Future directions in conservation and development: Incorporating the reality of climate change

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Abstract. Biodiversity conservation benefits from involvement of local stakeholders to link conservation and development in site-specific, synergistic frameworks. The reality of climate change and continuing widespread development of land for settlement, agriculture, and resource extraction underline the urgent need to accelerate conservation efforts, while also necessitating review of whether current management strategies remain appropriate to reach their objectives.Since biota have been documented to respond to climatic changes via individualistic adjustment of phenology, phenotypic plasticity and range shifts, novel ecological communities without present analogs are projected to emerge. Some protected species may be displaced outside the boundaries of current conserved lands. Expansion of existing and establishment of new protected areas in anticipation of such scenarios is rarely feasible. Climate change impacts on stakeholders may further compromise conservation objectives if agricultural and resource extraction practices change.

This paper reviews impacts of climate change relevant to biodiversity conservation, highlighting the interdependence of ecology, socioeconomics and policy across temporal and spatial scales. A regionally coordinated management framework with local stakeholder involvement is proposed and illustrated using the case example of REDD to achieve traditional conservation objectives and adaptation to climate change simultaneously by alleviating stresses, maximizing functional redundancy, and increasing both connectivity and local genetic diversity of conservation areas. Development objectives are addressed by integration with existing or proposed policy instruments for transfer of 'green' technologies and payments for carbon sequestration based on the principles of additionality or avoided deleterious land conversion.

INTRODUCTION

Successful integration of conservation and economic development into a synergistic framework has emerged as a central objective in interdisciplinary conservation biology. This paradigm developed following realization that approaches focusing on single goals to the exclusion of others have frequently yielded suboptimal results despite significant capital investment. As detailed by Holt (2005) and Brown (2002), lack of consideration for local peoples' resource needs and land use practices in design and management of protected areas, in some cases to the point of total exclusion or forced resettlement, inevitably results in high rates of noncompliance, creating conflicts and undermining conservation objectives. The flip side of the coin is resource exploitation-based development in the absence of conservation planning, which, given high population pressure in much of the developing world, tends to result in rapid environmental degradation and a multitude of socioeconomic impacts ranging from increased income disparity to loss of traditional culture and identity. Integrated views of conservation and development seek to ameliorate these issues through participation of local stakeholders and encouraging conservation through sustainable use while minimizing exclusionary eco-protectionism (Holt 2005; Brown 2002).

Experience has shown that this integration process is not straightforward. Not only have long-standing incongruities among theoretical frameworks guiding research and management in natural, social and economic sciences proven difficult to overcome, but, more significantly, approaches successful in one geographic location often fail in others. Complicating factors include, but are not limited to, difficulty quantifying the true economic value of ecosystem goods and services (Azqueta & Delacámara 2006; Turner *et al.* 2003; Wilson & Carpenter 1999; Edwards & Abivardi 1998), difficulty identifying and delineating areas most deserving protection (Brooks *et al.* 2006), false assumptions about homogeneity of stakeholder communities (Brown 2002), incomplete models, insufficient data, corruption and lack of strong institutions to enforce regulations (Damania & Hatch 2004; Ferraro 2001), non-recognition of local people's property and use rights (Harris 2005; Ferraro 2001), and barriers to international technology transfers limiting dispersal of resource-efficient technology to industrializing nations (Gallagher 2006). For the foreseeable future, conservation projects will continue to be most successful when designed site-specific, taking local ecological and socioeconomic complexity into full account, as both have dynamic, emergent properties that cannot be fully predicted using strictly reductionist approaches.

