversy in 2008 than biofuels. Sweeping rhetoric has both championed biofuels as a renewable, low-carbon energy solution and condemned their production as a threat to human and environmental wellbeing. For many, the juxtaposition of 'food versus fuel' captures the central tension of the biofuel industry.

Dramatic increases in grain prices throughout much of 2008 brought food security and vulnerability issues to the fore. Experts disagreed over the extent to which biofuel production contributed to these price increases, with perhaps the highest estimate of 75 per cent responsibility attributed to a combination of diversion of grains into biofuels, farmers setting aside land for energy crops, and financial speculation (Chakrabortty 2008). Others saw a less clear relationship between biofuels and food prices, contending that biofuels may actually be able to reduce local food shortages and raise the incomes of the world's most impoverished—if proper policies are implemented (Müller and others 2008). Looking beyond a direct trade-off between food and energy, another perspective sees land use management as the lens for assessing the linked implications of biofuels, biodiversity, ecosystem integrity, and food.

Approaches such as smallholder production for local consumption stand in contrast to the dominant model of large-scale agribusiness biofuel production. As well, such approaches represent an important ongoing experiment within the broader effort to promote rural energy self-sufficiency, livelihood opportunities, and environmental integrity in the developing world.

Using an eco-agriculture approach, smallholders producing biodiesel or vegetable oil for local use can achieve conservation benefits including crop diversity and restoration of degraded land (Milder and others 2008). This strategy has the potential to enhance local energy security, increase household incomes, and generate new economic opportunities that rely on a small but steady energy supply (Ejigu 2008). Such small-scale biofuel projects are now underway in several countries.

Large, monoculture plantations invite environmental damages related to intensive chemical use, biodiversity loss, soil degradation, wildlife displacement, and water consumption (**Table 1**). They can also have significant social repercussions in terms of livelihoods and human rights. In places where the land tenure situation is insecure or contested, an increase in biofuel production can cause poorer groups to lose crucial access to land (Cotula and others 2008). Still, many developing countries see an opportunity for economic development in the growing international biofuel trade.

Table 1: Biofuels and water projections for 2030

	Biofuel production (billion litres)	Crop	Irrigated water needed (km^3) for biofuels	Percentage of irrigation water used on biofuels
US/Canada	51.3	Maize	36.8	20
Brazil	34.5	Sugarcane	2.5	8
EU	23.0	Rapeseed	0.5	1
China	17.7	Maize	35.1	7
India	9.1	Sugarcane	29.1	5
South Africa	1.8	Sugarcane	5.1	30
Indonesia	0.8	Sugarcane	3.9	7

Sources: Molden 2008, Serageldin and Masood 2008

Research attempts to analyse the full costs and benefits of various biofuel production processes, including the implications of large scale land-use change, predict the loss of stored carbon, and raise the possibility of biofuels as a net contributor to climate change (Fargione and others 2008). A new study using a worldwide agricultural model to estimate emissions from land-use change reveals that corn-based ethanol would increase greenhouse gas emissions by nearly 100 per cent over 30 years and would continue emitting for 167 years (Searchinger and others 2008). As initial enthusiasm over biofuels is tempered by concerns about the social and environmental trade-offs in places where energy crops would be grown, several governments with fuel-blending mandates have recently revisited their targets or considered adding conditions related to sustainable sourcing.

The development of a global standard outlining sustainability principles and decision making criteria will be an important step towards appropriate policy decisions when applied in combination with enhanced bioenergy mapping tools and an understanding of local preconditions and needs. Small-scale biofuel projects designed to promote rural energy self-sufficiency in the developing world pose a creative challenge to the dominant scenario of biofuels for international transport needs (UN-Energy 2007). Whether these efforts will translate into an effective strategy for meeting rural energy needs while enhancing livelihoods and ecosystem integrity will remain an important question in the months and years to come.

Cycle of poverty and environmental degradation

Environmental degradation has created uncertainty and risk across the globe. Yet the greatest burden continues to fall on the most impoverished regions, and on marginalized and indigenous communities (Levin and others 2008). If current trends persist, the disruptive effects of climate and ecosystem change will continue to impair the wellbeing of at least 2 billion of the world's human population and to diminish their prospects for a better future (See Climate Change, Chapter Three) (WRI 2008). And yet, attempts to mitigate the current global economic downturn have cost considerably more than the amounts allocated for official development assistance (See Environmental Governance, Chapter Six) (Ban 2008).

Poverty and the environment are inextricably linked. It is well accepted that ecosystem degradation and natural resource depletion are exacerbated by socio-demographic factors, particularly when combined with poverty (WRI 2008, UN 2008). The co-incidence of rapid population growth and environmental degradation has emphasized the importance of understanding the complex linkages among societies, ecosystems, and governance. While the overall changes that humans have made to ecosystems have contributed to substantial overall benefits in human wellbeing and economic development, these gains are not equitably distributed: They have come at the serious and growing cost of displaced degradation, increased risks of non-linear changes, and exacerbation of poverty among the most vulnerable populations (Holden and others 2006, WRI 2008, Hazell and Wood 2008).

For most people in developing countries, especially those living in rural areas, functioning natural environments form an essential part of their livelihood strategies. A balanced relationship between people and functioning ecosystems is crucial when addressing sustainable ecosystem management and poverty reduction (IAASTD 2008, WWF 2008, UNEP 2007). Nature-based income routinely accounts for more than half of the total income stream for the world's rural poor (WRI 2008). Reliable estimates suggest that 90 per cent of the rural poor depend on forests for at least a portion of their income (WRI 2005). In rural Africa, small-scale agriculture, the backbone of developing country economies, is the principal source of income for over 90 per cent of people (UN 2008). As a function of these critical dependencies, impoverished regions and rural indigenous communities have consistently suffered disproportionately from degradation and changing climatic and ecosystem conditions.

