Forest Carbon Sequestration: Some Issues for Forest Investments

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Abstract

A major problem being faced by human society is that the global temperature is believed to be rising due to human activity that releases carbon dioxide to the atmosphere, i.e., global warming. The major culprit is thought to be fossil fuel burning, which is releasing increasing amounts of carbon dioxide in the atmosphere. The problem of increasing atmospheric carbon dioxide can be addressed a number of ways. One of these is forestry and forest management.

This paper examines a number of current issues related to mitigating the global warming problem through forestry. First, the overall carbon cycle is described, and the potential impact of forests on the buildup of atmospheric carbon is examined. A major focus is the means by which forests and forest management can contribute to the sequestration of carbon. The potential role of forests and forestry in sequestrating carbon to reduce the buildup of greenhouse gases in the atmosphere is now well recognized. A number of alternative approaches to utilizing forestry and forest management for carbon sequestration are examined. These include forest protection; the management of forests for carbon for joint products, i.e., the management of forests to generate both carbon and timber as products; the establishment of plantation forests dedicated to carbon sequestration; and increased production of wood products. Replacing other materials with wood will sequester carbon while reducing energy requirements, thereby reducing carbon emissions. Studies examining the costs of carbon sequestration using forestry are also discussed.

The recent Kyoto Protocol (K.P.) explicitly recognizes certain forestry activities as “certifiable” for sequestration credits. But some definitions and aspects of carbon sequestration through forestry were left incomplete or inadequately defined by the Protocol.   Furthermore, the KP has changed due to the recent withdrawal of the US for the Protocol (although not from the Kyoto Process).

Nevertheless, further clarification is necessary to understand the full potential and set of opportunities from forestry both within the framework of the Protocol and more generally. Alternative types of vehicles for sequestration credits are discussed below,m both within and outside the context of the KP , and their advantages and disadvantages in terms of periods covered and liability are also examined. Finally, some ongoing real-world activities utilizing forestry specifically to sequester carbon are discussed.

Key Words: forests, carbon, sinks, sequestration, forest management, Kyoto Protocol

JEL Classification Numbers: Q10,Q15,Q21,Q23,Q24

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Background

A major problem being faced by human society is that the global temperature is believed to be rising due to human activity, i.e., global warming. The major culprit is thought to be fossil fuel burning, which is releasing increasing amounts of carbon dioxide in the atmosphere. Carbon dioxide is the major one of the greenhouse gases believed to be precipitating global warming. Carbon releases from land-use change may also contribute to increasing atmospheric carbon, e.g., through carbon releases associated with the conversion of forestland to cropland. However, land-use changes are generally believed to be a secondary source of net carbon being released into the atmosphere (Bolin et al. 1996). The evidence today indicates that forests are expanding in the temperate regions of the world, while declining in much of the tropics. There are a number of ways to address the problem of increasing atmospheric carbon. One of these is through forestry and forest management.

It is estimated that over the last 10,000 years, 20–40% of ecosystem biomass has been lost as a result of human interventions. This suggests an upper limit of the sequestration potential is in the order of 600—1,200 billion tons (Gts) of carbon (Watson et al. 2000). Although this is an overestimate of the feasible sequestration potential, it does suggest that there is substantial sequestration potential using forestry.

Early studies determined that the potential volume of carbon that could be stored in expanded forest ecosystems was substantial relative to the net volume of carbon being released into the atmosphere (Marland 1988; Sedjo and Solomon 1989). These studies indicated that up to three Gts of carbon per year could be captured by these large-scale forestry operations.

The potentials of forestry are intriguing. Although sequestration through forestry does have limitations, it is generally agreed that large amounts of carbon could be sequestered utilizing existing technology (IPCC 2001). Additionally, these activities could be undertaken over the next couple of decades. Although not the complete answer to the carbon problem, carbon sequestration through forestry does have the potential of stabilizing, or at least contributing to the stabilization, of atmospheric carbon in the near term (20–50 years) and thereby allowing time for the development of a more fundamental technological solution in the form of reduced carbon emission energy sources.

The Carbon Cycle

Carbon is held in the terrestrial system in vegetation and soils. Oceans also hold large volumes of carbon, as does the atmosphere. Additionally, fossil fuels, e.g., coal, petroleum, and natural gas, contain large amounts of carbon, which are released upon burning. The problem being faced by human society is that large volumes of carbon previously held captive in fossil fuels are being released into the atmosphere due to intensive fossil fuel burning to meet energy demands.

Additionally, rocks hold carbon that is generally captured and released only very slowly, through the processes of weathering and rock formation. These processes are supplemented by volcanic action and the venting of gases from the earth. Such releases of carbon occur on a much longer time scale than the others and are ignored in this discussion.

The global carbon cycle involves carbon flows among the various systems—terrestrial, atmospheric, and oceanic. Biological growth captures carbon from the atmosphere and distributes it within the terrestrial system. Decomposing vegetation and respiration releases carbon back into the atmosphere. Annual plants have a cycle that includes growth during some parts of the year and death and decomposition during others. Thus, the level of atmospheric carbon increases in the Northern Hemisphere in the winter and decreases in the summer. (Because of its much greater landmass, the Northern Hemisphere has more vegetative activity and therefore dominates this cycle.).)