Accelerating climatic change underlines the urgent need for sustainable development and successful conservation measures. It also forces changes to their implementation, as conventional approaches may no longer yield positive outcomes under rapidly changing climatic conditions (Harris *et al.* 2006). Ecosystem management, because of its intrinsic properties and dynamics, is a complex mix of science and policy practiced by unevenly participating stakeholders within institutions that may, in many cases, be ill-prepared for the added complexity and uncertainty introduced by climate change. Ecology, socioeconomics, technological development and political realities, themselves actors responding dynamically and at times unpredictably to climate change, are becoming increasingly complex and intertwined as they shape future conservation outcomes. Adapting to these developments requires multidisciplinary cooperation and interdisciplinary thinking, backed by appropriate funding for research and monitoring needs, to build on the principles outlined in this introduction and find solutions to highlighted problems if devastating future scenarios are to be avoided.

ANTICIPATED CLIMATE CHANGE IMPACTS IN THE 21ST CENTURY

BACKGROUND

Global climate change is universally acknowledged as a significant environmental concern (Oreskes 2004). According to the most recent Intergovernmental Panel on Climate Change [IPCC] assessment report, mean global temperatures increased by 0.74°±0.2°C during the past 100 years, recently increasing at 0.2°C per decade (IPCC 2007*a*). By 2100, emission scenarios project CO_2 concentrations at 1.9 to 3.5 times of pre-industrial values, contributing to an additional mean global temperature increase of 1.8° to 4.0°C relative to the 1980-1999 average (IPCC 2007*a*). Warming exceeding 2° to 2.5°C relative to preindustrial times is considered 'dangerous', potentially triggering positive feedback mechanisms that cannot be reversed within centuries and will produce deleterious impacts at all levels of biological organization (Lenton *et al*. 2008; Bierbaum & Raven 2007; IPCC 2007*b).*

Climate change is not limited to temperature change alone, but includes changes in atmospheric and oceanic circulation patterns, altered precipitation regimes, increased frequency of extreme weather events, ocean acidification and sea level rise. Regional impacts are diverse, although trends of more warming over land than oceans, and at high latitudes, particularly in the northern hemisphere, are discernible (IPCC 2007*a*; IPCC 2007*b*). These effects are accompanied by substantial existing anthropogenic resilience-depressing stresses (McCarty 2001), including land transformation, unsustainable resource extraction, hydrological manipulation, habitat fragmentation and nutrient enrichment.

Since the late 1990s, socioeconomic and political changes have been initiated by some international organizations and individual nations to establish a policy foundation to manage, mitigate and adapt to climate change (European Commission 2008; Pew Center on Global Climate Change 2006; European Parliament & Council of the European Union 2003; UNFCCC 1998). While there has been moderate progress in reducing domestic greenhouse gas (GHG) emissions by some Kyoto protocol signatories (UNFCCC 2007*a*), global emissions continue to grow at an increasing rate (Canadell *et al*. 2007; Raupach *et al*. 2007). Many nations with significant emissions, including the United States, China and India, have either not ratified the Kyoto protocol or are not bound to mandatory cuts. While it is accepted that G8 nations have historically been responsible for an overwhelming share, on both total and per capita bases, approximately 25% of annual carbon dioxide emissions is caused by land use change such as deforestation (IPCC 2007*a*), predominantly in the developing world. Given the limited impact of the Kyoto protocol and contentious ongoing debate about its post-2012 successor, it appears increasingly unlikely that policy initiatives will achieve necessary emission reductions of ca. 70% within a few decades to stabilize mean global temperatures at 2-2.5°C above pre-industrial conditions (Friedlingstein 2008; Bierbaum & Raven 2007).

Delineation of likely ecological and socioeconomic impacts under various scenarios of climate change has emerged as a central research priority. Since climate change exhibits substantial spatial and temporal complexity, analysis at regional scales is required for risk assessment informing conservation and mitigation efforts. Yet, general circulation models (GCMs), despite their increasing complexity, remain insufficient to characterize small and irregularly-shaped landmasses, heterogeneous land cover and small-scale circulation processes adequately. Regional climate models (RCMs) and various downscaling methodologies are beginning to address this information gap. However, while models can assist in evaluating potential consequences of various scenarios of climate change, a number of research articles have highlighted important limitations to the ability to fully predict future climates and ecological systems due to their inherently uncertain or chaotic properties (Beninca *et al.* 2008; Lenton *et al.* 2008; Roe & Baker 2007). On local to regional scales – those most applicable to conservation management - factors indirectly or completely unrelated to global processes such as land use change become increasingly important in shaping climate (Pielke Sr. *et al.* 2002). For these reasons, prescriptive, site-specific bioclimate forecasts are unlikely to ever be produced, highlighting the importance of accepting and managing for uncertainty as a key element of climate change ecology.

