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Beyond carbon: Redefining forests and people in the global ecosystem services market

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Abstract

The need to reduce emissions from deforestation and forest degradation is more urgent now than ever. International efforts through REDD+, CDM and voluntary carbon markets aim to encourage complementary activities of forest preservation, reforestation, afforestation and sustainable forest management. Many existing programs for sustainable forest management, agriculture and development dovetail with payment for ecosystem services (PES) programs in their similar concerns regarding the allocation of rights and responsibilities, agreements on service provision, and the verification and quantification of benefits. Recent efforts to link biodiversity conservation with national scale REDD+ initiatives depend on the explicit regulatory linkage of biodiversity preservation goals with carbon targets. We emphasize the need to include biodiversity conservation and sustainable development as integral components of forest carbon projects. As fundamental social, political and cultural issues have yet to be addressed in the current market structure, we urge a better understanding of the tradeoffs between the full suite of ecosystem services provided by different forest types. Here, we provide a conceptual framework for the integration of payment for ecosystem services programs with biodiversity conservation and sustainable development.

Keywords: Carbon credits, Payments for Ecosystem Services, socio-ecological resilience, land-use mosaics

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1. INTRODUCTION

Ecosystem properties and functions are intimately linked with human wellbeing. This critical link has gained publicity and international support as the focus of a clearly defined research agenda (MEA, 2005; Diaz *et al.,* 2006). A rapidly expanding interest in the ability of trees to sequester carbon has spawned numerous initiatives for forest conservation, regeneration and improved management. Alongside large international initiatives borne of the Kyoto Protocol (the Clean Development Mechanism) and the UN Framework Convention on Climate Change (UNFCCC) program aimed at Reducing Emissions from Deforestation and Degradation (REDD+), a variety of voluntary and national markets for 'trading' the carbon stored by forests are developing.

A consensus is emerging across these different approaches that the scope of the forest carbon market should expand to incorporate social and ecological complexity associated with forests (UNCBD, 2010; CCBA, 2010; UNEP-FI, 2011). The science surrounding forest carbon has evolved from quantifying rates of carbon accumulation across forest ecosystem types to disentangling the drivers and feedbacks between carbon sequestration, ecological community composition, management strategies and climatic variability (Clark and Clark, 2000; Luizao *et al.,* 2004; Chave *et al.,* 2005; de Deyn *et al*., 2008; Kirby and Potvin, 2008; Ruiz-Jaen and Potvin, 2010; Jonsson and Wardle, 2010). More recently, mechanistic linkages between the effects of land-use history on carbon storage have been identified (Kauffman *et al.,* 2009). Understanding, quantifying and valuing the suite of ecosystem services provided by forests is fundamentally linked to the political, ecological and economic relationships of people among each other and forests. Ideally programs aimed at creating, enhancing and protecting forest carbon should be based on the idea that mixed-use landscapes, if properly managed, can conserve biodiversity and maintain ecosystem services (Kirby and Potvin, 2007; Harvey *et al.,* 2008; Chazdon *et al.,* 2009a,b), while supporting sustainable development goals (Saxena *et al.,* 2001).

Expanding upon the work of the Millennium Ecosystem Assessment (2005) and Diaz *et al.* (2006), we aim to clarify the connection between forest carbon projects, biodiversity conservation, sustainability of ecosystem services and equitable sustainable development. Following on this analysis, we propose a conceptual framework that unifies resilience theory with our knowledge of ecosystem services and the goals of sustainable development.

2. THE FOREST CARBON MARKET TODAY

The carbon stored by forests can be valued as part of a national level greenhouse gas inventory or, increasingly, credited as a unit of carbon to be sold in the global carbon market. Market projects require a methodology for determining carbon stocks, certification by an applicable set of standards, and registration and/or sale in a given marketplace. These markets are shaped by the policy, legal and cultural environment in which they operate.

2.1 METHODOLOGIES

A number of methodologies have been developed to quantify Greenhouse Gas sequestration of different forest project types. Although they vary in the carbon pools, environmental and social considerations that are accounted for, all methods contain three basic elements: a baseline measurement, a project plan and associated emissions reduction projections (including leakage assessments), and a monitoring, reporting and verification protocol (MRV).

2.2 STANDARDS

In the early days of the carbon market, a number of 'carbon cowboy' type projects were able to generate and sell carbon credits via proprietary, non-disclosed methods without adhering to any agreed upon standard or third party verification protocol. Today, a number of standards compete in the existing carbon market, each one seeking to provide assurance that a given project will generate its projected carbon credits and in some cases, biodiversity and social co-benefits. Interestingly, the various standards act more as a market gateway for project developers, than in providing a price premium for their certified carbon (Ecosystem Marketplace, 2011a). The International Carbon Reduction and Offset Alliance requires six principles for acceptance of a project standard, namely that emission reductions/sequestration are: 1. Real 2. Measurable 3. Permanent 4. Additional 5. Independently Verified and 6. Unique (ICROA 2011). Generally, standards apply to the design of the project (the validation phase), to the implementation (whereupon the project is verified), and to the continued issuance of carbon credits of the project (requiring periodic re-verification).