Carbon and Forests: An Overview

The process of photosynthesis combines atmospheric carbon dioxide with water, subsequently releasing oxygen into the atmosphere and incorporating the carbon atoms into the cells of plants. Additionally, forest soils capture carbon. Trees, unlike annual plants that die and decompose yearly, are long-lived plants that develop a large biomass, thereby capturing large amounts of carbon over a growth cycle of many decades. Thus, a forest ecosystem can capture and retain large volumes of carbon over long periods.

Forests operate both as vehicles for capturing additional carbon and as carbon reservoirs. A young forest, when growing rapidly, can sequester relatively large volumes of additional carbon roughly proportional to the forest's growth in biomass. An old-growth forest acts as a reservoir, holding large volumes of carbon even if it is not experiencing net growth. Thus, a young forest holds less carbon, but it is sequestering additional carbon over time. An old forest may not be capturing any new carbon but can continue to hold large volumes of carbon as biomass over long periods of time. Managed forests offer the opportunity for influencing forest growth rates and providing for full stocking, both of which allow for more carbon sequestration.

Forest systems operate on a cycle of many decades and centuries, rather than annually or over a few years as would be the case with most crops and non-tree vegetation. As forest biomass expands, the amount of carbon contained increases. As the biomass contracts, the forest holds less carbon.

In an unmanaged state, forests ebb and flow in response to disturbances in the natural system. Forest disturbance regimes are part of the natural ecological system, with wind, disease, fire and other natural, i.e., non-anthropogenic, events causing forest destruction and death. These events result in the release of carbon into the atmosphere but also are typically followed by the regrowth of the forest, which, in turn, begins a new process of carbon buildup in the forest.

In some cases, these disturbances are catastrophic in that large areas of the forest landscape are disturbed, as with large wildfires such as are common in many pine and boreal forests. In other cases, the disturbances are highly localized, as with an occasional tree death due to disease or old age such as is common in many tropical forests. Carbon release is occasioned by the disturbance and often in the decay and decomposition of dead matter that follows. However, most natural forests have provisions for natural regeneration and regrowth, which, once again, captures carbon.

Forests to Sequester Carbon: A Global Overview

An important question is the extent to which forest management can significantly contribute to carbon sequestration and the types of management that are best suited to this task. The Intergovernmental Panel on Climate Change (IPCC) estimates that appropriate policy could increase the amount of carbon sequestered as a carbon pool in the terrestrial system by up to 100 Gts over the level of carbon that would be sequestered without that policy (IPCC 2001). (Note that this is well below the potential of 600—1,200 Gts that is believed to have existed in much earlier times or that is estimated under certain circumstances (IPCC 2001)). This amount of carbon is roughly equal to about 30 years of atmospheric carbon buildup at current rates. Thus, forest management directed at carbon sequestration could make a significant difference in global carbon sequestration over the near and medium term. However, to achieve this result, or any serious portion of it, there must be a net increase in global forests so that the total global forest biomass increases—or that it decreases less than would be the case in the absence of such management.

Forest management for carbon sequestration would have associated with it a relative increase in stock of carbon held captive in the forest ecosystem over what would have occurred in the absence of such focused management. Increases in the stock of carbon could be accomplished as the result of an increase in the forest biomass and/or as a result of an increase in forest soil carbon directly. Finally, if the stock of long-lived wood products increases, the carbon held captive in wood products stock would increase. According to the U.S. Forest Service, almost 40 million metric tons (MMT) of sequestered carbon is believed to have been held captive in wood products in 1990, and this is projected to grow to 90 million MMT by 2008.

There are a number of activities that could result in an increase in forest and forest-related carbon compared withthe base situation. These include reducing deforestation, expanding forest cover, expanding forest biomass per unit area, and expanding the inventory of long-lived wood products inventory. Each of these is discussed below.

Reduction of Tropical Deforestation: From a pragmatic perspective, the most straightforward approach seems to be that of reducing deforestation. Although forests in the Northern Hemisphere's temperate region have been expanding modestly in recent decades, deforestation in the tropics is still proceeding at a substantial rate. Tropical deforestation is driven primarily by the conversion of forests to agricultural uses. If this trend could be slowed, stopped, or reversed, less carbon would be released into the atmosphere the forests would become a net sink for carbon.

Tropical deforestation has been recognized as a problem for several decades. However, programs to mitigate this problem have been notable for their lack of success. Most data indicate that the level of tropical deforestation has been relatively high and essentially constant for at least the past two decades. The problems are many. In many cases tropical deforestation is promoted by government policies that provide incentives for land clearing and/or subsidies for certain types of agriculture. Thus, often the deforestation is an artifact of government policy and does not truly reflect market incentives. Furthermore, the value of the forest for carbon sequestration and other environmental values is typically ignored. In addition, tropical forests are often on a country's frontier: an area where government control is limited, property rights weak, and law enforcement sporadic.

Forest Expansion: Any expansion of global forests implies the capture of atmospheric carbon. Forests have been expanding in the Northern Hemisphere as marginal agricultural lands have reverted to forest. In Europe, for example, the reversion began as early as the beginning of the 19th century and in New England, perhaps at the middle of the 19th century. However, it was probably not until the latter part of the 20th century that the reversion in the northern temperate forest generated an overall net expansion of forest area as agriculture declined in many regions as the lands reverted to forests, often through natural regeneration. In many cases, however, afforestation has been due to conscious human efforts. Whatever the cause, an expansion of the land area in forest means additional carbon sequestration. Net carbon sequestration occurs if new areas are converted to forests and sequestration occurs more rapidly than losses, some of which may be occurring elsewhere.