ECOLOGICAL EFFECTS

Climate directly controls or affects many ecological and biological processes, including nutrient cycling, onset and duration of the growing season, timing of reproduction, environmental sex determination, animal behavior, and body size in some taxa (Parmesan and Galbraith 2004; Walther *et al.* 2002). Sustained temperature and precipitation deviations beyond historical variability force climate-sensitive species to adjust phenology, exhibit phenotypic plasticity and/or shift habitat ranges to maintain suitable conditions for survival. Numerous studies have established observational evidence that such responses are already occurring in many taxa (IPCC 2007*b*; Parmesan 2006; Parmesan & Galbraith 2004; Parmesan & Yohe 2003). The number of on-the-ground observations of ongoing impacts has increased greatly during the past decade, but their spatial distribution is highly heterogeneous. Of nearly 29,000 long-term observational data series examined by the IPCC that showed significant biological changes, 98% were collected in Europe, with only two documented impacts in Africa (Nature Editors 2007; IPCC 2007*b*). 90% of these observed changes are consistent with expectations for a warming world (IPCC 2007*b*).

Because tolerances and the speed and ability to migrate vary between species, non-synchronous responses are expected to occur as climate change accelerates, altering symbiotic interactions such that extant communities and trophic webs become progressively uncoupled (Williams & Jackson 2007; Hannah *et al.* 2002*b*; Walther *et al.* 2002). Projected implications include reduced carbon uptake by terrestrial ecosystems, increased extinction risk for up to 30% of plant and animal species, and major reorganization of ecosystem structure and function, potentially severely disrupting provision of goods and services with cascading socioeconomic effects (IPCC 2007*a*, IPCC 2007*b*).

Evolutionary responses are likely limited to adaptation via phenotypic plasticity for long-lived species, whereas those with rapid generation times respond via natural selection, favoring dispersal ability and adaptations beneficial under altered local conditions (Pearson & Dawson 2003). Similar processes occurred following the last glacial maximum, albeit over several thousand years, requiring slower rates of dispersal. There is no evidence for changes in climatic tolerances of species via evolutionary mechanisms (Petit *et al*. 2008; Parmesan 2006).

Projecting structure and function of future ecosystems is subject to considerable uncertainty, since models of imperfectly known systems incorporate assumptions, parameterizations and inevitably exclude some variables from consideration. Bioclimate envelope models are commonly used to produce initial assessments of potential future species range shifts over large spatial scales, although they have inherent limitations of their own. Discussing these is beyond the scope of this paper, but they are addressed in detail by Pearson & Dawson (2003). Bioclimate envelope shifts of dozens to hundreds of kilometers are not uncommon in projections, potentially resulting in species of conservation concern adjusting their habitats beyond borders of protected areas established to preserve them (Hannah *et al*. 2002*a*).

Successful habitat adjustment is further constrained by anthropogenic barriers, as well as resource availability and community dynamics in the new geographic range (Walther *et al.* 2002). These combined effects may ultimately produce unique communities consisting of species not co-existing currently. Williams & Jackson (2007) suggest that novel climate regimes are expected to develop throughout the tropics and subtropics, including areas considered biodiversity hotspots. Attempting to project future ecological organization in climates without present analogs is fraught with additional uncertainty due to the extrapolative nature of such projections (Williams & Jackson 2007).