Whereas the methods for carbon accounting are well documented, few standardized methodologies exist for verifying social and biodiversity benefits. Standards that do include social and biodiversity benefits depend on the defensibility of their applicability to the particular project and their verifiability by third party auditors. The main standard for co-benefits, the Climate Community and Biodiversity Alliance standard is not prescriptive to the type or method of monitoring biodiversity attributes. Such flexibility is troubling given recent research by Baker *et al.* (2010) showing that there exist large variations in the efficacy and costs associated with different biodiversity monitoring approaches. As has been shown to be the case for Forestry Stewardship Council Certification (van Kujik *et al.,* 2008) little systematically collected data indicate that certification schemes deliver real benefits. As it stands, most of the co-benefits to be expected from a project depend on that specific project's architects' intentions and abilities (Baker *et al.,* 2010).

2.3 MARKETS

Broadly defined, the sum of transactions of forest carbon credits make up the forest carbon market. The forest carbon market is composed of two basic types, compliance markets and voluntary markets. Increasingly the voluntary market has been the primary forum for forest carbon trading, having increased to ~42% of the overall voluntary market share in 2010 (Ecosystem Marketplace, 2011b).

Voluntary Markets are composed of project developers, wholesalers, retailers and brokers who sell credits to parties interested in offsetting their emissions. Within the voluntary market, pre-compliance markets are made up of organizations expecting to deal with regulatory pressure to reduce or offset their GHG emissions. Most voluntary transactions are over-the-counter (OTC); meaning directly purchased from a supplier by a buyer through private negotiation, a broker or a retailer reselling credits.

The *compliance markets* that deal in land-based carbon are: the Australian Carbon Farming Initiative (ACFI), (Box 1), the New Zealand Emissions Trading Scheme (NZ-ETS, which has a stated goal of planting more trees (NZ-ETS 2011)), the Kyoto-based Clean Development Mechanism (CDM) and Joint Implementation (JI). The others have their own complex internal calculus that accounts for energy demand, emissions allotments, and the cost/emission ratio of different fuels. This "grey-green spread" is largely driven by the price differential between natural gas and coal, and determines how many credits major energy companies require to meet their emissions allotment for a given operational period. This fundamentally financial driver of market activity has given rise to criticism that carbon markets are essentially a way to purchase the right to pollute. Market proponents point to the fact that the carbon market internalizes an external cost and rewards those who are able to meet targets the most efficiently, driving innovation.

2.4 REDD+

The UNFCCC initiative on Reducing Emissions from Deforestation and Degradation, and the conservation, sustainable management of forests and enhancement of forest carbon stock (REDD+) intends to pay forest-rich countries for the preservation of forest carbon stocks. Currently, deforestation and degradation are responsible for ~18% of global GHG emissions (IPCC, 2007). The language of the UN Framework Convention on Climate Change (UNFCCC, 1994) is nothing short of visionary, in that it calls for a cooperation between actors seeking to adapt to and mitigate the effects of climate change, provide for an eradication of poverty through sustainable development and provide greater impetus to conserve the earth's biodiversity. REDD+ is a "complex and moving target" requiring coordination among local stakeholders, scientists, national and international organizations (Tipper *et al.*, 2011).

THE CARBON FARMING INITIATIVE (CFI) IN AUSTRALIA

Having undergone significant struggle (a struggle that ousted her predecessor, Kevin Rudd) in order to create a domestic price on CO_2 emission, Australian Prime Minister Julia Gillard announced a carbon price of 23 AUD per ton of CO_2 in November, 2011. The Australian Carbon Farming Initiative targets the top 500 emitters in Australia, who are responsible for over 60% of the country's emissions. The carbon pricing mechanism is set to commence on July 1st, 2012, and will transition to a flexible price cap and trade emissions trading program on July 1st, 2015. Given the fierce controversy over what opposition leaders dubbed the "great big tax on everything," the current Government has taken make clear that money from the carbon pricing initiative will be reinvested in social programs, carbon reduction strategies and a clean energy future.

As part of its overall program, the CFI will allow carbon credits from land-based projects to be used by regulated polluters to meet their reduction targets. Most of the project types are related to reducing emissions during agricultural operations, but also include the activities of reforestation, revegetation, savanna fire management, native forest protection and forest management. Project types that are eligible to meet Australia's Kyoto obligations can be sold to companies with liabilities under the Carbon Pricing Mechanism (but only for 5% of their targeted reduction). Project types not currently accepted under Kyoto obligations will receive financial support from the CFI non-Kyoto Carbon Fund (250 million AUD over the first 6 years). The current Government also states in their Clean Energy Plan (CEP) that they will continue to lobby for the inclusion of these land based mitigation measures in international agreements.

The Australian Biodiversity Fund (946 million AUD available over the first six years) will be created to protect biodiverse carbon stores and secure other environmental outcomes from carbon farming. The CEP recognizes the contribution of biodiversity to industries such as agriculture, aquaculture, tourism, forestry and fisheries through providing ecosystem services. Furthermore, the CEP recognizes the need to reforest and revegetate biodiverse carbon stores in areas of high conservation value, and the need to manage and protect biodiverse ecosystems.

Through the Carbon Farming Futures Initiative, a 201 million AUD program, the Australian government has invested in research and development of programs to reduce pollution and improve adaptation to climate change across land use sectors. With the CFF, 20 million AUD will be used to transform this research into methodologies for the creation of CFI carbon credits. Grants of up to 99 million AUD will be made available for land owners to 'take action on the ground,' with particular emphasis on integrating carbon farming into normal farm business, increasing farm productivity and improving agricultural resilience in the face of climate change. A much smaller pool of money (22 million AUD over the first five years) will be made available to specifically assist Indigenous land managers in Australia.

