Carbon Sinks in the Post-Kyoto World

I N T E R N E T   E D I T I O N

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About RFF

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Introduction

The Kyoto Climate Protocol prepared in December 1997 contained several defining features. It provides for legally-binding emissions targets for Annex I (industrial) countries, although no targets are required for developing countries. Additionally, it recognizes human-induced carbon sequestration as a way of meeting legally binding greenhouse gas emissions targets. The Protocol specifically mentions emissions from sources and removals by sinks resulting from direct human-induced land-use change and forest related activities – deforestation, reforestation and afforestation – undertaken since 1990. However, the Protocol is silent on the role of other sinks in meeting national emission inventories. Agricultural land, for example, is mentioned as a possible carbon source which must be included in a country's emission inventory (see Annex A of the Protocol), but there are no provisions for national credits for the buildup of the agricultural soil carbon sink. However, Article 3.4 of the Protocol appears to allow for expansion of recognized human-induced sink activities. Finally, the Protocol is largely silent on how such credits would be calculated or verified.

In this paper we first review some basic concepts related to the definition of carbon sinks, the functioning of forest ecosystems as sinks, and forest-related activities that change carbon balances. We then examine briefly trends in global forests that affect their carbon balances. Following this discussion we review some of the questions that must be addressed in defining an effective system of forest carbon sequestration credits as part of a national strategy for meeting emission reduction targets. Next, we point out several ways in which the Kyoto Protocol is ambiguous as it applies to carbon sinks and sink credits. Finally, we discuss some broad concepts and practices for projects designed to provide carbon credits.

Global Carbon Sinks: Some Basic Concepts

Global carbon is held in a variety of different stocks. Natural stocks include oceans, fossil fuel deposits, the terrestrial system and the atmosphere. In the terrestrial system carbon is sequestered in rocks and sediments, in swamps, wetlands and forests, and in the soils of forests, grasslands and agriculture. About two-thirds of the globe's terrestrial carbon, exclusive of that sequestered in rocks and sediments, is sequestered in the standing forests, forest understory plants, leaf and forest debris, and in forest soils. In addition, there are some non-natural stocks. For example, long-lived wood products and waste dumps constitute a separate human-created carbon stock. Given increased global timber harvests and manufactured wood products over the past several decades, these carbon stocks are likely increasing as the carbon sequestered in long-lived wood products and waste dumps is probably expanding.

A stock that is taking-up carbon is called a "sink" and one that is releasing carbon is call a "source." Shifts or flows of carbon over time from one stock to another, for example, from the atmosphere to the forest, are viewed as carbon "fluxes." Over time, carbon may be transferred from one stock to another. Fossil fuel burning, for example, shifts carbon from fossil fuel deposits to the atmospheric stock. Physical processes also gradually convert some atmospheric carbon into the ocean stock. Biological growth involves the shifting of carbon from one stock to another. Plants fix atmospheric carbon in cell tissues as they grow, thereby transforming carbon from the atmosphere to the biotic system.

The amount of carbon stored in any stock may be large, even as the changes in that stock, fluxes, are small or zero. An old-growth forest, which is experiencing little net growth, would have this property. Also, the stock may be small while the fluxes may be significant. Young fast-growing forests tend to be of this type. The potential for agricultural crops and grasses to act as a sink and sequester carbon appears to be limited, due to their short life and limited biomass accumulations. However, agricultural and grassland soils have substantial potential to sequester carbon. Their role for human management of carbon could increase as we learn more about their characteristics and new approaches, conservation tillage for example, are introduced.

How Forest Ecosystems Act As Sinks

Oceans, soils and forests all offer some potential to be managed as a sink, that is, to promote net carbon sequestration. The role of forests in carbon sequestration is probably best understood and appears to offer the greatest near-term potential for human management as a sink. Unlike many plants and most crops, which have short lives or release much of their carbon at the end of each season, forest biomass accumulates carbon over decades and centuries. Furthermore, carbon accumulation potential in forests is large enough that forests offer the possibility of sequestering significant amounts of additional carbon in relatively short periods – decades. However, forest carbon can also be released fairly quickly, as in forest burning.

Fortuitously, forests managed for timber, wildlife or recreation have as a by-product carbon sequestration. Forests may also be managed strictly to sequester carbon. Such a focus on biomass accumulation could provide a somewhat reduced amount of other forest ecosystem services such as biodiversity. However, if forests managed for carbon sequestration are allowed to mature and remain unharvested, one of the long-term effects may be enhanced biodiversity.