SOCIOECONOMIC EFFECTS

The total cost of unmitigated climate change as direct human impacts and indirect impacts resulting from the disruption of ecosystem services has been estimated to reach up to 20% of the global gross domestic product by 2100, implying that the cost of inaction vastly exceeds that of comprehensive mitigation (Stern 2007). Direct socioeconomic impacts are caused by limitations of human physiology to withstand weather extremes, and displacement as a result of sea level rise, glacial outburst floods and other climate-linked processes. If projections are correct, tragic events such as the European heat waves of 2003 and 2006 will recur at higher frequencies and intensities (IPCC 2007*a*). Implications for tropical cyclone frequency and intensity are still subject to considerable debate, with published research yielding conflicting results about the relative contributions of increasing sea surface temperatures and wind shear in the Atlantic Ocean (Saunders & Lea 2008; IPCC 2007*a*; Vecchi & Soden 2007). There is a need to prepare for potentially tens of millions of 'climate change refugees' expected to be displaced from their homes (Bierbaum & Raven 2007) as a result of climate-change related impacts, most significantly flooding of densely settled coastal areas and inundation of low-elevation island nations due to sea level rise.

Indirect effects are imposed by changes in ecosystem structure and function, and will be particularly hard-felt by people dependent on ecosystem goods and services for provision of food, water and other essential resources. Spread of disease vectors affecting humans and their food crops is an added concern. Impacts on food production will be regionally and temporally heterogeneous, as multiple variables ranging from carbon fertilization to altered water budgets interact to boost or depress yields. In general, low-latitude agrosystems are projected to be among the first to experience adverse impacts (IPCC 2007*b*), potentially forcing rural people to increase use or conversion of land to compensate for loss of income and sustenance. The 4th assessment report of IPCC Working Group II describes scenarios including increased drought and flash flood risk in currently semi-arid to arid areas, altered volume glacial melt that is a major source of drinking water in many parts of the world, major losses of coastal ecosystems and infrastructure due to increased erosion, flooding and salt water intrusion, and a variety of human health impacts (IPCC 2007*b*). Generally, these consequences will be more acute in developing countries due to lower adaptive capacity, with Africa likely the most adversely affected continent.

The Sahel and other transitional ecosystems have been subjected to climatic change for decades, mostly via altered precipitation regimes associated with progressive desertification. Giles (2007) noted that local adaptation to these processes remains poorly studied, but evidence suggests that many communities have proven surprisingly resilient. Changing agricultural practices and a focus on collective production, allowing for diversification and risk sharing, have occurred. While it is impossible to generalize from these isolated studies, they suggest that adaptation is possible even in the absence of a modern technological base. The question remains as to how much additional change can be absorbed by local ingenuity without further deterioration of already marginal living conditions.

IMPLICATIONS FOR CONSERVATION AND DEVELOPMENT

Current strategies for minimizing climate change impacts on biota and human populations fall into the broad categories of mitigation (reducing and sequestering emissions) and adaptation (infrastructure upgrades, climate change-integrated conservation strategies) (Bierbaum & Raven 2007; Hannah *et al*. 2002*a*). Both go hand-in-hand within the general framework of conservation and development and present opportunities for synergies. Ultimately, success of future biodiversity conservation endeavors hinge on: (1) minimizing the magnitude of additional climate change, (2) developing and applying climate change-integrated conservation and development strategies, and (3) taking advantage of funds available through carbon markets to reach conservation objectives.