The CFI forms part of an integrated approach to addressing overlapping concerns of sustainable agricultural and forestry practices, improved land management, and the conservation of biodiversity via a highly regulated market structure. Credits generated through the CFI can be sold in the domestic marketplace or internationally in voluntary markets. (Commonwealth of Australia, 2011)

REDD+ is also highly controversial, as it touches on a number of sensitive issues, such as land tenure, 'climate debt,' and emergence of a perceived and real CO_2 colonialism extracting carbon credits for the developing world while limiting the opportunities of developing countries. As of the last UNFCCC Conference of the Parties (COP 17), Kyoto based commitments have been extended until 2020 (however without Canada, Japan, the United States, Russia and other 'developing' large emitters such as China and India), and the UNFCCC will seek new binding emission reduction commitments as early as 2017. The COP reaffirmed the desire for meaningful and binding emissions reduction commitments, and authorized the creation of a Green Climate Fund to administer funds through thematic windows to countries undertaking programs to adapt to and mitigate climate change (UNFCCC, 2011a).

Such large-scale, top-down injections of foreign aid and capital, if successfully applied, may be an effective means of poverty alleviation and economic development (Sachs, 2005). Mounting evidence suggests, however, that top-down approaches prove ineffective at providing the necessary conditions for lasting economic growth and social development (Iimi, 2005; Easterly, 2006). In developing countries with poorly organized yet highly centralized governance processes, top down approaches which increase the value of standing forests can reverse historical processes of decentralizing forest governance (Sandbrook *et al.,* 2010). In response to the threat that centralized and undemocratic governance processes pose to forest communities, a number of NGO and Primary People's organizations have organized against REDD+. Seeking to ameliorate these conflicts, the Climate Community and Biodiversity Alliance has published a set of Social and Environmental Standards for REDD+ projects (CCBA, 2011). It is widely acknowledged by the UNFCCC that REDD+ efforts can only succeed as part of an integrated approach of environmentally conscious social development (UNFCCC, 2007; UNFCCC, 2011a; UNFCCC, 2011b). Exactly what form this integration will take is unclear, but at this stage the UNFCCC is committed to respecting *'...national sovereignty, national legislation and national circumstances'* in the provision of information on safeguards (UNFCCC, 2011b). While this commitment to national sovereignty may be commendable, it may relativize social and biodiversity safeguards to the point of meaninglessness.

It remains to be seen whether or not REDD+ credits will be bought and sold as part of a post-Kyoto mechanism set up by the *Ad hoc* Working Group on Long-term Cooperative Action under the Convention (AWG-LCA), used only to meet within-country emission reduction targets, or funneled and supported by emerging compliance markets (or all three). In the meantime the voluntary carbon market has embraced REDD+ methodologies and project types, outpacing *all other forms* of forest carbon (from 2% in 2006 to 71% of the voluntary forest carbon market in 2010 (Ecosystem Marketplace, 2011a)).

3. CAN A FOREST CARBON MARKET DELIVER?

Recently, there has been an explosion in literature relating to REDD+, carbon credits, ecosystem services, multiple benefits, social and environmental safeguards, governance issues, and the efficacy of certification schemes on providing tangible benefits. Several key insights emerge regarding the intersection of forest carbon, biodiversity conservation and multiple benefits.

First, carbon-centric approaches may be effective in the short term in providing 'additional, real and verifiable' emission reductions, but they may not be effective in addressing the underlying drivers of habitat loss and land degradation or in supporting integrated goals of biodiversity conservation, ecological restoration, and sustainable development. Existing certification schemes (Box 2) and safeguards have been created to deal with these concerns to some degree. Nevertheless, biodiversity and ecosystem services are difficult to monitor. Second, significant issues loom with purely market-based mechanisms dependent upon large influxes of private capital into ill-defined governance and project development systems. In many areas under threat of land conversion, current prices for REDD+ credits are not competitive with the opportunity costs of oil palm plantations (Butler *et al.,* 2009; Ghazoul *et al.,* 2010). Such economic considerations can even trump legal agreements between project developers and government agencies, as has been demonstrated dramatically by the large-scale failure of the Rimba Raya Biodiversity Reserve project in Central Kalimantan, Indonesia (Ecosystem Marketplace, 2011c). Third, these types of failures are inevitable in the absence of effective regulatory structures, and community, private and public sector capacity for defining the agenda of the carbon market (Munden Project, 2011). A number of horror stories have come to light regarding the disenfranchisement of rural people for carbon plantation projects, and allegations have surfaced regarding the displacement and

CERTIFICATION FOR MULTIPLE BENEFITS

Ciscell (2010) outlines five problems with carbon offset projects in general; Carbon offsets do not address overconsumption in the developing north, offsets can exploit developing countries, they can be environmentally destructive, are not always effective, and have no accurate method for calculating and monitoring co-benefits. Ciscell (2010) proposes a 'Fair Trade' certification mechanism whereby the social and environmental aspects of offset projects are taken in consideration. However, to a large degree, the Climate Community and Biodiversity Alliance and a range of other standards have already accomplished the creation of a standard that is equivalent to a 'fair trade' standard and relies on a similar model of periodic re-evaluation and separation between the certifying body and validating body (see below). Certification programs for sustainably managed forests tentatively appear to positively impact biodiversity as compared to other forms of logged forests, although few data are available for comparison to intact forests (van Kuijk *et al.* 2009). Further evaluation of the real value of certification on meeting multiple goals requires addressing the dual challenge of creating standardized methods for forest (or ecosystem) evaluation that are both robust and locally sensitive.