There are four components of carbon storage in a forest ecosystem. These are trees, plants growing on the forest floor (understory material), detritus such as leaf litter and other decaying matter on the forest floor, and forest soils. Carbon is sequestered in the process of plant growth as carbon is captured in plant cell formation and oxygen is released. As the forest biomass experiences growth, the carbon held captive in the forest stock increases. Simultaneously, plants grow on the forest floor and add to this carbon store. Over time, branches, leaves and other materials fall to the forest floor and may store carbon until they decompose. Additionally, as forest soils may sequester some of the decomposing plant litter through root/soil interactions.

Forest transitions from one ecological condition to another will produce substantial carbon flows – forests can be a carbon source or a sink. It is important to carefully assess exactly what is happening to the carbon as the forest changes to determine the forest's sink/source contribution. Net forest carbon may be released, thereby making the forest a source, due to biomass reductions from fire, tree decomposition, or logging, any of which will reduce the forest biomass. In the case of decomposition or fire, forest carbon is released into the atmosphere. However, the forest may again become a carbon sink as it is restored through forest regrowth.

In much of the world wood is used as a source of energy and this burning will release carbon into the atmosphere. Where the fuelwood is taken from a forest and regrowth occurs, no net carbon is emitted. Furthermore, to the extent that biofuels are produced sustainably and used as a substitute for fossil fuel energy, fossil fuel emissions are avoided and no new net carbon emissions are created, since biofuel regrowth offsets the initial biofuel emissions.

Deforestation, Reforestation and Afforestation

Deforestation occurs when forestland is cleared and reforestation does not take place. Commonly, land clearing is associated with the permanent conversion of forestlands to other uses, such as croplands, pasture or development. When forest is converted to some other use, there is a net loss of carbon in the terrestrial stock since most other land uses will sequester less carbon than the forest. Under these circumstances net carbon transfers occur. If the site is cleared and the vegetation burned, most of the carbon is released into the atmosphere. However, to the extent that the vegetation is converted into long-lived wood products or substituted for fossil fuel energy, only a portion of the carbon in the forest will be a net release into the atmosphere.

Although reforestation typically refers to the practice of re-establishing a forest on a site that has recently been harvested, it may also refer to the reestablishment of forest on a site that has been cleared for some period of time. In either case, reforestation acts as a carbon sink since it results in the build-up of carbon stocks in the newly established biomass.

The creation of a forest on land never forested or not forested for a very long time is called afforestation. Often the distinction between afforestation and reforestation blurs as the period during which the forest has been absence from the land lengthens. Afforestation occurs when forests are established on grasslands, never previously forested. It may also be said to occur as lands once in forests, but which have been in agriculture for long periods of time as in parts of the US South, are converted into forests, due to either natural processes or tree planting. On afforested lands the additional carbon stored in trees and other components of the forest ecosystem constitutes a net addition to the terrestrial forest stock.

Forest Management and Natural Disasters

Commercial timber harvests are typically accompanied by reforestation, whether natural or human induced, although land use conversion away from forests to other uses, primarily agriculture and pasture, are still common in the tropics. When commercial harvests are accompanied by reforestation, the land-clearing effects of the harvest on the forest carbon stocks are offset, in the long term, by carbon sequestration and the build-up of carbon stocks in the newly regenerated forest. The long term change in carbon storage will depend directly on the type and volumes of forest harvested and regenerated. In some cases second growth forest will not sequester as much carbon as the original forest. For instance, when old-growth forest is harvested, the replacement forest will typically involve less volume, especially if it is being managed for timber harvests. However, when storage in long-lived wood products is considered the net carbon of the managed replacement forest and its products will more closely approach that of the initial forest over a longer period.

Forest management can contribute to carbon sequestration through promoting forest growth and biomass accumulation. Additionally, management can choose to extend the harvest rotation, thereby increasing the average forest stock and hence the average carbon sequestered in a forest.

