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Engaging Western Landowners in Climate Change Mitigation: A Guide to Carbon-Oriented Forest and Range Management and Carbon Market Opportunities

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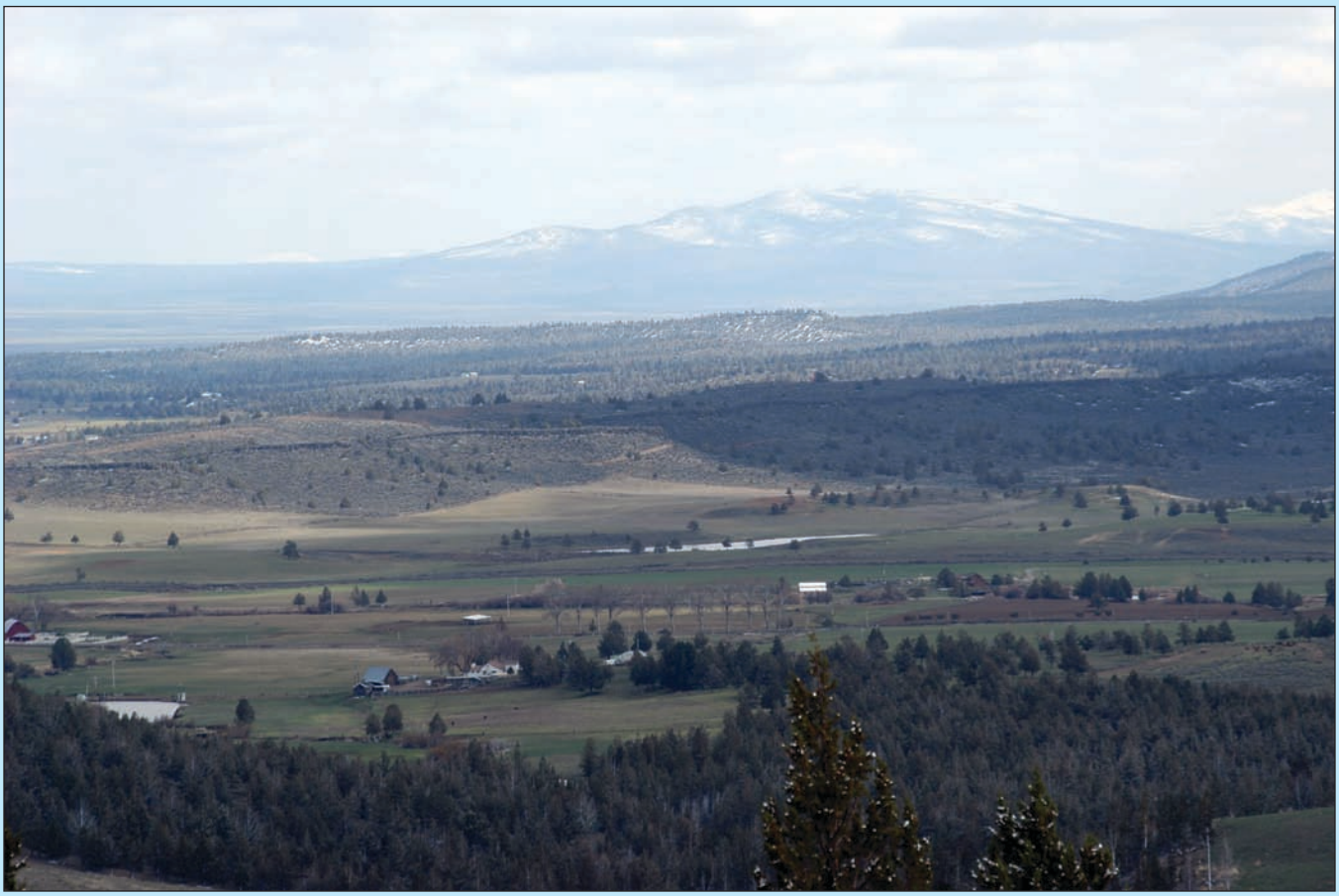

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Abstract

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There are opportunities for forest owners and ranchers to participate in emerging carbon markets and contribute to climate change mitigation through carbon-oriented forest and range management activities. These activities often promote sustainable forestry and ranching and broader conservation goals while having the potential to provide a new income stream for landowners. We describe current carbon market opportunities for landowners, discuss common steps they must typically undergo to take advantage of these opportunities, and address related questions. We also provide a synthesis of the existing scientific literature on how different forest and range management practices are thought to contribute to carbon sequestration, including current debates on this topic. The science regarding forestry and carbon sequestration is more advanced and less controversial than that for range management, and more opportunities exist for forest owners to participate in carbon markets than for ranchers. We describe some of the challenges of including landowners in carbon markets, and issues that will likely need to be addressed to develop relevant policy.

Keywords: Climate change, forest owners, ranchers, land management, carbon sequestration, carbon markets, United States.

Executive Summary

Countries around the world are seeking ways to reduce their emissions of greenhouse gases and greenhouse gas concentrations in the atmosphere to avoid significant and potentially catastrophic environmental change. Forest and range management for carbon sequestration are low-cost, low-technology, relatively easy ways to enhance carbon sequestration and can help mitigate climate change now while additional long-term solutions are developed. Carbon-oriented management of forests and rangelands also offers landowners an opportunity to obtain a new source of income, and commonly has broader ecological and social co-benefits. Interest in emerging carbon markets among landowners and others is growing in the United States. One analysis of the potential for forest and agricultural land management to contribute to climate change mitigation suggests that with greater financial incentives, the carbon sequestration achieved in these lands could be scaled up to offset as much as 30 percent of U.S. emissions for two to three decades. Consequently, many of the policies being developed to reduce greenhouse gas emissions over the next century include opportunities for landowners to be compensated for managing their lands in ways that sequester carbon to offset the emission of these gases by others.

This paper provides an overview of current and emerging opportunities for forest owners and ranchers in the Western United States to contribute to climate change mitigation. Our focus is on land use, land use change, and forestry; we do not address in detail options such as renewable energy generation using biomass or indirect emissions abatement strategies such as substitution of wood products for other building materials. Our purpose is to provide organizations that work with landowners in the American West, natural resource managers, policymakers, and other interested parties, some of the basic information needed to understand and navigate the emerging opportunities for forestry and ranching to contribute to climate change mitigation strategies, and specifically, to facilitate landowner access to emerging carbon markets through land management that sequesters carbon in plants and soil. We focus on carbon markets because, as of this writing, there are few nonmarket opportunities that reward landowners specifically for carbon-oriented management in the United States.

This paper concludes with a discussion of what landowners can expect when pursuing market opportunities, and addresses frequently asked questions. The policy and market context for forestry and range offsets in the United States is shifting rapidly; our information is current as of October 2009. Following is a summary of some of the key information contained in this document.

The Policy and Market Context

As of this writing, there is no comprehensive federal mandate for reducing greenhouse gas emissions in the United States. More than 10 cap-and-trade bills have been proposed by members of Congress. Only one of these bills has passed through the U.S. House of Representatives (the American Clean Energy and Security Act) and none have yet passed the Senate. In September 2009, a new bill (the Clean Energy Jobs and American Power Act) was introduced to the Senate that builds on the House bill and lays the groundwork for negotiation. The Senate bill states that forestry and range projects should be considered as a source of carbon offsets in any national cap-and-trade system. In the absence of federal mandates, most greenhouse gas regulation in the United States to date has been pursued through the actions of individual states and through the formation of regional agreements between groups of states.

There are two major types of carbon markets: compliance markets and voluntary markets. Compliance markets are based on government regulations that mandate emissions reductions from particular industries or polluters. The most common approach to creating a compliance market is to implement a cap-and-trade system. Voluntary carbon markets occur in the absence of, or alongside, government mandates to control emissions, and participation is purely voluntary. Today the only compliance market that operates in the United States is the cap-and-trade system associated with the Regional Greenhouse Gas Initiative. Only landowners who reside in the 10 Eastern States that are party to the initiative are eligible to participate in this market as offsetters. Elsewhere, many companies and individuals are pursuing voluntary greenhouse gas emissions reductions by participating in voluntary carbon markets. In the United States, there are two kinds of voluntary carbon markets: the Chicago Climate Exchange (CCX), and over-the-counter (OTC) transactions.

To ensure the integrity and reliability of carbon markets, a number of standards, rules, and institutions have been established to help demonstrate that a forest or range management activity truly increases carbon sequestration and provides real, measurable, offsets over time. A number of entities have developed carbon offset standards for forestry, and to a lesser extent, rangeland management in the United States. Each standard commonly includes several protocols describing the permissible types of activities and the specific requirements associated with the standard. Landowners wishing to participate in a carbon market must decide which standard to adopt and comply with. In general, compliance markets and the CCX have set standards, whereas credits traded in OTC markets may comply with a range of different standards or none at all. Credits verified to a well-known third-party standard

usually transact at higher prices, meaning it may be cost-effective for landowners to undergo the process of verification and registration. Compliance with a more rigorous standard is not a guarantee that the price for the resulting offset credits will be higher, however. Registries are another key component of a viable carbon market because they provide a transparent and reliable way of tracking the sale and use of pollution allowances and carbon credits to prevent fraud and double counting. Registries also have standards for participation that must be rigorous and transparent to be credible.

Landowners who wish to participate in a carbon market must typically develop an offset project plan, undergo verification of offset activities by an independent third party, and obtain certification that their land is being managed in a sustainable manner before the project can be placed on a registry and carbon offset credits issued. Once credits have been issued and registered, they may be sold through existing exchange platforms with transparent prices, or they may be sold in OTC transactions to other buyers through private agreements. Offset credit prices in OTC transactions have generally been higher than those from the Chicago Climate Exchange.

Forest and Range Management for Carbon Sequestration

Landowners who are interested in participating in carbon markets can benefit from understanding the science behind forest and range management practices that help sequester carbon. It is also important that landowners understand which practices are recognized as qualifying carbon offset activities in existing markets and registries. Forest carbon projects are primarily concerned with carbon storage in trees and wood products, whereas rangeland carbon projects focus on carbon storage in soils. The current body of research into how forests—and trees in particular—cycle carbon is broader and more robust than the research pertaining to rangeland carbon cycling, and the evaluation of offsets from soil carbon is somewhat more contentious than from other carbon pools such as live plant biomass.

Most forestry offset standards in the United States are outcome-based, relying on carbon inventories to measure changes in forest carbon over time. Consequently, landowners have the leeway to choose the forest management practices that are best suited to their circumstances. Offsets from three general categories of forest management are eligible in U.S. carbon markets: afforestation and reforestation, avoided deforestation, and improved forest management. Afforestation is the term used for the establishment of forests on land that has not been forested for a long time, or never was (e.g., agricultural land). Reforestation involves reestablishing forests on land where forests were recently removed or destroyed (e.g. land severely

affected by forest fire). Planting new forests is a relatively straightforward way to sequester carbon and is the simplest carbon sequestration activity to account for in forest carbon offset programs.

Deforestation occurs when forested landscapes are converted to other land uses (e.g., agriculture, development). It typically involves a dramatic release of carbon to the atmosphere, even if wood products are produced in the process. Unsustainable timber harvesting can also lead to deforestation and forest degradation. Although forest clearing and land conversion represent a straightforward loss of carbon, the methods used to estimate carbon losses that could be avoided by preventing them are complicated and contentious. Thus, a major barrier to accepting avoided deforestation offset projects in the United States has been the difficulty of estimating reliably the real threat of future forest conversion in specific places. Another barrier is the risk of leakage—when the carbon sequestration or emissions reductions achieved by offsetting activities result in increased carbon emissions in another form or location. The challenges presented by quantifying and verifying offsets from avoided deforestation may largely account for its limited use as a source of offsets to date.

Several forest management practices can increase carbon sequestration and storage in forests through improved forest management. These include extending harvest rotation intervals, partial harvest and reduced utilization practices, and reducing dead biomass removal from forests. Fertilization may provide an opportunity for net carbon gains, but the overall carbon balance may vary dramatically between forests. Although more research is emerging on the issue, wildfire mitigation treatments such as thinning and prescribed burning appear unlikely to present clear carbon benefits.

The science is inconclusive about how range management practices such as rotational versus continuous grazing, low versus high stocking rates, erosion control, invasive species control, and adding organic amendments to soil affect carbon sequestration and storage. However, revegetating bare ground and employing sustainable grazing practices that maximize plant productivity over time can potentially lead to higher inputs of carbon to soils, and increase carbon storage over time. Allowing woody encroachment can also lead to net carbon gains in some circumstances, although these gains may place stored carbon at higher risk to wildfire loss. Range management practices unlikely to have net carbon benefits include the use of prescribed fire and irrigation. Nitrogen additions (synthetic or through nitrogen-fixing plants) currently appear to provide no clear carbon benefits.

All of the offset standards and trading programs that exist in the United States today allow afforestation and reforestation projects. Most allow improved forest

management projects, and about half allow avoided deforestation projects. In contrast, only a few allow offsets from rangeland management. Offset standards for rangeland management commonly require landowners to follow specific management practices believed to increase carbon sequestration that are outlined by the relevant protocols.

We conclude by providing guidance to landowners regarding which offset program they might choose depending on the characteristics of their properties, land use restrictions they may encounter, how managing for carbon might affect timber-oriented management goals, the timing and sale of carbon credits, the costs of market participation, and other benefits and opportunities associated with managing for carbon. We hope it provides timely and informative coverage of many of the issues and opportunities western landowners may encounter when considering managing their forests and rangelands for climate change mitigation.

Acronyms

AFOLU	agriculture, forestry and other land uses
CCB	climate, community and biodiversity (standard)
CO_2	carbon dioxide
EPA	Environmental Protection Agency
GHG	greenhouse gas
LULUCF	land-use, land-use change and forestry
NRCS	Natural Resource Conservation Service
OTC	over the counter
REDD	reduced emissions from deforestation and forest degradation
tCO_2e	metric tonnes of carbon dioxide equivalent
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Voluntary Carbon Standard

Relevant Emissions Trading Schemes and Components for the United States:

CAR	Climate Action Reserve
CCAR	California Climate Action Registry
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
JI	Joint Implementation
MGGA	Midwestern Greenhouse Gas Accord
RGGI	Regional Greenhouse Gas Initiative
WCI	Western Climate Initiative

Contents

1 **Introduction**

3 **The Carbon Cycle**

6 **The Policy and Market Context**

6 Greenhouse Gas Emissions Policies in the United States

10 Current Carbon Market Opportunities for Biological Carbon Sequestration

16 **Common Steps and Requirements for Pursuing Carbon Offset Projects**

16 Major Players in Carbon Markets

18 Common Project Components

22 Third-Party Verification, Monitoring, and Sustainability Certification

22 Registering and Issuing Offset Credits

22 Sale of Credits

23 **Forest and Range Management and Carbon Sequestration**

24 Our Current Scientific Understanding of Forest and Rangeland Carbon Cycling

25 **Forestry**

26 Management Practices That Encourage Carbon Sequestration

34 Management Practices With Unclear or Unlikely Carbon Benefits

39 Timber Harvesting and Carbon Storage in Wood Products

41 **General Conclusions on Forest Carbon Sequestration**

41 **Rangeland Management**

42 Grazing Management

45 Plant Community Management

48 Soil Conservation and Amendments

51 General Conclusions on Rangeland Carbon Sequestration

52 **Common Questions About Market Participation**

52 Which Offset Program Should a Landowner or Project Developer Choose?

54 How Long Does it Take to Sequester Enough Carbon to Register and Sell Carbon Credits?

54 At What Point in This Process Will Payments for Offset Activities Occur?

55 Are There Any Time Constraints on Selling Carbon Credits?

55 How Much Does Third-Party Verification and Posting With a Registry Cost?

55 Will Managing a Forest for Carbon Sequestration Affect Timber Yields?

56 Will Following Carbon-Oriented Management Practices Reduce Income?

56 Do Carbon Markets Provide an Opportunity for Financing Restoration Projects?

57 What Does the Future of the Crediting Program Look Like?

57 Are Forestry or Range Projects on Public Lands Eligible for Offset Credits in Existing Carbon Markets?

58 Is Participation in Carbon Markets the Only Way to Financially Benefit From Carbon-Oriented Land Management, or Are There Other Options?

59 **Conclusions**

60 **Acknowledgments**

60 **Further Reading and Resources**

60 Forestry References and Resources

61 Forest References About Wildfire Mitigation and Carbon Balance

62 Rangeland References and Resources

62 **English Equivalents**

62 **Glossary**

67 **References**

77 **Appendix: Guidance and Standards for Offset Projects**

Introduction

> "A viable carbon offsets market—one that rewards farmers, ranchers and forest landowners for stewardship activities—has the potential to play a very important role in helping America address climate change while also providing a possible new source of revenue for landowners."
>
> —U.S. Secretary of Agriculture Tom Vilsack[1]

The scientific consensus surrounding the relation between **greenhouse gas**[2] (GHG) emissions and global climate change has indicated a clear need for countries around the world to find new ways to reduce their emissions of these gases and their concentrations in the atmosphere to avoid significant and potentially catastrophic environmental changes. Land management for **carbon sequestration** is one of many opportunities available to countries seeking to reduce their net emissions of GHGs.

The purpose of this booklet is to provide organizations that work with landowners in the American West, natural resource managers, policymakers, and other interested parties, some of the basic information needed to understand and navigate the emerging opportunities for forestry and ranching to contribute to climate change mitigation strategies, and specifically, to facilitate landowner access to emerging carbon markets through land management that sequesters carbon in plants and soil. We focus on carbon markets because, as of this writing, there are few nonmarket opportunities that reward landowners specifically for **carbon-oriented management** in the United States. Our geographic focus is the Western United States.

Carbon-oriented management of forests and rangelands may offer landowners the opportunity to obtain a new source of income while simultaneously helping to mitigate climate change. Many of the policies being developed to reduce GHG emissions over the next century through regional, national, and international agreements are being pursued using market-based mechanisms. These policies often include opportunities for landowners to be compensated for managing their lands in ways that sequester carbon and thereby **offset** the emission of GHGs by others. Carbon-oriented management practices not only offer landowners the opportunity for financial gains, but also commonly have broader ecological benefits such as enhancing wildlife habitat, improving soil quality, increasing water storage and filtration, and conserving biodiversity. Fifty-six percent of the forest lands in the

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[1] From a subscription Web site http://www.eenews.net/climatewire/2009/06/12/1.