The proportion of rural people in poverty rises markedly in locations that are marginal for agricultural productivity, remote from services, and prone to natural disasters. Under these conditions, people are often compelled to over-exploit adjacent resources to survive (Hazell and Wood 2008). The UN Food and Agriculture Organization estimates that 7.8 million hectares of forest are lost each year to subsistence hillside farming and shifting cultivation as a result of declining yields on traditional agricultural land (FAO 2008, FAO 2008b). Pressures exerted through low-productivity agricultural practices, overgrazing, slash and burn activities, soil-mining, deforestation, and expansion into forested areas threaten not only the ecological balances of an increasingly fragile natural resource base, but also livelihoods and wellbeing of the communities that depend on these ecosystems. The result is a negative feedback loop, in which poverty contributes to ecosystem degradation and ecosystem degradation contributes to the perpetuation and intensification of poverty (Wade and others 2008).

Mainstreaming ecosystem management into poverty reduction

Ecosystem approaches to alleviating poverty have received substantial attention in recent years. Integrating environmental issues and ecosystem management with poverty reduction strategies has become central to sustainable development programmes (UNDP 2007, WRI 2008, Svadlenak-Gomez and others 2007). Given the huge disparity between average incomes and those of the rural poor, as well as the important relationships these populations have with the land and natural ecosystems, development strategies stand little chance of success if they do not take into account the circumstances, knowledge, capabilities, and environmental needs of the rural poor.

With a deliberate shift to a strong governance regime, ecosystem management could become a powerful model for nature-based enterprise that delivers continuing economic and social benefits to the poor as it improves the natural resource base, and that sustains those ecosystems as they provide essential services at regional and global scales (WRI 2008). So far, the poorest and most vulnerable segments of society lack the necessary means and empowerment to utilize nature-based enterprise to improve their wellbeing. Even where resources are abundant, revenues are often appropriated by elites, leaving rural communities and their local ecosystems worse off (Gardiner 2008, FAO 2007).

Development in poor rural communities requires innovative strategies and processes that promote local interests while building local capacity. Meeting such challenges was inherent in the Millennium Development Goals. But momentum towards those goals is faltering.

The need for action is urgent. We face a global economic crisis and a food security crisis, both of uncertain magnitude and duration. In the meantime, climate change has become more apparent—usually in the background but more frequently as a phenomenon that cannot be ignored. These developments will directly affect our efforts to reduce poverty: The economic slowdown will diminish the incomes of the poor; the food crisis will increase the number of hungry people in the world and push millions more into poverty; and climate change will have a disproportionate impact on the poor. The need to address these concerns, pressing as they are, must not be allowed to detract from our long-term efforts to achieve the Millennium Development Goals (UNDESA 2008).

Women agricultural workers harvesting tea leaves at a tea plantation in West Java, Indonesia. *Source: M. Edwards/ Still Pictures*

NEW MANAGEMENT PARADIGMS

Ecosystem management practices continue to evolve as new science emerges, leading to re-consideration of fundamental principles, values, and the specific nature of management interventions. The underlying problem is ultimately quite simple: Management approaches that do not respond to, and adapt faster than, changing ecosystems will invariably fail—as will the societies that are content with such mismanagement.

While the challenge is daunting, new advances offer hope. The closer we come to achieving an accurate, holistic picture of the distribution of the ecosystem costs, benefits, and trade-offs of our actions, the better positioned we will be to formulate responses.

Degradation, conservation, and productivity

Over the next four decades the amount of available cropland per person is projected to drop to less than 0.1 hectares, due to biological limits, requiring an increase in agricultural production that is unattainable through conventional means (Montgomery 2008). A sense of urgency has been growing, in response to the universal decline of soil quality that results from various systems of intensive agriculture.The problem of soil degradation, which has affected all but 16 per cent of the world's croplands, presents serious implications for agricultural productivity and broader ecosystem services, including biodiversity (Hazell and Wood 2008).

An emerging body of scientific research focuses on spatially integrated management approaches to agriculture. This would involve a move away from the conventional model of land-use segregation, in which some areas are dedicated wholesale to food production, while others are set aside for conservation or other uses (Scherr and McNeely, Holden and others 2008). For decades, biodiversity conservation and agricultural productivity were thought to be incompatible and mutually exclusive pursuits. But practitioners of eco-agriculture challenge these notions. Their approach transforms large-scale, high-input monoculture plantations at the farm level to a more diverse, low-input, and integrated system at the landscape level.

Given the necessary management, policy, and governance structures, these new eco-agricultural land-use mosaics could support biodiversity while meeting increasing demands for wider ecosystem services and achieving critical goals of agricultural sustainability (Scherr and McNeely 2008). By treating food production as just one of many possible ecosystem services, eco-agriculture in a sense encourages landholders to cultivate clean air, sweet water, rich soil, and biological diversity, as well as food (**Box 2**).

Forms of eco-agriculture have been practiced in the past and at impressive scales: Terra Preta soils of central Amazonia exhibit approximately three times more soil organic matter, nitrogen, and phosphorus and 70 times more charcoal compared to adjacent soils. The Terra Preta soils were generated by pre-Columbian native populations by adding large amounts of charred residues, organic wastes, excrement, and bones. Large-scale generation and utilization of Terra Preta soils would decrease the pressure on primary forests that are currently extensively cleared for agricultural use. This would maintain biodiversity while mitigating both land degradation and climate change and, if done properly, can alleviate waste and sanitation problems in some communities (Glaser 2007).