Forest Density: If the density of the forest biomass increases, the implication is that the forest carbon will increase. For example, in recent decades the forest area of the United States has remained roughly constant. However, timber inventories have indicated that the volume of growing stock in United States forestshas been substantially increasing, perhaps the equivalent of about 300 million metric tons (MT) of carbon annually (U.S. Department of State 2000). This reflects an increased forest density on the land. Increased density may be the result of conscious management practices, because wild natural forests often have less than full stocking of the forest land. Increased density may also reflect the age of the forest. Mature and older forests tend to have a greater biomass density, thereby holding captive more carbon. The forests of the United States, particularly in the East, are increasing in biomass and carbon as the forests age and move toward greater maturity.

Carbon in Wood Products: Finally, harvested wood that is converted into long-lived wood products adds an additional stock of captive carbon. Wood products do not last forever. However, the global inventory of wood products increases when more products are added to the inventory than are removed from the destruction and dissipation of some products. As the wood products' inventory stock increases, more carbon is held captive, i.e., sequestered, in that stock. Globally, the total stock of wood products appears to be increasing gradually.

Forest Management with Carbon as an Output

Forest management traditionally has involved managing the forest for the production of a single output—timber. However, the single output, industrial wood, may come in various forms, e.g., pulpwood and sawtimber, which have different production costs, harvest cycles, and market prices. For example, pulpwood can be produced more quickly than sawtimber, but pulpwood's value per unit volume is lower than that of sawtimber. The prudent forest manager must consider questions of timber volume and timber quality (type) when managing to maximize the profitability of the timber operation. Additionally, the existence of an opportunity cost of capital (a discount rate) dictates that harvests will usually take place before biological growth is maximized (sometimes referred to as the culmination of mean annual increment).

Thus, a traditional forest manager must consider, at least, the costs and prices of various outputs obtainable from the forest, the yield function, and the discount rate when determining management regimes and harvesting rotations. The manager then determines the appropriate lengths of the harvesting rotation, thinning, and other silvicultural operations to achieve the output mix and time profile required to maximize the present value of the timber. In the simplest case, the question is simply one of choosing the harvest rotation that will maximize the net discounted present value of the forest, given the product and anticipated product price. This will maximize the profitability of the forest.

Forests have always sequestered carbon, but this ecosystem service went unnoticed and uncompensated. In the past, the forest manager would have been expected to ignore any carbon considerations in his management actions. Suppose now, however, that payments were made for both carbon sequestration and timber. Under this arrangement, timber and carbon sequestration would be viewed as joint products, and the owner would have two market outputs to consider. As the forest matures, its timber stands become more valuable, as does the value of its carbon sequestration services.

Suppose an owner receives an annual payment for carbon services on the basis of the volume sequestered but that this payment is forthcoming only as long as the timber remains "on-the-stump." This approach recognizes the fact that forests need not last forever, and trees do eventually die.[1] Because the amount of carbon sequestered will depend on the forest biomass, the payment for carbon services would be expected to rise as the forest matures. Additionally, suppose payment is received for the timber, but only when it is harvested. Thus, the manager must make a choice between receiving an annual payment for the carbon sequestration value or receiving a one-time payment for the value for the timber.

[1] In fact, although individual trees die, a steady state forest many last for many generations of trees.

If the payment for carbon were zero, then the timber values would predominate, as has been the case historically. However, once annual payments are being received for carbon, the harvest and payment for timber would mean the loss of payments received for the carbon sequestration services.[2] In fact, if a regulated forest were established on previously unforested lands where the annual harvest of mature timber would simply equal the net annual growth of the forest system, carbon sequestration could last longer than one rotation. A steady-state amount of carbon would be sequestered in such a steady-state forest (see Sedjo 1999 In such a situation, annual payments for the sequestered carbon could continue indefinitely. [3]

Given the relevant prices of timber and carbon, the yield function, and the discount rate, an optimal financial rotation can be calculated. As the price of carbon rises relative to timber, the advantages of keeping the timber on the stump will grow (Sedjo 1999). Moreover, it has been shown that, as carbon takes on value, the optimum financial timber rotation age will be extended (Van Kooten et al. 1995 Furthermore, at a price of carbon sufficiently greater than that of timber, the harvest rotation will cease, as the manager will find that his best financial returns would be associated with extending the rotation indefinitely. Additionally, since payments would now be made for carbon sequestration as well as timber, the financial returns to the entire joint production of timber and carbon will be higher than that for timber alone.

Finally, there is the issue of liability in the case that the sequestered carbon is released, inadvertently or otherwise. In the case of the unplanned loss of sequestered carbon, does the forest owner compensate the purchaser of the carbon offset for unplanned carbon losses, or does the certificate purchaser bear the liability risk and thus go uncompensated even though the certificate is now worthless? It can be argued that the liability should be borne by the tree owner (seller of sequestration services) to maintain incentives to continue the existence of the planted forest and discourage fraud. With a long-term certificate, however, buyers of certificates that became invalid would need to try to recover losses from the tree owners. Recovering such

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[2] A recent arrangement of this type was under discussion between the Australia Plantation Timber (APT) company and a major Japanese oil company, whereby options to the carbon rights associated with the establishment of a new forest could be purchased. The carbon sequestration rights for sale would reflect an anticipated 11-year rotation, and those rights would disappear upon harvest (phone conversation with Paul Brazenor, Chief Financial Office of Australian Plantation Timber May 22,2001).