[2] Words in boldfaced type are defined in the "Glossary" at the end of this document.

United States are privately owned, and 35 percent are under nonindustrial private forest ownership (Butler 2008); 61 percent of the rangelands are privately owned (Lubowski et al. 2006). Engaging these landowners in carbon-oriented management can contribute to global climate change mitigation. For landowners to participate, however, it is important that they be provided the necessary information to do so. Landowner participation will also be encouraged where these opportunities involve financial rewards that can help prevent the conversion of forests and rangelands to developed uses or compensate for the opportunity costs associated with shifting away from non-carbon-oriented management.

Carbon-oriented forestry and ranching provide low-cost, low-tech, relatively easy ways to enhance carbon sequestration relative to other options. These opportunities can contribute to climate change mitigation now while additional, longer term solutions to climate change mitigation are developed. The management of forest and range environments for carbon sequestration may also promote a variety of social and environmental benefits (commonly referred to as co-benefits) that other climate change mitigation strategies do not typically include.

The potential to simultaneously improve environmental conditions and obtain financial benefits has generated significant interest in emerging carbon markets from landowners and others. Together, forests and farmlands sequester a volume of carbon every year equivalent to 10 to 12 percent of all annual U.S. GHG emissions (Murray et al. 2005, Woodbury et al. 2007). With greater financial incentives that could come with a regulated market including offsets, the carbon sequestration achieved in these lands could be scaled up to offset as much as 30 percent of U.S. emissions for two to three decades (Murray et al. 2005). The financial up side to many of these practices is that they offer opportunities to reduce or offset emissions often at a lower cost than many other strategies currently available (e.g., Enkvist et al. 2007).

This document provides an overview of carbon-related opportunities for landowners, along with some of the concepts and challenges that may be encountered when managing forests or rangelands for carbon sequestration and compensation through carbon markets. Our discussion focuses on offset opportunities associated with forest and range management (commonly referred to along with other agricultural land uses as land use, land-use change, and forestry or **LULUCF**); we say little about opportunities associated with farming and renewable energy using **biomass** fuels. Although many of the specific laws, policies, and programs pertaining to carbon markets in the United States are currently being developed and revised, they share common principles and elements that are discussed here.

Although we have made an effort to focus on the major elements of various emerging market opportunities that are less likely to change, these elements as well as many specific details of each program discussed may change in the near future. The details and general elements discussed for each program in this document are current as of December 2009.

This document has several sections. First, we give a brief overview of the science of climate change and the global carbon cycle to provide background for later sections. This background discussion is followed by a review of current U.S. government regulations and policies that have been developed to address global climate change. Next, we give an introduction to carbon markets in the United States and current opportunities for landowners to participate in them through forestry and range offset projects. We then provide a synthesis of scientific research about how different forest and range management practices that landowners could potentially adopt affect carbon uptake and prevent carbon release from forests and rangelands, and the potential for forest and range management to increase carbon sequestration. We conclude with a discussion of what landowners can expect when pursuing offset opportunities, and address frequently asked questions. We also include a brief list of resources available for further information on the topics covered in this document.

The Carbon Cycle

The global carbon cycle plays an important role in the science of climate change. A basic familiarity with this cycle and how it operates can help increase understanding of why carbon markets are currently being pursued to combat climate change.

On time scales ranging from seconds to centuries, carbon is exchanged between the atmosphere and the surface of the Earth (see fig. 1). Carbon enters terrestrial environments through the process of photosynthesis, in which plants harness energy from sunlight and convert atmospheric carbon dioxide (CO_2) into useful plant compounds that allow these ecosystems to grow and thrive. Carbon can be stored over long periods in a variety of places, or pools, within an ecosystem—including plant tissues such as live wood, woody debris, and soil. Carbon enters soils through the addition of plant materials above ground (litterfall) and below ground through root activities, death, and decomposition. Carbon usually transforms and moves between different pools and is eventually released back to the atmosphere. Carbon leaves terrestrial ecosystems primarily through plant respiration and the decay of dead plant and soil matter, returning to the atmosphere as CO_2.

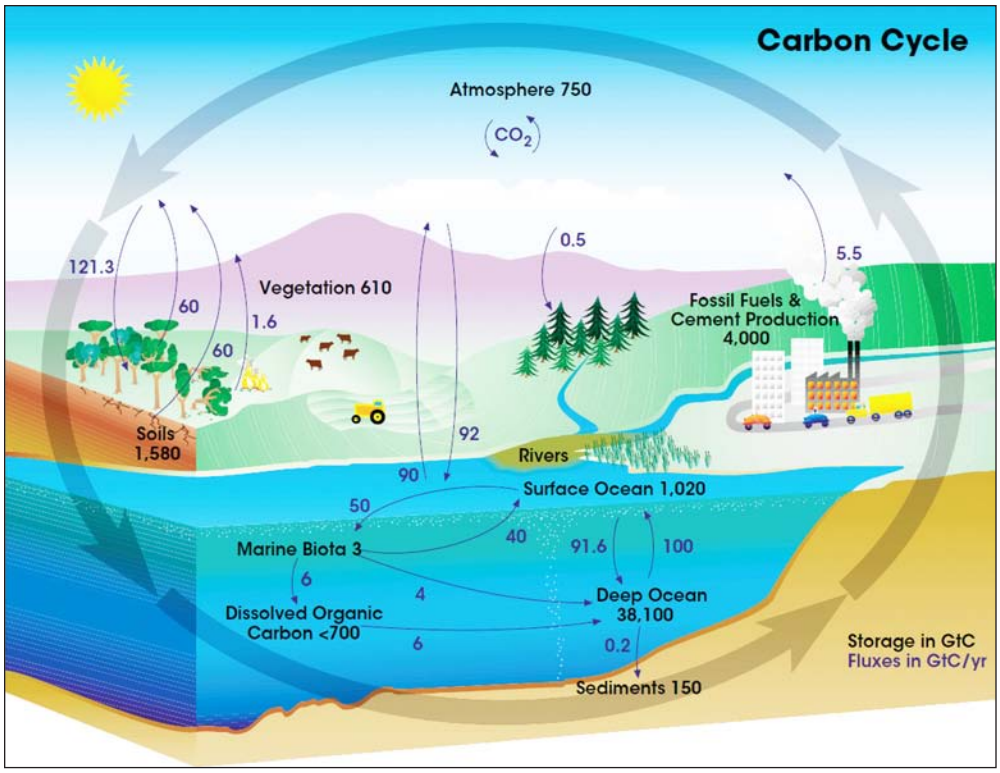

Figure 1—This diagram portrays the major pools and fluxes in the Earth's carbon cycle, as estimated in 2004. The numbers next to words indicate the amount of carbon stored in each pool in billions of metric tonnes (or gigatonnes, GtC). The numbers next to arrows show much carbon moves between each of these pools every year. The movement of carbon into plants and soils each year roughly equals the amount of carbon returned to the atmosphere. Carbon sequestration entails managing forests and rangelands to increase carbon uptake and reduce carbon releases from plants and soils to increase the total amount of carbon stored in them, and to reduce the amount in the atmosphere. Source: NASA, http://earthobservatory.nasa.gov/Features/CarbonCycle/carbon_cycle4.php.

The basic biological processes that increase carbon uptake and storage in forests and rangelands involve enhancing plant growth, minimizing plant and soil respiration, and preserving biologically stored carbon in plants and soils.

A growing body of scientific research is improving our understanding of the specific mechanisms that govern how the natural environment captures carbon from the atmosphere and how it releases it back to the atmosphere over time. One thing is clear: the forests and rangelands of the world contain a significant proportion of the total carbon stored in the world's terrestrial environments, and large-scale changes in the carbon balance of these ecosystems can affect atmospheric GHG concentrations and climate change for the entire planet. Earth's terrestrial ecosystems contain more than three times as much carbon in plants and soils than is currently found in the atmosphere, and about half of this carbon is stored in forest ecosystems (IPCC 2007).

The basic biological processes that increase carbon uptake and storage in forests and rangelands involve enhancing plant growth, minimizing plant and soil respiration, and preserving biologically stored carbon in plants and soils.

The primary control on the carbon balance in terrestrial environments is the disturbance regime that governs the release of carbon from plants and soils and initiates a new cycle of ecosystem recovery (Chapin et al. 2002). The loss of carbon from plants occurs through plant breakdown and decomposition following disturbances such as fire, windthrow, pest and pathogen infections, water shortages, and mechanical disturbances such as tree harvesting and removal. Significant disturbances may expose litter and soils in these environments to increased levels of decay and decomposition, which can represent a significant loss of carbon from an ecosystem. Apart from the natural decomposition of soil organic matter, carbon in intact soil may be exposed and lost through mechanical disturbances such as plowing, or moved offsite through erosion. Following disturbance, it can take decades for carbon storage in forest and rangeland environments to return to predisturbance levels.

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The potential for carbon sequestration in the trees and soils of forest and rangeland environments has been recognized by policymakers, leading to the inclusion of select forest and range management activities in many GHG reduction programs. The guiding principle for including land management in climate change mitigation strategies and in carbon markets is that land should be managed in a way that increases its rate of, and capacity for, carbon capture, and decreases the rate at which carbon is returned to the atmosphere from land conversion, land-use intensification, or other human or natural disturbances.

What is Carbon Sequestration?

Carbon sequestration refers to the accumulation of carbon in an ecosystem over time. The amount of carbon held in an ecosystem is a product of how much carbon enters the system and how much leaves it. When carbon inputs to an ecosystem outpace carbon releases from that ecosystem over time, carbon sequestration occurs. The potential to increase the amount of carbon held in forest and rangeland ecosystems or to minimize losses of existing carbon offer landowners an opportunity to manage their lands in ways that contribute to climate change mitigation by encouraging carbon sequestration. This can be done by increasing carbon inputs and uptake, decreasing or preventing carbon releases, or both. In some circumstances, carbon sequestration through biological processes (such as plant growth) is referred to as biological carbon sequestration to distinguish it from the capture and storage of CO_2 emissions in geological formations.

Hannah Gosnell

The Policy and Market Context

Greenhouse Gas Emissions Policies in the United States

In 1992, the United States ratified the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC served as the framework for negotiating international agreements to reduce GHG emissions and led to the development of the Kyoto Protocol. Since the ratification of the UNFCCC, the United States has yet to sign on to any further international agreements that require emissions reductions over time. The next round of international GHG emissions regulation negotiations through the United Nations is scheduled to occur in December 2009 in Copenhagen, Denmark. This meeting is designed to lay out the future of international climate change policy after the expiration of the Kyoto Protocol in 2012.

U.S. federal policies—

As of this writing, there is no comprehensive federal mandate for reducing GHG emissions in the United States, although a voluntary GHG accounting registry, known as the 1605(b) registry, has been maintained since 1992 and was recently updated by the Department of Energy. More than 10 cap-and-trade bills had been proposed by members of Congress as of December 2009. In contrast to the current approach in the European Union, many of these bills explicitly mention a role for offsets from land use. Only one of these bills had passed through the U.S. House

The Kyoto Protocol

The first global attempt to regulate greenhouse gas emissions (GHG) was embodied by the Kyoto Protocol. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was established to accomplish "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, Article 2).* In 1997, an international protocol was designed at a United Nations meeting in Kyoto, Japan, that established mechanisms for reducing GHG emissions to meet UNFCCC goals. As of February 2009, the Kyoto Protocol had been ratified by 184 parties around the world. Although the United States participated in the design of the Kyoto Protocol and was one of the initial signatories, the treaty was never ratified by the U.S. Senate and thus did not become a binding agreement for the United States. Kyoto established an international **cap-and-trade** program among signatories that operates from 2008 to 2012. The program has two carbon offset mechanisms known as the Clean Development Mechanism (CDM) and Joint Implementation (JI) that govern the crediting of offset projects in developing and developed countries, respectively. The CDM recognizes some aspects of forestry and Joint Implementation recognizes some aspects of both forestry and ranching as sources of carbon offsets. However, because the U.S. government chose not to ratify the Kyoto Protocol, landowners in the United States cannot participate in either program. The Kyoto Protocol has prompted some signatory countries to develop regulations that control GHG emissions nationally to meet the emissions reduction targets stipulated by the protocol. A prominent example is the European Union **Emissions Trading Scheme**. This scheme does not currently accept offsets from forestry or ranching, however.

* Available online at http://unfccc.int/essential_background/convention/background/items/1353.php.

of Representatives (the American Clean Energy and Security Act[3]) and none have yet passed the Senate. In September 2009. a new bill (the Clean Energy Jobs and and American Power Act) was introduced in the Senate that builds on the House bill and lays the groundwork for negotiation. The Senate bill states that forestry and range projects should be considered as a source of carbon offsets in any national cap-and-trade system. Although President Obama has expressed the desire to have legislation approved by both houses of Congress prior to the December 2009 meeting in Copenhagen to negotiate the followup treaty to the Kyoto Protocol, he will instead participate in the meeting with a national emissions reduction target but no completed legislation.

[3] The American Clean Energy and Security Act (H.R. 2454) is also commonly referred to as ACES or Waxman-Markey. Complete text of the version of the bill passed by the House is available at http://www.opencongress.org/bill/111-h2454/show.

Some initial steps have been taken by the government to promote the inclusion of forest and ranch owners in carbon markets. Section 2709 of the 2008 Farm Bill (enacted in June 2008) calls for the Secretary of Agriculture to give priority to the establishment of guidelines related to farmer, rancher, and forest landowner participation in carbon markets (Food, Conservation, and Energy Act of 2008). These guidelines include the development and implementation of protocols for measuring, reporting, and registering **carbon offset credits**. In December 2008, the U.S. Department of Agriculture announced the formation of a new Office of Ecosystem Services and Markets. This office is expected to play a significant role in the development of federal policy relating to natural resources and carbon markets.

What Are Offsets?

Carbon offsets refer to activities that either reduce emissions or increase sequestration but are not required under a regulated or voluntary cap. These offsets are provided by landowners and other entities. Offsets are intended to counterbalance the release of greenhouse gases (GHGs) from emitters. Offset projects will commonly quantify the emissions reductions or sequestration associated with their project as individual credits (each typically representing 1 metric tonne of carbon dioxide (CO_2) equivalent offset, or 1 tCO_2e) that may then be bought and sold in carbon markets. Individuals or organizations that wish to offset their own GHG emissions can do so by purchasing and retiring offset credits. Retirement of an offset credit is essentially the permanent removal of the credit from being traded in the market, an action that would be carried out by whichever registry was listing the offset at the request of the credit's owner. If an offset credit is not retired by its purchaser, it may continue to be bought and sold by others in a carbon market, similar in principle to other types of markets and exchanges. The inclusion of offsets in carbon markets allows a broader and more diverse range of participants (such as private forest owners and ranchers) in carbon markets, and when used in cap-and-trade programs, enables the market to reward innovative and cost-effective emissions reduction practices employed by entities not included in the cap, such as forest and range landowners. The inclusion of offsets in the most recent climate change legislation passed by the House of Representatives has been estimated to bring the cost of emissions permits down by as much as 69 percent (Congressional Budget Office 2009).

State and regional actions—

In the absence of federal mandates, most GHG regulation to date has been pursued through the actions of individual states and through the formation of regional agreements between groups of states. Many states throughout the country have implemented renewable energy standards and passed resolutions establishing emissions targets to be met in the future, but few have yet to pass binding legislation regulating the emissions of GHGs. In 1997, Oregon passed the first regulation controlling CO_2 emissions in the United States, requiring new powerplants to spend a set amount of money per ton of CO_2 emissions for the development of carbon offsets. Ten Northeastern States launched the Regional GHG Initiative (RGGI) in 2008 to regulate emissions of CO_2 (the only GHG included in this program) from major powerplants using a cap-and-trade system. Also in 2008, California became the first state to pass legislation supporting the implementation of a market-based strategy covering emissions of all GHGs by passing Assembly Bill 32, which calls for creating a statewide emissions reduction program to meet 1990 emissions levels by 2020, and for launching a cap-and-trade system by 2012. Both the Oregon CO_2 Standard and RGGI are smaller in scope as well as in the number of GHGs being regulated compared to the cap-and-trade bills proposed in Congress, adopted by California AB 32, and being discussed through other regional agreements.

Elsewhere in the United States, regulations are still under development. The governors of seven Midwestern States signed the Midwestern Greenhouse Gas Reduction Accord (MGGA) in November 2007, which calls for the establishment of a regional emissions trading program to reduce GHG emissions. The rules for the program are expected to be finalized in 2010, and although the use of offsets has been included in the program design, the specific types of eligible activities have not yet been disclosed. The Western Climate Initiative (WCI) is a regional agreement that was signed by the governors of seven Western States (Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington) and the premiers of four Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec) in 2007. Six other U.S. states (Alaska, Colorado, Idaho, Kansas, Nevada, and Wyoming), six Mexican states (Baja California, Chihuahua, Coahuila, Nuevo Leon, Sonora, and Tamaulipas), and two Canadian provinces (Nova Scotia and Saskatchewan) have joined the WCI as "observers." The WCI includes a cap-and-trade program planned to launch in 2012. There has been significant collaboration between state governments, industry, tribes, environmental groups, and other stakeholders in the development of this program, including the design of an offset

program. Although the specific details of which activities will be eligible for generating carbon credits had not been announced as of December 2009, the program is being designed with private landowner participation as offset providers in mind.

Current Carbon Market Opportunities for Biological Carbon Sequestration

A carbon market is a tool designed to place an economic value on the social and environmental costs of GHG pollution and the benefits of emissions reduction activities. The market functions by translating emissions into exchangeable permits. There are two major types of carbon markets: compliance markets and voluntary markets. Compliance markets are based on government regulations that mandate emissions reductions from particular industries or polluters. The most common approach to creating a compliance market is to implement a cap-and-trade system. Voluntary carbon markets occur in the absence or alongside government mandates to control emissions, and participation is purely voluntary.

This section discusses both the compliance and voluntary carbon markets that are operating in the United States and associated opportunities for biological carbon sequestration through forest and range management projects. Note that as the regulatory environment, carbon markets, and associated opportunities for landowners are changing so rapidly, we only present basic concepts and current opportunities here and omit finer details.