Scaling up financial incentives

The Fourth Global Environment Outlook Report called attention to the critical role the environment can play in enabling development and human wellbeing. It also rendered a compelling argument that Earth's ecosystems and the goods and services they provide offer tremendous economic opportunities valued at trillions of dollars (UNEP 2007). This conclusion reinforces the growing movement to incorporate inventories of our natural capital and nature-based assets into our efforts to develop and execute ecosystem management.

In recent years, interest in and scientific research on the assessment of ecosystem services, particularly biophysical valuation, has grown markedly (Cowling 2008). Valuation of ecosystem services has created a basis for innovative financial interventions and economic incentives as powerful instruments that can help regulate the use of ecosystem goods and services and even redistribute benefit flows.

Box 2: Semi-natural and cultural landscapes: Reservoirs of biodiversity and ecosystem services

Conservation of biodiversity and landscapes is often framed as a 'human versus nature' tradeoff: Pristine, untouched nature is considered optimal, while human influence in the ecosystem is considered unwanted intrusion. Conservation programs that limit human impact on natural ecosystems are important, but conservation of semi-natural landscapes is also necessary for both biodiversity and ecosystem services.

Historically, there are many semi-natural landscapes developed in association with societies' traditional land use over long periods of time. These semi-natural ecosystems, or cultural landscapes, are associated with traditional livelihood activities. The most common cultural landscape types, managed meadows and forests, are kept in a stable but artificial state through activities such as animal grazing, fodder collection, forest floor litter clearance, and harvesting of forest resources. These activities alter important environmental features of the landscape, including moisture levels, light penetration, temperature regimes, and nutrient cycles. Many such sites are high in biodiversity and, more importantly, contain a higher percentage of rare and endangered species than either monoculture plantations or natural ecosystems on the margins of cultivated areas.

Coon Creek Watershed in southwest Wisconsin was once one of the most heavily eroded regions of the United States. Advances in soil and farmland restoration have revitalized both form and function of this impressive landscape. *Source: Jim Richardson*

Cultural landscapes were traditionally managed for the provision of a particular ecosystem service. The grasslands of Europe, for example, have been managed for grazing and fodder production for domesticated livestock. Indigenous peoples of the Americas used controlled burns in forests to create wooded meadows for deer to graze. In North America, sugar bush woodlots are maintained to produce maple syrup. In Central Asia, the natural fruit and nut forests have been managed to enhance the production of these important foodstuffs.

Most ecosystems in Europe are managed or semi-managed. However, these semi-natural ecosystems have declined in both quality and quantity in the past century. In Finland, for example, traditionally managed forest and meadows are the most threatened habitats, with the majority of these landscapes now critically endangered. At the same time, nearly one-third of all endangered species in Finland are found primarily in these threatened and endangered grazed forests and meadows.

In letting these landscapes go, we lose not only important habitat for species, but also landscapes that have high cultural value. These landscapes have irreplaceable aesthetic and historical value by providing cultural ecosystem services. Semi-natural and cultural landscape have inspired great painters, musicians, and poets and help to form peoples' cultural identities. The aesthetic value of cultural landscapes is evident in the importance they have in tourism and in attracting new residents from urban areas.

What does this mean for future management of ecosystems, when human impact is felt in every ecosystem on Earth? Although humans have been responsible for massive environmental changes and large-scale extinctions, our valuable cultural landscapes show that people can manage ecosystems sustainably. Although we need wild places, too, it may be time to revisit the past to learn how to manage for the future.

Sources: Wittemyer and others 2008, Lindborg and others 2008, Furura and others 2008, MOE 2007, Raunio and others 2008, Kareiva 2007, Merchant 2005, Schama 1995

Among the possibilities, a rapidly evolving instrument called 'payment for ecosystem services' (PES) offers great potential. The objective is to ensure that individuals, groups, and communities are compensated for their efforts in protecting critical ecosystem functions. This approach offers the necessary institutional platforms for poor and marginalized populations to engage in good ecosystem management while they claim economic and other benefits that emerge (WRI 2008). New initiatives to scale up PES arrangements offer promise for achieving both ecological and social progress without detracting from the primary objective of balancing conservation and development (Tallis 2008, Svadlenak-Gomez 2008). Through use of rigorous monitoring and appropriate valuation for both ecology and human wellbeing, PES could provide an important remedy for the tendency to shift burdens of ecosytem damages onto the vulnerable, poor, and future generations (Schultz 2008, WRI 2008, Hazell and Wood 2008).

Compensated reduction of deforestation

The consensus among scientists and experts is that conserving tropical forests represents one of the central ecosystem management priorities of our time. Yet forest destruction continues at the staggering rate of 13 million hectares a year, an area equivalent to half the UK. Attributed mainly to land conversion and agricultural expansion, tropical forest loss accounts for an estimated 17 per cent of all greenhouse gas emissions, making it a major cause of global warming (Ceccon and Miramontes 2008, IPCC 2007). Until recently, tropical forests' critical role in influencing and potentially moderating our changing climate was only conjecture: It is now observed reality.

This recognition has given rise to the concept of 'compensated reduction'. Reducing emissions from deforestation and forest degradation (REDD) promotes avoided deforestation as eligible activities for participating in the international mandatory carbon market. Carbon offset payments would provide compensation to encourage developing countries to reduce and stabilize national deforestation below a previously determined historical level (See Environmental Governance, Chapter Six).