[3] One would expect the market to create a trading price relationship between a permanent emissions carbon credit and a temporary carbon offset based upon the discount rate, the expected life of the temporary credit, and the perceived relative risk of the two instruments.

compensation could be difficult and costly, especially if it involved inter-country litigation. An alternative would be for certificates to be good for relatively short time periods, e.g., one year. Each year the certificate would need to be renewed. Of course, this type of approach would require periodic monitoring of the forest to ensure its continued existence and its carbon content. However, monitoring would also be required for a long-term certificate. The advantage of short-term renewable credits is there is no need for placing liability or compensation should the forest be destroyed either intentionally or by accident. This result could be assured if payment is made for carbon that has already been sequestered.For example, if payment were made at the end of the sequestration year for carbon that had been sequestrated the previous year.

Related Aspects of Forestry and Sequestration: Some Issues

Given the above considerations, there are alternative perspectives as to the efficacy of various approaches. At one end of the spectrum is the view that a cessation of all timber harvesting would result in the largest potential for mitigating atmospheric carbon. At the other end is the view that, given the sequestration potential of long-lived timber products, the promotion of wood products can lead to desired carbon mitigation.

The issue is more complicated than it appears initially. Suppose, for example, that there were a decision not to produce any products from wood. One implication would be that many products would be produced with a substitute material—iron, steel, aluminum, brick, cement, plastic, and so forth. Most of these substitute materials are much more energy intensive in their production than wood. Thus, more energy would be required, more fossil fuel burned, and more carbon released. Additionally, if the prohibition on wood harvesting applied to biofuels, renewable energy production using biofuels would be inhibited by prohibitions on wood harvesting, and biofuel could not be a substitute for fossil fuel. Such an approach would result in an increase in fossil fuel use and the associated higher level of carbon releases into the atmosphere. Thus, the simple notion that a prohibition on timber harvests would result in net reductions in carbon releases into the atmosphere is highly problematic and contrary to the goal of reducing the carbon dioxide concentration in the atmosphere.

Finally, it is estimated that about 2.5 million acres of new industrial plantation forest are established globally per year. Most of this land was previously in crops or pasture. The conversion to forestry is clearly driven by the desire to harvest these forests at maturity to be utilized for timber and other industrial wood uses. The absence of a market for timber, such as would be associated with a global ban on harvesting, would remove any incentive for planting these forests, thereby precluding any forest sequestering function that these new forests would have provided.

However, this argument does not imply that no logging restraints should be offered. One notion that probably does have merit, however, is that a reduction in tropical deforestation would probably be beneficial in terms of carbon releases. Most tropical deforestation is from land conversion: forest is converted to various forms of agriculture. Often the timber values are negligible, and the downed forest is burned, thereby releasing carbon. Furthermore, if the land is converted to agricultural use, forest regrowth is prevented, and a new forest, which would have sequestered carbon, is never reestablished.

Costs of Carbon Sequestration through Forestry[4]

A substantial amount of economic research is focused on obtaining estimates of the costs of carbon sequestration through the establishment of newly planted forests under varying conditions to determine how these costs compare with alternative programs for mitigating the buildup of atmospheric carbon. Early studies provided estimates of the costs of sequestering carbon for various projects (see Sedjo et al. 1995). Most of these cost estimates were in the range of $1–$50 per ton of carbon (e.g., see Turner et al. 1993, Dixon et al. 1994).[5] However, many of the early estimates were single-point estimates for a relatively small project area. Additionally, there were typically methodological problems such as failure to discount appropriately or consider appropriately the opportunity costs of the land.

Subsequently, a number of more sophisticated studies that more adequately recognized opportunity costs and introduced discounting considerations were undertaken to estimate cost functions. These studies provided a range of costs depending upon the land areas and carbon volumes involved. For example, Moulton and Richards (1990) found a range of costs from $16 to $62 per ton of carbon for a U.S. program that sequestered about one-half of annual U.S. net

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[4] These studies assume that sequestration costs will be less than the price received up to the final marginal unit where cost equals price. Thus, forest owners will collect net revenues for their investments in sequestration.

[5] For perspective, Sweden imposes a carbon tax of about $3.67 and $15.8 per ton of carbon. The United States has no carbon taxes at this time. The tax is denominated in Swedish krona (SKr) and imposed on CO_2 emissions. The values have been converted from SKr per metric ton of CO_2 to U.S. dollars per metric ton of carbon.

carbon emission (roughly 1350 million tons in 1990). Parks and Hardie (1995) estimated a range of $10– $82 per ton of carbon for a hypothetical program similar to the USDA Conservation Reserve Program.

More recently Stavins (1998, 1999) and Plantinga, Mauldin, and Miller (1999) have used a somewhat different methodological approach, one which reallocates a fixed amount of agricultural land to forestry and focuses on the rising opportunity costs of the land being utilized to estimate costs within selected regions of the United States. Their results have generally generated somewhat higher costs, sometimes in excess of $100 per ton. However, for Stavins' estimates very large amounts of carbon are sequestered. Additionally, Stavins (1999) and Plantinga, Mauldin, and Miller (1999) discount the benefits of the future sequestrated carbon. Much of the higher costs found in these studies reflect the discounting, but much of the higher costs also reflect the fact that these studies were undertaken primarily for areas that have relatively high opportunity costs of land, often prime agricultural areas of the United States. Many analysts argue, however, that the most economically viable regions for carbon sequestration forestry will be established in areas with low land-opportunity costs. Large areas with these characteristics are found largely outside the United States, in places such as South America (e.g., see Sedjo 1999).