Compliance markets—

Although other market-based systems have been experimented with in the past, the compliance markets that exist in the United States and around the world today take the form of cap-and-trade systems. In a cap-and-trade system, regulators set a cap on the total quantity of emissions allowed from the regulated polluters within a given industry or sector (e.g., powerplants, manufacturing, transportation). The cap creates a limited supply of pollution permits. For every ton of emissions allowed within the cap, a permit called an **allowance** is distributed through an auction or given for free to the polluting companies in each regulated sector. The polluters are then required to surrender one allowance for every ton of CO_2 (or equivalent amount of other more potent GHGs, **tCO_2e**) they produce. The allowances are exchangeable among the polluting companies, and companies that can reduce their own emissions below mandated levels can sell their surplus allowances. This trading feature enables the market to find and reward the most cost-effective ways to reduce overall emissions. The cap is the backbone of the cap-and-trade system. A strict cap ensures high demand for pollution allowances, and increases the value of innovation in emissions reduction strategies by rewarding companies that can

effectively reduce their emissions. The cap is typically reduced over time to further cut overall emissions from the regulated sectors in accordance with environmental goals.

Compliance markets are commonly based on the supply and demand of two interchangeable types of pollution permits: allowances and offset credits.[4] Allowances are issued to polluting industries by a regulatory agency. Offset credits are issued to persons or organizations who perform offset activities by a regulatory agency or by an organization in charge of managing GHG **registries**. Across the market, companies that can reduce their emissions cheaply and effectively will hold extra allowances that they can then sell to companies that have not been able to meet their emission reduction requirements. Companies in need of allowances (because it is not feasible or cost-effective for them to reduce emissions in-house) may purchase emissions allowances from other companies or may purchase offset credits. The net effect of this market activity is that those companies that reduce their emissions are rewarded by their ability to sell allowances while those that maintain or increase their emissions foot the bill. The underlying rationale behind a cap-and-trade system is that polluting companies can determine how and where to reduce their emissions to comply with the regulations more efficiently than would be possible through the decisionmaking process of a regulatory agency. Thus, the cap-and-trade approach prioritizes cost-effective emissions reductions to meet the mandatory cap and allows the regulated industries to make their own business decisions about whether they should reduce emissions internally or purchase allowances or credits from other market participants. This type of a cap-and-trade system has been previously implemented by the EPA to reduce emissions of sulfur dioxide from powerplants as part of the Acid Rain Program, which began in 1990 and continues to operate today. The Acid Rain Program is commonly considered to be the strongest success story for a cap-and-trade system in the United States. The EPA has also implemented a variety of other types of emissions trading programs beginning in the 1970s with varying levels of success. A review of some of these programs can be found in publications by Tietenberg et al. (1999) and Ellerman et al. (2003).

The cap-and-trade approach prioritizes cost-effective emissions reductions to meet the mandatory cap and allows the regulated industries to make their own business decisions about whether they should reduce emissions internally or purchase allowances or credits from other market participants.

Confronting global climate change means reducing GHG emissions to the atmosphere, and simultaneously increasing the removal of these gases from the atmosphere to reduce GHG concentrations. It is important to recognize that taking a ton of CO_2 out of the atmosphere by altering forest or range management

[4] It is important to note, however, that offsets are not a prerequisite component of emissions trading schemes, but are generally included to help reduce the cost of emissions permits compared to the use of allowances alone.

Hannah Gosnell

(for example) is considered to be just as effective at affecting atmospheric greenhouse gas concentrations as a ton of emissions reduction on the part of a polluter. Although the focus of the cap-and-trade system is primarily on reducing GHG emissions by major polluters, many scientists and economists have argued that restricting the carbon market to major emitters alone (and not allowing offsets) will significantly limit the number of cost-effective ways to reduce GHG concentrations. In some circumstances, the management practices of landowners may be more efficient at mitigating climate change than the emissions reduction practices of polluting industries. Carbon-oriented management of forest and rangeland ecosystems can also have many environmental and social co-benefits such as restoration of degraded wildlife habitat, enhanced water quality, and diversified income streams for natural-resource-based communities.

Existing compliance markets are generally not restricted to emitters alone and will also allow carbon offsets. There are a number of different types of offsets, including renewable energy projects, methane capture projects from landfills, and terrestrial carbon sequestration projects associated with farms, forests, and rangeland management. Different systems allow different types of offsets and not all allow forestry and range projects. Today the only compliance market that operates in the United States is the cap-and-trade system associated with the Regional Greenhouse Gas Initiative. The RGGI allows for the use of offsets but currently limits offsets associated with forestry to afforestation and reforestation (described

in the next section). It does not allow range management offsets. Only landowners who reside in the 10 Eastern States that are party to RGGI are eligible to participate in this market. Which types of offsets to include is currently a subject of debate among developers of California climate legislation, the WCI, and the MGGA, as well as among legislators devising a federal program. The creation of state, regional, and national mandatory cap-and-trade systems is expected to significantly increase the demand for carbon credits from offset projects and will likely provide more opportunities for landowners to be compensated for carbon sequestration activities.

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Voluntary markets—

In the absence of a mandated cap-and-trade system, many companies and individuals have taken the initiative to pursue voluntary GHG emissions reductions by participating in voluntary carbon markets. They are most often motivated by a sense of corporate or social responsibility, and by public relations incentives (Hamilton et al. 2009). In the United States, there are two kinds of voluntary carbon markets: the Chicago Climate Exchange (CCX), and over-the-counter (OTC) transactions.[5]

The CCX has been open since 2003 and offers opportunities for rangeland and forest management offset projects throughout the United States. The CCX is a legally binding cap-and-trade program composed of member companies and organizations that enter into the program voluntarily and trade emissions allowances and credits from offsetters according to an emissions cap set individually for each participant by the CCX. Offset participants follow CCX protocols and can register and sell their carbon credits (known as Carbon Financial Instruments or CFIs) through the CCX to other members; CFIs may also be sold over the counter through private contracts with any private or public entity. More information about CCX can be found at http://www.chicagoclimatex.com/.

Over-the-counter transactions involve the sale of offsets to companies or individuals through private contracts between an offset provider and an offset buyer. The purchasers have a variety of motivations. Some may be individuals or employers who wish to offset emissions from personal or business travel. Others may be interested in marketing their company or product as carbon neutral or carbon friendly. The diversity of buyers and their interests in OTC transactions have made this voluntary market a new and potentially valuable niche market for offset providers. Because OTC transactions are based on private contracts, the contract terms—such as the types of offset activities allowed, verification

[5] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

and documentation requirements, and the price of offsets—are negotiable. The exchange of voluntary offsets through OTC transactions are not currently coordinated or regulated by any centralized market exchange or institution.

Offset standards, registries, and pricing—
To ensure the integrity and reliability of carbon markets, a number of standards, rules, and institutions have been established, in part because it is important to demonstrate that a land management activity truly increases carbon sequestration and provides real, measurable, offsets over time. Carbon offset activities typically involve some type of verification and certification prior to being registered and traded as credits. A clear set of standards is associated with the verification or certification scheme so that the buyer of offset credits understands the quality of the credit being purchased. These procedures are designed to prevent fraudulent or inaccurate offset calculations and sales. Without transparent and rigorous standards and accounting methods, knowledge about and confidence in carbon markets will suffer.

***Offset standards*—**Standards serve as a way to certify that an offset activity is credible. A number of entities have developed carbon offset standards for forestry, and to a lesser extent, range projects. Each standard commonly includes several protocols describing the permissible types of activities and the specific accounting procedures used to calculate the amount of carbon sequestration. The CCX, for example, has protocols for rangeland soil carbon, forest carbon, and agricultural soil carbon, among others. A landowner wishing to participate in a carbon market will have to decide which standard to adopt and comply with. In general, compliance markets and the CCX have set standards, whereas credits traded in OTC markets may comply with a range of different standards, or none at all. In 2008, a survey of carbon market participants suggested that as much as 96 percent of all credits (not just forest or range-based credits) traded on voluntary carbon markets had been third-party verified (Hamilton et al. 2009). There are a number of different standards, not all of which include protocols for forest and range projects. The most commonly used standards reported from the voluntary market are the Voluntary Carbon Standard, followed by the Gold Standard, the Climate Action Reserve (CAR), and the American Carbon Registry (Hamilton et al. 2009). The main entities currently operating in the United States with standards that allow offsets from forestry or range projects are described in the appendix. Table 1 indicates the category of forestry or range projects that are allowed by each. A landowner wishing to participate in a compliance market (such as RGGI), or in the CCX voluntary market, must follow the standards and protocols approved for use in that market.

Table 1—Activities allowed by different offset standards and trading programs

	Forestry			Grazing
	A/R	FM	REDD	GM
Department of Energy 1605(b) (1992 to present)	Y	Y	N	N
American Carbon Registry (1996 to present)	Y	Y	Y	N
The Climate Trust (1997 to present)	Y	Y	Y	Y
Climate Action Reserve/California Climate Action Registry (2001 to present)	Y	Y	Y	N
EPA Climate Leaders (2002 to present)	Y	N	N	N
Plan Vivo (2002 to present)	Y	Y	Y	N
Chicago Climate Exchange (2003 to present)	Y	Y	N	Y
Clean Development Mechanism (2006 to present)	Y	Y	N	N
Joint Implementation (2006 to present)	Y	Y	N	Y
Voluntary Carbon Standard (2006 to present)	Y	Y	Y	N
CarbonFix (2007 to present)	Y	N	N	N
Climate, Community and Biodiversity Standard (2008 to present)	Y	Y	Y	Y
Regional GHG Initiative (2008 to present)	Y	N	N	N
Midwestern Governors GHG Accord (planned for 2010)	?	?	?	?
Western Climate Initiative (planned for 2012)	?	?	?	?

A/R = afforestation/reforestation; FM = forest management; REDD = reduced emissions from degradation and deforestation; GM = grazing management.

***Registries*—**Registries are another key component of a viable carbon market because they provide a transparent and reliable way of tracking the sale and use of pollution allowances and carbon credits to prevent fraud and double counting. Registries are databases that allow market participants to establish and publish GHG emissions inventories, document verified offset activities, and track and trade allowances and credits. Registries also have standards for participation that must be rigorous and transparent for them to be credible. Some entities that have developed carbon offset standards for forestry and range projects also maintain carbon registries, although some do not. In contrast to compliance markets and the CCX, a landowner wishing to participate in an OTC transaction does not necessarily need to comply with an established standard or participate in a registry. However, standards and registries provide increased confidence for buyers interested in purchasing offset credits in voluntary carbon markets, and such credits commonly command higher prices.

***Pricing*—**In compliance markets (and the CCX) at any one point in time, there is only one prevailing price, which is the same for both allowances and offset credits. Although the price in compliance markets may change over time, all credits in the market will trade at the same price. In the voluntary OTC market, prices are determined through private negotiations between offset buyers and sellers. The price of an offset credit varies depending on the perceived quality of the offset,

which is often a function of the standard with which it complies. In general, credits verified to a well known third-party standard transact at higher prices, meaning it may be cost-effective for landowners to undergo the process of verification and registration. Despite this general expectation, however, compliance with a more rigorous standard is not a guarantee that the price for the resulting offset credits will be higher, as there are many examples where credits verified to a third-party standard do not gain a discernible price premium (Hamilton, K. 2009. Personal communication, Ecosystem Marketplace). Also, some offsets are more attractive to buyers than others (and command a higher price) because of their perceived co-benefits. Thus, in voluntary transactions, offsets from different project types (e.g., landfill methane and reforestation) may trade at different prices even if they were verified to the same standard.

Common Steps and Requirements for Pursuing Carbon Offset Projects

Although the specific requirements for carbon sequestration and avoided emissions projects associated with forest and range management differ among markets, registries, and standards, they have several shared components that a landowner or manager is likely to encounter in the process of market engagement. We first provide a brief description of common participants that landowners may interact with in carbon markets and then review some of the most common procedures in the conduct of offset projects. The items listed below are not requirements for all offset programs, but represent some of the common procedures and requirements used in evaluating offset projects that a landowner may have to undergo. Landowners should carefully consider the requirements of each relevant standard and be sure to fully understand what is required of them for compliance before choosing one standard over another. Following this discussion, we address some common questions landowners may have about participating in carbon markets.

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Major Players in Carbon Markets

Project developers—

The persons or organizations that prepare all the necessary documentation for submitting and running an offset project. Although landowners may participate as project developers, many offset programs may require complex modeling or other specialized skills that may be beyond the capacity or interest of participating landowners.

Aggregators—
A specific type of project developer, **aggregators** oversee the combination of multiple smaller projects into one larger project to reduce the various costs for each landowner. Aggregators are commonly involved in projects when the land area of the project is beneath some set limit, or the carbon sequestration potential of an individual project is too low to enable it to meet all the costs associated with measuring, monitoring, verifying, or listing the project on a registry.

Registries and standards organizations—
These organizations provide the rules and venue for registration of offset projects. Each registry and standards organization generally maintains a variety of offset project protocols that define the rules and expectations of projects seeking registration or certification using their standard.

Third-party verifiers—
Most offset programs require an independent organization to verify that offset activities reported to them by project developers are real and have been conducted in accordance with the relevant protocol. These organizations are commonly accredited by the registry or standards organization verifying their offset projects. Each standard or registry will likely provide a list of approved third-party verifiers.

Offset buyers—
These are the people or companies who purchase offsets directly from the project developer or through brokers. Offset buyers may be entities regulated under a cap-and-trade compliance market or they may be voluntary purchasers of offsets through OTC transactions. Offset buyers may retire offsets or resell the offsets to another buyer.

Brokers—
A special type of offset buyer, brokers are people or organizations that function as intermediaries in the selling of emissions permits and do not take final ownership of a credit. Brokers typically facilitate the buying and selling of offset credits and allowances in much larger volumes than those of individual projects. Most brokers will have access to a portfolio of credits available for potential buyers and may enable buyers to purchase offsets created from particular locations, project types, or standards.

Common Project Components

Offset project plan—

Most credit-generating offset programs require project developers to submit a project proposal for their offset activities. The proposal is reviewed and accepted or rejected by an advisory committee or other oversight group. The project plan allows each standard or registry group to ensure that projects meet their eligibility requirements and must contain sufficient documentation to support approval of the offset project. The major components of a project plan are discussed in more detail below.

Demonstration of land ownership (and carbon ownership)—

Prior to the approval of any offset project, most programs require the landowner or project developer to demonstrate ownership of the land being used for the offset project. Documentation of any relevant easements or other property restrictions or stakeholder interests in the property (such as loans against the property) will typically need to be provided as well. Although there is currently no widely accepted legal framework for separating property rights to carbon in offset projects from more traditional timber or land property rights, this issue is arising as an important topic in the aggregation of several different landowners into a single project and will likely be a component of aggregation programs in the future.

Land-use history—

Many offset programs require a description of recent land-use activities on the land being used for the offset project, such as previous management practices or conversion from other land uses. Some standards allow offset projects that have already begun prior to submitting the project plan. Forestry standards for afforestation/reforestation activities typically require documentation that demonstrates the land has not been forested for a specified number of years prior to the start of the offset project.

Establishing a baseline—

Project developers are generally required to create a scenario showing how the land would be managed in the absence of the offset program. This scenario, commonly referred to as "business as usual," describes the types of land management activities that would be carried out if the landowner did not intend to participate in a carbon market, and how business as usual would affect the amount of carbon storage and emissions from the land. Each offset standard will provide its own guidance for development of the **baseline** scenario.

Additionality and Early Actors

One of the basic principles the procedures and requirements for offset project initiation are designed to address is that of **additionality**. Carbon offset markets were developed to incentivize sequestration activities that would not have occurred in the absence of the market. Therefore, many offset programs apply additionality criteria to guarantee that projects actually represent new sequestration (or net emissions reductions). In some circumstances, although landowners may already engage in land management practices that help sequester carbon, these may not necessarily qualify for carbon offset credits. Landowners who have been following sustainable management practices for reasons other than carbon sequestration may commonly have generated higher levels of carbon storage in their plants and soils than those who have not (i.e., their baseline is higher). These "**early actors**" present a unique challenge for offset programs because although their management activities may provide the same level of carbon sequestration as projects initiated by other landowners, they may not necessarily reflect new and additional carbon storage that would not have occurred in the absence of the market. In general, carbon offset programs will require landowners to employ practices that are above and beyond "business as usual." Each offset program uses its own definition of "business as usual," so activities considered additional (and therefore eligible for offset crediting) in some standards may not be considered additional in others. Some of the common additionality criteria are discussed in this chapter.

Demonstrating additionality—

A variety of tests are used to guarantee that project activities are being pursued for the primary purpose of reducing GHG emissions or sequestering carbon, and to ensure that the offset practices are not part of previously planned business or management activities being conducted for other reasons. These tests may include (but are not limited to):

1. Regulatory test: Management practices required by law (e.g., riparian buffers) are not additional. Additionality requires carbon storage to be above and beyond that which occurs for compliance with relevant laws and regulations.

2. Financial test: If the management plan associated with the offset project is less financially attractive than alternative business-as-usual options, it may be considered additional. To demonstrate additionality in this case, there must be an anticipated reduction in income or other financial benefits from the project, compared to what would occur if the project did not participate in the carbon market.
3. Common practice test: If the activities described in the management plan are common practice in the industry—independent of participation in carbon markets—those activities may not be considered additional.

Permanence and leakage—

Increased carbon storage that occurs through land management can be reversed through changes in land use, resource management practices, or natural disturbances, which gives rise to a concern over the "**permanence**" of sequestered carbon. Permanence is a common requirement for most offset programs, and the project developer may need to describe what efforts will be taken to minimize the risk of future carbon losses (or reversals) from events such as wildfire, changes in timber harvesting, or land sales. Permanence is commonly addressed through the use of buffer or reserve pools where a certain amount of the carbon credits earned by a project are held essentially as insurance to recoup carbon losses from reversals.

Leakage refers to the risk that the carbon benefits gained by one project will be negated by increased carbon emissions in another location as a direct or indirect result of the project. Although project developers typically cannot control the land management decisions of other landowners, they will generally be required to commit to not pursuing activities on other lands within their control that increase the release of carbon from those lands. For example, a forestry offset project that involves reduced timber utilization in one stand cannot simply relocate timber harvests to another stand not included in the project area.