Enthusiastic proponents speculate that REDD offers a crucial set of new incentives for reducing greenhouse gas emissions that could simultaneously accomplish several ancillary benefits: biodiversity conservation, watershed protection, capacity building in tropical forest nations, and poverty alleviation for rural communities. In principle, compensated reductions should enhance the welfare of the poor through the provision of stable and long-term revenue-sharing arrangements and non-financial benefit flows to rural communities. In practice, however, these systems could pose new risks to already vulnerable populations including restricted access to land, conflict over resources, centralization of power, and distortion effects in local economic systems (Preskett and others 2008). Although existing mechanism proposals for REDD emphasize the delivery of pro-poor and social ancillary benefits, most appear to leave achievement of these ends to chance.

From food crisis to agricultural renaissance

In spring 2008 precipitous increases in staple food prices, which threatened the lives of tens of millions, provoked demonstrations and food riots in 37 countries (Gidley 2008). These events may signal the arrival of an era in which longstanding relative inequalities have reached a breaking point for the global poor.

It has become clear that ecosystem management and food security are intimately linked. The surplus living resources and ecological margin of error in many regions are gone. As societies struggle over diminishing tracts of fertile and irrigable land—and over traditional fishing grounds—the accelerating threats of changing climate, ecosystem collapse, and population stress have converged in a way that calls the very future of food availability into question (**Box 3**). The debates are vigorous and highly contentious, but the issue of food security created global political panic in 2008 and will no doubt continue to occupy much of the international agenda for years to come.

There is a growing consensus within the international community that our current global agricultural system needs to be reorganized and rationalized; some are calling for a new agricultural revolution (Montgomery 2008, Wade and others 2008). While the issues at play are complex, involving diverse geopolitical and agro-ecological circumstances, the underlying distinctions are not hard to identify: Agricultural intensification through increased emphasis on chemical and technological inputs—or a move toward an integrated eco-agriculture approach at nested scales (Hazell and Wood 2008).

There is no denying the achievements of past agricultural intensification in the mid to late 20th century. The economic and social advances that characterize India, China, and much of Latin America today are, to a significant degree, due to that agricultural intensification. The problem is that while the global agricultural system that emerged is undeniably more productive, in a mid 20th century sense, its practice has accelerated soil erosion, soil salination, nitrification of water bodies, and overuse of synthetic pesticides with subsequent loss of natural pest control and other ecosystem services affecting agricultural sustainability. As well, our agricultural systems' distribution flaws make whole populations vulnerable to supply shocks as we witnessed in 2008 (Surowiecki 2008). Despite higher crop yields in many countries, we still face vast, persistent, and widening gaps in the ability of societies to feed themselves, much less to protect future resources and ecosystem services (Hazell and Wood 2008). For most developing countries, entrenched and deepening poverty stems from the fact that millions of small-scale farmers, many of whom are women, are simply unable to grow enough food to sustain their families, their communities, or their countries (AGRA 2008, Ngongi 2008) (**Box 4**). The efficiencies derived from the economy of scale in intensified agricultural systems do not apply at the scale of these families and communities (Dossani 2008).

As the human population continues to grow and the pool of land available for agricultural production shrinks, the costs and efforts required to avert a worst-case global food crisis will inevitably increase for developing countries. A new land grab may already be underway in Africa, with rich governments and corporations competing for some of the last remaining cheap land in the world, hoping to secure their own long-term food or biofuel supplies. In 2008, a number of countries, including Sudan, Ethiopia, and Madagascar, were entangled in wholesale land deals, the details of which have been largely concealed, causing many to speculate on whether these transactions have built-in safeguards for local populations (Borger 2008). Another new trend involves industrial food

Box 3: Avoiding marine ecosystem collapse through rights-based catch shares

Global fisheries have exerted enormous demands on the ecosystem goods and services of the world's oceans for decades, and this is becoming increasingly difficult to sustain. A recent study, which synthesized 17 global data sets of various human-induced drivers of ecological change, used nested scale spatial modeling to map the global extent of impacts on marine ecosystems from human activities.The findings were grim, revealing that humans have adversely influenced all marine ecosystems examined, with 41 per cent affected by more than one human-induced driver.

As commercial fisheries across the globe descend towards widespread collapse, due to systematic over-exploitation and cumulative mismanagement, calls for an ecosystem approach to fisheries management are being raised. Incremental progress has been made in the improvement of stock assessments and spatial indicators of ecosystem status, which in turn have led to more scientifically credible catch limits for some species. However, many of the inherent problems of overfishing have been institutionalized through poor fisheries governance and a systemic absence of resource stewardship. This lack of stewardship has marginalized many artisanal fishers who may be forced to turn to other marine-based economic activities.

The movement to use an ecosystem approach has been paralleled by efforts to stimulate reward-based management strategies and regulatory incentives for promoting stewardship. A new study from the University of California, Santa Barbara (UCSB) is advocating an innovative and controversial solution called 'rights-based catch shares'. This approach offers incentives for promoting ecologically responsible behavior by guaranteeing individual fishers a fixed portion of the total allowable catch. By granting fishers a share in—and responsibility for—the natural resource, regulatory and management objectives including sustainability are likely to be more closely aligned with the economic incentives of the resource users. Similar to corporate stock shares, catch shares can be bought and sold and are subject to the market signals of supply and demand, thereby creating a stewardship incentive. As fisheries are better managed and fish populations increase, so do the value of the catch shares.

