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Tropical Forests and Climate Change
(Revised 2007)

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1. INTRODUCTION

Are we experiencing climate change? Is the Earth's climate getting hotter or colder, wetter or drier? And if it is, what is the cause? What will be the impact? Can we adapt? Are catastrophic weather events of recent years, like the prolonged droughts in Africa and the many violent hurricanes in the Caribbean like Katrina in 2005, indications of a real shift in the global climate?

This FORESTRY ISSUES paper examines global climate change and its causes, describes climate change's impact on forests, summarizes the Kyoto Protocol as it relates to forests, summarizes forests' role in mitigating climate change, and provides recommendations for international cooperation in the forest sector.

Without a doubt, the world's climate is changing. The climate change referred to in this paper is the long-term change in the climate as a consequence of the atmosphere being altered by humankind's activity. Scientists predict there will be an increase in the Earth's average surface temperature, shifts in weather patterns, and more frequent extremes in weather events. Warmer temperatures will allow more moisture to be held in the atmosphere, resulting in more frequent and more severe storms. Coastal areas in the tropics will see more violent storms, hurricanes, and typhoons develop over the warm ocean currents. In contrast, arid regions like the Sahel that have experienced droughts in this century will likely become even more arid with rising air temperatures. Polar regions will witness increasing temperatures and accelerated melting of their ice caps.

The current average global surface temperature of approximately 15°C is nearly 0.8°C higher than it was 100 years ago - most of the increase has been the consequence of human activity. Even though the 1990's was the warmest decade on record and 2006 was the warmest year on record, the recent higher temperatures are very modest in comparison with the predictions for the coming years. Scientists now estimate that the average global surface temperature will rise another 1.4°C to 5.8°C by the end of the 21st century. Precipitation is also on the rise. In the northern hemisphere, precipitation has increased by 0.5% to 1.0% per decade whereas the increase in tropical countries has been 0.2% to 0.3% per decade. This trend is expected to accelerate.


Hurricane Katrina 2005 (1)

Dramatic changes in the global climate will impact on our food security, our health, and the world's ecosystems. Rising temperatures and irregular precipitation patterns will impact negatively on agricultural crop yields and food security. Food production in arid and semi-arid regions will be at greater risk especially in Sub-Saharan Africa. An increased incidence and intensity of violent storms and monsoons will produce more flooding which in turn will cause greater infrastructure damage and an increase in the incidence of vector-borne and water-borne diseases. With the predicted 5.8°C rise in the average global surface temperature, the incidence of mosquito-borne diseases like malaria, dengue fever, and yellow fever will rise dramatically. The socioeconomic impact of climate change in Developing Countries will be significant. The least privileged in society are also the least equipped to adapt to climate change. Poverty, limited infrastructure, poor access to technology, inadequate education, and limited management skills; combine to frustrate the ability of Developing Countries to respond to the challenges.

The changes in the global climate are causing a reduction of the snow pack in northern latitudes, a melting of mountain glaciers, a thawing of the Arctic permafrost, and a shrinking of the polar ice caps. This is effecting the average sea level of the world's oceans which have risen 17 cm in the last century. If sea level rises 20 to 60 cms. in the next 100 years, as the IPCC studies predict, it will have serious impacts on coastal lowlands. Other estimates put seal level rise much more, some over 300 cm. by 2100 which would bring devastating consequences. For example, Bangladesh would lose one-sixth of its land area. River deltas that are currently being farmed and estuaries that are now important wildlife habitats will be flooded and become saline, making them unsuitable for these uses. Warmer ocean temperatures will have an impact on marine life, affecting their abundance and distribution. For example, with rising ocean temperatures the range of the Pacific salmon is expected to shift dramatically northwards and threaten the survival of many salmon runs, resulting in serious economic implications for commercial fishing. Similarly, there will be impacts on the terrestrial ecosystems that will challenge all species ability to adapt. Many plant species whose seeds are not disseminated by wind or animals could have their ranges reduced or even become extinct. If so, this will have an effect on the animal species that depend on them for food and shelter. With increasing temperatures and decreasing precipitation, semi-arid regions will be subject to desertification and accelerated soil erosion. Mountain ecosystems and wetlands will be particularly venerable. As will be seen in this paper, the impact on the world’s forest ecosystems will be considerable.

The burning of fossil fuels is the most important source of greenhouse gases (2)

In addition to anthropogenic-induced climate change, there are short-term variations in global temperatures that are associated with atmospheric disturbances resulting from solar activity, geological events like volcanic eruptions, or temporary shifts in ocean currents like the recent influences of El Niño and La Niña in the Pacific Ocean. The Earth's climate has a history of cycles of warmer periods be followed by cooler ones. One of the most dramatic examples of this cycle in recent history was the last glaciation period some 10,000 years ago when the average global temperature was 5C to 7C lower than our present temperature. More recently, there was a warm period from 900 to 1200 AD that was followed by a cooler period from 1300 to 1900 AD. However, the principal concern today is that the present trend is not cyclical in nature; rather it is a long-term warming of the global climate. Since the early 1900s, a definite warming trend has been detected which is considered by scientists to be distinct from the cyclical variations that the Earth has experienced for millennia.