Carbon inventory—

For programs that require them, landowners will need to have a carbon inventory prepared for the lands included in their project. In forestry projects, this inventory is similar in some senses to traditional timber inventories, but may require the measurement of additional carbon pools, such as nonmerchantable species, snags, and downed woody debris, as well as requiring additional constraints on the level of sampling and statistical errors allowed. These inventories are typically used to

Tom Iraci

quantify and model a baseline scenario to estimate carbon sequestration over time. Most programs require a description of the sampling methodology that will be used to calculate and model changes in carbon storage. Examples include the location and number of sampling plots, the type of measurements that will be taken in the field, any laboratory tests, and any models or other published guides that will be used. To avoid overestimation of carbon storage and sequestration in projects, many offset standards will also use a conservative approach to the calculation of carbon storage in a forest by restricting the allowable statistical sampling error of an inventory (e.g., to a maximum of 20-percent sampling error at a 90-percent confidence level) and then subtracting some amount of the statistical error (e.g., one standard error of the mean) from the inventory estimate. This is a unique consideration for carbon inventories that is not commonly considered in traditional timber inventories and should be kept in mind when designing any carbon inventory to make sure that it will comply with a desired standard.

Third-Party Verification, Monitoring, and Sustainability Certification

Most (but not all) offset standards require verification of offset activities by an independent third party. Many offset programs will provide a list of appropriate organizations that can be used for third-party verification. Others will require the use of an approved verifier. Many offset programs also require certification that the land is being managed in a sustainable manner. For forestry projects, this means the landowner may need to obtain forest certification through a program like the Forest Stewardship Council, Tree Farm, or the Sustainable Forestry Initiative. For range management projects, this usually means complying with the Natural Resource Conservation Service's (NRCS) Best Management Practices for grazing and rangeland management. These standards may vary from state to state depending on state and local regulations as well as different environmental concerns. Information on best management practices can be found by contacting a NRCS state office. Links to the Web sites for these offices can be found at http://www.nrcs.usda.gov/about/organization/regions.html.

Registering and Issuing Offset Credits

Once a project plan is approved and the offset activities are verified, the project can be placed on a registry and carbon offset credits issued. Many programs will charge a fee per ton of carbon to support the administration and operating expenses of the standard, registry, or trading program. Each carbon credit is typically representative of 1 tCO_2e. Some registries use metric tonnes of CO_2e, whereas others use English units of short tons of CO_2e.

Sale of Credits

Once credits have been issued and registered, they may be sold through existing exchange platforms with transparent prices, or they may be sold in OTC transactions to other buyers through private agreements. Many registries or offset programs may require processing or transfer fees to be assessed when offset credits are transferred or sold. Under some standards, it may also be possible to negotiate **forward sales** of credits that essentially entail a contractual obligation to deliver credits anticipated to be earned in the future in exchange for up-front payment. This type of sale is distinct from ex-ante crediting because credits are not actually being sold in a forward sale, but instead the contract involves the promise to deliver credits once they have been issued. In the OTC market, the price of carbon credits varies from sale to sale. Price ranges for some of the major offset standards and markets are shown in table 2.

Table 2—Reported prices for offset standards and trading programs

Standard/protocol	Price range	Average prices
	US/tCO_2$e	
American Carbon Registry	~2.50–20[*A]	3.80[*A]
CarbonFix	14–25[A] 14–27[B]	18.40[A]
Chicago Climate Exchange	1.90–15[*A] 1.40–2.70[*C]	4.00[*A] 2.10[*C]
Climate Action Reserve/California Climate Action Registry	~2–20[*A]	8.90[*A]
Climate Community and Biodiversity	~2.50–15[A] 6.90–13.70[C]	10.30[C]
Kyoto's Clean Development Mechanism and Joint Implementation	~7.50–40[*A] 19.20–41.10[*C]	21.30[*A] 30.20[*C]
Plan Vivo	~5–11[A] 3.40–13[C] 8–30[B]	5.60[A] 8.20[C]
Voluntary Carbon Standard	~2.50–30[*A] 6.90–20.60[*C] 12–18[B]	5.50[*A] 13.70[*C]

Values with asterisks (*) next to them are based on ranges and averages for all offset project types allowed within a standard and not restricted to forestry or range projects. Letter codes represent sources of price ranges and averages as estimated by: A = Hamilton et al. (2009), prices from transactions in 2008; B = Merger (2008), expected prices for 2009; C = Kollmuss et al. (2008), prices on trades as of March 2008.

Forest and Range Management and Carbon Sequestration

Landowners who are interested in participating in carbon markets can benefit from an understanding of the science behind forest and range management practices that help sequester carbon. It is also important that landowners understand which practices are recognized as qualifying carbon offset activities in existing markets and registries. It is likely that there are management practices that can produce carbon benefits that are not currently recognized in carbon offset programs. Similarly, there may also be requirements placed on management that do not have clear carbon sequestration effects. Ultimately, understanding the scientific underpinnings of how land management affects carbon sequestration in forest and range environments will enable concerned landowners to more critically evaluate why various offset programs require particular practices.

In carbon markets, land-management practices used for carbon sequestration are commonly referred to collectively as LULUCF (land-use, land-use change, and forestry) or as agriculture, forestry, and other land uses (**AFOLU**). We use the term LULUCF to describe land-use-related offset projects except in circumstances where AFOLU is the term used internally by the specific offset standard being discussed.

Our Current Scientific Understanding of Forest and Rangeland Carbon Cycling

Forest carbon projects are primarily concerned with carbon storage in trees and wood products, whereas rangeland carbon projects focus on carbon storage in soils.

Current carbon market opportunities reflect a combination of practical and scientific concerns in both forestry and range management. Although LULUCF projects in general are somewhat more complicated than more technology-oriented offsetting projects, there are major differences between our current understanding of forest versus rangeland carbon science that affect how these activities are handled in carbon markets. As will be described in more detail in the sections that follow, forest carbon projects are primarily concerned with carbon storage in trees and wood products, whereas rangeland carbon projects focus on carbon storage in soils. As a practical matter, carbon is easier to measure above ground than it is below ground. Moreover, the current state of technology is such that measuring changes in soil carbon is expensive. Measuring carbon is also more similar to the kinds of measurements commonly taken as part of traditional forest management than is the case with range management. And there is uncertainty over how to assess soil carbon baselines and additionality. As a result of these and other issues, the current body of research into how forests—and trees in particular—cycle carbon is broader and more robust than the research pertaining to rangeland carbon cycling, and the evaluation of offsets from soil carbon is somewhat more contentious than from other carbon pools such as live plant biomass. These challenges have made the verification and determination of value for soil carbon sequestration complicated, and as a result, there are not currently many offset standards for soil carbon sequestration in rangeland environments.

Practical matters of measuring carbon storage have led to divergent methods for documenting carbon benefits from offset projects. The ease and relatively low cost of measuring tree carbon makes it possible for forestry offset projects to demonstrate that management activities are leading to carbon sequestration by inventorying their carbon over time. Standards that use this type of inventory program to measure changes in forest carbon are known as **outcome-based standards**. In contrast, the cost and difficulty involved in detecting changes in soil carbon make carbon inventories less suitable for rangeland offset projects. Instead, offset standards for rangeland management commonly require landowners to follow specific

management practices believed to increase carbon sequestration that are outlined by the relevant offset protocols. These are known as **prescriptive standards**. The overview of forest and range management practices that follows reflects these divergent requirements. Our discussion of forestry and carbon sequestration anticipates that landowners have the leeway to choose specific management practices. Conversely, our discussion of range management practices and carbon sequestration provides the scientific background for understanding how these practices may affect carbon balances in rangeland ecosystems, and specifies which of these practices are currently required by the CCX, the primary venue for rangeland carbon credits to date.

Forestry

Forests are distinct from other terrestrial ecosystems in that they can sequester much larger amounts of carbon in plant biomass than other environments and plant communities. Total forest ecosystem carbon storage refers to the amount of carbon held on forest lands in both live and dead pools, including biomass, litter, and soils.[6] The proportion of total forest ecosystem carbon that is stored in tree biomass relative to other pools like litter and soil differs with forest type, productivity, disturbance regime (including harvesting), and land-use history. Forests that are more productive or that foster the growth of very large trees (e.g., redwood forests and the temperate rain forests of the Pacific Northwest) typically contain higher proportions of carbon in tree biomass than less productive forests or those containing smaller trees. Across all forest types in the United States, the average amount of carbon stored in each pool is approximately 50 percent in soils, 33 percent in live trees, 10 percent in woody debris (including standing dead trees, stumps, and snags), 6 percent in the forest floor, and 1 percent in understory plants (Turner et al. 1995).

In forests, carbon is sequestered by trees and can be stored in tree biomass (including wood products) and soils for long periods. The uptake of carbon into tree biomass generally occurs more quickly, and is easier to measure, than the uptake of carbon in soils. Many studies, though not all, have shown a measurable increase in soil carbon following establishment of new forests (Guo and Gifford 2002, Post and Kwon 2000). Most studies that have carefully considered soil carbon balance in managed forests have not found significant changes in soil carbon owing to harvesting and other common management practices, and the dearth of evidence showing effects of forest management on soil carbon stores has been argued by

[6] When wood products are added to the total carbon estimate for a forest, this is commonly referred to as total forest "system" carbon storage.

Lal et al. (2003) to be a knowledge gap in forest carbon sequestration (Johnson and Curtis 2001, Johnson et al. 2002, Yanai et al. 2003). The main methods of increasing carbon sequestration in forests are therefore to encourage carbon uptake by trees, and to enable long-term storage of that carbon in tree biomass. Forest management has traditionally focused on growing and harvesting trees, which are proportionately very large and easily measured carbon pools. Thus, there is a fair amount of scientific knowledge about forest management strategies that encourage tree growth, which informs our knowledge about forest management to encourage carbon sequestration. Although this discussion focuses largely on forest carbon storage and sequestration, carbon is only one factor among many that should be considered in sustainable forest management.

Management Practices That Encourage Carbon Sequestration

Carbon sequestration and associated carbon offset credits from forest environments can be generated by increasing the net uptake of carbon into forests, decreasing carbon releases from forests, or preventing carbon emissions caused by the conversion of forests to other land uses. Broadly speaking, there are three general categories of forest management that are considered in carbon markets: afforestration/reforestation, avoided deforestation, and improved forest management.

Afforestation/reforestation—
The easiest way to visualize carbon storage by forests is to think about the growth of trees in a new forest. Afforestation is the term used for the establishment of forests on land that has not been forested for a long time, or never was (e.g., agricultural land). In many cases, afforestation can lead to rapid and dramatic accumulations of carbon in tree biomass. Carbon accumulation in litter and soil organic carbon may also increase with afforestation—depending on the status of the soil—although these gains will likely be smaller and accumulate more slowly than carbon in tree biomass (Guo and Gifford 2002, Post and Kwon 2000).

In contrast, reforestation involves reestablishing forests on lands where forests were recently removed or destroyed. This includes land that has lost forest cover that is not recovering naturally (e.g., land severely burned by forest fire). Many offset standards distinguish between afforestation and reforestation activities on the basis of how much time the land has been under a land use other than forestry. Offset standards may also stipulate how long a land area must have lacked forest cover to be considered as a source of carbon offset credits. For example, the CCX only allows areas that were not forested prior to 1990 to be eligible for afforestation carbon credits; the RGGI and the CAR require a minimum of 10 years of nonforest land cover. The timeframe set by different standards for qualifying afforestation

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projects is an important consideration for those interested in planting forests as a means of sequestering carbon and receiving carbon credits. To encourage the adaptation and resilience of forests in the face of climate change, offset standards may require the planting of native species in these projects and provide guidelines for species diversity. Planting new forests is a relatively straightforward way to sequester carbon and is the simplest carbon sequestration activity to account for in forest carbon offset programs.

Avoided deforestation—

The conversion of forested landscapes to other land uses (e.g., agriculture, developed uses) typically involves a dramatic release of carbon to the atmosphere, even if wood products are produced in the process. Deforestation and forest conversion lead to significant losses of carbon from live and dead biomass, litter, and often from soil organic matter as well. Preventing deforestation, particularly in tropical forests, has been investigated as a means to control carbon emissions because deforestation contributes roughly 20 percent of all GHG emissions (IPCC 2007). Unsustainable timber harvesting can also lead to deforestation and forest degradation. In carbon offset discussions, avoided deforestation is commonly referred to as "reduced emissions from deforestation and forest degradation," or REDD.

Although forest clearing and land conversion represent a fairly straightforward loss of carbon, the methods used to estimate carbon losses that could be avoided

by preventing them are complicated and contentious. In contrast to afforestation/reforestation activities that sequester carbon and are fairly easy to document, avoided deforestation activities require preventing emissions that may occur in the future. Rigorous carbon offset standards seek to make accurate estimates of prevented future emissions. Standards and methods that improperly calculate the threat of forest loss from deforestation can create a lack of confidence in associated offset credits, and can also reduce the effectiveness of offset activities in mitigating climate change. The challenges presented by quantifying and verifying offsets from REDD have led to its relatively less common adoption as an offset type in existing standards and emissions trading programs.

A major barrier to accepting avoided deforestation offset projects in the United States has been the difficulty of reliably estimating the real threat of forest conversion in specific places. Determining the risk for conversion of forest land to developed uses is generally the responsibility of the authorities associated with a particular GHG trading program or offset standard. Calculating development risks does not typically require developing new methods for every offset project, but rather the use of accepted forest conversion rates, or a proxy for conversion risk such as competing property values provided by the offset standard's authorities.

Perhaps the largest dispute over avoided deforestation projects has been the risk of leakage (discussed above and defined in the glossary). When forests are controlled by one landowner, leakage of carbon benefits in one stand by increased harvesting in another is not a difficult problem to control, and is commonly included in contractual agreements for offset crediting. Leakage to forests outside of the landowner's ownership and control is much more difficult to prevent and measure. Leakage is one of the biggest issues slowing down the wider adoption of avoided deforestation activities as carbon offsets. Ultimately, how leakage is measured and controlled will probably be decided by the authorities of individual GHG trading programs and offset standards. For example, one common approach to address leakage is to apply a discount (or explicit deduction applied to the measured carbon storage) to all credits earned by forest projects. The approaches involved may differ among programs, and should be examined closely prior to choosing a particular offset standard or trading program to participate in.

Improved forest management—

Several forest management practices that can increase carbon storage in forests are summarized below. This is not intended to be a comprehensive list of all forest management practices, and this is not an exhaustive list of all the management

Variations in Potential Carbon Sequestration by Region and Forest Type

Just as forest types and productivity vary from region to region across the country, so too does the regional potential for forest carbon sequestration. The predominant land-use patterns in different regions also influence what types of projects will produce the largest carbon gains. An analysis of the potential for forest and agricultural management to sequester additional carbon above a baseline scenario (Murray et al. 2005) found that at a price of \$15/ tCO_2e, the South-Central and Midwestern Corn Belt regions of the United States would be the center for the vast majority of afforestation potential. The analysis also found that the South-Central and Southeast regions of the country would provide the largest potential for additional carbon sequestration through improved forest management. These findings were based on the high proportion of timberland ownership by private entities in these regions, and the fact that they have large amounts of marginal agricultural and other lands that may be converted to forests in carbon offset projects. Outside of the Rocky Mountain and South-Central regions of the United States, the primary strategy for forest carbon sequestration is predicted to be through improved forest management rather than afforestation/reforestation projects (Murray et al. 2005).

The different growth rates and productivity of diverse forest types also makes for unique carbon sequestration potentials. Forest types that grow more quickly when they are young will also generally accumulate carbon more quickly during that time. It is important to note however that achieving optimal carbon sequestration through forest management is not simply a matter of growth rate, but of total carbon storage (see sidebar on growth rate vs. carbon storage). As forests age, the picture becomes considerably more complicated as other pools such as standing dead wood and downed woody debris begin to assume larger proportions of carbon stored in forests. Estimates of the carbon sequestration and wood products storage potential of different forest types throughout the country are provided in yield table form for both afforestation and reforestation in Smith et al. (2006). In the West, redwood forests and the rain forests west of the Cascades in the Pacific Northwest have the greatest sequestration potential.

practices that may have effects on forest carbon storage. The practices described in more detail below encompass the management practices commonly discussed in this field of research and other prominent management practices that are regularly employed in forestry.

Forests that grow more and bigger trees are generally more effective at sequestering and storing carbon than those that are harvested, even when the carbon stored in wood products is taken into account

***Extending harvest rotation intervals*—**Forests that grow more and bigger trees are generally more effective at sequestering and storing carbon than those that are harvested, even when the carbon stored in wood products is taken into account (Harmon et al. 1990, see discussion of wood products storage later in this chapter). Therefore, the primary means of increasing tree carbon is to allow managed forests to grow for longer periods before harvesting them. Lengthening harvest rotation intervals allows carbon to accumulate in larger living trees, and reducing harvest disturbance can increase carbon storage in dead biomass pools like standing dead and downed trees, which are often counted in forest carbon inventories (Harmon et al. 2009, Janisch and Harmon 2002, Murray et al. 2005). The concept is straightforward: bigger trees store more carbon than smaller trees. By extending the time between harvests, the forest manager allows the forest to grow larger and store more carbon. The amount of additional carbon storage that could be added by extending rotation intervals will vary depending upon the composition, productivity, and current management scheme of each forest. Although longer rotations generally equate to higher carbon storage, a 40-year increase in rotation interval may not necessarily create twice the additional carbon of a 20-year increase in rotation intervals.

This concept must be understood from the perspective of more than one forest stand. At the individual stand level, carbon storage is dramatically reduced by harvest removals, and may take many years to recover to preharvest carbon store levels following a harvest. It may be hard to imagine that increasing harvest intervals to increase carbon storage will make a difference until the stand grows larger than it was when last harvested. When harvest intervals are extended across entire watersheds or regions, however, the annual fluctuations in carbon storage caused by harvesting in individual stands are dampened, and this practice leads to older forests on average at the landscape scale, which can make a substantial contribution to national carbon sequestration goals and efforts to mitigate climate change. Some offset programs combine small landowners into groups so that the effects of each individual's forest management practices add together to make a more obvious difference.