Artisanal fishers on the Zambezi River cast a net for today's catch. *Source: David Gough/ IRIN*

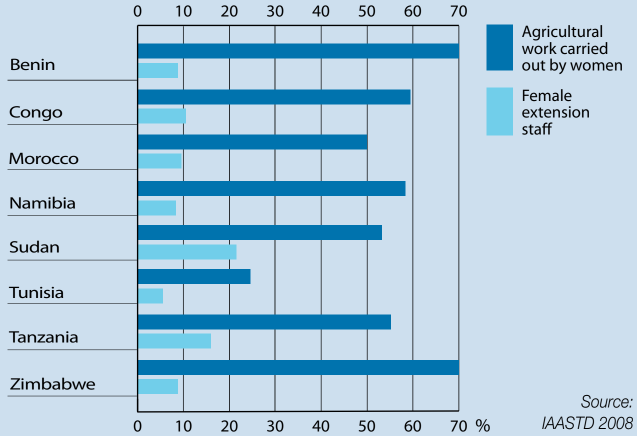
The UCSB study, which analyzed data from 11 135 fisheries worldwide, found a striking correlation between fisheries that implemented catch-share reforms and a reduction, or even reversal, of the trend towards collapse. The study posits that well-designed catch share programmes assigning secure resource rights to fishers reduces the probability of collapse by 9.0 to 13.7 per cent. In addition to addressing overfishing and ecosystem performance, various catch-based programs in New Zealand, Canada, Mexico, Chile, and the USA have shown an increased ability for individuals and fishing communities to improve their livelihoods.

Source: Costello and others 2008, Festa and others 2008, Halpern and others 2008, Mutsert and others 2008

Box 4: The role of women in agriculture in developing countries

A woman with her child prepares for planting at the Mshikamano women's group-farm in Bagamoyo, Tanzania where approximately 30 women share a small plot to raise fruits and vegetables. The socially constructed gender relations of agriculture are important dynamics in existing global farming systems, and a formidable challenge to ongoing agricultural restructuring. In most developing countries the percentage of rural women involved in agricultural production and post-harvest activities is disproportionately higher than men, with the proportion of agricultural management services skewed in the opposite direction. With the proliferation of export-oriented irrigated farming at low pay, the demand for female labour is increasing further. These developments have brought some benefits, but the situation for rural women worldwide must be improved. If they are shut out from higher paying agricultural roles, they will continue to face deterioration of health, working conditions, access to education, and rights to land and natural resources.

Source: Tara Thompson



Source: IAASTD 2008

production in one country, cultivated by another. Sudan is exporting wheat for Saudi Arabia; sorghum for camels in the United Arab Emirates; and wheat, beans, potatoes, onions, tomatoes, oranges, and bananas for Jordan. Sudan supplies the land while its neighbors supply the money, the management, the science, and the equipment (Gettleman 2008).

A number of institutions and research bodies are pressing for a complete rethink of the role of agriculture in achieving equitable development and sustainability. Increasingly, they are advocating for approaches to agriculture that recognize the importance of multiple ecosystem services. An extensive intergovernmental assessment of agriculture knowledge, science, and technology, released in 2008, advocates for a radical move away from technologically-based production enhancements to a focus on the needs of small farmers in diverse ecosystems, particularly in areas of high vulnerability to ecosystem change. Recognizing that the poor have benefited the least from increased productivity, the study argues for improving rural livelihoods, empowering marginalized stakeholders, enhancing ecosystem services, integrating diverse knowledge, and providing more equitable market access for the poor (IAASTD 2008).

In November 2008, the UN's Food and Agricultural Organization called for an immediate plan of action on a new 'World Agricultural Order' to ensure that production meets rising demand in the face of climate change, while safeguarding the goals of sustainable ecosystem management (FAO 2008). It proposed a new governance system for world food security and agricultural trade that offers farmers, in developed and developing countries alike, the means of earning a decent living (Diouf 2008).

In this new World Agricultural Order, can we learn from those experiences with high-input, high-yield agriculture to define a rational eco-agricultural system? While increased chemical and technological inputs may keep the agricultural production system going over the short term, it becomes progressively more difficult to sustain (See Harmful Substances and Hazardous Waste, Chapter Two) (Montgomery 2008, Pretty 2008). Sooner or later, the existing realities will compel those responsible for the new agricultural paradigm to reach a balance between production and ecosystem integrity. If we can establish the balance sooner, we will avoid the inevitable shocks and panics that result from business-as-usual practices (Montgomery 2008).

CONCLUSION

As the first decade of the 21st century draws to an end, virtually all ecosystems on the planet have been significantly modified in both structure and function (Seastedt and others 2008). To a greater or lesser extent, they have all been adversely affected by human activity. The most widespread human impacts include extensive deforestation, land conversion and fragmentation, desertification, the disruption of freshwater systems, the pollution and over-exploitation of marine ecosystems, excessive nutrient loading, severe changes in species distribution, and loss of biodiversity. Given humankind's cumulative influence on Earth's ecological systems and the consequent disruption of vital processes—especially carbon, water, nitrogen, and phosphorus cycling—it is too optimistic to describe future prospects for the planet's ecosystems as precarious and uncertain.

Rather than continue with business-as-usual practices that allow cascades of environmental and social damage to result from ecosystem mismanagement, we should be designing ecosystem management systems that minimize wasted resources, maximize community self-sufficiencies, and optimize access to emerging opportunities among the most vulnerable populations to build their resilience. Approaching ecosystem management from an industrial perspective has increased productivity, but at a high cost to the quality of soils, water, atmosphere, and ecological health. Based on insights revealed by 2005's Millennium Ecosystem Assessment, new approaches under consideration suggest that productivity can be decoupled from environmental degradation. Imminent critical thresholds require that this decoupling proceed at once.