A weakness in all of the abovementioned studies is their reliance on a partial equilibrium approach, which ignores the obvious general equilibrium features of the problem. As more land is drawn out of other uses, primarily agricultural, and converted to forests, the price of agricultural products is likely to increase while those of forest products will decrease relative to what they would have been in the absence of these carbon sequestration activities.[6] Thus, price incentives would move in the direction of choking off more forests and encouraging more agriculture. Some researchers have finessed this problem by arbitrarily limiting the amount of land that can be established in new carbon forests so as not to alter the underlying timber and agricultural price relationships. With such a constraint, however, the amount of newly created

[6] For new forests established on lands not formerly in forests, carbon sequestration can be achieve even if these forests are harvested. Since carbon sequestration only requires that the new forests move toward some form of sustained-yield forestry with a steady-state stock of forests where harvest equals net growth.

forests that could be established would be severely constrained, thereby restricting the ability of forestry to impact global carbon sequestration.[7]

Two recent efforts have attempted to overcome the partial equilibrium problem by introducing a more complex systems approach to address the general problem of properly calculating costs of carbon sequestration through forestry. The systems approaches emphasize the interrelation between the price effects of new planting and the entire vector of global planting decisions. Adams et al. (1993) have developed a model for the United States that provides for land shifting between agriculture and forestry. In this approach, as land moves into forestry, product and land prices adjust. As well as allowing for market adjustments, this approach provides a vehicle that can estimate the size of policy instruments, e.g., taxes and subsidies, required to achieve forest carbon objectives in a more general equilibrium setting. Unfortunately, at this time the model is not global but largely is focused on the United States.

Efforts to broaden the analysis include those of Sohngen, Mendelsohn and Sedjo (1999) and Sedjo and Sohngen (2000). Their approaches use a global timber sector supply model that considers price and quantity adjustments within the timber sector. In this model, timber prices are related to the price of all other goods, and the establishment of new carbon sequestration forests in any region affects the current and future relative timber price throughout the system. The anticipation of higher future timber supplies, as generated by an expansion of carbon forests, *ceteris paribus*, depresses future relative timber prices, causing a reduction in tree planting. Thus, the carbon sequestration generated by new tree planting is offset, partially or wholly, by reduced planting elsewhere for timber purposes. As with the Adams et al. (1993) model, this approach provides a vehicle that can estimate the size of policy instruments, e.g., taxes and subsidies, required to achieve forest carbon objectives in a quasi-general equilibrium setting.

The systems approach also highlights the fact that subsidies (or taxes) on some forests but not others can cause distortions.[8] Tree planting can occur in the areas where carbon subsidies are

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7 An earlier study indicated that the area of newly created forest required to offset all of the total increase in carbon would be massive indeed, in the range of 1,500 million acres (Sedjo and Solomon 1989). Although forestry and land are only one of a set of tools that would likely address atmospheric carbon levels, for forests to account for 10—20% of the mitigation would still require 150–300 million acres of new forest.

8 One of the weaknesses of the Kyoto Protocol is that it distinguishes between Kyoto forests, for which carbon credits may be obtained, and non-Kyoto forests, which are out of the accounting loop. Thus major distortions can happen as activities occur to shift planting and harvesting to take advantage of the differential incentives.

given, while offsetting tree planting and/or harvesting activities are occurring elsewhere where subsidies are not present. The implications of a systems analysis of the global forests are that the cost estimates of partial equilibrium approaches are likely to systematically underestimate the true (private) costs of net carbon sequestered through forestry.

Benefits

The benefits of carbon sequestration activities are typically estimates in the amount of carbon sequestered, number of tons of carbon sequestered indefinitely or the number of tons of carbon sequestered for a time period, e.g., for one year. More accurately, the benefits of carbon sequestration are the future damages avoided by reducing the amount of atmospheric carbon. However, the monetary value of the sequestered carbon is difficult to estimate since the potential damages associated with global warming are very uncertain (e.g., see Bolin 1997[[REF list has no Bolin 1997]]). Some analysts have used the level of proposed carbon taxes as a proxy for the value of the benefits society believes it would receive from sequestration.

The Kyoto Protocol

The Kyoto Protocol, negotiated in 1997, was the result of a two-and-one-half-year negotiating process initiated by the first Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 1995. The protocol is meant to further the objective of the Framework Convention, which is:

> … to achieve, in accordance with the relevant provisions of the Convention, 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 support of this objective, the commitments in the convention address anthropogenic contributions to atmospheric concentrations of greenhouse gases. This mainly means focusing on reducing emissions to the atmosphere from energy production and consumption, industrial processes, and other activities. However, increasing the removals of greenhouse gases from the atmosphere by sinks can also be an important means of reducing anthropogenic interference with the climate system. It is for this reason that countries accepted a commitment in the convention to conserve and enhance greenhouse gas sinks and reservoirs (UNFCCC, Article 4.1(d)).

Recently the U.S. announced that it would not be a party to the Protocol nor would it be bound by its targets and objectives. However, the U.S. made it clear that it would continue to participate in climate discussion and that it believed that climate change and global warming were to be taken seriously and required careful attention.