Growth Rate vs. Carbon Storage

Many foresters are familiar with the fact that younger trees usually grow more quickly than older trees. This observation is commonly misinterpreted to mean that because younger forests are more productive, we should convert older, slower growing forests into young forests that can capture carbon more quickly. The reason this strategy has not been pursued for carbon sequestration is that the end goal of carbon-oriented management is to have more carbon stored in forests (including wood products storage) than was there previously—to increase the total amount of carbon stored, not the rate at which it is stored. This goal is in contrast to traditional timber management, which strives to optimize the rate at which timber (or timber revenue) is produced from a stand. It is also important to remember that growing trees are not the only pool of carbon in forest ecosystems. In fact, in the average U.S. forest, living trees only contain one-third of total ecosystem carbon (Turner et al. 1995). Carbon management in forests thus requires consideration of a broader range of pools than are typically considered in traditional timber strategies.

Older forests can store significantly more carbon than younger forests. For example, a 60-year-old Douglas-fir (*Pseudotsuga menziessi* (Mirb.) Franco) forest typically contains approximately 259 to 274 tonnes of carbon per hectare; the same forest at 450 years of age can contain over 600 tonnes of carbon per hectare (Harmon et al. 1990). Because most of the carbon removed from forests via harvest is lost to the atmosphere within several years of harvesting (Smith et al. 2006), the amount of carbon stored in wood products will be less than would be gained by continued forest growth, even in many highly productive forests.

Moreover, for years following a clearcut or other high-utilization harvest, the total uptake of carbon in the postharvest stand is very low, and is often outweighed by the amount of carbon being released from the decomposition of soil organic matter, forest floor materials, and harvest residues, causing many postharvest forests to be net emitters of carbon to the atmosphere (Janisch and Harmon 2002). When maximum timber yields or timber revenues are the goal, short-rotation forestry may be preferred; but when carbon storage is the goal, short-rotation forestry, which maintains forests at younger ages, will correspond to less carbon storage in trees and wood products compared to longer rotation forestry that maintains older forests. Although younger forests commonly grow and capture carbon more quickly than older forests, they do not store as much carbon as older forests. The goal of carbon sequestration programs (and the policies that enable payment for carbon sequestration services) is to store more carbon, and growing older forests is one of the most straightforward ways of achieving this goal.

Harvest strategies can be planned in such a way as to provide sustainable timber yields and simultaneously encourage carbon sequestration.

Partial harvest and reduced utilization—As discussed above, there is typically a net carbon benefit to keeping carbon in forests rather than removing it through harvesting. In many circumstances, however, harvest strategies can be planned in such a way as to provide sustainable timber yields and simultaneously encourage carbon sequestration. Disturbance is one of the main causes of carbon release from forests to the atmosphere; thus, management practices that reduce harvest-related disturbances will lessen the potential for forest carbon loss during and following harvest operations. Disturbance effects on ecosystem carbon can be minimized through the use of partial harvest techniques (removing part of a stand instead of clearcutting all of it), and through reduced utilization by leaving whole or parts of cut trees on site during and after a harvest.

In the Pacific Northwest, at least two forest modeling studies of carbon-oriented management that include the wood products carbon pool have found that transitioning to partial harvest techniques and reducing slash burning can provide carbon storage in wood products that is comparable to that which occurs under clearcut harvesting, while dramatically increasing ecosystem carbon storage (Harmon and Marks 2002, Harmon et al. 2009). For example, a model of the Douglas-fir–western hemlock forest ecosystem showed that a shift from 100-percent clearcutting to a partial harvest scenario in which 80 percent of the tree mass was cut and 80 percent of the felled boles were removed (the remaining felled boles were left to decompose) resulted in significantly higher forest ecosystem carbon stores. In addition, the size

Eini Lowell

of the wood products carbon pool was sometimes larger under the partial harvest scenario. Although reducing the percentage of trees cut during a harvest can decrease short-term timber yields, the continued growth of forests under carbon-oriented management may sustain yields over time at a level that is comparable to the yields produced under traditional even-age management practices. The monetary value of the changes in carbon sequestration and timber yields following a transition to carbon-oriented management will vary, depending on site and environmental conditions, forest types, existing management practices, and the prices of both timber and carbon. Landowners interested in pursuing carbon offset opportunities should carefully evaluate the short-term and long-term tradeoffs involved in pursing carbon-related forest management.

***Reducing dead biomass removal*—**When trees die in a forest, the carbon they contain is not immediately released to the atmosphere. Instead, the carbon held in standing and downed dead trees and snags, and in other dead biomass like forest floor litter and debris, can persist in the forest for very long periods. Carbon in dead and downed biomass is slowly transformed into litter and soil organic matter where it continues to decompose over time. In the United States, dead biomass on average makes up approximately 16 percent of the total carbon stored in forest ecosystems (Turner et al. 1995). In old-growth forests of the Pacific Northwest, dead biomass pools can compose as much as 23 percent of total ecosystem carbon (Smithwick et al. 2002). These pools represent significant storage reservoirs of carbon that are commonly included and measured in many (but not all) offset programs. Management practices that involve burning—such as harvest residue removal or site preparation—have the potential to dramatically reduce the amount of carbon stored in dead biomass pools by releasing it back to the atmosphere. By minimizing or ceasing management practices that prevent the natural increase of dead biomass over time, landowners can achieve measurable and potentially valuable gains in forest carbon storage.

In some environments, high levels of dead biomass may mean increased fire risk. Thus, the carbon benefits of leaving dead biomass on site need to be weighed against the risk of higher fuel loading. The relationship between fire and carbon balance in forests is a complicated one (see discussion of wildfire and prescribed fire below).

***Fertilization*—**In many forest ecosystems, the availability of soil nitrogen and phosporus can be the main factor limiting tree growth. In these environments, the addition of nutrients through the application of fertilizers or organic amendments can enhance tree growth, and in turn, carbon sequestration (Chen et al. 2000,

Pregitzer et al. 2008). The key carbon tradeoff in using fertilizers to enrich forest soils is the carbon cost of manufacturing, transporting, and applying the fertilizer, versus the expected gains in carbon storage following enhanced growth. The carbon costs of nitrogen fertilizer production and transport are estimated to range from as low as 0.06 kg CO_2/kg of ammonium sulfate, and approximately 0.5 kg CO_2/kg of urea, to as much as 0.65 kg CO_2/kg of ammonia; the carbon costs of phosphorus and potash fertilizers are typically below 0.1 kg CO_2/kg of fertilizer (Markewitz 2006). Because the net carbon balance depends on the application rate and expected forest growth following fertilization, the use of fertilizer to enhance carbon sequestration should be evaluated on a case-by-case basis. For example, a relatively heavy application of ammonia fertilizer at 200 kg/ha (~175 lbs/ac) would correspond to a carbon cost of 0.13 tCO_2e/ha (130 kg CO_2/ha). If the expected forest growth enhancement is greater than this carbon cost (e.g., if forest biomass is increased by more than 70 kg/ha—approximately equivalent to 0.13 tCO_2e/ha—in the scenario above), fertilization may on balance increase carbon sequestration. Offset programs may require a landowner to account for fertilizer use by using carbon cost estimates different from the ones given here, so fertilization as a management strategy should be carefully evaluated.

Management Practices With Unclear or Unlikely Carbon Benefits

Wildfire mitigation and carbon sequestration—
The frequency and extent of wildfires in the Western United States are expected to increase with altered precipitation and temperatures caused by global climate change (Westerling et al. 2006). Thus, the management of forests to reduce wildfire risks is likely to become a more prominent issue. Wildfire control and mitigation is and should be an important component of sustainable forest management, but evaluating its effects on carbon sequestration and storage is complex. Because fuel treatments and wildfires both cause carbon losses from forests, the challenge for assessing carbon balances with regard to wildfire mitigation is to compare the carbon cost of expanded fuel treatments carried out in the present to the carbon losses from potential wildfires in the future.

The challenge for assessing carbon balances with regard to wildfire mitigation is to compare the carbon cost of expanded fuel treatments carried out in the present to the carbon losses from potential wildfires in the future.

The most dramatic impact of wildfire on forests in terms of carbon storage is the intense and rapid loss of carbon that occurs during the wildfire. Following severe wildfires, carbon loss from forests may persist for decades as large numbers of trees killed by the fire decompose and release carbon back to the atmosphere. In many cases, the release of carbon from dead trees in the years following a fire exceeds the amount of carbon lost during the fire event itself (Dixon and Krankina 1993, Janisch and Harmon 2002).

Compared to the carbon sequestration of an unburned forest, the carbon sequestration potential lost in severe wildfire can be immense. For example, severely burned areas from the Biscuit Fire, a very large fire that burned over 200 000 ha (about 494,000 ac) in Oregon in 2002, are estimated to have lost 17 percent of the carbon stored in the affected forests, not including the carbon released from soil deeper than 10 cm (Campbell et al. 2007). Although this 17 percent may seem fairly small for such an immense and severe fire, the authors estimated that the 3 800 000 metric tonnes of carbon lost, represents over 18 times the annual carbon uptake of the preburned forest. Thus, it will take decades before the amount of carbon lost from this catastrophic wildfire will be sequestered again by a regrowing forest. Nevertheless, although the carbon remaining in snags and large woody debris was then exposed to increased decomposition, it is also important to recognize that significant amounts of carbon remained in the burned forests (83 percent of carbon remains according to estimates by Campbell et al. 2007).

To limit the frequency and severity of wildfires, forests are managed to reduce fuel loads. The amount of carbon removed from forests by fuels reduction treatments differs among stands, depending on their fuel loads and associated fire risks. Because it is not possible to know precisely where forest fires are going to occur, forest managers treat many acres of forests each year. Although it is now clear that fuel reduction treatments can reduce the amount of carbon lost should a wildfire burn through a treated forest, the treatments that take place in those forests that do not subsequently burn cause real carbon losses that need to be considered (Hurteau and North 2008, Hurteau et al. 2008, Mitchell et al. 2009). The major question confronting scientists who study the carbon balance of wildfire versus wildfire mitigation treatments is how to appropriately compare the amount of carbon lost from fuel reduction treatments to the amount of carbon likely to be lost from wildfires. This is a problem with complex spatial challenges because fuel reduction and wildfires occur in different locations and to different extents every year. Relatively few studies have been published on this topic to date. Those that have been have helped raise awareness of the carbon-related aspects of wildfire, but more research is needed before a clear and confident conclusion can be drawn about how managing for wildfire risks affects forest carbon balances. More references on wildfire mitigation and carbon balance can be found in the “Further Reading” section toward the end of this document. Prescribed fire and thinning, two common fuel reduction treatments, are addressed below.

Tom Iraci

The ability of prescribed fire alone to reduce the risk of carbon loss from wildfire is generally not great enough to compensate for the amount of carbon emitted from repeated applications of prescribed fire over the life of a stand.

Prescribed fire—

Prescribed fire can be a quick and effective way to remove harvest residues and woody debris to reduce fuel loads or prepare sites for planting and other silvicultural activities. However, a significant amount of carbon stored in dead—and to a lesser extent in live—biomass pools is immediately released to the atmosphere by the use of prescribed fire. The ability of prescribed fire alone to reduce the risk of carbon loss from wildfire is generally not great enough to compensate for the amount of carbon emitted from repeated applications of prescribed fire over the life of a stand. Scientific evaluation of prescribed fire suggests that allowing a wildfire to burn a forest produces fewer carbon emissions than the repeated application of prescribed fire needed to mitigate wildfire risk (Hurteau and North 2008). Therefore, although it may offer some protection against wildfire occurrence, prescribed burning does not appear to offer an overall carbon benefit, and is not likely to be supported in carbon offset programs as a management tool to increase carbon sequestration or storage in forests. Some standards may factor in considerations of prescribed fire to reduce the risk of wildfire-related carbon losses, but documentation of emissions associated with prescribed fire may be required.

Thinning—

Forest thinning is commonly used to meet a variety of management goals. Thinning to remove and utilize trees that would otherwise be suppressed and die may make sense in terms of timber yield, but in terms of carbon storage, the effect is not as clear. All of the carbon in a tree is not immediately lost once the tree dies. Larger trees that are suitable for use as long-term wood products may retain significant levels of carbon over time. One study estimated softwood saw log use in the Pacific Northwest resulted in retention of 49 percent of the carbon originally contained in the rough log 10 years after harvest, and 23 percent 50 years after harvest (Smith et al. 2006). When small-diameter trees that are not useful for long-lived wood products are thinned, the amount of carbon lost to the atmosphere is greater. If thinned biomass is used as a source of renewable energy generation to offset fossil fuels, the net carbon balance may be more favorable (see sidebar).

Forest growth is central to carbon sequestration; thus, the role of thinning in stand development deserves closer attention in order to understand its effects on the carbon balance of forests. The removal of trees from a stand is well known to enhance growth among the trees that remain in the stand because it reduces competition for scarce soil nutrients, water, and sunlight (Langsæter 1941). Although this effect is well established, it is often misinterpreted to imply that the total growth rate of the forest will increase as a result of thinning. Instead, a common outcome of thinning is that it concentrates growth among fewer trees. In the short term, tree removal reduces the amount of leaves that are present in the forest to capture carbon and sunlight. As the remaining trees grow new leaves and branches and take advantage of new gaps, water, and soil nutrients, the growth rate of the forest stand approaches the rate it experienced prior to thinning. Thinning does not commonly cause a direct increase in total forest biomass growth, or in carbon sequestration (Schroeder 1991). In cases where forests are densely overstocked, thinning may lead to increased biomass growth and carbon storage, but this is an exception to the general rule (Cooper 1983, Finkral and Evans 2008).

In cases where forests are densely overstocked, thinning may lead to increased biomass growth and carbon storage, but this is an exception to the general rule.

The carbon balance associated with thinning is directly tied to the growth rate of a particular stand and the fate of the trees harvested from it. Typically, the more the thinned trees are used for long-lived wood products and biofuels, the less the carbon losses from thinning. Leaving stands unthinned typically supports greater total carbon storage, but the use of thinning to achieve other management goals can still be a part of carbon-oriented forest management.

Mark Nechedom

Biomass Energy and Biofuels

The use of forest biomass as a renewable energy source has received renewed attention and interest in recent years (Malmsheimer et al. 2008a). There is currently considerable interest in utilizing forest biomass removed through wildfire mitigation thinning treatments to not only enhance financing for fuel reduction treatments, but to support the development of sustainable energy production, and to support natural-resource-based economies in rural communities. Many of the climate change policies currently being discussed in Congress include some efforts to incorporate forest biomass into renewable energy standards. Although biomass for fuels is a very promising avenue for diversifying and increasing revenue for forest landowners, the relationship between biomass energy and carbon markets is generally not a direct one that can be made by landowners. Specifically, although biomass use for energy may qualify for carbon offset crediting in some standards, it is typically treated as a renewable energy offset rather than as a land management-based offset, the focus of this document. Thus, the generation of offset credits from biomass energy will go to the energy producer that uses the biomass, as opposed to the landowner who provides the forest biomass for use as energy. The carbon accounting methods used with biomass energy are beyond the scope of this document. Nevertheless, the use of removed biomass for energy, particularly in circumstances where thinning or other harvesting treatments are already planned, may offer renewed opportunities for landowners to sell forest products as a source of energy and simultaneously contribute to climate change mitigation, whether or not they directly receive carbon credits.

Timber Harvesting and Carbon Storage in Wood Products

Managing forests to promote carbon sequestration is to some extent compatible with traditional forest management to produce wood products, but there are several important distinctions. From a carbon perspective, timber harvesting fragments aboveground biomass pools and moves them to different locations both on and off site. Branches, leaves, and in some cases tree trunks—and the carbon they contain—remain on site following harvest, where they are exposed to natural decomposition processes or treated during site preparation practices. One study in the Pacific Northwest revealed that emissions from common industrial timber harvest and site preparation management may correspond to as much as 12.5 percent of the carbon stored in these managed forests (Sonne 2006).

When harvested trees are processed into wood products, approximately 40 to 60 percent of the carbon they contain is released back to the atmosphere.

Biomass that is harvested will be transformed into a variety of wood products. When harvested trees are processed into wood products, approximately 40 to 60 percent of the carbon they contain is released back to the atmosphere (Harmon et al. 1996). The remaining 40 to 60 percent of the carbon flows into and is stored in a wide range of wood products, such as paper and lumber. Short-lived wood products typically have a shorter lifetime than biomass that is left to decompose in the forest. However, some forest biomass may be incorporated into long-lived wood products, such as wood in houses, where their carbon may be stored for long periods comparable to the lifetime of decomposing tree trunks in forests.

Because there are significant losses of carbon when trees are processed, and because most wood products have shorter lifetimes than trees, trees in forests are more efficient for carbon storage and sequestration than wood products. Therefore, most carbon sequestration guidance from scientific bodies prioritizes the accumulation of carbon in live and dead forest trees as a prerequisite to including carbon storage in wood products as a valid method of sequestering carbon and mitigating climate change (Nabuurs et al. 2007). Timber harvesting and carbon sequestration are not mutually exclusive, however. Well-managed forests may be grown both as a source of wood products and for carbon sequestration benefits (Malmsheimer et al. 2008c). We do not expect forests to be managed for carbon sequestration alone. The point remains, however, that forests left undisturbed by harvest will typically have higher levels of carbon storage than harvested forests, even when accounting for carbon storage in wood products. Ultimately, the balance between carbon storage and timber removals will be determined by landowners with access to viable timber and carbon markets.

In theory, substituting wood products for other more carbon-intensive building materials (such as concrete and steel) may prevent emissions associated with the production of those materials. In many studies, this “substitution effect” is used to

argue for a higher potential for the use of wood products to offset or reduce GHG emissions. If this substitution effect is not included, there is usually a clear carbon benefit to keeping carbon in intact forests (see sidebar on wood products substitution).

Several offset programs (such as Kyoto's CDM) have treated carbon removed through timber harvesting as though it were immediately released to the atmosphere. This view ignores the nontrivial amount of carbon that can be stored in long-lived wood products, and discourages timber harvest in general. Other offset programs have methods for estimating the amount of harvested carbon that persists in the form of long-lived wood products. For landowners interested in pursuing forest offsets, it will be important to consider how different standards treat carbon in long-lived wood products.

Wood Products Substitution

Many discussions of forest management for carbon sequestration will commonly refer to the potential for wood products to be used as a substitute for more carbon-intensive materials such as concrete and steel. Many authors addressing this comparison commonly argue for increased use of wood to replace these other construction materials (Malmsheimer et al. 2008b). Although the debate on the proper carbon accounting methods for wood products substitution is still ongoing, wood products substitution as a climate change mitigation strategy is not likely to provide a direct link for landowners to carbon markets. The substitution of wood products for other materials is very difficult to document and quantify, and no consensus has emerged on how this may be approached. Ultimately, however, any potential carbon crediting opportunities from wood products substitution in the future would accrue to those who make the decision to switch to wood rather than other materials. As landowners providing wood products to the timber market are not involved in these decisions, they will be unable to claim responsibility for any carbon offsetting or crediting resulting from these decisions.

General Conclusions on Forest Carbon Sequestration

The wealth of research that has gone into forest growth and management over the past decades provides a strong foundation for understanding how forest carbon sequestration can contribute to climate change mitigation. In general, forests offer a unique opportunity for biological carbon sequestration that is relatively easy to document, and that commonly provides a variety of other ecosystem services. Although there remain many contentious issues surrounding accounting practices and the scientific basis for optimal use of the many resources forests provide, our current understanding of carbon cycling enables forests to assume a key role in efforts to address climate change, and will likely continue to do so for decades to come. The potential for carbon financing to serve as a revenue stream for forest owners creates a new opportunity to support the sustainability of diverse forest ecosystems and the people and economies that rely on them.

Rangeland Management

Most of the carbon in rangeland ecosystems is found in soil. Carbon storage in soil changes more slowly and unpredictably than carbon storage in plants. Rangeland carbon sequestration therefore typically (but not always) focuses on increasing carbon inputs to soils, or decreasing carbon losses from soils. Our scientific understanding of soil carbon uptake, storage, and release in rangeland ecosystems is not as clear as it is for plants in forests. However, the processes governing carbon inputs and outputs in semiarid and arid rangelands appear to be dominated by the amount and timing of rainfall (Conant and Paustian 2002, Gilmanov et al. 2006, Huxman et al. 2004). Many rangeland environments shift from being carbon **sinks** to carbon **sources** seasonally, and from year to year (Svejcar et al. 2008).

Many rangeland environments shift from being carbon sinks to carbon sources seasonally, and from year to year.

Carbon sequestration research in rangelands is a relatively new field. Scientists have begun to evaluate range management practices and their carbon benefits, but more study is needed to improve our understanding of how these practices affect rangeland carbon balances. The relatively small body of research on the effects of range management practices on carbon balances significantly limits our ability to predict which practices will lead to carbon storage or release from rangelands over time. Therefore, the discussion of range management practices presented here draws on the current understanding of carbon cycling from soil science in inferring whether activities might be expected to increase or decrease soil carbon. Further study of the ecological drivers of carbon balance in soils, and of the effects of range management practices on soil carbon, are needed to verify many of these inferences.

One challenge in rangeland carbon science is that change in soil carbon is difficult and costly to measure. As a result, many studies of common range management practices and carbon balance to date have either produced conflicting results, or have failed to demonstrate clear carbon benefits. Adding to these problems is the difficulty of generalizing findings from one study site to broader areas and different grazing environments; a number of environmental variables change from one range ecosystem to another, and these differences can have important consequences for rangeland carbon balances. Because the science is still developing, our current understanding of how best to manage these landscapes for carbon is comparatively limited. With that in mind, we do not present the management practices discussed below in clear groups distinguishing those that are known to sequester carbon from those that are not because there is not yet enough scientific certainty to draw these major distinctions for many management practices. Instead, we discuss management practices by theme: those that are primarily concerned with grazing management, plant community management, and finally soil conservation and amendments. The ordering among and within sections does not imply any hierarchy of scientific certainty or the validity of any of the practices discussed for sequestering carbon.

Although this discussion focuses solely on carbon balance issues, the other environmental values associated with these management practices should not be overlooked. For example, improved soil water storage and filtration capacity, soil fertility, and erosion control are known to correspond to increases in soil carbon storage. Although these values may not be explicitly rewarded through carbon offset credits, they are environmental benefits that generally contribute to sustainable land management, and hold potential for participation in emerging markets for other ecosystem services. Carbon is only one factor among many that should be considered in sustainable range management.

Studies examining the effects of various grazing strategies on soil carbon storage have produced conflicting results, making it impossible to recommend specific stocking rates or utilization rates that will encourage carbon sequestration.

Grazing Management

Practicing sustainable grazing—

Grasses (their roots in particular) are the main source of carbon input to soils in grazing environments. The level and duration of grazing on a rangeland affects the production of grasses there. It follows that the control of grazing to maximize plant productivity can potentially lead to higher inputs of carbon to soils and increase carbon storage over time (Frank et al. 2002). Unfortunately, studies examining the effects of various grazing strategies on soil carbon storage have produced conflicting results, making it impossible to recommend specific stocking rates or utilization rates that will encourage carbon sequestration (Milchunas and Lauenroth

Soil Inorganic Carbon

Most scientists and carbon offset programs considering soil carbon sequestration typically focus on the storage of soil organic carbon only (i.e., carbon derived from living and formerly living things). Carbon also exists and cycles through soils in inorganic forms. Inorganic forms of soil carbon may be particularly abundant in arid and semiarid environments. For example, soil inorganic carbon is commonly observed as white salt crusts in soil known as carbonates. There have been several studies investigating the effects of management practices such as irrigation on the occurrence of soil carbonates (Entry et al. 2004, Eshel et al. 2007, Sartori et al. 2007, Wu et al. 2008). Although the chemical reactions producing these carbonates are fairly well understood, there is considerable disagreement among scientists about whether the formation of these crusts represents a net release or net uptake of GHGs from the atmosphere (Lal et al. 2000). Calculating carbon sequestration in inorganic forms is complicated, and there is currently no consensus among soil scientists about how to do so. The significant measurement challenges as well as the fundamental lack of agreement over whether carbonates represent a net storage or net release of carbon will likely hinder the inclusion of inorganic soil carbon pools in future offset programs. The slow rate of soil inorganic carbon accumulation and the apparent difficulty of controlling changes in it through management decisions have led researchers in the field to conclude that soil inorganic carbon is not a viable avenue for land-based sequestration (Eswaran et al. 2000, Suarez 2000).

1993, Reeder et al. 2004, Rice and Owensby 2001, Shrestha and Stahl 2008). Nevertheless, it is clear that utilization rates that exceed sustainable levels and decrease plant productivity over time place the carbon stored in the soils and plants of grazed ecosystems at higher risk of loss. Unsustainable grazing reduces long-term plant productivity and thereby reduces carbon uptake by the ecosystem while simultaneously increasing the risk of erosion and decomposition of soil organic matter. All of these outcomes, in turn, affect the long-term capability of rangelands to support grazing animals, diverse wildlife habitat, and other environmental services. Although it is difficult to model or predict the effects of small changes in grazing activities on soil carbon, once overgrazing begins to affect plant productivity, the potential of rangelands to capture carbon is progressively reduced, and the

risk of carbon loss (and the loss of other environmental services) progressively increases (Conant and Paustian 2002). The net effect of unsustainable overgrazing on soil carbon storage is long-term carbon loss (Lal 2004a).

Rotational vs. continuous grazing—
A recent survey by Briske et al. (2008) found that there has been very little research comparing the effects of rotational and continuous grazing on carbon balances. Most of the research to date has focused instead on how these management strategies affect forage condition and animal productivity. Until the carbon effects of these grazing strategies are measured and reported, it is not possible to provide a scientifically based assessment of the benefits of continuous versus rotational grazing for sequestering carbon in rangeland plants or soils. Despite this lack of scientific evidence and the high level of uncertainty surrounding the carbon balances associated with these practices, some carbon offset programs require the use of one strategy over the other. For example, up until August 2009, CCX required ranchers participating in their program as offset providers to practice rotational grazing, although they have since removed that requirement and now only demand the completion of a formal grazing plan.

Gene Alexander, Natural Resources Conservation Service

Stocking rates—

Research considering the relationship between stocking rates and rangeland carbon balances has found dramatically conflicting results. Some research has shown that high stocking rates (including but not limited to use in a short-duration, high-intensity grazing system) may increase carbon storage compared to light or no grazing (Owensby et al. 2006, Reeder et al. 2004). A review of many studies around the world suggested that excessive utilization reduced the carbon sequestration achieved by many grasslands and that the capacity to restore these grasslands to higher sequestration by reducing utilization rates improved with increasing amounts of annual precipitation (Conant and Paustian 2002). Still other research has found that grazing does not affect soil carbon sequestration, regardless of intensity (Lecain et al. 2000, Shrestha and Stahl 2008). These conflicting results are not simply a product of comparing research in different ecosystems. Studies conducted in tallgrass, shortgrass, mixed grass, shrub-steppe, and other grazing ecosystems around the world have also found conflicting results (Conant and Paustian 2002, Milchunas and Lauenroth 1993). This high level of uncertainty makes it difficult to predict the carbon benefits of low versus high stocking rates. The main exception to this uncertainty is where grazing is practiced at unsustainable levels that reduce plant productivity over time, as described above.

Research considering the relationship between stocking rates and rangeland carbon balances has found dramatically conflicting results.

Plant Community Management

Organic amendments—

Organic amendments, such as manure and biosolids (municipal waste), are nonsynthetic materials that may be applied to the land for a variety of reasons. Rangeland soil amendments have been primarily investigated for their potential to mitigate erosion or to enhance nutrient availability for grass production. Studies that have measured how the application of organic materials to soils affect soil carbon have often found a positive response, with organic amendments leading to measurable changes in soil carbon storage (Conant et al. 2001, Follett et al. 2000, Moffet et al. 2005, Paschke et al. 2005). Soil amendment applications have also shown other rangeland benefits, including increased plant production and decreased erosion over time (Martinez et al. 2003, Meyer et al. 2004, Pierce et al. 1998, Walter et al. 2000). It is unclear, however, whether organic amendments actually enhance carbon sequestration following their application, or whether the increased soil carbon storage observed is due to remnant carbon from the organic materials themselves (Conant et al. 2001).

Because quantifying the carbon benefits of organic amendments is complex, regulators and other carbon market participants may be hesitant to recognize and accept organic amendments as a quantitatively verifiable means to sequester carbon in soils and as a management practice that should qualify for carbon offsetting. Moreover, the use of some organic amendments is controversial from a carbon perspective. For example, in the case of farmed land, adding manure to fields is a less efficient way of returning plant carbon to soils than simply leaving cows out of the equation altogether; the simplest and most direct way to introduce carbon to farm soils is to retain existing plant tissues to decay in the field, or to return dead plant material directly to the land. The diversion of plant tissues from farm land to feed animals that produce the manure in turn leads to a variety of other emissions and environmental issues (Schlesinger 2000). The policy debate surrounding such calculations is outside the scope of this document; such debate highlights some of the contentious issues surrounding management actions that may have local carbon benefits but raise larger environmental and policy questions.

Encouraging woody encroachment or forest growth—
The expansion of woody plants such as shrubs and trees onto landscapes previously dominated by grasses is a topic of particular interest for scientists investigating carbon cycling (Pacala et al. 2001). The encroachment of woody vegetation onto rangelands is a widespread phenomenon across the Western United States, and the effects of this shift on ecosystem carbon balances have been investigated in several locations, with mixed results (McKinley and Blair 2008, Smith and Johnson 2003). Woody plants commonly contain more of their carbon in aboveground plant tissues than do nonwoody plants; this fact may place sites with higher levels of woody encroachment at greater risk for carbon losses to wildfire should they burn. In contrast, in grassland ecosystems, significant amounts of plant production take place below ground in roots, which, as they die and decompose, can lead to the formation of soils high in carbon content. A key question is whether the replacement of grasses with woody plants that hold more carbon above ground and put less below ground will lead to a net gain or net loss of carbon for the ecosystem as a whole. In cases where woody encroachment is dense enough to lead to forest establishment, the carbon gains above ground are likely to compensate for any potential losses below ground. This phenomenon would generally be considered afforestation rather than woody encroachment. In situations where woody encroachment is sparse, its effects on the carbon balance appears to depend on other variables such as precipitation and the distribution and productivity of the resulting plant community. For example, a review of several studies conducted by Jackson et al. (2002) found that woody encroachment on wetter sites receiving 660 to 1070 mm/yr precipitation

resulted in a net carbon loss to the atmosphere, whereas woody encroachment on drier sites receiving 230 to 322 mm/yr resulted in net carbon sequestration. This area of research is still young, and further study is necessary to make general predictions about the direction and size of shifts in carbon storage following woody encroachment.

Revegetating bare ground—

Plants are the primary vehicle for adding carbon to terrestrial environments. It follows that increasing plant cover or productivity should lead to increased carbon inputs to soils. In some circumstances, however, increased plant productivity may also lead to increased decomposition, resulting in no net carbon gains. In the case of bare ground, on balance, revegetation is a means not only to prevent soil erosion and land degradation, but to increase vegetation and soil carbon storage. To date, most of the research investigating revegetation by planting grass and vegetation control has taken place in the context of converting marginal agricultural lands to grasslands, rather than range management (Derner et al. 2005). Studies examining the restoration of agricultural fields to grasslands have shown that doing so increases carbon storage by replenishing some of the carbon lost from years of soil disturbance through tillage and erosion. More research is needed to quantify and characterize changes in the carbon balance resulting from revegetation of bare ground in rangeland environments, but preliminary results from agricultural soils suggest that planting grass may help to increase soil carbon storage. One example of how bare ground can enter into carbon considerations on rangeland project areas is through requirements from CCX that devegetated areas surrounding prairie dog towns not be counted toward acreage that is sequestering carbon (Graham, T. 2009. Personal communication, Aeroscene Land Logic).

Invasive species control—

The spread of invasive species on rangelands in the West has become a major concern for range managers, and will likely continue with the changes in temperature and precipitation that are predicted to occur with climate change. Invasive species such as cheatgrass (*Bromus tectorum* L.) can establish monocultures rapidly, outcompeting more desirable species for forage, and leading to dramatic increases in wildfire frequency that can, in turn, lead to long-term exclusion of other species not adapted to frequent fires. The increased occurrence of fire has led some researchers to be concerned about the release of GHGs to the atmosphere from the burning of plants, and to an interest in determining the effects of these invasions on ecosystem carbon storage. Although the results have not always been statistically significant when comparing between cheatgrass and native steppe and grassland communities,

several studies have shown cheatgrass invasion to result in considerable carbon losses from aboveground plant biomass, particularly in sagebrush communities following fires, with the potential to shift these environments from net carbon sinks to sources (Bradley et al. 2006, Norton et al. 2004, Prater et al. 2006). Although the invasion of cheatgrass represents a concern for increased carbon losses from invaded communities, the ability to affect the carbon balance in these environments is complicated by the difficulty in preventing cheatgrass invasions as well as in restoring invaded areas to native plant cover. Further efforts to prevent and control these invasions, and research on how to do so, are needed for a number of environmental reasons.

Prescribed fire—

Wildfire in rangeland environments can exert a strong influence on the type and abundance of vegetation that grows there over time. Wildfire risk stems from the nature of the fuels present and wind and moisture conditions, which may be altered as climate change progresses. The increase in wildfire occurrence in many ecosystems over the past decade has led to management actions like fuel removal and prescribed burning that aim to reduce the severity of fires in these ecosystems. Although rangeland wildfires can release a significant amount of carbon to the atmosphere, they do not appear to affect long-term ecosystem carbon storage in rangeland environments (Davies et al. 2007). This is because fires do not significantly change belowground carbon storage, and the largest reservoir of carbon in rangelands is located below ground. Despite this lack of long-term observed effects, offset programs may require the removal of burned acreages from consideration for crediting for carbon sequestration for a specific number of years. For example, CCX excludes burned acres from counting for carbon crediting in the year they burn (Graham, T. 2009. Personal communication, Aeroscene Land Logic). Ultimately, the use of prescribed fire in rangeland environments does not appear to offer any distinct carbon benefits compared to allowing wildfires to burn. The lack of clear carbon benefits associated with prescribed burning make this practice unlikely to qualify for offsetting as a carbon sequestration strategy.

Although rangeland wildfires can release a significant amount of carbon to the atmosphere, they do not appear to affect long-term ecosystem carbon storage in rangeland environments.

Soil Conservation and Amendments

Erosion control—

Just as erosion removes soil from a site and transports it to a depositional area or body of water, erosion also moves the carbon contained in soil from one place to another. Surface soils are higher in organic matter, carbon, and nutrients for plant growth than deeper soil layers. Consequently, surface erosion leaves the eroded environment less capable of supporting a thriving plant community and other

Hannah Gosnell

important ecosystem functions. Erosion can also negatively affect other areas—for example, by increasing sediment loads in streams and rivers, which can interfere with critical biological processes there. Thus, it is apparent for reasons unrelated to carbon sequestration that the control of soil erosion is important for sustainable land management in the United States and around the world.

Although the process of erosion is well known to negatively affect the soil environment and related ecosystem processes in the places where soil is lost, there is much disagreement among experts on how erosion affects local, regional, and global carbon balances (Harden et al. 2008; Lal 2003; Lal and Pimentel 2008; Lal et al. 2004a, 2004b; Renwick et al. 2004; Smith et al. 2001; Stallard 1998; Van Oost et al. 2004, 2007). The debate has focused primarily on agricultural fields rather than rangelands because soil erosion is a common problem associated with farming. The major difficulty in evaluating how erosional processes affect the carbon balance of soils is determining how quickly carbon can be replaced by plant growth, and whether the movement, deposition, and burial of eroded sediments in basins or water bodies actually reduces its decomposition rate.

At smaller scales, the issue of erosion is more straightforward. Locally, the removal of soil through erosion commonly causes its transport to another site located beyond a given landowner's property boundaries and control, potentially leaving behind bare ground or areas with sparse vegetation or low productivity.

This represents a clear loss for the landowner not only of the carbon contained in the eroded soil, but also of important ecological functions provided by the soil. Lands used for carbon offset activities that include soil carbon in their measurements will therefore benefit from the prevention of soil erosion through good soil management practices. When eroded soils are redeposited onsite, it is more challenging to calculate the resulting site-specific carbon balance.

In general, GHG policies are concerned with carbon balance questions at much larger scales than that of individual properties. It is therefore unclear whether carbon sequestration standards or policies will recognize erosion control as a means to avoid carbon loss, and as a stand-alone land management practice eligible for carbon credits. Regardless, erosion control remains an important strategy for sustainable land management, and should not be considered solely a carbon issue.

Irrigation—

Irrigation is a method commonly used to enhance plant growth, particularly in environments where water is the most limiting plant resource. Although most of the research on irrigation and carbon balance has focused on croplands, and to a lesser extent on pasture lands, the high carbon costs of developing irrigation systems make the limited gains that might occur from enhanced plant growth in rangelands unlikely candidates for carbon sequestration offsets in markets. The construction of irrigation systems and the pumping of irrigation water require the use of materials and energy that release GHGs to the atmosphere (Lal 2004b, Schlesinger 2000). Furthermore, water removed from belowground reservoirs can have CO_2 concentrations more than 25 times atmospheric levels. When this water is brought to the surface, most of this CO_2 leaves the water and returns to the atmosphere (Martens et al. 2005). Although some research in croplands has shown a potential for carbon sequestration following irrigation, few studies have included the carbon costs of establishing and running the irrigation system. Schlesinger (2000) estimated that irrigation to increase plant production in semiarid and arid environments often leads to a net release of carbon to the atmosphere. Simply put, the carbon costs of irrigation are difficult to recoup through the slow and indirect process of soil carbon sequestration. Ultimately, the practice of irrigation in arid and semiarid rangeland environments appears unlikely to produce enough soil carbon gain from increased plant growth to overcome the significant carbon costs of building and operating the irrigation system.

The carbon costs of irrigation are difficult to recoup through the slow and indirect process of soil carbon sequestration.

Nitrogen additions—

In many plant communities, nitrogen is the most limiting nutrient for plant growth. Adding nitrogen to soils would therefore seem like a straightforward way to stimulate plant growth and thereby encourage soil carbon sequestration. In the case of synthetic fertilizers, the GHG emissions associated with producing, transporting, and applying them compete against the increased carbon uptake rates enabled by fertilization. Some studies of the use of synthetic fertilizers have shown modest carbon sequestration gains in agricultural soils, but few have weighed these gains against the GHG emissions costs associated with using the fertilizer (Schuman and Derner 2004). Other studies have found either no change in soil carbon from nitrogen fertilization, or that the carbon costs of fertilizer use outweigh any carbon sequestration benefits (Schlesinger 2000, Verburg et al. 2004).

Introducing plants such as legumes that naturally fix nitrogen to rangelands is one means of increasing nitrogen in soils to promote plant growth and carbon sequestration. However, the leading studies to date on the effects on soil carbon have not shown convincing results. One study in South Dakota showed some increase in soil carbon stores with alfalfa seeding, although the results were not always significant (Mortenson et al. 2004). In a study in Wyoming, seeding with alfalfa did not produce significant changes in soil carbon storage (Robles and Burke 1997). Based on these findings, it remains uncertain whether the use of nitrogen-fixing plants such as alfalfa is a reliable way to sequester carbon.

General Conclusions on Rangeland Carbon Sequestration

The science of carbon cycling in rangelands is a relatively new field, and considerable additional research is necessary to enable reliable quantification of management effects on carbon storage. In general, carbon sequestration occurs more slowly and is more complicated and costly to measure and monitor in soils than in plant pools. Despite these apparent hurdles, many scientists believe there is a significant potential for sustainable rangeland management to complement other offset types at mitigating climate change (Follett et al. 2000). Compared to opportunities for forestry, the carbon market currently offers relatively few standards for rangeland management. Nevertheless, sustainable rangeland management will be an important component of adapting to climate change throughout the world, and opportunities for ranchers to participate in carbon markets will likely continue to emerge and evolve.

Common Questions About Market Participation

The following questions cover what we anticipate will be the major issues of interest to landowners and project developers who are considering carbon market participation. The list is not comprehensive, but provides basic information and direction towards further resources where appropriate.

Which Offset Program Should a Landowner or Project Developer Choose?

Although many offset standards have been developed with similar goals and requirements, each standard is unique and may yield different results for your project. If you begin a project with the expectation of selling credits through voluntary OTC transactions, you can expect different standards to correspond to different prices for offset credits. Web links to references that compare some of the standards are provided in the "Further Reading" section at the end of this document. Some of the questions that should be asked when choosing an offset standard or trading program include:

- **What activities are eligible?**

  As indicated in table 1, different offset programs allow different types of activities. The standards are evolving, and the most current version of the standard should be consulted to determine what management activities are eligible under a particular standard.

- **Is an existing forest or rangeland environment or management plan in line with the standard?**

  Some standards place restrictions on the types of forest or rangeland that can be enrolled in a program. For example, CCX has a list of counties and precipitation zones that a range management project must fall within to participate. Rangelands lying outside of these zones are excluded. The CAR forestry project protocol requires maintenance of diverse forest age classes and has minimum requirements for native species planting and diversity. Finally, every standard defines "forest" and "rangeland" in a slightly different way. It is important to make sure that your land and management plan are compatible with the standard.

- **Does a landowner's property have enough sequestration potential to enter a project on its own?**

  The smaller the area, or the lower the productivity of land being managed for carbon sequestration, the more likely it is that you will have to seek

the assistance of an aggregator. Smaller landowners will commonly find that their carbon sequestration activities may not provide enough income to support the costs of verification and other expenses and program fees. Some offset programs also have a minimum sequestration amount for participation. This requirement may lead to a minimum threshold of acreage for landowners to participate without the assistance of an aggregator. The aggregation of projects reduces the financial hurdle for each landowner by combining verification and monitoring expenses, as well as other fees assessed for market entry and participation.

- **What are the requirements for carbon measurement and monitoring, and how much do they cost?**

  The methods required for measuring and monitoring carbon storage may differ among standards and are continuing to evolve over time. Most standards have been designed to balance the costs of measurement against the need for precise and accurate inventories. In forestry projects, the shift from a traditional timber inventory to a carbon inventory may or may not require the field measurement of additional carbon pools not traditionally counted but commonly includes estimates of the amount of carbon stored in wood products. Each program will mandate how and when inventories should be conducted and have guidance on acceptable sampling error. The cost of a carbon inventory for forestry projects can be expected to be at least as expensive as that of a traditional timber cruise and will likely be somewhat higher, depending upon the program's requirements. Most programs will also require some form of annual or periodic monitoring and reporting to describe intentional or unintentional changes to the project's carbon stores, including natural disturbances, shifts in harvesting strategies, or increased confidence from further inventories. The cost of monitoring and reporting will differ among offset programs depending upon the role of third-party verifiers and how frequently monitoring updates must be submitted.

- **Are there any land use restrictions? How are they enforced?**

  To discourage landowners from abandoning their carbon-oriented management plan following enrollment in an offset program, landowners may be required or encouraged to implement a conservation easement or other land-use restriction to guarantee the permanence of stored carbon on their lands. These restrictions may or may not stay with the land following its sale or transfer to another owner. The contract terms for how long the

land must stay enrolled will vary from program to program, and can be an important issue in determining which standard best fits your management goals. Because many offset programs are very young, there is not a clear record of procedures for enforcing program rules or addressing noncompliance. Most programs rely on the use of contracts between landowners or project developers and the credit-issuing organization (i.e., a registry or standards organization). The general expectation is that enforcement will be based on legal actions resulting from failure to comply with contractual obligations.

How Long Does it Take to Sequester Enough Carbon to Register and Sell Carbon Credits?

Depending upon the nature of the project and the accounting procedures used by each standard, carbon credits may be generated in the first year of a project. Some standards may recognize (explicitly or indirectly) the carbon storage achieved by early actors. Depending upon the arrangement used to sell credits, income streams can vary widely. The significant upfront costs of many projects (particularly forest planting) make forward selling of credits a particularly useful strategy. By creating a contract with a buyer that commits the seller to deliver credits once they become available (i.e., are verified and/or registered) from the project, offset project developers may tap into some of the value of those credits to meet startup or other expenses. Most projects should be able to start generating income beginning in the first years of the project, but both the rate of growth and total expected additional growth of the forest may have a direct impact on how much money can be expected. Ultimately, the cashflow associated with carbon offset projects is highly dependent upon the arrangements made between the project developer and offset buyers as well as the current forest condition and potential for growth.

At What Point in This Process Will Payments for Offset Activities Occur?

As mentioned above, a variety of arrangements can be made between buyers and sellers of offset credits. Credits may be committed to buyers through forward sales or may be sold to buyers after they have already been verified and registered. Note, however, that verification and registration of offset activities does not guarantee any particular price for the credits or that the credits will even necessarily be purchased. Although verification and registration of offset activities may increase the visibility of the credits generated, it is up to the landowner or project developer to make connections with potential buyers who would then purchase the offset credits.

Are There Any Time Constraints on Selling Carbon Credits?

In some trading programs, carbon credits may expire after a certain period of time, so it is important to consider when and how you are planning to sell your credits. Over-the-counter transactions have been the most popular venue for trading carbon credits in voluntary markets (compared to CCX), and can have different prices from contract to contract. Compliance markets (e.g., RGGI, WCI) have one price for carbon that will change over time based on the supply and demand of allowances and credits.

How Much Does Third-Party Verification and Posting With a Registry Cost?

Third-party verification is paid for by the project developer or landowner and can be one of the largest single expenses of the project. Estimates of the cost of verification for forestry standards range from $2,000 to $40,000, depending on the standard used, the amount of land to be verified, and the type of project (Merger 2008). Many registries or offset programs also charge a fee for posting a project's credits to the registry. These fees differ from program to program and can be flat fees or a set percentage of each registered credit.

Will Managing a Forest for Carbon Sequestration Affect Timber Yields?

In the short term, shifting away from short rotations or high levels of utilization will cause reduced timber removals while trees continue to grow and sequester carbon. Longer term yields will depend on the management strategy and composition and growth conditions of each forest. Forests managed for carbon sequestration may provide sustainable timber yields from older and larger trees, but the difference in yields between traditional forestry practices and practices that maximize carbon sequestration will differ from forest to forest. Because the price of carbon credits is expected to rise in the future, the value of storing carbon in trees may eventually compete with the timber value of some tree species. As carbon sequestration activities become more common and regulated markets for carbon credits are established, the prices for offset credits are expected to rise, but it is not clear whether they will outpace timber values. Carbon-oriented practices may complement other forest management practices, and will likely be compatible with, rather than exclusive of, several different forest management goals.

Carbon-oriented practices may complement other forest management practices, and will likely be compatible with, rather than exclusive of, several different forest management goals.

Will Following Carbon-Oriented Management Practices Reduce Income?

Depending on current management practices, a shift to managing for carbon sequestration may result in reduced income from traditional sources. Because these programs are voluntary however, a landowner is able to carefully consider any tradeoffs involved in starting an offset project and enter into these commitments only if he or she feels that it makes the most sense. For example, a management plan for carbon sequestration in forests may include reduced amounts of timber harvesting, thereby leading to reduced timber sales, at least in the short term. These short-term reductions in timber revenue may be compensated for by revenues from carbon sequestration, depending upon the capacity for the forest to sequester additional carbon. Similarly, reducing rangeland stocking levels to meet sustainability requirements could lead to lower livestock sales. In both circumstances, this reduction in income may at least be partially compensated for by the income earned from the sale of carbon credits. However, the net change in income will depend on the current management strategy and the capacity of the land to sequester carbon. The price of carbon credits has varied dramatically over the past few years, and the economic viability of managing for carbon will likely depend on the price of carbon credits and the income they can generate. Before making a decision to pursue a specific carbon offset activity, offset standard, or GHG program, careful consideration of the associated economic, environmental, and social benefits and costs should be made by the landowner. The carbon market and offset standards have been designed to encourage particular types of activities that may or may not be suitable for every forest and rangeland. There are a variety of opportunities for landowners to become involved in these markets and it is to the landowner's benefit to become aware of their options and consider the costs and benefits associated with diversifying the sources of revenue from their land.

Do Carbon Markets Provide an Opportunity for Financing Restoration Projects?

The carbon market may provide an opportunity for financing restoration projects if there is a clear carbon benefit associated with the restoration activity. In recent years, carbon offset standards have developed to include broader environmental and social benefits, but the main thrust of the project must be carbon sequestration or emissions abatement. Some restoration activities that have unclear or disputed carbon benefits will face significant challenges to entering carbon markets, whether or not they have other social or environmental benefits. One example is the case of forest thinning and prescribed fire to mitigate the risk of wildfire (see "Forestry" section).

Most offset standards have been developed to streamline carbon offset activities into paths that are efficient to verify and account for using general project types such as afforestation or forest management, among others. Some restoration projects that offer carbon benefits may not be included in current offset standards because they present unique measurement challenges or for other reasons. If a restoration activity is not currently included in the existing protocols or standards, offset programs generally have an established process for reviewing proposals for new offset activities that are not currently included within their rules. The OTC transactions in the voluntary market provide a bit more flexibility for restoration activities that provide carbon benefits (or other environmental benefits) that may be outside the scope of the offsets allowed by other existing standards or compliance markets. As with all OTC transactions, financial compensation for these projects will depend on the individual contract negotiations between the buyer and the seller of the carbon credits.

What Does the Future of the Crediting Program Look Like?

Many compliance markets are expected to come on line in the next few years. It is not clear how the voluntary market will change as a result, or whether particular standards or credits will be grandfathered into these new markets. To manage this risk, it is important to consider whether the standard you are pursuing is rigorous enough to be supported by other markets. For example, the CAR/California Climate Action Registry standard has been approved by the Voluntary Carbon Standard (VCS), meaning that if you follow CAR protocols, you are eligible to post your credits not only to CAR but also to VCS registries. Similarly, Kyoto's CDM protocols have been endorsed by several standards and cap-and-trade systems, and international credits registered through CDM (or whatever standard takes its place post-Kyoto) are likely to be eligible for domestic cap-and-trade programs. Because the policies for these regional and any future federal cap-and-trade programs have not yet been finalized, it is not possible to guarantee the price or future of any specific standard or crediting program.

Are Forestry or Range Projects on Public Lands Eligible for Offset Credits in Existing Carbon Markets?

Ranchers, forest owners, and other residents of communities that surround public lands may engage in forestry and grazing activities on public lands. At present, public lands in the United States have not commonly been used for carbon offsetting, and it is unclear whether they will be eligible in the future. The CAR allows participation of state-owned forests in their offset program, but does not currently

allow for activities on federal lands. Many of the policies governing cap-and-trade programs in the United States are still being developed; it may take a year or more before the role of state and federal lands in carbon and other ecosystem services markets is clear. Some of the primary concerns with public lands include unique challenges for assessing the "business-as-usual" scenario and how and whether carbon and other ecosystem service benefits from public lands should be sold to private entities. The specter of the potentially large volume of offsets from federal lands flooding the market has also been raised by market observers, but this potential is likely to be significantly constrained by additionality requirements that would be placed on activities carried out on public lands. For example, although the CAR does not currently allow federal lands to participate in the offsetting program, the additionality requirements placed on publicly owned lands are considerably more restrictive than those placed on privately owned lands.

Is Participation in Carbon Markets the Only Way to Financially Benefit From Carbon-Oriented Land Management, or Are There Other Options?

For landowners who are unable to pursue viable offset projects in carbon markets, there are also new funding opportunities emerging from government agencies that may provide financial or technical support to landowners interested in incorporating the types of sustainable management practices discussed throughout this document on their land. To find out more about these opportunities, we recommend that landowners contact their local Natural Resources Conservation Service (NRCS) office, Soil and Water Conservation Districts, Extension office, or other organizations serving landowners locally. Programs such as the Conservation Reserve Program, Conservation Security Program, and the Environmental Quality Incentive Program commonly provide support for the development of sustainable land management plans, and cost-sharing opportunities for specific management activities. Landowners interested in pursuing new conservation practices may also inquire about the Conservation Innovation Grants administered through NRCS. The availability of funding from each of these programs may vary from year to year and region to region, so the best source of information about these opportunities is the local offices of these conservation organizations. The use of conservation easements is also one other opportunity for landowners to reduce their tax burden while maintaining the property as a working forest or rangeland.

Conclusions

The rapid increase in GHG emissions over the past century has initiated a dramatic shift in the behavior of the global climate system, and is expected to have a significant influence on the functioning of terrestrial and marine ecosystems around the world. To address this problem, many local, regional, national, and international bodies have begun regulating the emissions of GHGs in an attempt to mitigate the impacts of potential climate change. Carbon markets and offset strategies have arisen as one of the leading tools governments are adopting to reduce GHG emissions. These offset markets offer new opportunities for forest and rangeland owners to finance sustainable land management activities and to help mitigate climate change. The state of our scientific understanding of land management practices to achieve carbon sequestration is more robust for forest ecosystems than it is for rangelands, but, nevertheless, there are opportunities for landowners to pursue sustainable land management of both forests and rangelands and engage with these emerging markets.

A variety of standards have arisen in recent years to help instill more confidence and transparency in offset markets, and each available standard presents unique opportunities and considerations for landowners interested in starting offset projects on their lands. These markets have not been designed explicitly as conservation support programs, and thus there may be landowners whose lands are not suitable for market participation, even though they may have valuable conservation potential. Markets for other ecosystem values may offer opportunities in such cases. A variety of different rules and regulations apply for each offset program, so landowners should review their options for creating and selling offset credits carefully, including possibly not using a published standard.

Biological sequestration presents many unique considerations not found in other types of offset projects. Concerns over additionality, permanence, leakage, and verifiability are all pressing policy considerations that need to be addressed for this market to thrive. Although many voluntary standards have emerged in recent years to address these issues, the future function, structure, and even existence of many federal, regional, and state GHG market programs remains unclear. Policymakers throughout the United States are considering issues like these and many others as they go about the formulation of policy for our states and country to address the challenges presented by climate change and the need for a renewed economy. The policy choices made by legislators and government agencies in coming years will exert a very strong influence in the development of these markets and the potential for landowners to participate in them.

Although much of the policy and market landscape for GHG emissions and payments for other beneficial services provided by natural ecosystems are likely to grow and evolve over time, there are several opportunities currently open to landowners wishing to pursue carbon-oriented management. The emergence of carbon markets has raised the potential for offset credits to simultaneously incentivize sustainable land management, increase and diversify income streams for landowners, and contribute to efforts at mitigating climate change. It is our hope that this document provides a first glance for many landowners and related groups at these emerging markets and the opportunities they may present.

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Further Reading and Resources

Forestry References and Resources

Forest Carbon Portal. http://www.forestcarbonportal.com/.