Standard	**Description**	**Funding Source**	**Market share 2010***
CCBA	Co-benefits standard for biodiversity and social benefits	Corporate and Philanthropic Sponsors	68.6%
Plan Vivo	Creates an integrated living plan for community that equitably distributes benefits from environmentally sensitive carbon PES	Levy on credits issued	.6%
SOCIAL CARBON	Co-benefits standard based on Sustainable Livelihood Approach, for Verified Emissions Reduction (VER) credits. Measures six dimensions: Human, Natural, Biodiversity, Carbon, Financial, and Social.	Corporate, Government and NGO Partners	←.1%
CarbonFix	Unified standard for forest projects including social and environmental components;.	Fees paid by project developers	.1%
CDM Gold Standard	Premium project management and technical standard for CDM projects	Corporate Sponsorship	0%, though CDM alone is 4.6%

*Forest Carbon market share from State of the Forest Carbon Markets 2011 (Ecosystem Marketplace, 2011a)

abuse of indigenous and local peoples for REDD and carbon credit projects (Grainger and Geary, 2011; Climate Connections, 2011). In many cases, the problem does not lie with existing methodologies and standards per se, but that these safeguards do not account for systematic abuses of power and corruption in the highest levels of national government.

These problems are complex, and a full evaluation of strategies and options is beyond the scope of this paper. We propose a framework to unify different research, policy and market agendas. We propose that supporting biological and cultural diversity, identifying and enhancing relevant ecosystem services, and better understanding sustainable development options and their impacts on land use become the three pillars that support the creation of sustainable and resilient socio-ecological systems (Fig. 1). In this framework, carbon credit projects should be assessed as appropriate depending on their contribution to a resilient socio-ecological system.

3.1 THE CENTRALITY OF BIOLOGICAL AND CULTURAL DIVERSITY

Programs designed to create maximum carbon credits will not coincide with the highest degree of biodiversity protection (Putz and Redford, 2009; Strassburg *et al.*, 2010). Reorientation of carbon credit programs to include protection of biodiversity (and other ecosystem services) potentially complicates their timely implementation under the current market framework (Skrotch and Lopez-Hoffman, 2009; Harvey *et al.*, 2010). Adding to this complexity, opportunity costs for combined biodiversity conservation and carbon credits vary significantly between ecosystems (Venter *et al.*, 2009). Engineering intensively managed systems to quickly capture carbon using fast-growing species actually delivers lower carbon and lower biodiversity values in comparison to more traditional plantations and intact forests in medium to long term time scales (Kanowski and Caterall, 2010). In the case of lowland tropical forests in Indonesia, a lack of systematic conservation planning backed by strong regulations will contribute to continued losses of biodiversity from a combination of carbon and development priorities (Paoli *et al.*, 2010).

Although global analyses show a high overall correlation between carbon storage and biodiversity, many biodiverse ecosystems will be subjected to increased development pressure if only carbon rich areas are slated for conservation (Strassburg *et al.*, 2010). Strassburg *et al.* (2010) also found that many threatened and restricted range species occupied relatively low carbon value areas, which would face increased threats should other land be locked up for carbon. However, within highly fragmented landscapes, prioritizing REDD in areas under ongoing threat of conversion may protect relatively large amounts of biodiversity per unit of carbon (Strassburg *et al.*, 2010). Including implementation costs in a global analysis, Venter *et al.* (2009), showed that funding apportioned to the lowest opportunity cost countries to maximize carbon