Finally, natural disasters can impact forest stocks and often result in forests becoming a carbon source – at least for a time. Large portions of the world's natural forests are subject to natural disturbances, which occur periodically as part of natural cycles. Forest are subject to substantial carbon-releasing disturbances, particularly in the form of wildfires, which often occur after the forest is first disturbed by other forces such as drought, disease or pests. Natural disasters may release large amounts of carbon in a short period of time. However, where land is not converted to other uses, the forest typically reestablishes itself and again begins to sequester carbon. In many forests natural disturbance regimes create a cyclical pattern of growth (sequestration), disturbance (emission) and regrowth (sequestration) over period of many hundreds of years.

World Forest: The Existing Situation

Although it is well known that the world's tropical forests are declining, it is less widely recognized that the world's temperate and boreal forests have been expanding, albeit modestly. Thus, while the tropical forest carbon stock has become smaller, the temperate/boreal forest has been expanding. Some analysts believe that the failure to fully account for the sources of all of the carbon build-up in the atmosphere, the "missing carbon sink," is explained by the expanding the forests of the Northern Hemisphere. However, since the Protocol limits carbon credits to "human-induced" activities, it is unlikely that Northern Hemisphere countries will get credit for this missing sink, even if forest expansion occurs within their national boundaries.

Nevertheless, overall, the size of the global forest carbon stock appears to be declining, thereby generating a net carbon source. However, while forest decline contributes to the build-up in atmospheric carbon, analysts widely agree that the primary cause of the build-up in atmospheric carbon is not attributable to land use changes, but rather is due largely to fossil fuel burning and its associated emissions.

The Kyoto Protocol and Sinks: Some Unresolved Questions

Article 3 of the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC) focuses on the net change in greenhouse gas emissions by source, and on removals by sinks resulting from direct human-induced land-use change and forestry activities. The national commitments to emission targets of the Annex I countries are articulated in the Protocol and are tied to base-year 1990 emission levels. The sink changes that can be considered for meeting the commitments in the national emission inventories under the Protocol are limited to afforestation, reforestation and deforestation since

1990, measured as verifiable changes in carbon stocks in each commitment period. Initially, only sink accumulations *during* the 5-year commitment period 2008-2012, will be counted in meeting net emission targets. However, subsequent commitment periods would be contiguous after 2012.

How helpful the inclusion of sinks in the Protocol ultimately will be in assisting a country in meeting its emission targets will depend importantly on how the activities of afforestation, reforestation, and deforestation are ultimately defined for purposes of the Protocol. The language of Article 3.3, however, has been regarded as confusing and complicated and has resulted in different interpretations. Some analysts contend that the apparent omission of forest management, conservation and protection implies that these activities would not qualify as an emission reduction in the future. Others contend that forest management and conservation are encompassed within the terminology – deforestation, reforestation, and afforestation. Article 6, which mentions that projects can be developed in "any sector of the economy," could be interpreted as indicating that conservation and forest management could qualify for emission reduction credit. One problem with including forest conservation is that Article 3.3 states that the activity needs to be measured as a verifiable change in stock. It is not clear how much of what is considered conservation and protection would produce positive changes in verifiable stocks. It may simply protect stocks that already exist. However, much of conservation's contribution to carbon sequestration is captured in reducing deforestation, and thereby reducing the accumulation of new debits in national emissions inventories.

The Protocol provides for countries to gain credit toward their Protocol requirements through afforestation and reforestation that werew undertaken after 1990 on lands that, prior to 1990, were not forested. However, countries that are net carbon emitters from their forestry sector may lose credits since, under the Protocol, countries must count the carbon activity, positive or negative, on land on which the designated forestry activities have occurred since 1990.

The question of how commercial timber harvests are to be treated is also unclear in the Protocol. One interpretation is that harvesting simply has not been included in the Protocol and should be ignored. Alternatively, this issue may depend upon the definitions of forests, deforestation and reforestation. Since most commercial timber harvests involve logging followed by regeneration, often natural-regeneration, one could argue that neither carbon released from commercial harvests nor the carbon sequestered from the reestablishment of a forest and growth after harvest is to be considered for meeting the levels called for in the Protocol. Additionally, Article 3.4 allows for the possible future inclusion of other categories of land use changes and forestry activities. Future categories may be an avenue for eventually including forest management, agricultural soils, and other managed sinks. At this time, however, the interpretation of the Protocol remains unclear.