2. HOW ARE WE CAUSING CLIMATE CHANGE?

The Earth's climate is changing because the composition of our atmosphere is being altered, primarily as a consequence of human activity. The world's population continues to grow at an alarming rate with our numbers now estimated at 6.7 billion persons in 2007, a six-fold increase during the last century. Despite the fact that most of the world's people still live in unacceptable levels of poverty, our collective wealth is growing and with it there is a corresponding increase in demand for natural resources, energy, food, and goods to consume. In the process, we discharge vast quantities of gases and effluents that change the atmosphere's composition and its capacity to regulate its temperature.

Table 1 illustrates the main greenhouse gases that are related to land use. In addition to those mentioned in the table; water vapour and industrial emissions (in particular, nitrogen oxides (NOx), ozone, sulphur dioxide, CFCs, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluorides) are important as greenhouse gases, although they are not significant in terms of their impact on forests or forests' ability to mitigate climate change.

Table 1 - PRINCIPAL GREENHOUSE GASES

Greenhouse Gases	Importance to Climate Change	Trend in the Atmosphere	Land Use Related Sources of Greenhouse Gases
carbon dioxide	very high	increasing; +30% in last 250 years	mostly produced by deforestation, forest fires, and other land use sources
methane	moderate	increasing; +150% in last 250 years	generated by livestock waste, the decomposition of wetlands, and burning of biomass
nitrous oxide (N2O)	moderate	increasing; +17% in last 250 years	caused by deforestation, burning of other biomass, application of nitrogen fertilizer, agricultural soils, and livestock feed lots
carbon monoxide	moderate	increasing	comes from the incomplete burning of pasture and grasslands

Source: adapted from IPPC (2001) and Ciesla (1995)

The consensus in the scientific community is that we are now also experiencing a non-cyclical rise in the global temperature caused by the accumulation of the so-called "greenhouse gases" --carbon dioxide, methane, nitrous oxide, and others. Energy received from the sun is absorbed as short wavelength radiation and is eventually returned to space as long wavelength infrared radiation. Greenhouse gases absorb the infrared radiation, trapping it in the atmosphere in the form of heat energy.

Greenhouse gases are known to be increasing dramatically in the atmosphere, but estimates of the rate of increase, what the important sources are, and their relative importance are still scientifically imprecise. The IPCC estimates that the level of carbon dioxide in the atmosphere today is 31 percent higher than it was at the start of the Industrial Revolution, 250 years ago. Most of this increase has occurred in the second half of the 20th century. For the next century, carbon dioxide levels will rise 90 percent to 250 percent over pre-Industrial Revolution levels. Research suggests that the other greenhouse gases like methane and nitrous oxide will also continue to increase. Since greenhouse gases remain in the atmosphere long after they have been emitted, it would take centuries for the atmosphere to return to 1990 levels, even if all new emissions were eliminated tomorrow.

About three-quarters of the anthropogenic emissions of CO2 to the atmosphere during the past 20 years is due to fossil fuel burning. The rest is predominantly due to land-use change, especially deforestation.

Climate Change 2001: IPCC

It is now widely accepted that the burning of fossil fuels is the most important source of greenhouse gases. Coal and petroleum are the principal fuels for power generation, industry, and transportation, accounting for about 75 percent of all emissions. As the global economy has grown, there has been a dramatic increase in the consumption of fossil fuels, witnessed most dramatically in the virtual revolution of the transportation sector. Cars and trucks have increased from a mere handful a hundred years ago to the tens of millions of vehicles currently on the road. Airline travel has gone from non-existent to thousands of flights per day. All of this change has been accompanied by a skyrocketing consumption of fossil fuels. As well, energy needs for heating and domestic cooking have not only increased with the growth in population, but also with the changes in technology. There has been a shift away from biomass fuels to more convenient, less expensive petroleum-based sources.

After the burning of fossil fuels, the most important sources of greenhouse gas emissions are activities related to land use, primarily tropical deforestation. Currently, the carbon dioxide emissions from human activity are estimated to be 7.5 billion tonnes of carbon annually, of which 1.5 to 1.8 billion tonnes comes from forest-related sources (although some accounts put the actual amounts higher). Greenhouse gases from deforestation are mostly carbon dioxide with lesser amounts of methane and carbon monoxide. Tropical deforestation is one of the most critical environmental problems facing the developing countries today in terms of its long-term, catastrophic impact on biodiversity, economic opportunities lost, social problems created, and contribution to global climate change.