CLIMATE CHANGE-INTEGRATED CONSERVATION STRATEGIES

According to Folke (2006), "a major shift in perspective is currently taking place with an emphasis on complex adaptive systems characterized by nonlinear relations, path dependency, thresholds, regime shifts, and multiple basins of attraction. […] Conservation thinking needs to move away from steady state solutions to accept that change is the rule rather than the exception". Climate change-integrated conservation strategies build upon these principles, with resilience management and adaptive management at multiple spatial and temporal scales being central elements. As pointed out by Harris *et al.* (2006) and others, not all classic conservation biology wisdom will still apply as global warming accelerates, requiring a comprehensive re-evaluation of traditional conservation practices. The inappropriateness of continuing to utilize historical benchmarks as restoration targets, and species conservation efforts in static preserves that may soon experience abiotic conditions falling outside the target organisms' tolerance, are just two examples. Identifying and embracing concepts and methodologies in need of change will be a key challenge for conservationists. Opportunities for synergistic management exist that simultaneously seek to achieve traditional conservation and climate change-proofing objectives by alleviating stresses, maximizing functional redundancy, and increasing connectivity between conservation areas. Increasing local genetic diversity by facilitating reproduction among specimens from distal portions of their natural range could be utilized to maximize the adaptive potential of protected species (Harris *et al*. 2006).

The rapid rate of projected climate change may exceed the ability of some species to keep up with shifting climate zones (Petit *et al*. 2008). This has given rise to a debate among conservation scientists about the merits of creation of migration corridors and assisted migration (also known as assisted colonization) (Hunter 2007; Mclachlan *et al*. 2007). Where economic and geopolitical realities preclude creating new protected lands along leading edges of shifting bioclimatic envelopes, and for species whose bioclimatic envelopes are projected to collapse entirely, attempts may focus on delaying responses to preserve the *status quo* in protected areas for as long as possible via strategic human intervention to boost resilience. Such measures could conceivably incorporate disease control, removal of invasive species and assisted propagation as well as techniques learned from management of non-native specimens in zoological and botanical gardens.

Generally, vulnerability increases in systems subject to other stresses that depress overall resilience and adaptive capacity (IPCC 2007*b*), a condition sometimes referred to as "general stress syndrome" (Western 2006). This may be particularly applicable to coastal systems, such as salt marshes, mangrove swamps and dune communities as they tend to be squeezed between the figurative rock and a hard place, comprised of rising seas and ever-expanding human settlements that fringe many of the world's coastlines with few opportunities for migration or adaptation. Similar scenarios apply to montane and polar environments.

As previously discussed, models are an important tool to evaluate potential impacts under scenarios of climate change and to assist in formulating risk assessments to inform management, but they cannot predict the precise timing and consequences of climatic and biotic threshold events, many of which will come as a 'surprise', unanticipated until they occur. For this reason, robust adaptive management frameworks need to be implemented that are capable of responding to unanticipated events and adapting to new types of ecological communities lacking current analogs. This necessitates development of temporally nested management schemes that retain current 3-5 year planning intervals while also incorporating long-term, multi-decadal visions under a variety of impact scenarios (Hannah *et al.* 2002*a*). Monitoring will contribute greatly to success, providing data necessary to critically evaluate the adequacy of the planning framework in regular intervals, while also providing opportunities for model validation and refinement. Experiments, both in controlled laboratory environments and in the field, augment the toolbox of adaptive management by providing data points on how representative sample plots, functional groups or individual species may respond to altered environmental conditions in the future.

Spatially hierarchical organization is also important. Ideally, management should be global in extent, local in implementation, and regionally coordinated. The regional nexus is an indispensible component, as traditional top-down and bottom-up approaches tend to lose focus at the far end of their scalar spectra, creating issues of noncompliance and free-ridership, respectively. Regional coordination is also best-suited for landscape-scale management of the matrix between conservation lands and other 'pristine' areas, which is crucial to allow species to migrate as they adjust their ranges (Hannah *et al.* 2002*a,* Hannah *et al.* 2002*b*). Finally, the regional nexus allows for economies of scale in monitoring and modeling by sharing resources.