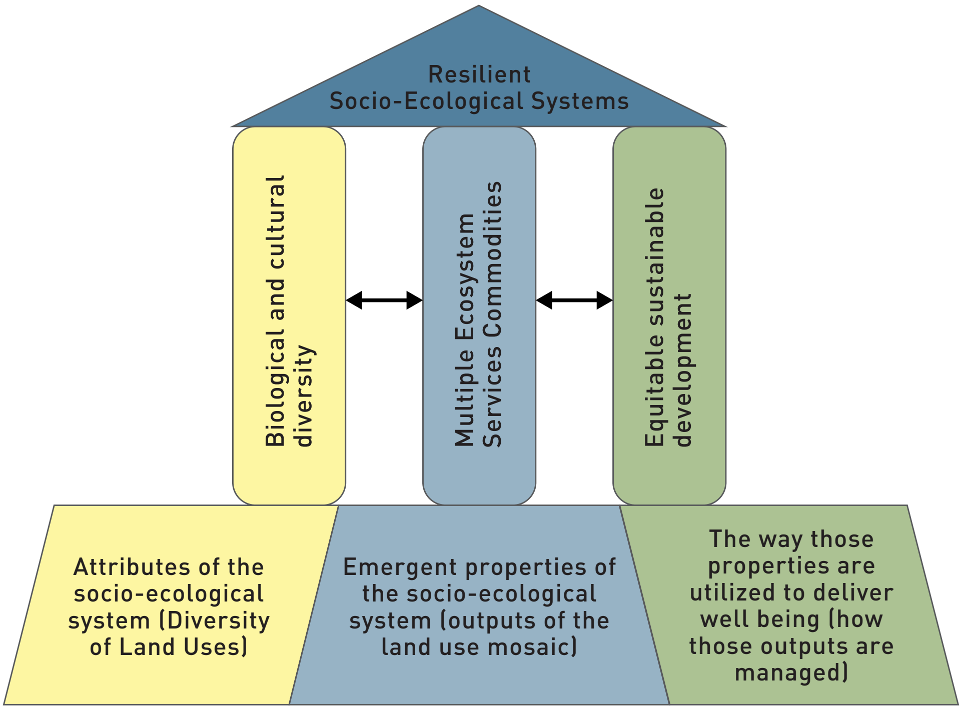

Figure 1: Resilient socio-ecological systems critically depend on their biological and cultural diversity, their consumption and supply of a variety of ecosystem services and commodities, and their ongoing equitable and sustainable economic and cultural development. Resilient socio-ecological systems may be defined using a hybridization of definitions for ecological and economic systems. Here we define a resilient socio-ecological system as comprising the sum of abiotic, biotic and human social attributes which maintain their core functions in the face of perturbation.

preservation would yield biodiversity benefits indistinguishable from a random distribution of preserved areas. However, relatively small reductions (4-8%) in carbon storage could result in four fold increases in biodiversity conservation value (Venter *et al.,* 2009). Such non-linearity between carbon storage potential and biodiversity needs to be accounted for in conservation and carbon planning (Venter *et al.,* 2009). It is also worth noting that a significant body of research examines the importance of biodiversity in maintaining ecosystem function and longer-term biomass (and hence carbon) accumulation (Ruiz-Jaen and Potvin, 2010; Kanowski and Caterall, 2010). Clearly, more research is needed to understand the cost efficiency frontiers of different restoration and forest conservation approaches and their carbon, biodiversity and other ecosystem service outputs. On top of these economic analyses, we cannot ignore the lessons from the conservation literature that call for meta-analysis of the efficacy of specific types of conservation interventions, be they based on systematic review (Sutherland *et al.*, 2004), or program evaluations (Ferraro and Pattanayak, 2006).

Although tree species diversity and the diversity of functional traits cannot reliably be used as a predictor of plot carbon storage (Ruiz-Jaen and Potvin, 2009), naturally regenerating tropical forests sequester carbon at high rates and also harbor diverse flora and fauna (Marín-Spiotta *et al.,* 2007; Chazdon *et al.,* 2009b). During forest regeneration, carbon sequestration and biodiversity increase in concert, linked by increasing complexity in forest structure and composition (Chazdon, 2008a). Forest restoration that mimics natural regenerative processes may yield the highest benefits in carbon storage, biodiversity, and other ecosystem services (Chazdon, 2008b). Naturally occurring forest regeneration may be the most effective means of providing long term biodiversity and carbon benefits. Overall, protecting the ecological function of a given ecosystem, of which biodiversity plays a central part, is critical for maintain a flow of ecosystem services (Peterson *et al,* 2010).

The success of using carbon programs to protect biodiversity at large scales depends upon making those goals explicit in international agreements on REDD+ and carbon policy. Concurrent subsidization of ongoing carbon projects by conservation organizations may provide the necessary initial funding for projects that have higher opportunity costs but provide greater benefits to biodiversity protection (Venter, 2009). At the international scale, Grainger *et al*'s (2009) analysis of COP15 expressed concerns about limited coordination between the UN Convention on Biological Diversity (UNCBD) and the UNFCCC to include biodiversity targets in climate change initiatives. At the onset of COP16 in Cancun, efforts to combine biodiversity and ecosystem service protection with climate protection initiatives were clearly underway (UNCBD, 2010). While strong and binding international agreements for combined biodiversity and climate protection are certainly necessary, we question the efficacy of broad international programs that are not rooted in effective ground level action.

Local effectiveness of such a broad agenda is contingent upon effective engagement of communities and individuals. Daunting at first, this task is aided by new paradigms for bio-cultural conservation that demand scientific-social engagement, interdisciplinarity, and the implementation of international agreements at local to global levels (Rozzi *et al.,* 2006). Similar to the ways in which biodiversity affects ecosystem service provision (Diaz *et al.,* 2006), human cultural diversity creates a mosaic of human environmental interactions with the ability to promote or degrade the provisioning of ecosystem services. New approaches require merging studies of social science, cultural anthropology, and ecosystem services in human-modified landscapes (Chazdon *et al.,* 2009a). To allow coupled human and natural systems to evolve in the changing climate regime, we will need to better understand the relationship between cultural practices and ecosystem function.

3.2 MANAGING FORESTS FOR MULTIPLE ECOSYSTEM SERVICES

Ecosystems are complex mosaics of habitat patches displaying hierarchical self-organizing dynamics that provide distinct ecosystem services. PES programs focusing *solely* on carbon undermine efforts to increase socio-ecological resilience, as practices designed to store the most carbon will not provide the full complement of potential ecosystem services in the short- or long-term (Figure 1; Boyd, 2010; Lal, 2010). A continuum approach treating PES as part of a continuum of integrated land management policies is important to understand the relationship between land uses and ecosystem services consumed and produced by local land economies (Wunder, 2006; Laurance, 2008). Although tradeoffs between service types do exist, there are stable points, as many land uses that degrade ecosystem services simultaneously rely on their provision from elsewhere in the system (Nelson *et al.,* 2009). Managing landscapes to provide sustainable levels of services (e.g. agricultural products, carbon sequestration, hydrological services, forest products, etc…) depends upon identifying areas at local and global scales that are most appropriate for those activities (Harvey *et al.,* 2008). Identification of areas and sites significant for services allows us to understand their spatial and functional linkages, as has been done for pollination services integrated into timber and carbon agroforestry systems in Ecuador (Olschewski *et al.,* 2010). Adapting PES programs and regulatory frameworks to address the range of ecosystem services in mixed-use landscapes requires an understanding of the relative value and history of human involvement in different areas (Harvey *et al.,* 2008; Kauffman *et al.,* 2009). The principles for the creation of PES programs (Heredia Declaration, 2007; Jack *et al.,* 2008) can then be applied. Coordination of national goals and international programs also requires that we measure functionality of ecosystems (in terms of multiple services) across a range of ecosystem types (Harvey *et al.,* 2008).

Human demands for and impacts on ecosystem services vary with the degree of economic and industrial development of a society. For hydrological services, many have found that investing in watershed protection can be more cost effective than technological infrastructure for water treatment (Herrador and Dimas, 2006; Forest to Faucet, 2007), yet data are often deficient for measuring the effectiveness of service delivery (Bauman *et al.,* 2006). Hydrological services are intimately related with plant functional traits that may have feedbacks on large-scale climate processes (Makarieva and Gorshkov, 2007; Sheil and Murdiyarso, 2010; Ellison *et al.,* 2011). These issues with hydrological services highlight the need to better define interactions between services across the range of provisioning, regulating, supporting and cultural services identified in the Millennium Ecosystem Assessment (2005). At the very least, we need refined measures of the appropriateness of reforestation projects for carbon credits based upon their ecological context. Without them, policies and projects may contribute to ecosystem degradation, as occurred during the conversion of grasslands to exotic pine plantations in highland Ecuador, resulting in loss of soil carbon, depletion of soil nitrogen stocks, and reduction of soil water content (Farley, 2007).

Ultimately, most if not all of our efforts at forest conservation will fail if certain thresholds in the earth climate system are crossed (Rockström *et al.,* 2009). Particularly worrying is the large degree of uncertainty inherent in current estimations of anthropogenic GHG loading of the atmosphere (Nisbet and Weiss, 2010). Changing patterns of precipitation and seasonal temperature fluctuations, increased pollution, and flow of invasive species can all reduce the ability of a given ecosystem to sequester carbon. We are already witnessing significant range shifts of forests from the combination of rising temperatures, changes in precipitation regimes and feedbacks between insect predator populations (Schlyter *et al.,* 2006; Beckage *et al.,* 2008), on top of the documented changes in global forest distributions due to human activity (Williams, 2008). Although adaptation to the expected impacts of climate change is a central component of an integrated carbon planning process, the thresholds of many ecosystems are poorly understood. One way forward through this uncertainty is to incorporate the resilience principles of dynamism, ecological heterogeneity, cultural and biological diversity, overlapping levels of governance, and action in the face of uncertainty (Walker *et al.,* 2006). With increased fluctuations in the earth's climate, standard practices must reflect the need to design carbon and ecosystem service projects for resilience to climate change.

3.3 ADDRESSING TRADEOFFS IN SUSTAINABLE DEVELOPMENT

Who benefits from the global marketing of ecosystem services? Many hope that payment for ecosystem services projects will improve the fit between institutions and ecosystems, supplement diverse rural incomes, and alleviate poverty (Pagiola *et al.,* 2005; Folke *et al.,* 2007). In some cases, they have done so (Turpie *et al.,* 2008), yet elsewhere there are strong tradeoffs between carbon, biodiversity (Paoli *et al.,* 2010), and social wellbeing (Smith *et al.,* 2007). Global analysis of health vulnerability indices, areas of conservation concern, and the potential economic benefits from REDD+ programs show a strong dependency on improving governance mechanisms to achieve co-benefits (Ebeling and Yasué, 2008). The idea that carbon projects automatically generate co-benefits has, to a large degree, been a naïve one (Smith *et al.,* 2007; Naidoo *et al.,* 2008; Harvey *et al.,* 2010; Strassburg *et al.,* 2010).

To integrate carbon-credit projects (and other PES programs) into existing sustainable development activities (Fig. 1), we need to identify tradeoffs between multiple benefits for local, regional, and global stakeholders.

3.3.1 Multiple Benefits

Few carbon credit projects consider multiple benefits as part of their overall design. From a systematic review yielding 121 case studies pertaining to carbon credit projects, only 10 projects had a methodology for quantifying carbon sequestration, and/or biodiversity and/or social benefits (Barozi and Grabowski, April 2009 unpublished data). Of these, two projects were based on integrated natural resource management approaches (Yin *et al.,* 2007; Saxena *et al.,* 2001) and one probed the success of carbon credit projects using socio-economic data (Wang *et al.,* 2007). Saxena *et al.* (2001) provided a case study from the Himalayas where a carbon project was used to create significant on-site benefits in terms of improvements to soil fertility, biodiversity, protective cover, and carbon sequestration, and off-site benefits from more productive use of labor, reduced pressure on protected areas, and the introduction of medicinal and rare species to former croplands. Yin *et al.*'s (2007) 'Integrative Assessment' framework explicitly linked the economic sustainability of different forestry practices with their respective rates of carbon sequestration. Wang *et al.* (2007) found that success of China's Grain for Green agriculture to forest land conversion program was strongly linked to a family's availability of labor, age structure and access to capital.

3.3.2 Governance

Issues such as land tenure, social and political equity, and free and prior need to be accounted for when dealing with local communities that have generally benefited from historical decentralization of forest governance (Phelps *et al.,* 2010; Sandbrook *et al.,* 2010). Carbon credit programs that ignore these issues may undermine their long-term success by increasing pressures on forest resources elsewhere through the displacement of peoples and resource use in the project zone, potentially contributing to corruption and conflict, and reinforcing existing social and economic inequalities. One poignant example of reinforced social inequalities is the use of monoculture oil palm plantations in carbon credit projects that have contributed to the displacement of communities and ecosystems in the name of carbon sequestration (Koh and Ghazoul, 2008). Increasing strife in communities where these projects operate is no trivial matter, as irresponsible practices can result in local to global political and social backlash, un-saleable 'immorally branded' credits, and project failures, all tangible components of project risk. PES programs need to account for the competing economic interests of different social actors. Incorporating common pool resource theory, and better understanding the underlying relationships between cultural practices, economic tradeoffs, and ecosystem characteristics is one way to address these issues (Steffan-Dewenter *et al.,* 2007).

3.3.3. Identifying Reinforcing Land Uses

Various groups have explored the potential for carbon credit projects to contribute to the provision of ecosystem services, conservation goals and sustainable development (Box 3; Chan *et al.,* 2006; Nelson *et al.,* 2009). Increasing the diversity of land uses in mixed agriculture and forest systems can potentially reinforce mutually supportive services and increase economic outputs (Swift *et al.,* 2004). Communities participating in PES programs in Costa Rica, Ecuador and Mexico demonstrate that it is possible to combine PES, sustainable agriculture and community forestry in the landscape context (de Jong *et al.,* 1995; Wunder, 2006). In coastal California, Chan *et al.* (2006) found that in landscapes designed for a specific purpose (forage production and crop pollination), there were clear tradeoffs in providing for conservation of biodiversity and the ecosystem services of carbon storage, erosion control, forage production, crop pollination, flood control, water provision, and outdoor recreation. Using an iteration of Chan *et al.*'s approach, in the Willamette Basin, Nelson *et al.* (2009) showed that existing planning processes failed to maximize the landscape's potential economic outputs or ecosystem services.

Understanding the feedbacks between land use, economic outputs and ecosystem services include and go beyond existing additionality (the degree to which a project's benefits surpass a business as usual scenario) criteria in forest carbon projects. To a lesser degree they address issues of leakage whereby benefits derived from rewarding forest preservation in one area can lead to forest and environmental degradation elsewhere, e.g. Costa Rican policies protecting local forests from logging resulting in increased timber imports from forests and plantations in Chile, Argentina, Venezuela, and Nicaragua (OET, 2008). Furthermore, if revenues from forest carbon contribute to irresponsible patterns of consumption and/or agricultural and built development in areas adjacent to the project then benefits to ecosystem services (e.g. water quality, flood protection, nutrient cycling, and air purification) can be lost.

EXAMPLES OF ORGANIZATIONS AND INITIATIVES ON THE PATH TOWARDS BUILDING SOCIO-ECOLOGICAL RESILIENCE THROUGH BIOLOGICAL AND CULTURAL CONSERVATION, MANAGEMENT FOR ECOSYSTEM SERVICES AND SUSTAINABLE DEVELOPMENT.

Mamirau Sustainable Development Reserve

In the Mamiraua Sustainable Development Reserve and the Pantanal Sul Mato-grossense Project in Brazil, indigenous villages charged with protecting their natural resources have begun to be powered by solar, wind and small-scale hydro projects, supported by partnerships with the Study Group for the Development of Renewable Energy (GEDAE) (www.mamiraua.org). Integrating agricultural systems with technology to reduce labor and increase resilience to climatic change has been an ongoing project of Ecologica, a Brazilian NGO that formed to address the linkages between ecosystems, sustainable development and energy (www.ecologica.org). Ecologica also focuses on integrating alternative livelihoods with carbon credit projects and agricultural improvement.

Conservation Through Poverty Alleviation (CPALI)

A Massachusetts-Madagascar partnership organization Conservation through Poverty Alleviation (CPALI–www.cpali.org) seeks to reduce pressure on buffer forests around conservation zones by diversifying wild silk based economies in agroforestry systems. As shown in Columbia, silvopastoral systems can increase pasture quality and ecosystem services (Pagiola et al. 2005). Not only does CPALI intend to create these economically self sustaining silk farming systems, but it combines conservation education with economic diversification that reduces pressure on existing forests and endangered lemur populations.

Ecologic

The Cambridge, MA based organization Ecologic operates in a similar way, working with local communities to diversify livelihoods by using revenue from the carbon market (www.ecologic.org). Acting simultaneously on fronts of energy security, community development and the provision of ecosystem services, Ecologic creates partnerships between NGOs, local communities and government entities. In its Bosques Pico project in Honduras, Ecologic supports large-scale tree nurseries to create local jobs, while supplying communities with renewable energy while sequestering carbon and restoring watersheds.

EcoTrust

Founded in 1991, EcoTrust (http://www.ecotrust.org/) is an impressively wide-ranging organization aiming to build 'reliable prosperity' by concurrently addressing the needs and roles of society, nature and capital. Hosting a variety of initiatives, they support the work of First Nations, run a Natural Capital Investment Fund, and most pertinently to us here, support research on and implementation of methods for sustainably managing land for its ecosystem services and biodiversity while contributing to an equitable and sustainable regional economy.