Another potential role for sinks in the Protocol is through the newly developed Clean Development Mechanism (CDM), which allows projects to be initiated by the developing countries themselves and also allows investments and participation by Annex I countries. It is not yet clear whether Article 3.3, which limits the activities that can provide net changes to be included in Annex I national emission inventories to deforestation, reforestation and afforestation, also applies to projects under the CDM.

Finally, the Kyoto Protocol is almost silent on the role of other sinks in meeting national emission inventories. Although agricultural land is mentioned (in Annex A of the Protocol) as a possible carbon source which must be included in a countries emission inventory, there are no provision for national credits for the buildup of the agricultural soil carbon sink. There are, however, some provisions of the Protocol (for example, Article 3.4) that might provide credit for additional sink activities.

There are at least five important points to recognize: a) forests are definitely included in the Protocol; b) the Protocol provides for credit for some human induced forest based emission reduction 2012 commitment period, d) forest management, conservation, and agricultural soil sinks are not specifically mentioned and hence their role in obtaining credits is currently subject to varying interpretations; and e) it is unclear whether the emerging CDM will allow broader sink activities. How the CDM is ultimately treated depends on whether it is covered by the same limitation on sink activities as is called for in Article 3.3. Finally, the recent June 1998 Bonn meetings have turned the scientific issues of the Protocol over to the Intergovernmental Panel on Climate Change (IPCC) for clarification with the target of a special report in the year 2000.

Designing Projects for Carbon Reduction Credits: Concepts and Practice

In addition to the substantive issues associated with clarifying the language of the Protocol so that forest based emissions credits (debits) can be efficiently incorporated into the portfolio of carbon reduction mechanisms, there are a number of practical issues in need of formalization. Current thinking indicates that carbon sequestration projects under Kyoto will be managed on a project by project basis. What remains to be determined is how issues of baseline determination, “additionality,” “leakage,” verification and the potential for perverse incentives to motivate forest management decisions will be addressed at the project level. Reconciliation of these issues tops the carbon sequestration agenda. In addition, the costs of afforestation and reforestation, the land use activities that support carbon sequestration, are being estimated with widely divergent results. The cost aspect of forest based carbon sequestration as an offset mechanism is particularly important. It determines how carbon sequestration compares with other potential carbon offset mechanisms in the broader scheme of greenhouse gas reduction policies.

The determination of a baseline by which to assess carbon sequestration is critical as it provides the frame of reference for determining how carbon sequestration projects are contributing to the net carbon sink at either the project or national level. Determining business as usual baseline measures of the total stock of carbon for a defined area has thus far proved to be scientifically challenging, particularly in cases where heterogeneous forest ecosystems are the land use being examined. Evidence indicates that the measurement of total carbon is a complex process, and is likely to have very high transaction costs due to the site-specific nature of forest ecosystems. Monoculture plantations appear to offer more straightforward measurement options, likely at much lower costs.

It may not be necessary to evaluate the total terrestrial stock of carbon in a defined area. Instead, one can focus on the carbon flows that result from land use changes in this area over a specified time period. This would allow carbon sequestration to be incorporated into a “cap and trade” policy in which changes in land use that gave rise to increases or decreases in long-term carbon sequestration would be covered as part of the national inventory of carbon flows relative to a national baseline. The alternative of allowing voluntary opt-in of individual carbon sequestration projects provides a less clear-cut determination of overall changes in the carbon stock relative to a previously defined baseline.

A related issue is the “unintended consequences” associated with the development of a carbon sequestration system. Simply focusing on forests for carbon sequestration would probably lead to the almost exclusive establishment of single species tree plantations. As was noted earlier, old growth forest has limited potential for absorbing additional atmospheric carbon. When ecosystem climax levels are reached, old growth forests in effect become neutral, acting primarily as a fixed carbon sink rather than a net sequesterer. Without proper incentives, there exists the possibility that monoculture crops, which are known to sequester carbon rapidly, and thus offer greater short-term carbon storage gains than the previously existing ecosystem, will replace biodiverse heterogeneous forest ecosystems. It is important that in the determination of baselines, either through regulatory enforcement or market-based mechanisms, that the incentives are appropriate to the entire set of social objectives to be met by the forest ecosystem.