How much forest is being lost annually to deforestation? Using the Food and Agriculture Organization of the United Nations statistics from the Forest Assessment Report 2005, it is estimated that the annual deforestation in developing countries between 1990 and 2005 was 12.3 million hectares. With the clearing of forests on such a massive scale and the burning of most of the wood associated with them, there has been an enormous release of greenhouse gases into the atmosphere. The above-ground biomass of tropical moist forests (those most subject to deforestation) is often more than 175 tonnes of carbon per hectare. When cleared and burned, much of this carbon ends up in the atmosphere as carbon dioxide. Most of this loss in forest cover is the result of land clearing for agricultural use. Unlike the situation in boreal forests where forest fires burn and new forests regenerate afterwards, tropical deforestation destroys the forest as a "carbon reservoir" for the future because the land on which the trees grew is converted to other uses. The other uses like farms or pastures have a lower carbon sequestration and storage potential than forests, resulting in a net discharge of greenhouse gases into the atmosphere.

Climate Change Terms

- **additionality** - emission reductions that are new and in addition to those which would have occurred anyway
- **afforestation** - the conversion of land that has not been forested for at least 50 years to forested land through human activities such as planting and seeding.
- **carbon pool** - a system having the capacity to accumulate or release carbon; examples of carbon pools are forest biomass, wood products, soils, and the atmosphere.
- **deforestation** – the conversion of forested land to non-forested land as a direct result of human activities.
- **greenhouse gases** – water vapour, carbon dioxide, methane, nitrous oxide, and other gases that modify the heat retention capacity of the Earth's atmosphere
- **GtC -** 1 billion metric tons of carbon, equivalent to 3.7 billion tonnes of CO2
- **leakage -** a reduction that causes an equivalent emission elsewhere
- **reforestation** - planting or natural regeneration of forests after harvesting, fire, or other type of forest disturbance (perturbation)
- **reservoir -** where sequestered atmospheric carbon is stored (e.g., forests)
- **sink** - any process, activity, or mechanism that removes greenhouse gases from the atmosphere
- **sequestration** - the process of increasing the carbon content of a carbon pool other than the atmosphere.
- **source -** any process, activity, or mechanism that emits greenhouse gases

Agriculture also contributes to the build-up of greenhouse gases, particularly methane and nitrous oxides from livestock wastes, burning of pastures and crop residues, and the application of nitrogen-based fertilizers. Agricultural crops capture atmospheric carbon as part of photosynthesis, but due to the short-term nature of the crops, they have a very limited ability to store it. Carbon is quickly returned to the atmosphere through the digestion of the crops and the respiration of their residues. Roots and plant residues become part of the soil carbon cycle.

Table 2 illustrates the global carbon budget according to the currently accepted estimates for sources, sinks, and atmospheric accumulation.

Some of the emissions of greenhouse gases are absorbed by so-called "carbon sinks," the most important of which are the oceans, soils, and forests. Like agricultural crops, forests sequester carbon from the atmosphere as part of photosynthesis. However, because trees have a much longer lifespan, they act as long -term reservoirs that lock up the carbon for decades, even centuries, in the form of cellulose and lignin. The carbon that is not captured by the sinks accumulates in the atmosphere.

Table 2 - SIMPLIFIED GLOBAL CARBON BUDGET					
CO_2 Sources	**GtC/year**	**CO_2 Sinks**	**GtC/year**	**Atmospheric Accumulation**	**GtC/year**
fossil fuel emissions and cement production	6.3(+/-0.6)	oceans	2.3(+/-0.8)	accumulation in the atmosphere	3.3(+/-0.2)
emissions from land use change, mostly tropical deforestation	1.6(+/-0.8)	northern hemisphere forests	0.7(+/-0.2)		
		other terrestrial sinks	1.6(+/-1.3)		
total	7.9	total	4.6	total	3.3

Source: adapted from Ciesla, 1995; IPCC 2000

3. IMPACT OF CLIMATE CHANGE ON FORESTS

Most of the carbon that is not present in the atmosphere is stored in the oceans and in petroleum reserves. In addition to these, carbon is stored in ground litter, soils and plants. Forests contain about 80 percent of all above-ground and 40 percent of all below-ground terrestrial organic carbon. As part of photosynthesis, trees absorb carbon dioxide from the atmosphere and convert it to biomass. Young trees that are growing rapidly, capture and store carbon more rapidly than mature trees do, whereas the older trees can store carbon for long periods of time. The length of time a tree can store carbon depends on many factors – such as the normal longevity of the tree species, the occurrence of natural events such as fire, or the end use to which a tree is put. Species like poplars or willows are typically short-lived whereas oaks or sequoias live for centuries. The old growth forests of British Columbia's west coast are composed of carbon sequestered from the atmosphere more than 600 years ago. When trees die, they decay and slowly release their carbon back to the atmosphere and to the soil. If trees are harvested, their stored carbon can be released immediately (fuelwood), over a short period of time (paper products), or can continue to be stored for a long time (furniture or construction wood).

Will warmer atmospheric temperatures and higher concentrations of carbon dioxide (essential ingredients for photosynthesis) favour forest growth? What impact will climate change have on the world's forests and on the people who depend on them? