Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

EDITORIAL OPINION

Carbon Offsets as Ecological Restorations

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Abstract

The explosive growth of carbon markets is creating unprecedented opportunities for landscape-scale restoration worldwide. Most mandatory and voluntary greenhouse gas reduction programs allow use of carbon offset credits, including biosequestration projects, to replace actual emission reductions. Are the market schemes configured in a way that promotes ecosystem recovery and long-term carbon storage? As importantly, is it likely that these efforts will provide significant social and environmental co-benefits to justify trading offsets rather than actually reducing emissions? Compared with social scientists working in sustainable development, restoration ecologists have not offered much advice on the way carbon markets could be configured to support lasting restorations. Under current standards, the market price is likely governing the quality of restorations, not the reverse. A variety of reforms are needed to ensure that biosequestration projects deliver real, additional, and permanent removals of carbon dioxide. In particular, developing and adopting social and environmental impact assessment tools, changing accounting practices to allow for natural disturbances, universal adoption of strong additionality testing, and supporting critical research through tonnage fees could substantially improve what is accomplished through carbon offsets. Given the magnitude and importance of what carbon markets are attempting to achieve, insights from restoration ecologists are urgently needed to help shape their future.

Key words: carbon markets, carbon storage, climate change, forest restoration, monitoring, sustainability.

Introduction

By providing $2 million (USD) for reforestation in Guatemala 20 years ago, one of the world's largest power companies, Applied Energy Services, devised a way to mitigate impacts from their proposed coal-fired power plant, won regulatory approval for their project, and became the world's first investor in carbon markets. The carbon dioxide emissions now being generated by the AES power plant in Connecticut (U.S.A.) are, in theory, being offset by biosequestration from 50 million trees planted in the Western Highlands region of Guatemala. Carbon offsets were invented as a mechanism to mitigate carbon emissions that would also yield broad social and environmental co-benefits (e.g., Klooster & Masera 2000). Since 1989, the world's carbon markets have grown to nearly $120 billion/year, doubling in value in each of the past 2 years according to climate finance analysts, New Carbon Finance (London) and Point Carbon (Oslo).

The scope of offsets has expanded, too, and now includes energy efficiency, renewable energy, methane/carbon capture/geological storage, and a greater array of biosequestration options (Ristino 2008; Kollmus et al. 2008a). Large-scale forestry projects like the AES offset remain the most common application of biosequestration, but some trading programs also include soil carbon storage projects, such as grassland and wetland restoration/protection as eligible offset types. Both the pool of investors and projects of most trading programs are multinational. The result is that funding for landscape-scale ecological restorations is rising worldwide along with trading volumes in carbon markets. With increasing evidence that focusing on forest restoration rather than liquid biofuels has greater potential for climate mitigation (Righelato & Spracklen 2007; but see Read 2007), carbon offsets should remain central to climate change public policy. Will the marriage of carbon markets and ecological restorations produce genuine results? Given the trial-and-error, chronically underfunded nature of ecological restoration and the urgent need to reverse habitat fragmentation, perhaps uncritically hoping for the best is reasonable. After all, ecological restoration is inherently uncertain and so the prospect of a few successfully restored landscapes emerging from a large number of well-intentioned attempts may be viewed as acceptable.

Or, are the stakes too high to adopt this perspective? Averting a serious significant increase in average global temperature (i.e., 2°C) is a daunting goal that requires global emissions peak in the next decade and, by 2050, decline to 80% below 1990 levels (Baer & Mastrandea 2006). In the view of many climate policy experts, accomplishing reductions in global emissions of this magnitude are unlikely and so offsets will be essential to stem global warming. What is also essential is that carbon offsets truly mitigate their share of carbon emissions. As restoration ecologists, our leadership is needed to: (1) evaluate whether carbon market practices

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doi: 10.1111/j.1526-100X.2009.00587.x

currently in place are likely to result in ecological restorations capable of carbon offset, (2) determine whether the standards guiding selection, design, implementation, and monitoring of offset restorations reflect the state of our understanding, and (3) advocate for changes needed to ensure restoration produces genuine carbon offsets and vise versa.

How Carbon Offset Markets Work

Climate policies, such as the Kyoto Protocol or the Regional Greenhouse Gas Initiative in the northeast United States, establish quantified emission reduction goals, or caps, in units of metric tons of CO_2e per year. Carbon dioxide equivalents, or CO_2e, is a measure of the global warming potential of all greenhouse gases in terms of their equivalence to CO_2 (Intergovernmental Panel on Climate Change [IPCC] 2007, Table 2.14, p. 212). Countries or companies covered by these caps are given (or sold) a specified number of "allowances" (also delineated in tons of CO_2e). If the entity is unable to meet the required reduction, they may purchase a certified offset credit to cover excess emissions. Various registries and trading programs have been established in the United States and internationally to facilitate the sale of both allowances and offset credits. Carbon contracts, or tradable units, are typically denominated in metric tons of carbon dioxide equivalents (CO_2e).

Offset contracts are offered to investors through mandatory (or compliance) and voluntary markets (Fig. 1; Table 1). About 95% of total carbon market activity happens in mandatory markets, mostly regulated by the Kyoto Protocol (Kollmuss et al. 2008a, 2008b). Under the Kyoto Protocol's Clean Development Mechanism (CDM), developed countries are importing "Certified Emission Reductions" from developing countries as offsets because actual emissions' reductions are much more costly (Ware & Victor 2008). Biosequestration comprised 7% of the 2006 trading volume of compliance markets, but 36% of voluntary markets (Kollmuss et al. 2008a). In the United States, where all markets are voluntary, two-thirds of the offset credits are biosequestration projects (Hamilton et al. 2007). Although voluntary markets are minor compared with compliance markets, in the United States alone, the voluntary carbon market was valued at $91 million in 2006, with a total trading volume of 23.7 million metric tons of CO_2e (through Chicago Climate Exchange, CCX); an additional $55 million in offsets (13.4 $MMTCO_2e$) were sold in over-the-counter markets (Di Peso 2007).

The general approach for carbon offsetting is project based and the seller of projects commits to provide a stable and permanent reservoir of carbon. Projects may be sold directly to investors ("over-the-counter") or to intermediaries such as brokers, retailers, or aggregators (Ristino 2008). These intermediaries are typically affiliated (e.g., as a certified professional) by the organization (e.g., exchange, alliance, network, registry) established by the offset standard or trading system. Through these intermediaries, many small projects can be aggregated into lots of 100,000 or more tons of CO_2 so they can be marketed more efficiently.

Universally accepted standards for project eligibility, accounting for offsets, verification and monitoring do not exist. A carbon standard is, however, not considered reliable unless it adopts protocols intended to ensure its offsets are real, additional, and permanent (e.g., GAO 2008; Kollmuss et al. 2008a).

For offsets to be "real," reductions must be measured and independently verified. Third-party verification is meant to provide assurance to investors that a real reduction will occur. Verifiers, typically private environmental consultants certified by the trading platforms or registries, estimate the carbon sources and sinks in a defined project area. Verification may include baseline conditions, anticipated long-term storage, and incremental changes that accrue over decades, because uptake and storage will occur as vegetation establishes and grows.

To ensure CO_2e is actually reduced during the life span (i.e., crediting period) of a project, all compliance markets and most voluntary markets use accounting methods that are ex-post, or "retrospective" accounting, and the buyer only receives credits for carbon accumulations that have occurred over small time intervals. Some voluntary markets take a more speculative approach, relying on "ex-ante accounting" where all of the offset credits typically are awarded at the initiation of the project, based on a long-term average (e.g., 100 years) of anticipated future uptake and storage (TCNC 2005). These carbon storage averages are based on species, environmental conditions, and level of regular harvest (Bigsby 2009). Standards that prefer ex-ante accounting do so because it is convenient, does not require regulatory oversight to ensure buyers replace lost offsets, provides essential capital to sellers to establish projects, and avoids monitoring annual changes in carbon storage (TCNC 2005).

To be "additional," the reductions could not have taken place under business-as-usual conditions. Establishing additionality requires a comparison of alternative futures, with and without the offset project, and involves analysis of both the actual project and the larger context (i.e., landscape, social, technological) of the project (Kollmuss et al. 2008a). Permanence, according to the Intergovernmental Panel on Climate Change, is considered to be 100 years or perpetual and so international mandatory schemes require that credits are permanent (although they do allow initial temporary credits). Many voluntary trading standards, however, adopted crediting periods of 20–50 years for biosequestration projects (Table 1).

From Commodity to Sustainable Restoration

Carbon trading is much more than a business transaction—public perception is an important factor in buyer selection. By selecting offsets with popular appeal, businesses will more likely be recognized for their social and environmental responsibility. Ecological restoration projects are widely seen as being particularly appealing and many biosequestration offsets are advertised as restorations (e.g., www.trueoffsets.com, www.ducks.org, www.earthcarbonoffsets.com). The reality of carbon offset restorations is, however, much more variable

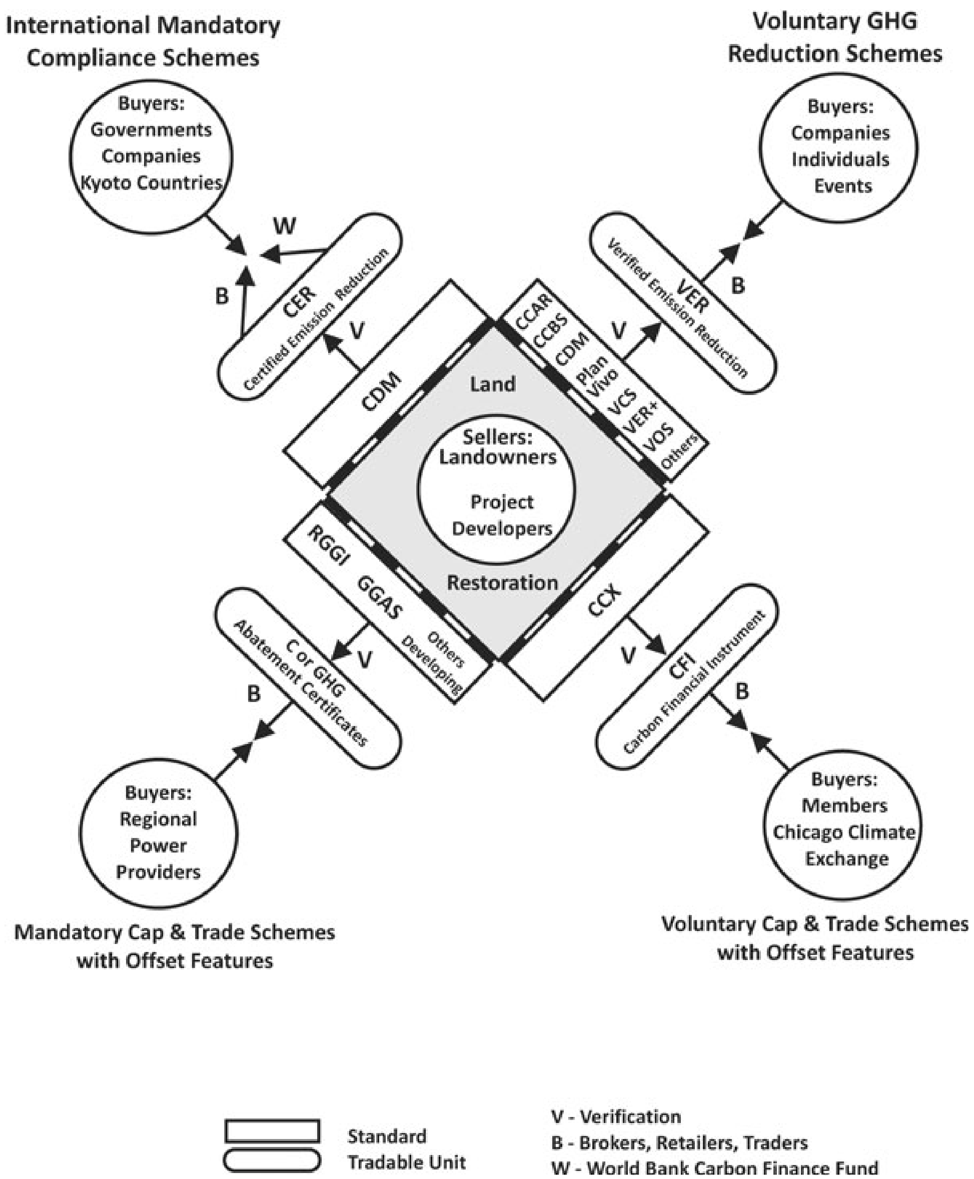

Figure 1. Restoration projects can be developed as offsets for four different kinds of carbon markets (schemes). International mandatory compliance schemes exist to enforce emissions reductions in Kyoto-participating countries, whereas mandatory cap and trade schemes are used by governments (generally states, provinces) as part of regulating power utility emissions. Voluntary schemes (general greenhouse gas reduction or utility cap and trade) patterned after mandatory schemes have been established to allow trading where regulations do not yet exist. Projects are developed following a particular standard which determines eligibility as an offset that can be registered as a tradable unit. Full standards also cover how the amount of carbon will be estimated, verified, registered, and enforced. Tradable units (e.g., one metric ton of CO_2e) will be sold to buyers through brokers, retailers, traders. See Table 1 for definitions of abbreviations.

than the image they project, ranging from plantations of exotic species to the re-establishment of somewhat diverse, indigenous vegetation. The potential for ecosystems to store carbon in biomass or in soils is often estimated from natural systems (Lal 2004), and so it is reasonable to frame these projects as restorations. How, then, do offset project developers resolve the design dilemma to maximize carbon credits with a minimal time lag while achieving long-term ecosystem recovery? Provisions for social and environmental co-benefits, estimation and accounting of carbon storage, and additionality tests are some of the key parameters that vary among carbon offset standards, either facilitating or hindering ecological restoration.

Carbon offsets have been promoted for their economic efficiency, environmental effectiveness, and co-benefits to sustainability and growth in both developed and developing countries (e.g., Swingland 2003; Harper et al. 2007; Kollmus et al. 2008a). Unfortunately, very few projects deliver environmental and social co-benefits when the focus is supplying cheap credits (Olsen 2007) and they are no longer considered integral to offsets. In the carbon-trading industry, people now

Table 1. Common standards that include biosequestration projects.

Standard	*Type*	*Project Locations*	*Project Developers*	*Accounting*	*Additionality Tests*	*Environmental and Social Provisions*	*Crediting Period Initial/Max (yr)*
International mandatory compliance schemes							
Clean Development Mechanism (CDM) http://cdm.unfcc.int/index.html	Full	Non-Annex 1 Countries	Mostly large carbon service companies	Ex-post	Comprehensive	Sustainable development focus; domestic environmental policy compliance required	20/60 (Temporary)
Mandatory cape and trade schemes with offsets							
Regional Greenhouse Gas Initiaive (RGGI) www.rggi.org	Full	Nebraska, U.S.A.	Not yet established	Ex-post	Standard	No formal assessment	20/40
Greenhouse Gas Abatement Scheme (GGAS) www.greenhousegas.nsw.gov.au	Full	New South Wales Australia	Carbon service companies	Ex-post	No formal assessment	No formal assessment	Not established
Voluntary cap and trade schemes with offsets							
Chicago Climate Exchange (CCX) www.chicagoclimatex.com	Full	Restrictions where mandatory trading occurs	Carbon service companies, NGOs	Ex-post	No formal assessment	No formal assessment	15/15
Voluntary GHG schemes							
Climate Action Reserve (CAR) www.climateregistry.org	Full	California, U.S.A.	Government agencies, carbon service companies	Ex-post	Comprehensive	Environment focus	Not established
Climate, Community, & Biodiversity (CCBS) http://www.climateregistry.org	Partial	No restrictions	NGOs	N/A	Standard	Comprehensive criteria for both environmental and social impacts, generation of co-benefits	Not applicable–design standards only
Plan Vivo www.planvivo.org	Partial	Developing countries	Local NGOs	Most ex-ante	Assessment linked to sustainable development	Sustainable development focus; social and environmental criteria	15/15
Voluntary Carbon Standard (VCS) www.v-c-s.org	Full	Restrictions where mandatory trading occurs	Large carbon service companies	Ex-post	Comprehensive	Requires avoidance of negative impacts	20/100
VER+ www.tuev-sued.de/climatechange	Partial	No restrictions	Large carbon service company	Ex-post	Comprehensive	No formal assessment	50/50
Voluntary Offset Standard (VOS) http://www.carboninvestors.org	Partial	Restrictions where mandatory trading occurs	Large carbon service companies	Ex-post	Comprehensive-Uses CDM	Uses CDM criteria	20/60

Full standards cover project design, carbon accounting, verification, certification, registration, and enforcement. Comprehensive additionality tests are multi-step, formal assessments. Standard additionality tests are formal but have fewer or less stringent criteria than CDM. Ex-post accounting issues credits after carbon offsets are generated; ex-ante credits are issued in advance. Information from Kollmus et al. (2008a, 2008b) and websites for standards (accessed January 2009).

distinguish minimum standard offsets from so-called gourmet offsets, or those based on strict standards of additionality and with processes to ensure co-benefits (Kollmus et al. 2008a). Some schemes do not assess social or environmental impacts (positive or negative) when accepting projects for trade (Table 1). Although CDM standards promote social sustainability, they have been criticized for ignoring impacts to endangered species, as well as soil and water quality (Madlener et al. 2006). Global biodiversity hotspots are considered especially vulnerable to CDM initiatives because of exotic species use and tree planting on lands not historically forested (e.g., Schulze et al. 2002). In spite of their high potential for carbon storage, monoculture plantations of exotic species are ineligible for trading under some schemes because of their risk to biodiversity (e.g., CCBS, Plan Vivo, CAR).

Some project developers (although none of the large carbon service companies) specialize in restorations that follow offset design standards consistent with restoration best practices (e.g., CCBS), including selecting sites based on vulnerability to weed reinvasion, restoring ecosystems that formerly occupied sites, using indigenous material of local provenance and minimizing herbicide use. These offsets, if well-sited, could be designed to increase the resilience of remnant natural areas as buffers or corridors and so may simultaneously serve climate mitigation and adaptation functions.

Biosequestration offset projects, which restrict nearly all land uses from extensive areas for long periods of time, can be disastrous for local communities. This is especially in developing countries, if designers ignore the consequences of lost employment and access to fuelwood and pastures (Sayer et al. 2004). Stakeholder processes are a key part of some standards (CDM, CCBS, and Plan Vivo) to minimize potential adverse social impacts. Explicitly addressing resource needs of local communities (e.g., establishing off-site fuelwood plantations) can reduce “leakage” and provide long-term socio-economic incentives, so projects are sustained (Brown et al. 2000). Landscape-level restoration has high potential to achieve both poverty alleviation and biodiversity restoration (Lamb et al. 2005), and so designers should not find this an intractable problem.

Reducing greenhouse gas emissions, alleviating poverty, and restoring biodiversity cannot be optimized simultaneously in most projects. Nonetheless, the pursuit of carbon storage should not be so single-minded as to cause significant social and environmental damage and agendas for social reform and conservation cannot encumber efforts to curb climate warming (Peskett et al. 2007). Concern for these extremes drives calls for universal eligibility rules, although many acknowledge these could hinder innovation and excellence. An alternative is to focus on assessment tools that can be used to inform site selection and project design decisions so that serious negative impacts are avoided and positive impacts promoted and emulated. Project development and monitoring assessment tools are need to guide offset decision making. Madlener et al. (2006) developed a comprehensive, practical framework for both design and monitoring assessment of biosequestration projects that potentially could serve as a basis for further development of assessment tools. Because of the orientation of CDM, research on social impacts and stakeholder processes have thus far received much more attention than have environmental impacts and ecological restoration (e.g., Koellner & Sell 2005). Several partial standards (notably CCBS) could serve as a starting point for environmental assessment tools.

Best Practices for Carbon Estimation, Verification, and Accounting

Unless co-benefits are an explicit factor in project eligibility, the primary and over-riding design factor for carbon offset projects is estimated carbon storage or accumulation. In some ways, carbon storage estimation exerts a reasonable constraint on the scope of restorations pursued as offsets. For example, there may be a critical need to restore wetlands in some landscapes, but the carbon storage benefits may be too marginal to justify these projects as offsets, even with consideration of co-benefits. Some kinds of wetlands emit significant amounts of methane, considered to have “global warming potential” approximately 20× that of CO_2 (Ramaswamy et al. 2001). Estimates for North American wetlands (based on limited data) suggest that most freshwater wetlands have negligible net annual sequestration of CO_2e (Bridgham et al. 2006).

Common approaches to carbon storage estimation can, however, hinder sound forest restoration decision making. Projects developed under some voluntary standards use individual trees planted as the unit for carbon storage estimation (e.g., 0.2 tC offset per tree) because it is appealing to consumers (TCNC 2005). Using this approach, project developers have a perverse incentive to maximize the number of trees planted, while ignoring landform and soil degradation that limit establishment and biomass accumulation. Many standards calculate carbon storage from direct measurement or accumulation tables, potentially avoiding this pitfall. Carbon storage estimation for offset plantations is much more complex than these common approaches, requiring region-specific knowledge of land use and valuation, and uncertain with respect to assumptions based on growth of natural vegetation (Strengers et al. 2008)

More problematic is the practice of basing carbon estimates on project-based, permanent sequestration, which only recognizes carbon held in place in the original form it was first sequestered (Bigsby 2009). There is no room for natural, canopy-removing disturbances, regardless of their importance to the regenerative dynamics of the ecosystem. Accounting adjustments are possible, but they are considered losses for which the buyer may be liable. Large projects may be able to balance losses and gains in sequestration, but small projects are especially vulnerable to losses.

The ecological consequence of managing ecosystems to prevent natural disturbances, such as fire, is well understood to be counterproductive and ultimately futile. Incentives are needed to counteract suppression especially in fire-prone systems; fuel loads potentially build so that when they inevitably burn, greenhouse gas emissions can be orders of magnitude above what would have occurred under a natural fire regime. Some organizations, like the CCX, hold in reserve 20% of all forestry offsets as insurance against these catastrophic losses (Ristino 2008), but since their crediting period is only 15 years, it is unlikely that the limits of this approach will be tested. Another solution is for standards to estimate long-term carbon storage for a project under a natural regime and with a fire after maximum fuel load build-up, for fire-prone systems. The difference in tradable carbon credits could be held in trust by a neutral third party (e.g., escrow). If monitoring shows that the site is being managed according to an approved fire/fuel load plan, the credits would be released over time to the seller, eligible for trading. Developing contractual guidelines for what should be an acceptable fire regime, however, will be increasingly difficult as climate changes and historical data become an irrelevant standard (Fule 2008).

Solving this problem likely requires a fundamental change in accounting practices or to financial institutional structures. Ex-post accounting is an improvement over the ex-ante approach because carbon credits are not offered for sale unless actual carbon storage was verified for a particular time interval. However, disincentive to sound, long-term management remains. An alternative and likely better approach is for all carbon trading to function like a capital market (e.g., carbon banks *in sensu* Kyoto Protocol) (Bigsby 2009). Forest owners would "deposit" carbon in exchange for an annual payment. The carbon bank would aggregate deposits of carbon and use these to meet buyers' demand. Those needing offsets "borrow" carbon by making an annual payment. A key strength of this system is that it provides long-term financial incentives for ecosystem stewardship.

An especially contentious aspect of carbon credit verification is additionality testing because it is an uncertain and subjective assessment. Various approaches have been used for this analysis, including spatial and non-spatial modeling of socio-economic, demographic, and biophysical drivers, for some CDM projects (Garcia-Oliva & Masera 2004). The most stringent protocols for additionality typically evaluate: could the project developer/seller have secured sufficient revenues to support implementation? Is implementation of the project or practice already required under existing regulations or policies? Will implementing this offset project result in a loss of carbon storage elsewhere? This last test addresses a significant problem of "leakage" in biosequestration projects. For example, when AES planted forests across 40,000 small holdings in Guatemala that could not be harvested, local residents were forced to cut other forests for fuelwood (House of Commons Environmental Audit Committee [UK] 2007). Most standards use additionality tests as part of project approval (Kollmus et al. 2008a). The largest voluntary market in the United States, CCX, does not require additionality as a condition of offset projects. Without project-based additionality testing, how much new biosequestration has resulted from the offset transaction is uncertain, as is any collateral habitat destruction.

The restoration ecology literature offers guidance for project goal-setting and planning but intentions and available resources are, in practice, often poorly aligned, with the consequences masked by inadequate monitoring. Consequently, the market price for carbon offsets should be assumed to govern the quality of restorations, not the reverse. Carbon offsets offered for trade with little assurance they are real and additional are likely also the riskiest ecological restorations, because landscape planning, monitoring, and long-term stewardship are vital to both aims. Carbon offset standards lacking these best practices can drive prices artificially low and increase the incidence of offset failure (Rostini 2008).

The Future of Carbon-Trading Schemes

Critics of carbon offsets question whether this strategy is a genuine way to address excess atmospheric carbon dioxide or whether policy should focus solely on direct reductions of emissions (e.g., Swingland 2003). For those who imagine a future for offsets, some believe voluntary markets should become more like mandatory markets and adopt more robust mechanisms to ensure carbon storage is real, additional, and permanent. Until an adequate infrastructure is in place, these assurance mechanisms can cause frustrating delays in project implementation and transaction, leading to calls to loosen regulations and follow the lead of voluntary markets. Still others support carbon offsets, but consider biosequestration unreliable. As the Kyoto Protocol enters Phase 2 of implementation (2008–2012) and some key non-signatory countries (notably the United States, e.g., Wara & Victor 2008) rethink their climate change policies, reforming or refining carbon offset trading schemes is actively being deliberated. What should the future hold for biosequestration, including ecological restorations, as carbon offsets?

Clearly, some ways carbon markets work diminish the chance that ecosystems are actually being restored, running counter to claims by carbon service companies. However, it is reasonable to temper disapproval, given that the current reality of carbon offset markets was mostly created in the past 6 years. Because land conversion has decreased the earth's capacity to store carbon, we need to work to improve the reliability and quality of restorations as carbon offsets. Carbon offsets will mitigate greenhouse gas emissions and result in sustainable ecological restorations only if: (1) co-benefits are an important part of all trading standards, (2) carbon estimation and accounting creates incentives, not disincentives, for long-term stewardship, including critical disturbance events, and (3) comprehensive assessments of additionality are universal.

In addition, research needs to be an integral part of carbon markets. Public policy on carbon markets has greatly outstripped the ecological knowledge needed to support it.

In particular, research focused on solving specific problems related to offsets is needed, including the development of impact assessment tools, predicting and monitoring soil carbon changes, landscape-scale approaches for forest restoration on altered soils and in unpredictable climates. Because the scope of offset projects is global, these research projects are likely best pursued through multinational consortia of scientists. Tonnage fees on carbon credits are a logical funding mechanism to support this research. Tonnage fees on fertilizers provide funds for water quality research in several U.S. states; tonnage fees on crop production have also been used to establish research foundations to address commodity-specific problems in the United States and Canada.

A comprehensive ecological evaluation of existing biosequestration offsets is clearly needed to more identify specific problems that need to be addressed in reforestation projects and to contribute to the larger policy debate about climate mitigation. For example, allowance auctions may have greater potential to support high-quality ecological restoration than does offset trading because the revenues available are not directly connected to estimates of CO_2e sequestered (e.g., Keohane 2009). Given the amount of money at stake, it is not surprising that discourse on carbon market is being shaped nearly entirely by business and economic professionals. But restoring ecosystems that contribute to climate mitigation should not be assumed to be equally possible under various trading schemes, established and proposed. Restoration ecologists have an obligation to be a voice in the fast-changing, interdisciplinary milieu of carbon trading.

Implications for Practice

- The growth of carbon markets is creating unprecedented opportunities for landscape-scale restoration worldwide. However, it is unclear if the market schemes are configured in a way that promotes ecosystem recovery and long-term carbon.
- The market price for carbon credit likely governs the quality of restorations, not the reverse. A variety of reforms are needed to ensure that biosequestration projects deliver real, additional, and permanent removals of carbon dioxide, notably: developing and adopting social and environmental impact assessment tools, changing accounting practices to allow for natural disturbances, universal adoption of strong additionality testing, and supporting critical research through tonnage fees could substantially improve what is accomplished through carbon offsets.
- The evolution of carbon markets, including offsets and allowances, needs to be informed ecological evaluations of established projects and by available published literature and experience from practicing restoration ecologists.

Acknowledgments

Discussions with Cheryl Miller, Minnesota Terrestrial Carbon Sequestration Initiative, contributed to the recommendations forwarded in this paper. Anthony D'Amato, Shelby Flint, and Cheryl Miller provided valuable feedback on early drafts of this paper.

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