Additionally, there is significant potential for locally based emissions reductions to simply shift deforestation and other carbon emitting land use practices to other locations. Leakage is most likely to happen if carbon sequestration is evaluated at the project level, rather than within the more comprehensive framework of a national carbon budget. Again, a cap and trade type of policy, administrated at the national level and requiring the monitoring of total additions and deletions in reference to a defined baseline is a likely option for dealing with leakage issues. The problem of leakage is especially relevant to nations where forested land falls in regions with poorly defined property rights and where large populations rely on forest resources for subsistence needs, particularly shifting cultivation.

It is clear that issues surrounding baseline determination, additionality and leakage require serious attention. Once measurement issues are resolved and the rules that will address additionality and leakage concerns agreed upon, it is likely that in many cases verification will occur through a neutral third-party. One of the probable institutional frameworks for the verification of forest-based carbon offsets will be third party audits conducted in a similar fashion to those which are currently being undertaken to certify timber harvested from sustainably managed forests. If the scope of carbon sequestration develops to include agriculture and other land uses, institutions established to verify carbon offsets will have to be adapted to accommodate the potentially infinite number of land use portfolios that will contribute to the global carbon stock.

Before carbon sequestration is widely accepted as a policy tool for reducing greenhouse gas emissions, the costs of carbon sequestration must be clarified. When analyzing carbon sequestration based on the opportunity cost of land, proponents of carbon sequestration note that a great deal of forested land is located in remote regions, often characterized by high timber extraction costs due to rugged terrain and limited access. From a financial cost-benefit perspective, the opportunity cost of these forested lands is very low, implying that if tree cover establishment costs are low, the total cost of afforestation or reforestation to establish permanent tree cover will likely be lower than many other carbon offset mechanisms. In addition, these lands are easily viewed as prime candidates for conservation easement programs that will deter deforestation and promote conservation. However, the convention of citing the opportunity cost of land, typically in the form of foregone agricultural rents, as the cost of carbon sequestration often omits important considerations in land-use decision making.

Research is currently underway to more clearly identify the costs of carbon sequestration, taking into account behavioral responses to alternative land-use values. The inclusion of non-market benefits and the consequences of potential irreversibility of land conversion may significantly affect a landowner's willingness to agree to a major land use change that will result in carbon being sequestered. When these factors are considered, the costs of carbon sequestration are often higher than the majority of values generally observed in previous studies (approximately $1-$20 USD per ton). However, many of the higher-cost estimates have been obtained in the US, where the opportunity costs of the land are often significant. Other parts of the world, for example regions of South America, appear to have the potential for lower cost carbon sequestration due in part to the inherently lower opportunity costs of land.

Based on current knowledge for the Annex I nations, afforestation on low cost lands is among the less expensive alternatives when compared with other greenhouse gas reduction policies, particularly in the near to medium term. The low-cost potential may even be greater in some developing countries.

Given that reduction of atmospheric CO_2 is a long run goal, carbon sequestration will likely be best used as one of a broader portfolio of carbon offset mechanisms. This carbon-offset portfolio will differ among nations, with developing countries perhaps relying heavily on carbon sequestration offsets in the short to medium term.

Concluding Remarks

The Kyoto Protocol has provided a vehicle for considering the effects of carbon sinks and sources, as well as addressing issues related to fossil fuels emissions. However, the approach of the Kyoto Protocol clearly is not comprehensive in its treatment of sinks, being inherently restrictive in its focus. The Protocol deals only with a small subset of the total carbon fluxes that are generated by selected sinks and sources, limiting its attention to human-induced carbon fluxes dealing with afforestation, reforestation and deforestation undertaken after 1990. Additionally, the approach is further limited by its focus on changes in carbon stocks only in the commitment period of 2008-2012. Thus, the Protocol ignores carbon changes during some periods and from some sources, many human-induced. For example, management and many human-induced actions will generate far more carbon sequestration than credit received. The Protocol also leaves unaddressed issue of measurement and monitoring. However, the Protocol does have provisions (Article 3.4), for making desired changes through time.

When the on-the-ground logistics of carbon sequestration projects are considered, several issues are still in need of clarification. Project details such as establishing baselines and controlling for leakage, and the institutions that will support project verification are currently being debated. However, carbon sequestration through forest activity has considerable potential to generate low-cost sequestration alternatives, especially in certain developing countries. Nonetheless, care must be taken to recognize the true opportunity costs of alternative land uses and to identify that, in many cases, social values other than carbon sequestration are also involved, and trade-offs are necessary.

# # #

Further Readings

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