TECHNOLOGY TRANSFER AND MARKET MECHANISMS IN SUPPORT OF BIODIVERSITY CONSERVATION

Even the best possible conservation management and climate change adaptation efforts cannot succeed without funding and successful mitigation to limit accumulation of atmospheric greenhouse gases to manageable levels. The remainder of this paper therefore transcends disciplinary boundaries to assume a more holistic perspective by highlighting a selection of evolving incentives promoting technology transfers, carbon trading mechanisms and conservation funding opportunities, illustrated by pending implementation of the concept of REDD (Reducing Emissions from Deforestation and Degradation). In countries with high adaptive capacity, technological innovation is a central part of climate change mitigation efforts. In Germany, large-scale deployment of renewable energy generation has contributed to reducing national CO_2 emissions by approximately 18.4% between 1990 and 2005 (UNFCCC 2007*b*). Carbon capture and storage (CCS) from large point sources is a potential, yet technologically complex 'fix' that is advocated as an attractive contribution to climate change mitigation, although it substantially decreases the efficiency of power plants utilizing this technology (IPCC 2005). This may have conservation implications by increasing demand for fuels, including mining of fossil sources and biomass. There are numerous other technological options in development and currently available that could contribute to stabilizing atmospheric greenhouse gas concentrations if widely adopted. This process is slowed in part by a lack of accounting for the true cost of carbon emissions, essentially subsidizing fossil fuel-intensive industries by allowing them to externalize those costs. More significant for developing countries, economic and capacity limitations as well as barriers to technology transfers (Gallagher 2006), pose severe limitations to deployment of low-carbon technologies in parts of the world where emissions are rising most rapidly. Removing these barriers and providing incentives via instruments like the Climate Change Adaptation Fund (Zahabu *et al*. 2007) to assist in capacity building are short-term necessities to reduce new construction of long-lived, inefficient infrastructure such as coal-fired power plants.

The question of economic incentives holds - as a general premise - the notion that it is advantageous, both for biodiversity conservation and economic development purposes, to create a market for GHG emissions. There are broad options for such mechanisms from ensuring that desirable clean or alternative technologies be developed, to the creation of disincentives by taxing emissions.

Debatable as it may be, an argument can be made that a market assigns 'values' in such a way that supply/ demand situations develop. This implies, for the CO_2 case, that once society becomes aware of the perils of emissions and the benefits of emitting less, capturing or storing carbon gasses, economic transactions reflecting such values will follow. Inherent to this concept is the idea of emission 'offsets'; that is, individuals or corporations can offset emissions by paying for them in some way. An institution – normally an international body or a sovereign state - sets a limit (*cap*) on the amount of CO_2 that can be emitted; various companies are issued emission permits that allow them to emit specific amounts. For example, the European Union (EU) set up a National Allocation Plan in 2001 with emission caps for each member state. Then each state put an emission cap on each major company at a level that would preclude the company's emissions to increase without penalty. This is the major difference and the core of the mechanism: any company needing to emit more will have an incentive to either invest in carbon credits or look for new technologies that will result in mitigation of emissions. To meet this demand, countries or companies will be searching to provide offset capabilities via lessening emissions or actually looking for new ways to capture or store carbon. The National Allocation Plan was applied in the form of European Union Allowances (EUAs) to 12,000 companies which account for over half of all the CO_2 emitted in the EU. The United States does not possess such a mandatory scheme, but the voluntary Chicago Climate Exchange is a sister company of the European Climate Exchange and is in a position to trade emission allowances if and when the United States government should adopt a similar system (Asplund 2008).

The main thrust of these market initiatives is the expectation that companies will lower emissions. A signal is being sent to markets everywhere that there may be advantages to investment in both innovation and carbon abatement. The trading segment of the EU's cap-and-trade system is the European Union Emissions Trading Scheme (ETS) – companies can buy and sell EUAs among themselves, or they can buy or sell in the cash market. In 2007, US$ 50 billion, almost entirely in EU ETS allowances, were traded, almost double that of 2006 (Capoor & Ambrosi 2008), involving more than 2 billion tons of CO_2 equivalent ($MtCO_2e$). The absolute number is not as important as the observed growth. It must be kept in mind that the EU-ETS underwent a successful trial period in 2005-2007 to provide experience for a cap-and-trade system to be enacted during 2008-2012 (Ellerman & Joskow 2008).