The Kyoto Protocol Commitments

The Kyoto Protocol contains several defining features. In addition to providing for legally-binding emission targets for industrial countries (K.P., Annex I), it recognizes human-induced carbon sequestration as a way of meeting legally binding greenhouse gas emission targets. The protocol specifically mentions emissions from sources and removals by sequestration resulting from direct human-induced land-use change and forest-related activities. Afforestation, reforestation, and deforestation undertaken since 1990 are explicitly mentioned (K.P., Article 3.3). The protocol is less clear, however, on the role of other sinks, e.g., forest management and agricultural land, in meeting national targets. Furthermore, the language is confusing, with a number of important details and definitions left for future clarification. The protocol (Article 3.4) allows for the possible future inclusion of other categories of land-use change and forestry activities. Thus, many of the crucial details of the protocol remain to be worked out at future Conference of the Parties (COP) meetings.

Some Aspects of the Kyoto Protocol

Although, as noted above, the Bush Administration has indicated that the United States will not abide by the Kyoto Protocol, much of the world appears to be ready to continue this process. Furthermore, the U.S. administration has indicated it is likely to continue its involvement with climate issues. A vehicle to continue this involvement is the U.N. Framework Convention on Climate Change, to which the United States is a signatory. Thus, it is still useful to examine aspects of the K.P..

The protocol establishes “Quantified Emission Limitation and Reduction Objectives (QELROs) for 2008–2012 for the industrialized countries, the so-called Annex I countries. The U.S. commitment, for example, is to a 7% reduction below the U.S. gross emissions in 1990. This 1990 baseline of gross emissions does not include any of the effects of land-use change and forestry activities on carbon stocks: it is based primarily on emissions from fossil fuel production and consumption, industrial processes, and agriculture. QELRO commitments for periods after 2008–2012 will be decided during future negotiations.

In attempting to bring land-use change and forestry into the protocol, negotiators had to address the difficult issue of defining anthropogenic removals and emissions from forests, while creating incentives for countries to conserve and enhance their sinks and reservoirs. The protocol does this by explicitly listing which activities must be accounted for in the 2008–2102 commitment period:

> The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each Party included in Annex I. (Article 3.3)

What this means is that the verifiable changes in carbon stocks between the beginning and the end of the first commitment period (i.e., between 2008 and 2012) resulting from afforestation, reforestation, and deforestation activity that has taken place since 1990 will be used to meet a country's commitment in 2008–2012. If the carbon stock grows between 2008 and 2012 (i.e., net carbon removal from the atmosphere) as a result of reforestation, afforestation, and deforestation activity that has taken place since 1990, then the amount of the carbon removal will be subtracted from a country's emissions in the period from 2008 to 2012. If the carbon stock (i.e., net carbon emission) declines between 2008 and 2012 as a result of reforestation, afforestation and deforestation activity that has taken place since 1990, then the amount of decline in stock will be added to the country's emissions in the period.

It is important to stress here that the current focus of the K.P. is not the whole forest or even some major component of it like the managed forest. Instead, as currently written, the protocol focuses only on two activities that take place within the forest, reforestation and deforestation, and an activity that takes place outside the existing forest area, afforestation.[9]

Carbon Sequestration Potentials Under the Kyoto Protocol

The preconditions are present in the K.P. for forestry to play a significant role in addressing the atmospheric carbon issue. That is, the K.P. recognizes forestry as an acceptable carbon sequestration vehicle, and forestry offers possibilities for significant carbon influence

[9] Recent interpretations have treated afforestation and reforestation as identical.

over the time period allowed. In addition, it should be noted that the use of forestry does not require the development of any new science or technologies. Societies know how to plant and manage fast-growing forests, and societies know where fast-growing forests will thrive and where they will not.

Carbon Markets: Carbon transfers or trading would have as a by-product the generation of financial transfers, usually from developed to developing countries. Potential candidates for “clean development mechanism” (CDM) projects include the developing countries of Southeast Asia, including China, as well as countries in south Asia, including India and Pakistan. Most of the countries of South America and Africa would also be eligible under the CDM. Additionally, Annex B countries such as Australia and Russia would be candidates for “joint implementation” (J.I.) projects.

As the details and terms of the protocol are further defined and clarified, there is an issue with regard to the types of projects that are likely to be acceptable domestically and under the J.I. and the CDM. Newly established, planted forests will almost certainly be acceptable for domestic carbon credits, as they would almost certainly be recognized as afforestation. Whether carbon captured by newly established forests would be eligible for transfer under J.I. and CDM remains a question. In part, it would relate to the question of how the K.P. might establish baselines.

It is also uncertain under what conditions forest conservation and protection will be eligible to generate credits. Although deforestation will create carbon debits for developed countries, which have Kyoto targets, it is less clear how deforestation will be treated in developing countries, which have no targets. Furthermore, it is the developing countries where the problem of deforestation is significant. As it stands currently, deforestation in developing countries will simply be noted as part of the developing world’s obligation to monitor its carbon releases. But there is no target by which to judge progress. However, if the K.P. recognized protection and conservation in developing countries, protection of forests that might otherwise be destroyed could generate credits that could be marketed to Annex B countries.[10] The mechanism that might be used could be the J.I. or the CDM.

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[10] A concern here is that countries might threaten to destroy forests that might not otherwise be in jeopardy in order to induce payments.

In summary, for the J.I. and the CDM to be useful tools for promoting carbon sequestering forestry activities, those tools must be recognized in the K.P. If they were recognized, they could generate credits for Annex B nations. As noted, a decision on this tactic has not been made, and the question of what types of activities will receive credits and under what conditions remains to be clarified.

The second point suggests that, for example, a country that is harvesting from a large managed, regulated (steady-state) forest[11] may receive carbon credits associated with post-1990 reforestation activities and for the growth that occurs on the reforested areas during the compliance period, 2008–2012. It should be noted that under this interpretation no overall net forest growth need occur. These points are particularly significant for countries with large domestic forests under management, as they offer a large potential for carbon sequestration credits.