REFERENCES

AGRA (2008). Revitalising Small-Scale Farming Across Africa. Alliance for a Green Revolution in Africa, 2008. http://www.agra-alliance.org/ [Accessed 20 November 2008]

Ban, K.M. (2008). A difficult time for world economy, global solidarity more important than ever. Secretary-General Press Release for European Development Day in Strasbourg, November 15, 2008 http://www.unbrussels.org/SS_SM_11929.pdf [Accessed 24 November 2008]

Beerling, D.J. and Osborne, C.P. (2006). The origin of the savanna biome. *Global Change Biology* (12), 2023-2031

Borger, J. (2008). Rich countries launch great land grab to safeguard food supply. *The Guardian* 22 November 2008

Ceccon, E. and Miramontes, O. (2008) Reversing deforestation? Bioenenergy and society in two Brazilian models. *Ecological Economics* 67, 311-317

Chakrabortty, A. (2008). Secret report: biofuel caused food crisis: Internal World Bank study delivers blow to plant energy drive. The Guardian, July 4, 2008 http://www.guardian.co.uk/environment/2008/jul/03/biofuels.renewableenergy [Accessed 24 November 2008]

Costello, C. Gaines, S.D. and Lynham, J. (2008). Can Catch Shares Prevent Fisheries Collapse? *Science* 321, 1678-1681

Cotula, L., Dyer, N. and Vermeulen, S. (2008). Fuelling exclusion? The biofuels boom and poor people's access to land. IIED, London

Cowling, M.R., Egoh, B., Knight, T.A., O'Farrell, J.P., Reyers, B., Rouget, M., Roux, J.D., Welz, A. and Wilhelm-Rechman, A. (2008). An operational model for mainstreaming ecosystem services for implementation. *Proc. Natl. Acad. Sci. PNAS* 105(28), 9483-9488

Dakos, V., Scheffer, M., Van Nes, E.H., Brovkin, V., Petoukhov, V. and Held, H. (2008). Slowing down as an early warning signal for abrupt climate change. *Proc. Natl. Acad. Sci. PNAS* 105(38), 14308-14312

Devi, N., Hagedorn, F., Moiseev, P., Bugman, H., Shiyatov, S., Mazepa, V. and Rigling, A. (2008). Expanding forests and changing growth forms of Siberian larch at the Polar Urals treeline during the 20th century. *Global Change Biology* (14): 1581-1591

Dietz, T. and Henry, A.D. (2008). Context and the commons. *Proc. Natl. Acad. Sci., PNAS* 105(36), 13189–13190

Diouf, J. (2008). FAO Reform: Director-General Diouf Calls for New World Agricultural Order. Food and Agricultural Organization of the United Nations Press Release, November 19, 2008 http://www.climate-l.org/2008/11/fao-reform-dire.html [Accessed 21 November 2008]

Dossani, S. (2008). Human Need and Corporate Greed, Understanding the Call for a New Green Revolution in Africa. Africa Action Special Guest Paper Series, Africa Action, August 2008

Ejigu, M. (2008). Toward energy and livelihoods security in Africa: Smallholder production and processing of bioenergy as a strategy. *Natural Resources Forum* (32), 152-162

FAO (2007). The State of Food and Agriculture: Paying Farmers for Environmental Services. Food and Agricultural Organization of the United Nations.

FAO (2008). Soaring Food Prices: Facts, Perspectives, Impacts and Actions Required. Report of High-level Conference on World Food Security: The Challenges of Climate Change and Bioenergy 3-5 June, Rome, Italy. Food and Agricultural Organization of the United Nations.

FAO (2008b). Global Forests Resources Assessment. Food and Agricultural Organization of the United Nations. Rome, Italy

Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008). Land Clearing and the Biofuel Carbon Debt. *Science* (319), 1235-1238

Festa, D., Regas, D. and Boomhower, J. (2008). Sharing the Catch, Conserving the Fish. *Issues in Science and Technology*, Winter 2008, 75-84

Furley, P.A. (1992). Edaphic changes at the forest–savanna boundary with particular reference to the neotropics. In: *Nature and Dynamics of Forest–Savanna Boundaries* (ed. Furley, P.A), 91-117. Chapman & Hall, London

Furuta, N., Iwatsuki, K., Nishida, H. and Kawamichi. M.(eds) (2008). Conserving Nature: A Japanese Perspective. Biodiversity Network Japan. 79p. http://www.cbd.int/doc/external/cop-09/bnj-nature-en.pdf [Accessed 10 November 2008]

Gardiner, B. (2008). Paying For Forests. GLOBE Forestry Dialogue, September 2008

Garnett, T.S., Sayer, J. and Du Toit, J. (2007). Improving the Effectiveness of Interventions to Balance Conservation and Development: A Conceptual Framework. *Ecology and Society* 12(1): 2

Gettleman, J. (2008). Darfur Withers as Sudan Sells Food. *New York Times* August 10, 2008

Gidley, R. (2008). Where's the global food crisis taking us? Reuters http://www.enn.com/agriculture/article/37559/print [Accessed 21 October 2008]

Glaser, B. (2007). Prehistorically modified soils of central Amazonia: a model for sustainable agriculture in the twenty-first century. *Phil. Trans. R. Soc. B* 362, 187–196 doi:10.1098/rstb.2006.1978

Halpern, B.S.,Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science* 319, 948-952

Hazell, P. and Wood, S. (2008). Drivers of change in global agriculture. *Philosophical Transactions of the Royal Society* 363, 495-515

Hobbs, P., Sayre, K. and Gupta, R. (2008). The Role of Conservation Agriculture in Sustainable Agriculture. *Royal Society Philosophical Transactions* 363(1491), 543-555

Holden, S., Otsuka, K. and Place, F. (2008). Emerging Land Markets in Africa – Implications for Poverty, Equity and Efficiency. Resources for the Future Press, Washington, D.C.