The Clean Development Mechanism (CDM) arrangement under Article 12 of the Kyoto Protocol allows industrialized countries to invest in projects that reduce emissions in developing countries to receive credits. CDMs today account for most project-based transactions, with values tripling in 2007 over 2006 to US$ 7.4 billion. 68 countries offered to reduce 2,500 $MtCO_2e$ via 3,000 mostly clean energy projects. In contrast, voluntary markets that support mitigation activities not mandated by policies effected only 42 $MtCO_2e$ of reductions in 2007 (Capoor & Ambrosi 2008; Wara 2007). As Laurance (2007) explained, "protecting an endangered forest in Madagascar might have the same net benefit, from a carbon-emissions perspective, as improving the efficiency of a coal-fired generating plant in Ohio. A transaction like this could have three important benefits: GHGs are reduced, a biologically important forest is protected, and Madagascar gains direly needed foreign revenues." This example, even if clarifying advantages of such schemes, also underlines some of the difficulties in making these widely viable and operational: difficulties that arise in emission measurements, in conservation effectiveness (e.g. how to define a deforestation 'baseline'), and in monitoring dynamics of investments in carbon funds.

Further questions remain, especially regarding the administration of the markets, the avoidance of speculation and making the projects work to full capacity. According to Wara (2007), "what matters in the long term is the type of energy infrastructure that gets locked into place in the world economy". Furthermore, from the larger viewpoint of biodiversity concerns, it is clear that market mechanisms should be only one part of a more comprehensive strategy that should also rethink protected area design, habitat improvements, and dispersal corridors (Rahel *et al.* 2008). Since monitoring changes that are bound to be accelerating over the next decades and beyond will require increased funding at the international and regional levels, utilization of funds generated by market payments for mitigation projects, particularly those with biodiversity benefits, are an attractive option to expand on existing conservation funding schemes.

CASE EXAMPLE: REALIZING CONSERVATION OBJECTIVES VIA SYNERGIES WITH REDD

Since anthropogenic GHGs are well-mixed in the atmosphere, mitigation has global applicability, meaning that sequestration does not have to occur proximal to emission sources. To date, credit for biomass sequestration is limited to afforestation and reforestation projects under the CDM, whereas efforts to reduce emissions via implementation of improved forest management and reduced deforestation are not currently credited (Zahabu *et al.* 2007). Efforts are underway to change this by incorporating REDD into the follow-up to the Kyoto protocol that is expected to be drafted by December 2009 and take effect, pending ratification, by 2012. Many developing nations have extensive forest cover experiencing rapid rates of deforestation and degradation to accommodate rapidly growing populations and global resource demand. REDD promises to provide funds to reverse these trends by assigning a direct, creditable market value to carbon sequestration services provided by forests. Globally, $1.2 billion to $10 billion have been cited as becoming available for forest protection (Miles & Kapos 2008). Zahabu *et al.* (2007) describe a scenario for implementation of REDD in Tanzania, whereby up to $119 per average rural household ($630 million total) could be gained annually by halting deforestation. Reducing deforestation also slows regional climatic changes that would otherwise occur via alteration of albedo and hydrologic cycles. Deforestation in Amazonia, for instance, creates warmer, drier climates that decrease evaporative cooling and increase both susceptibility to fires and forest dieback, initiating a positive feedback loop (Bonan 2008). Without intervention, critical thresholds may be exceeded to initiate conversion to alternate biomes such as savannahs, which would irrevocably result in mass extinctions of forest fauna and flora (Lenton *et al*. 2008).