Carbon Offsets: Carbon emission credits have been suggested in the energy sector as a vehicle for improving the efficiency of carbon-mitigating activities. A similar instrument, carbon offsets, is also being considered. The concept is that carbon offsets could be added to the stock of emission credits, thus expanding the number of credits in the system and thereby lowering costs and improving efficiency. Prototype activities have been undertaken whereby carbon credits can be obtained for protecting an existing forest in jeopardy, establishing a new forest, or undertaking procedures that reduce carbon emissions associated with timber harvests. Indeed, K.P. offers a variant of this possibility under the J.I. and perhaps under the CDM. In recent years, some electrical utilities have expanded their capacity and offset the increased carbon emissions through forestry activities.[12] Under the current exploratory mode, offset credits are being considered for protecting forests that otherwise would be destroyed, creating new forests, and reducing carbon emissions from some current practices, e.g., low-impact logging. Such activities would need some method of certification. However, certifying firms already exist, and carbon certification has been undertaken in some countries.

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[11] A regulated forest is one with an even distribution of age classes and in which the net growth of the forest system is harvested annually by harvesting the tree in the oldest age class. The age of the harvested class is defined as the harvest rotation age. Once mature, such a forest experiences no net increase (or decrease) in timber stock or harvest volumes over time. Nevertheless, a country could receive carbon credits under this interpretation if the forest is newly established on an previously unforested site. This model can be expanded by making additions to the area of forest and/or increasing biological growth due to more inputs or technical change.

[12] New York State requires utilities to offset additional carbon emissions and accepts offsetting forestry activities.

Carbon Parking

The idea of a carbon offset credit is straight-forward. Carbon emissions into the atmosphere can be "offset" to the extent that an equivalent amount of carbon is taken out of the atmosphere by sequestration. As discussed above, forestry offers unique opportunities for sequestering carbon for fairly long periods. However, sequestered carbon, as in an offset, can also be released quite rapidly, e.g., through a fire. Additionally, forest land can be readily converted to other uses. For a system of offsets to be feasible, the carbon sequestered must be measurable, and there must be assurance, e.g., with some type of certification process, that the additional carbon is sequestered. Additionally, the system must be monitored to ensure that the carbon continues to be held captive. The instrument to be used, the carbon offset credit, must be creditably backed by the belief that the carbon the offset represents continues to be held in sequestration. If such an instrument were recognized as a bona fide offset, it would be valued in carbon markets. This raises the question of liability. If the carbon backing the offset credit is known to have been released, the offset credit would be valueless. Who bears the loss (liability) when a carbon credit is found to no longer represent real carbon, as in a case where the forest that the credits represent is destroyed? A problem related to this is the question of what ought to be the term of the credit.

The following argues that carbon sequestration should be viewed more as a temporary activity like the parking of a car than a long-term activity like the purchase of a parking space. First, one reason for this viewpoint is that it substantially reduces the complications associated with liability. Suppose that a forest is created in what are the grasslands of Argentine and that the carbon sequestered by the forest is measured accurately. The carbon forest's investors now market carbon offsets from this forest, e.g., they sell an offset for one ton of carbon sequestered. What time period should be associated with this credit? Typically, the discussion has focused on a long time period—say 65 years—based on the expected life of a tree. Sometimes the view is that the credit is in perpetuity, assuming that the forest will be a regulated forest, meaning one which continues indefinitely since the harvest level is set equal to net growth. However, this view presents problems. What happens if the forest dies due to fire or disease, or the tree owner chooses to harvest in a shorter time than initially agreed? For any such system to work, it must have a way to monitor the trees (and carbon) to determine when certificates are valid and when they are not. Without updated information the system would be destroyed by fraud. Thus, a necessary prerequisite for this system to work is that the traders must know when the carbon is released from the forest, and at that point, the offset certificate no longer represents any sequestered carbon.

Second, who bears the liability? Does the forest owner compensate the offset purchaser for the unplanned loss of carbon, thus bearing the loss? Or does the certificate purchaser bear the liability risk and thus go uncompensated, even though the certificate is now worthless? An argument can be made that the liability should be borne by the tree owner (seller of sequestration services) to ensure that incentives to continue the existence of the planted forest are maintained and thus ensure that the carbon remains sequestered. However, with a long-term certificate, buyers of certificates that were no longer valid would need to try to recover losses from the tree owners. Recovering compensation could be difficult and costly and involve inter-country litigation. An alternative would be for certificates to be good for relatively short time periods, e.g., one year. Each year the certificate would need to be renewed. Of course this would require periodic monitoring of the forest to ensure its continued existence and its carbon content. However, as noted above, monitoring is also required for a long-term certificate.

With short-term renewable credits, there is no need for compensation should the forest be destroyed, either intentionally or by accident, particularly if payment is made after the carbon has been sequestered for the required time period, i.e., at the end of the sequestration year rather than at the beginning. The incentive to the tree owners to maintain the annual flow of income would generate the incentive to maintain the trees and their carbon for another year. Under this system, the tree owner would be free to eliminate the tree (for logging or land conversion) and release the carbon, but the cost to the owner would be the loss of the annual income that would have been received for sequestering the carbon. Liability compensation, however, need not be a problem for tree owners if the carbon payment, as discussed above, is based on the carbon that has already been sequestered for the previous period, e.g., the payment is for the past year’s carbon, not the future year’s. Note however, that purchasers of carbon, e.g., power companies, would need to find alternative sources of sequestered carbon.