The above organizations represent organizations emergent in a global grassroots movement of unprecedented proportions, for a more complete overview of this phenomenon, the reader is referred to Paul Hawken's Blessed Unrest (2007).

3.3.4. Poverty Alleviation

If REDD+ type and PES projects are to have a role in poverty alleviation (Pagiola *et al.,* 2005; Turpie *et al.,* 2008), they need to incorporate the ecosystem services, social service and infrastructural needs of communities where they are implemented. The metrics by which poverty are measured must also be further refined to include better measures of the overall well being, or quality of life of target communities (Such as in the World Health Organizations cross cultural quality of life matrix (WHO, 1998)). Areas of conservation concern overlap strongly with those of extreme poverty (Fisher and Christopher, 2007) and conservation organizations are in a unique position to improve the lives of some of the world's poorest people (Kaimowitz and Sheil, 2007; Redford *et al.,* 2008). Peoples living in degraded or working landscapes which are typically overlooked in conservation planning, can have positive and negative impacts on biodiversity and ecosystem service provision (Harvey *et al.,* 2008). Prior attempts to address these concerns come largely in the form of Integrated Conservation and Development Projects (ICDPs). ICDPs have, in name, fallen out of favor despite initial high expectations and conceptual uptake as they are more well known for their failures rather than success stories (Brandon and Wells, 2010). What is clear that ICDPs provide lessons for carbon and PES projects in that these projects need to have measurable and clearly defined goals, the project duration should be adequate to reach those goals, markets for goods and services of communities need to exist, and that mechanisms need to be in place for monitoring and evaluating project performance (Blom *et al.,* 2010; Brandon and Wells, 2010).

3.3.5. Holistic Sustainable Development

Here we discuss sustainable development mainly in terms of sustainable use of land; however we acknowledge that there are social, technological and economic complexities that will drive different types of built, industrial and economic development, all with their own demands and impacts on biodiversity and ecosystem services. Linking these disparate disciplines and approaches to create models for a truly sustainable and prosperous human existence should be at the forefront of the climate change debate. If efforts to reduce emissions from deforestation can contribute to the creation of carbon neutral, sustainable and environmentally sound economies, we can build a new template for human existence that transcends existing concepts of developed and undeveloped worlds.

4. EVOLVING OUR CULTURAL NARRATIVE

New research linking human cognitive and behavioral processes to ecosystem properties makes clear the dependency of human wellbeing on environmental quality (Kahn, 2001; Carpenter *et al.,* 2006; Diaz *et al.,* 2006). When designing PES projects, discussion between indigenous groups, scientists, and policy makers is necessary to avoid cultural losses (Turner *et al.,* 2008). Much of the opposition towards REDD+ stems from a common worldview that maintains that the planet, and all of nature, has inalienable rights that do not depend upon human social and political structures (World People's Conference, 2010; Yucatan Declaration, 2010).

Given these fundamental differences in perspective and approach there is a profound need for the scientific community to operate with indigenous peoples in a culture of mutual respect and appreciation of varied skill-sets. Clearly, indigenous communities will not accept REDD+ or similar initiatives if they are perceived and experienced as continued marginalization, exploitation and oppression (Doolittle, 2010). The framework of exchange where one party purchases ecosystem services provided by another is rooted in a particular narrative of human and property rights. Rights-based approaches and the principle of 'free, prior and informed consent have been shown to be crucial for truly sustainable development (Acharya and Acharya, 2007). Without a sense of ownership, or at the very least, inclusion, participants are likely to resist PES schemes as an encroachment upon their sovereignty (Pagiola *et al.,* 2005; Boyd and Banzaff, 2007). A caveat to rights-based approaches is that clear responsibilities need to be assigned to target communities in order to meet the desired project outcomes. However, many first nations and indigenous cultures worldwide have well developed spiritual and metaphysically grounded senses of responsibility for the natural order, some of which have documented biodiversity benefits (Khumbongmayum *et al.,* 2006). Further developing a common sense of responsibility, and ultimately humility towards and cooperation with the natural world are critical aspects of developing effective policy measures for building socio-ecological resilience in a changing world.

5. CONCLUSIONS

Unsustainable models of land and energy use with resulting increases in greenhouse-gas emissions have been driven by a global market economy that placed little or no emphasis on maintaining ecosystem services or empowering local communities. To avoid previous market pitfalls, REDD+ and PES projects need to be framed within evolved cultural and social norms: those of respecting socio-ecological resilience by caring for properties of ecosystems that feedback to human wellbeing. Spatially explicit methods of quantifying ecosystem services across a landscape exist, but have yet to be standardized for streamlined data collection in the field. Likewise, various and disparate methods exist for quantifying the social impacts of different land use regimes, but they have yet to be linked to carbon credit projects at a significant scale. Carbon credit and Payment for Ecosystem Services programs will only be successful if they are integrated into land use policies that balance human and ecological well being (Fig. 1; Diaz *et al.,* 2006; MEA, 2005; Nelson *et al.,* 2009). Long-term sustainability and survival involve much more than balancing carbon emissions—they demand an innovative transition to an economy, infrastructure, and cultural form that reconfigures itself to the ecological reality it inhabits.

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