Most REDD proposals target trading among nations rather than companies or individuals (Miles & Kapos 2008). To what extent funds would be used and re-distributed would be left to each government. However, because implementation would occur at the site-scale, landowning individuals and communities will be in a strong position to contribute to sequestration efforts, allowing them to negotiate with governments to maximize economic payments for maintaining or expanding land cover compatible with sequestration if empowered by property or use rights, fulfilling the criteria of integrated conservation and development discussed in the introduction to this paper. This will be most effective for collective efforts, whereby intracommunal competition is reduced, risks are shared, and better negotiating positions achieved, as governments will be keen to minimize transaction and monitoring costs by avoiding contracts with individual smallholders (Grieg-Gran *et al*. 2005). While governance challenges will have to be overcome in many countries to build administrative and enforcement capacity, a model framework already exists in Tanzania through village forest reserves, which experience less degradation from illegal resource extraction than traditional public reserves (Zahabu *et al*. 2007). As suggested by Koenig (2008), forest tracts may alternatively be leased from the government by rural communities, which receive payments for avoided deforestation or degradation, based on the principle of additionality relative to a pre-determined baseline, in return. This income replaces lost logging revenues and allows purchase of resources traditionally extracted from forests if such extraction would compromise sequestration objectives. Many forest uses, including limited harvest of timber and biomass, are compatible with climate change mitigation and can be integrated with sustainable stand management. Lease payments would cover government administrative costs and allow for monitoring to ensure that sequestration objectives are, in fact, met. Such an implementation scheme would provide the type of direct market integration for non-consumptive or low-impact use that has been so difficult to achieve.

Re- and afforestation projects established via the CDM framework complement primary forests protected under REDD by creating second-growth forests and plantations that, while less diverse than comparable old-growth plots, increase habitat connectivity and decrease fragmentation (Stokstad 2008). Therefore, development of carbon trading schemes that incorporate biomass sequestration and appropriate monitoring and enforcement mechanisms are the single most important steps towards integrating rural communities in the climate change adaptation and mitigation process.

Conservation objectives may not always coincide with forest plots assigned the highest priority through REDD, which is strictly based on carbon stocks and does not take other environmental services into account. Many conservation projects do not target forests at all. However, REDD funds may release conservation funding currently tied up in high-carbon, old-growth forests to be re-assigned to boost protection of non-forested areas that may be at increased risk for conversion and degradation as ranching and agricultural crop production is displaced from forests elsewhere (Miles & Kapos 2008), or from direct impacts of climate change. It is in this sense that the market integration REDD promises to generate opportunities that reach far beyond forests alone, but allow climate change-integrated conservation strategies to be more widely employed to boost resilience of many of the most vulnerable ecosystems to avert or delay the most devastating impacts of climate change. Conservation organizations should be prepared for the consequences of REDD implementation and identify at-risk areas in need of investment while following through by developing capacity for adaptive, regionally-coordinated management with a focus on resilience management and long-term monitoring.

CONCLUSIONS

Climate change presents a formidable challenge to biodiversity conservation, requiring substantial revisions to existing methodologies while also creating new opportunities for success. A central challenge for conservation managers is to ensure a continued supply of ecosystem services while facing substantial structural adjustments. Additional objectives include minimization of biodiversity losses, facilitation of migration by increasing habitat connectivity or partaking in assisted migration where appropriate, minimization of non-climate related stress to increase resilience, and fostering adaptation by increasing local genetic diversity, among others. Realization of these objectives requires climate change-integrated conservation strategies based on principles of adaptive management within a long-term visioning framework, supported by extensive monitoring and modeling efforts. Of crucial importance is development of market mechanisms that account for the true cost of carbon emissions, while simultaneously creating funds for mitigation and adaptation efforts that are in many cases directly compatible with conservation objectives or, alternatively, free up funding for conservation targets unsuitable for carbon sequestration. International cooperation to facilitate technology transfer and reduce free-ridership, empowerment of local communities to allow conservation-friendly development via payments for carbon sequestration, and regional coordination to monitor local compliance and ensure matrix management are important short-term goals to form a basis for success. There is no doubt that implementing these measures will be difficult, but that does not diminish their necessity. Climate change is a present reality, and no conservation organization can afford to ignore this fact if long-term success is to be achieved.

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