Some Existing Institutional Arrangements for Carbon Credits

Markets for carbon credits are not well developed, in part because the international community has not fully agreed as to what needs to be done nor precisely what will be the role of carbon offset credits. However, the concept of carbon emission activities in one country being used by other countries as credits is well recognized.

Institutions are being developed to allow these multi-country activities and transactions to be made. As noted, for example, Joint Implementation, which predated the K.P., has been redefined to allow one Annex B country to purchase carbon credits by undertaking carbon-reducing activities in another Annex B country. Also, the newly developed Clean Development Mechanism, which did come out of Kyoto, is designed to allow some types of multi-country purchases and trades between Annex B and non-Annex B countries.

In the United States there are a number of activities underway that utilize forestry and land-use activities to offset carbon emissions. An example of the development of a serious carbon offset program is one that has been encouraged by the state of New York's power authority. The program requires that electric power facilities that want to receive a license to increase their power generation capacity must demonstrate that they have provided for any increased carbon emissions resulting from the expansion. In an early case, a major power company made arrangements for tree-planting activities in Guatemala that would exactly offset the incremental increases in carbon emissions associated with the expanded power. This demonstrated to the state of New York authorities that the additional carbon emissions would be offset and hence justified the issuing of a license to increase power capacity. Other power companies have met these obligations in a similar way.

A similar activity is a series of exploratory projects undertaken by the electric power industry through the Edison Electric Institute (EEI), an association of private electrical power companies. Known as the Utility Carbon Management Tree Program (UCMTP), the project allows the various member companies to invest monies into a UCMTP project fund that is responsible for undertaking a number of forestry and tree-planting activities. In addition to the efforts of the UCMPT in the United States, there are other interesting efforts elsewhere. Perhaps the most well-developed system for collecting and marketing carbon offsets from the producer's side today is that of Costa Rica.

While carbon buyers need to identify needs and potential sources of secure and acceptable offsets, the producers of carbon offsets need to find ways to create and certify new offsets. This needs to be done in a context where buyers have offsets that are recognized and honored, probably via some creditable third-party certification.

Some Problems

Two obstacles need to be overcome before an effective offset system can be put in place. First, the problem of "leakage" needs to be adequately addressed. Leakage is a situation where a carbon-sequestering activity in one place results in partially or wholly offsetting activities elsewhere. For example, if when government forest planting for carbon-sequestering purposes discourages private forest planting, the offset would be termed a leakage. This could occur, for example, if large government tree-planting activities were viewed by the private sector as likely to depress timber prices at some future time or if large planting in some areas induced increased land conversion out of forests in another area.[13] In that environment, it would be quite reasonable for private timber growers to reduce the area that they plant in trees.

Possible approaches to address the leakage problem might involve a countrywide forest inventory to ensure that carbon-induced planting is additive or some policy to ensure that the carbon forests are not made available for timber purposes, e.g., planting in a very inaccessible area. Another approach would be to require some adjustment in the amount of carbon required for sequestration to account for average leakages, e.g., one-and-one-half tons of carbon might need to be sequestered in a project to generate one ton of carbon credit, with the discount based on estimates of leakage. A third possibility might be that carbon credits could be generated in a country only for total carbon countrywide sequestration above some baseline level. Elements of all three approaches might be required.

Second, there would need to be a market for permits. Note that the regulations of the New York state power authority provide the basis for a limited carbon market. However, recognition by the international community that some types of carbon offsets are efficacious for countries to meet international carbon reduction commitments is probably required before a fully functioning market would develop. The Kyoto Protocol offers the possibility of such recognition.[14] Certified offset credits could then be made available either to specific companies or traded on national or international markets like emission credits.

Summary and Conclusions

Forestry appears to offer a relatively low-cost approach to sequestering carbon. Furthermore, the technology required is well–developed, and effective carbon sequestration could begin fairly quickly. Also, early estimates of the cost of sequestering a ton of carbon probably did not reflect all the costs, especially opportunity costs, and hence were probably too

[13] Leakage is not unique to forestry. For example, reduced power plant emissions in theUnited States may simply be offset by leakage of fossil-fuel-intensive industries from industrial countries to other countries not covered by Kyoto targets.

[14] The progress to date in working out the details of carbon sequestration within the context of the Kyoto Protocol has, however, not been encouraging.

low; there are many places in the world where land opportunity costs are low, and there, carbon sequestration should be relatively low-cost.

The most serious problems with using forestry to sequester carbon would occur if forestry activity were truly undertaken on a very large scale. In this case, the impacts reducing atmospheric carbon could be substantial, but the leakage problems would also be expected to increase. This would be the outgrowth associated with the distortions that result from a dual system that rewards carbon sequestration in some circumstances while not rewarding it in other circumstances. Thus, for example, if carbon sequestered by new carbon forests is subsidized, while that in existing forests or in new industrial forests is not subsidized, a shift to new carbon forests at the expense of industrial forests would be expected. In this case, major leakages could occur, and much of the additional carbon associated with the new forests could be offset by carbon releases in other forests precipitated by the asymmetry in carbon incentives and credits. This problem, however, is not unique to forestry and is shared by other programs designed to address carbon mitigation. The solution to this problem would involve either the elimination of the two-tier system or, as a second-best solution, providing an incentive factor that includes an adjustment for the anticipated or average leakages.

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