This Web site provides a look into some of the different forest offset projects that have been launched around the world. A map of the globe shows projects listed with information about standards used, project type, and tons sequestered. This site is run by The Ecosystem Marketplace, a major provider of information and analysis on the emerging carbon markets.

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USDA Natural Resources Conservation Service. Field Office Technical Guides. http://www.nrcs.usda.gov/technical/efotg/.

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English Equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	0.0394	Inches
Centimeters (cm)	.394	Inches
Hectares (ha)	2.47	Acres
Kilograms (kg)	2.205	Pounds
Metric tonnes (t)	1.102	Tons
Tonnes per hectare (t/ha)	893	Pounds per acre
Kilograms per hectare(kg/ha)	.893	Pounds per acre

Glossary

additionality—Describes carbon offset activities, emissions avoidance, reductions, or sequestration that would not have been pursued in the absence of an emissions trading system or market. Activities or changes in emissions that would have occurred regardless of whether there was a carbon market in place do not meet the requirement of additionality. There are several tests that are commonly used to assess additionality. These generally consider the economic, social, or environmental barriers that prevent the conduct of the offset activity in the absence of a carbon market. Activities required by law such as replanting following harvests, or maintaining riparian buffers, are typically not considered additional and are therefore not eligible for carbon offsets.

AFOLU—See LULUCF

aggregator—A person or company that works with landowners or project developers to combine their carbon management activities so that they can access the market as if they had one bigger project.

allowances—Allowances represent a permit to emit a fixed amount of greenhouse gases. In cap-and-trade programs, allowances are distributed to polluters who must surrender one allowance for every equivalent amount of emissions they produce. Over time, the government may decrease the number of allowances distributed to reduce the cap on the total amount of allowable emissions.

baseline—The level of carbon emissions or sequestration that would have occurred without the existence of emissions regulations or a carbon market. There are many ways to determine baselines, and the specific calculation methods differ among offset standards and emissions trading schemes. Baselines are compared with actual carbon emissions or storage data to calculate the amount of emissions reduced, avoided, or sequestered by a project. A baseline is also commonly referred to as a business-as-usual scenario.

biomass—Living and dead plant material. Biomass is commonly broken down into aboveground biomass, belowground biomass, standing dead biomass, downed dead biomass (trees), and litter. Soil and litter are typically not considered biomass, but each offset standard will have its own definitions for biomass and various carbon pools.

cap-and-trade—The most common type of emissions trading scheme for controlling greenhouse gas emissions and reducing them over time. A limit, or cap, is set on the volume of emissions that are allowed from a particular activity or industrial sector (e.g., powerplants). For every ton of emissions allowed within the cap, the government (or other regulatory body) distributes or auctions allowances to the emitters within the regulated sector. At the end of a compliance period, all emitters are required to surrender one allowance for every ton of emissions they released during the period. The emitters who have not used all of their allowances are permitted to trade (sell) them to other emitters who exceed their allowances and need more to match their emissions levels. Alternatively, emitters who exceed their allowances may buy carbon offset credits from other suppliers.

carbon-oriented management—Land management that explicitly considers the effects of management activities on carbon storage and sequestration, with the general goal of enhancing the removal of greenhouse gases from the atmosphere through increased carbon sequestration, avoided emissions, or both.

carbon offset credits—Carbon offsets represent a specific quantity of greenhouse gas emissions that have been reduced, prevented, or neutralized by carbon sequestration or other emissions reduction activities. In emissions trading systems, offsets are quantified as credits that may be traded interchangeably with allowances, and used by emitters to meet their emissions requirements. Carbon offsets are so-named because the activities they describe offset emissions from another source.

carbon sequestration—The accumulation of carbon in an ecosystem over time. This can be achieved by increasing carbon inputs and uptake, decreasing or preventing carbon releases, or both. Biological carbon sequestration in plants and soils is commonly distinguished from the storage of CO_2 emissions in geological features, known as carbon capture and sequestration.

early actors/action—Early action is a term used to describe the activities of pioneer landowners and organizations that began emissions abatement activities prior to the startup of an emissions trading scheme. Many greenhouse gas (GHG) trading programs and offset standards have policies that require landowners to change existing management practices in order to participate in the carbon market. These policies may effectively leave landowners who have practiced carbon-oriented management for years out of emerging markets, even though they are contributing to the reduction of atmospheric greenhouse gases. Critics of crediting activities by early actors point out that these credits do not meet strict additionality criteria and would have happened under business-as-usual circumstances, thus failing to provide new or additional carbon benefits. Advocates of early action crediting argue that these activities have been providing a value to the environment, often at nontrivial expense, for some time and that these good actors should be rewarded for the activities and investments they have made that have carbon benefits. Each offset standard and GHG trading program has its own regulations regarding the cutoff period for eligible activities, and policies regarding the rewarding of early action.

emissions trading scheme (ETS)—This is a market-based approach to controlling emissions of pollutants. Polluters regulated by an ETS may trade credits or allowances with each other to meet a mandated level of reductions. By allowing emitters to trade with each other, those that can reduce their emissions at lower than average costs will do so and be compensated through the sale of unneeded credits or allowances to other companies who cannot reduce emissions at such a low cost. Emissions trading is seen as a more efficient way to reduce emissions across many industries and economic sectors than simply requiring all companies to reduce their emissions to a fixed level, regardless of the cost for each emitter. Cap-and-trade is one type of ETS.

forward sale—A type of sale that involves payment up front for a product to be delivered in the future. In the case of offsets, this will usually involve a contractual obligation to deliver credits in the future once they have been verified, registered, or issued. Project developers may use these contracts with potential offset buyers to deliver credits in the future in exchange for payments to help cover initial startup costs or other expenses.

greenhouse gases (GHGs)—Gases that absorb solar radiation and increase the trapping of heat in the Earth's atmosphere, giving rise to the "greenhouse effect." The most common GHGs are carbon dioxide, methane, nitrous oxide, sulfur dioxide, perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride.

land-use, land-use change, and forestry (LULUCF) and agriculture, forestry and other land-uses (AFOLU)—These are terms used to collectively refer to land management and land-use activities that contribute to greenhouse gas emissions reduction or sequestration potential. In common carbon market use, LULUCF and AFOLU are generally interchangeable terms. The LULUCF or AFOLU activities that are eligible for offset projects and GHG emissions trading programs will vary, and are specified by each program. These activities typically do not include renewable energy generation, even when this energy is derived from biological sources (such as ethanol, methane capture from manure, biomass energy, etc.). Common LULUCF and AFOLU activities include afforestation, avoided deforestation, improved forest management, conservation tillage in agriculture, and improved rangeland management.

leakage—The risk that the carbon sequestration or emissions reductions achieved by offsetting activities result in increased carbon emissions in another form or location. For example, if harvesting in one stand is reduced to encourage carbon storage for offset purposes, any increase in harvesting in other stands that compensates for that reduction diminishes the credibility of the offset activity, and is referred to as leakage. Many offset standards require some assessment of leakage risks, and a plan to mitigate those risks. Internal leakage refers to leakage within one project or landowner's control. External leakage is more difficult to control and refers to leakage that occurs outside of the offset project's boundary, for example on neighboring lands not owned or controlled by the landowner or offset project developer.

offset—Positive effects from one activity that compensate for negative effects from another activity are said to offset those negative effects. For the use of this term in regard to greenhouse gas emissions, see the definition of "carbon offset credits" in the glossary or the sidebar discussion "What are offsets?"

offset standards—A formalized collection of guiding principles for the character and quality of offset projects (regardless of the type of offset project) allowed to use the name of the standard's organization in the registry or sale of offset credits. In this document, we consider the term "standards" to be distinct from "protocols," which we use to refer to the specific rules governing the submission and review of individual offset projects of a particular type (e.g., a forest project protocol). The words "standard" and "protocol" are often used interchangeably in real world situations, but are used as defined above in this document to provide as much clarity as possible.

outcome-based standards—Standards that base the effectiveness or acceptability of an activity on the outcome of that activity, rather than on the requirements associated with specific management practices. Most forest carbon credits are calculated using field measurements that verify how much carbon is actually sequestered over time. Some outcome-based offset standards may also require certification that the enrolled land is being managed using sustainable practices. Most forest carbon offset standards are outcome-based.

permanence—The requirement that the amount of carbon sequestered, or emissions reduced by a project, is secured in perpetuity. Disturbances such as wildfire, pest/pathogen outbreaks, or unauthorized harvesting activities may expose the carbon previously sequestered in biological forms such as trees, litter, and soil to be released back to the atmosphere. Many offset standards or programs require some plan to mitigate the risk of carbon losses in the future, or may require that some carbon credits be reserved in a "buffer" account to insure against unanticipated future carbon losses.

pool—A term used to describe a particular form that carbon takes in an ecosystem. Examples of forest carbon pools that are commonly considered for offset purposes include living trees (live biomass), standing and downed dead wood (dead biomass), litter, and soil.

prescriptive standards—Standards that base the effectiveness or acceptability of an activity on adherence to a set of approved management practices or methods. These standards may or may not require the physical measurement of carbon storage. For example, the Chicago Climate Exchange rangeland soil standards do not require the physical measurement of soil carbon storage, but do require the land manager to follow specific management guidelines.

registry—A database that can be used to keep track of emissions inventories, carbon credits, allowances, or transactions between participants in greenhouse gas emissions trading programs. Registries are an important component of carbon markets because they provide an increased level of transparency in the functioning of the market.

sink/source—A carbon pool (such as soil or live trees) that takes up more carbon than it releases over time is described as a carbon sink. Carbon pools that release more carbon over time than they capture are called carbon sources (to the atmosphere). Many ecosystems can behave as both carbon sinks and sources over time, depending on how plant productivity and decomposition respond to seasonal or long-term changes in environmental variables like precipitation, temperature, and sunlight, and disturbances such as wildfire, pests, and diseases.

tCO_2e—Metric tonnes of carbon dioxide equivalent. This unit is used to describe quantities of greenhouse gas (GHG) emissions by comparing their global warming potential over time to that of carbon dioxide (CO_2), the most common GHG. One metric tonne of CO_2 is equal to 1 tCO_2e. Those gases that contribute more to global warming per tonne than CO_2 have higher values. For example, one tonne of methane, which is 25 times stronger than CO_2 in contributing to global warming over 100 years, is equal to 25 tCO_2e. A tonne of nitrous oxide, which is 298 times as strong a GHG over 100 years as CO_2, is equal to 298 tCO_2e. In the case of biological carbon sequestration, where the measurements collected in the field are usually used to calculate volume, then biomass and finally tonnes of carbon (not tonnes of carbon dioxide), one tonne of carbon is equal to ~3.67 tCO_2e. Prices for carbon credits and allowances are commonly expressed as dollars per tCO_2e.

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Appendix: Guidance and Standards for Offset Projects

American Carbon Registry

http://www.americancarbonregistry.org

The American Carbon Registry is a private registry designed with GHG inventory capabilities for companies, as well as a registration and tracking system for offset projects. The registry is run by Winrock International, a company that has been involved in the formation of many forest offset standards and projects around the world. A forest project protocol was released in March 2009. Registration with the American Carbon Registry includes certification of offset activities and the generation of carbon credits. The American Carbon Registry accepts offset projects verified under its own protocols as well as those accepted by VCS.

CarbonFix Standard (CFS)

http://www.carbonfix.info/

This standard is designed solely for offset projects involving the establishment of new forests. CarbonFix allows for credits to be certified and sold prior to field verification of the offset activities (ex-ante credits). The CFS has offset tracking capabilities that encourage companies to use the purchase of these offsets for green marketing by providing codes that allow the consumer to trace carbon-neutrality claims on products back to individual offset projects.

Chicago Climate Exchange (CCX)

http://www.chicagoclimatex.com/

The CCX opened in 2003 and provides offsets derived from land-use projects for both rangelands and forests (as well as many other agricultural project types) throughout the United States. The CCX is a voluntary, but legally binding, cap-and-trade program with both emitters and offsetters participating. Offset providers follow CCX protocols and can register and sell their carbon credits (known as Carbon Financial Instruments or CFIs) through the CCX to other members; CFIs may also be sold over the counter through private contracts with any private or public entity. The CCX protocols were recently updated as of August 20, 2009.

Climate Action Reserve/California Climate Action Registry

http://www.climateregistry.org/

California launched a Climate Action Registry (CCAR) in 2001 that allows offset activities through a new overarching organization known as the Climate Action Reserve (CAR). The reserve has also led the development of offset standards for several land-use, land-use change, and forestry (LULUCF) activities. Although

California plans to launch its own cap-and-trade program in 2012, the CAR has been designed to function with voluntary markets as well, and following the launch of its most recent forest protocol in September, 2009, is now open to forestry projects throughout the United States. Although the reserve allows livestock management offsets (through manure and methane management), it does not currently allow range management offset projects. Offset project developers follow reserve protocols and register projects for credits (known as Climate Reserve Tonnes or CRTs). Credits registered through the CAR can then be independently sold to any interested private or public entity using private contracts.

Climate, Community, and Biodiversity (CCB) Standard

http://www.climate-standards.org/

This standard is designed to recognize all land-based offset projects that include climate, community, and biodiversity benefits. It does not register or generate carbon credits, but rather certifies that all projects meeting CCB criteria provide additional social and environmental benefits beyond carbon sequestration alone. The standard complements other offset standards that do create and register carbon credits. The advantage of using this standard is that, by including community and biodiversity co-benefits, carbon credits may yield a higher sale price when sold on the voluntary market.

The Climate Trust

http://climatetrust.org

The 1997 Oregon legislation regulating carbon dioxide emissions created a non-profit organization called The Climate Trust to develop offset projects with the money provided by power companies. The Climate Trust periodically opens calls for offset project proposals to meet the need for these offset projects, which can include forestry and range projects provided they meet The Climate Trust's offset quality criteria.

Intergovernmental Panel on Climate Change's Good Practice Guidance

http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

Commissioned by the United Nations, this report provides guidance for "estimating, measuring, monitoring and reporting on carbon stock changes and GHG emissions" from land-use, land-use change, and forestry (LULUCF) activities. The guidelines do not lead to any kind of certification or to the creation of carbon credits; they were designed primarily to aid in the completion of national greenhouse gas (GHG) inventories as part of the United Nations Framework Convention on Climate Change (UNFCCC). Apart from UNFCCC commitments, this guidance

has also served as a guide for policymakers and market participants such as offset developers and verifiers.

The International Organization for Standardization (ISO) 14064 Standard

http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=546318

The ISO is a standard-developing organization that has published more than 17,500 standards on a wide variety of subjects and industries. The 14064 standard contains three sections, which provide guidance on quantifying and reporting greenhouse gas inventories, project-level accounting for offset projects, and guidance for the validation and verification of emission-related claims; 14064-2 is the standard that applies to offset projects. This standard is primarily used as an auditable framework for accounting and has been used as a building block for offset protocols. This standard provides detailed guidance for project-level accounting and quantification issues, but is not specifically applied to generate or register offset credits.

Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI)

http://cdm.unfccc.int/index.html and http://ji.unfccc.int/index.html

The CDM and JI are designed for offset projects carried out in developing and developed countries, respectively, as part of the international cap-and-trade program within the Kyoto Protocol. The CDM-approved offset project protocols have been used much more than JI and have served as a starting point for many other offset standards. This standard can be applied to offset projects regardless of their location, but for countries like the United States that are not party to the Kyoto Protocol, compliance with CDM standards does not generate credits within the Kyoto Protocol's cap-and-trade system. Instead, it serves solely to demonstrate that project activities were carried out and verified according to CDM guidelines. Owing to the very rigorous nature and high cost of verification and compliance with CDM, relatively few forestry projects have been registered through this mechanism. It does not include range management offset projects.

Plan Vivo

http://www.planvivo.org/

Plan Vivo focuses on sustainable development issues including the environmental and social co-benefits of managing for carbon. It is primarily targeted at offset projects in developing countries. Plan Vivo is a relatively small standard program and can include ex-ante credits, which are generated before an offset project begins in anticipation of its eventual carbon reduction benefits.

U.S. Department of Energy Voluntary Reporting of Greenhouse Gases Program [1605(b)]

http://www.eia.doe.gov/oiaf/1605/index.html

This registry was created by the Energy Policy Act of 1992. It allows participants to post emissions reduction and sequestration activities. The program does not involve the generation or sale of carbon credits, but rather is solely a registry for posting emissions-related activities. Emissions data entered into the registry do not require third-party verification or field-based measurement of carbon storage. Many of the accounting methods developed for the program have been used in the creation of other offset standards. The program underwent significant revision and updating in the early 2000s and now serves as a reference used for many other offset standards.

U.S. Environmental Protection Agency (EPA) Climate Leaders Program

http://www.epa.gov/stateply/

This program was primarily designed to facilitate the completion of greenhouse gas management plans and reduction strategies for private businesses. The EPA launched the Climate Leaders program in 2002. Companies that enroll in the program commit to completing a company-wide emissions inventory and setting reduction targets with periodic reports of progress made to the EPA. Although this program was primarily intended to ease the transition to greenhouse gas accounting and demonstrate early action for participating companies, the program has also recently been expanded to offer guidance for offset projects. Although this program provides a protocol for offset projects, it is generally provided as a recommendation for how to carry out project accounting and documentation because there is not currently a third-party verification system or registry system for projects generated using this protocol.

Voluntary Carbon Standard (VCS)

http://www.v-c-s.org/

The VCS protocols were developed in an effort to standardize and provide transparency to all offsets in the voluntary carbon market. Basic descriptions of the VCS goals for offset standards for agriculture, forestry, and other land uses (AFOLU) have been developed, but no specific protocols for these project types had been released as of December 2009. Projects verified using this standard are issued credits after carbon storage has been verified (ex-post credits) and registered on one of several registries. The VCS is one of the most widely used offset standards in the voluntary market to date. The VCS allows registration of offsets from projects certified by VCS standards as well as those from CAR.

World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) GHG Protocol

http://www.ghgprotocol.org/

The WRI/WBCSD GHG protocol provides guidance to governments, companies, and offset project developers for inventorying and reporting GHG emissions activities. Additional guidelines have been composed for LULUCF activities to aid in offset project implementation that address measurement and other accounting issues. This protocol does not offer carbon credits or registration, but has been used as a guide in the development of registries for GHG inventories such as CAR and the American Carbon Registry.

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