Holden, S., Barrett, T. and Hagos, F. (2006). Food-for-Work for Poverty Reduction and Promotion of Sustainable Land Use: Can it Work? *Environment and Development Economics* 11, 15-38

Homer-Dixon, T. (2007). *The Upside of Down: Catastrophe, Creativity, and the Renewal of Civilization*. Alfred A. Knopf and Random House, Canada

IAASTD (2008). Executive Summary of the Synthesis Report. International Assessment of Agricultural Knowledge, Science and Technology for Development

IPCC (2007). *Climate Change 2007: The Physical Science Basis*. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK

IUCN (2008). Triggering Behavioral Changes - Bringing Values and Principles of Sustainability into Education. International Union for Conservation of Nature - World Conservation Congress Proceedings, Barcelona 2008

IUCN (2008b). Red List Reveals World's Mammals in Crisis http://www.vector1media.com/index2.php?option=com_content&task=view&id=4725&pop=1&page=0&Itemid=133 [Accessed 24 November 2008]

Kareiva, P., Watts, S., McDonald, R. and Bouche, T. (2007). Domesticated Nature: Shaping landscapes and ecosystems for human welfare. *Science* 316(5833): 1866-1869

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S. and Schellnhuber, H.J. (2008). Tipping elements in the Earth's climate system. *Proc. Natl. Acad. Sci., PNAS* 105(6), 1786–1793

Levin, K., McDermott, C. and Cashore, B. (2008). The climate regime as global forest governance: can reduced emissions from Deforestation and Forest Degradation (REDD) initiatives pass a 'dual effectiveness' test? *International Forestry Review* 10(3), 538-49

Lindborg, R., Bengtsson, J. and Berg, A. (2008). A landscape perspective on conservation of semi-natural grasslands. *Agriculture Ecosystems and Environment* 125(1-4) 213-222

MA (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC. Millennium Ecosystem Assessment.

Merchant, C. (2005). *Reinventing Eden: The Fate of Nature in Western Culture. Routledge*, New York

Milder, J.C., McNeely, J.A., Shames, S.A. and Scherr, S.J. (2008). Biofuels and Ecoagriculture: Can bioenergy production enhance landscape-scale ecosystem conservation and rural livelihoods? *International Journal of Agricultural Sustainability* 6(2), 105-121

Miller, R.M., Rodríguez, J.P., Aniskowicz-Fowler, T., Bambaradeniya, C., Boles, R., Eaton, M.A., Gärdenfors, U., Keller, V., Molur, S., Walker, S. and Pollock, C. (2006). Extinction Risk and Conservation Priorities. *Science* 313, 441

Milton, S.J. (2003). Emerging Ecosystems - A Washing-Stone for Ecologists, Economists and Sociologists? *South African Journal of Science* 99: 404-406

MOE (Government of Japan) (2007). Cabinet Decision November 27, 2008. Outline of the Third Biodiversity Strategy for Japan. Ministry of the Environment, Government of Japan. http://www.env.go.jp/en/focus/attach/071210-e.pdf [Accessed 1 December 2008]

Molden, D. (2008). Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan/ International Water Management Institute

Montgomery, R.D. (2008). *Why we need Another Agricultural Revolution. Dirt: The Erosion of Civilizations*. In Print. University of California Press

Müller, A., Schmidhuber, J., Hoogeveen, J. and Steduto, P. (2008). Some insights in the effect of growing bio-energy demand on global food security and natural resources. *Water Policy* 10 Supplement 1: 83-94

Mutsert, de K, Cowan, J.H., Essington, T.E. and Hilborn, R. (2008). Reanalyses of Golf of Mexico fisheries data: Landings can be misleading in assessments of fisheries and fisheries ecosystems. *Proc. Natl. Acad. Sci. PNAS* 105(7), 2740-2744

Ngongi, N. (2008). Policy Implications of High Food Prices for Africa. Alliance for a Green Revoluation in Africa. http://www.ifpri.org/pubs/books/ar2007/ar07essay03.pdf [Accessed 10 December 2008]

Post, E., Pedersen,C., Wilmers, C. and Forchhammer, M.C. (2008). Warming, plant phenology and the spatial dimension of trophic mismatch for large herbivores. *Proc. R. Soc. B 275*, 2005-2013

Preskett, L., Huberman, D., Bowen-Jones, E., Edwards, G. and Brown, J. (2008). Making REDD Work for the Poor. Draft final report prepared for the Poverty Environment Partnership

Pretty, J. (2008). Agricultural Sustainability: Concepts, Principles and Evidence. *Royal Society Philosophical Transactions* 363(1491), 447-465

Raunio, A., Schulman, A. and Kontula, T. (eds). (2008). Assessment of Threatened Habitats in Finland: Parts I & II. The Finnish Environment 8/2008. Vammala Kirjapaino OY, Vammala. 264 pp. (part I), 572 pp. (part II)

Robbins, J. (2008). In a Warmer Yellowstone Park, a Shifting Environmental Balance. *The New York Times*, March 18, 2008

RRI (2008). Seeing People through the Trees: Scaling Up Efforts to Advance Rights and Address Poverty, Conflict and Climate Change. Rights and Resources Initiative, Washington DC

Sax, D.F. and S.D. Gains. (2008). Species invasions and extinctions: The future of native biodiversity on islands. *Proc. Natl. Acad. Sci., PNAS* 105: 11490-11487
Schama, S. (1995). Landscape and Memory. Knopf, New York

Scheffer, M., Brovkin, V. and Cox, P.M. (2006). Positive feedback between global warming and atmospheric CO2 concentration inferred from past climate change. *Geophys. Res. Lett.* 33: L10702.

Scherr, S.J. and McNeely, J.A. (eds.) (2008). Biodiversity Conservation and Agricultural Sustainability: Towards a New Paradigm of 'Ecoagriculture' Landscapes. *Royal Society Philosophical Transactions* 363(1491), 477-494

Schipper, et al. (2008). The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge, *Science* 322, 225-230

Schultz, L., Folke, C. and Olsson, P. (2008). Enhancing ecosystem management through social-ecological inventories: lessons from Kristianstads Vattenrike, Sweden. *Environmental Conservation* 34(2), 140-152

Searchinger, T. Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T. (2008). Land-Use Change Greenhouse Gases Through Emissions from Use of U.S. Croplands for Biofuels Increases. *Science* (319), 1238

Seastedt, T.R., Hobbs, R.J. and Suding, K.N. (2008). Management of Novel Ecosystems: Are Novel Approaches Required? *Frontiers in Ecology and the Environment* 6(10), 547-553

Serageldin, E. and Masood, I. (2008). Water for a growing planet. Draft report – Bibliotheca Alexandrina, Alexandria, Egypt

Shiva, V. (2008). *Soil not Oil. South End Press*. Cambridge, MA

Silva, L.C.R., Sternberg, L., Haridasan, M., Hoffmann, W.A., Miralles-Wilhelm, F. and Franco, A.C. (2008). Expansion of Gallery Forests into Brazilian Savannas. *Global Change Biology* 14, 2108-2118

Steiner, A. (2008). Nature-Based Enterprises Can Help Rural Poor Adapt to Environmental Threats. UNEP Executive-Director Press Release for IUCN World Conservation Congress,Barcelona, Spain October 8, 2008

Strum, M., Schimel, J., Michaelson, G., Welker, J.M., Oberbauer, S.F., Liston, G.E., Fahnestock, J. and Romanovsky, V.E. (2005). Winter Biological Processes Could Help Convert Arctic Tundra to Shrubland. *BioScience* 55(1), 17-18

Surowiecki, J. (2008). The Perils of Efficiency. *The New Yorker*, 46

Svadlenak-Gomez, K., Clements, T., Foley, C., Kazakov, N., Miquelle, D. and Stenhouse, R. (2007). Paying for Results: The WCS Experience with Direct Incentives for Conservation. In Redford K.H. and Fearn E. (eds.)

Tape, K., Sturm, M. and C. Racine. (2006). The evidence for shrub expansion in Northern Alaska and the Pan-Arctic. *Global Change Biology* 12, 686-702, doi: 10.1111/j.1356-2486.2006.01128.x

Tallis, H., Kareiva, P., Marvier, M. and Chang, A. (2008) An ecosystem services framework to support both practical conservation and economic development. *Proc Natl Acad Sci PNAS* 105(28), 9457-9464

Turner, W.R., Brandon, K., Brooks, T.M., Costanza, R., Da Fonseca, G.A.B. and Portela, R. (2007). Global Conservation of Biodiversity and Ecosystem Services. *BioScience* 57(10), 868–873

UN (2008). Sustainable Development Report on Africa: Five-Year Review of the Implementation of the World Summit on Sustainable Development Outcomes in Africa. United Nations Economic Commission for Africa, Addis Ababa, Ethiopia, April 2008.

UNDESA (2008). The Millenium Development Goals Report 2008. http://www.un.org/millenniumgoals/pdf/The%20Millennium%20Development%20Goals%20Report%202008.pdf [Accessed 2 December 2008]

UNDP (2007). Human Development Report 2007/2008, Fighting Climate Change: Human Solidarity in a Divided World. United Nations Development Programme, New York

UNEP (2007). Global Environmental Outlook 4: Environment for Development. United Nations Environment Programme, Nairobi

Wade, R.W., Gurr, G.M. and Wratten, S.W. (2008). Ecological Restoration of Farmland: Progress and Prospects. *Royal Society Philosophical Transactions* 363(1492), 831-847

Willis, K.J., Arau, M.B., Bennett, K.D., Figueroa-Rangel, B., Froyd, C.A., and Myers, N. (2007). How can a knowledge of the past help to conserve the future? Biodiversity conservation and the relevance of long-term ecological studies. *Phil. Trans. R. Soc.* B 362, 175–186 doi:10.1098/rstb.2006.1977

Wittemyer, G., Elsen, P., Bean, W.T., Burton, A.C.O. and Brashares, J.S. (2008). Accelerated Human Population Growth at Protected Area Edges. *Science* 321, 123-126

World Bank and FAO (2008). The Sunken Billions: The Economic Justification for Fisheries Reform. Agriculture and Rural Development Department. The World Bank, Washington DC.

WRI (2008). World Resources 2008: Roots of Resilience—Growing the Wealth of the Poor. World Resources Institute in collaboration with United Nations Development Programme, United Nations Environment Programme and World Bank, Washington, DC

WRI (2005).The Wealth of the Poor. Managing Ecosystems to Fight Poverty. World Resources Institute in collaboration with United Nations Development Programme, United Nations Environment Programme and World Bank, Washington, DC

WWF (2008). Living Planet Report 2008. World Wildlife Foundation, Geneva

Yadvinder, M., Roberts, J.T., Betts, R.A., Killeen, T.J., Li, W. and Nobre, C.A.. (2008). Climate Change, Deforestation, and the Fate of the Amazon. *Science* 11, 319(5860), 169-172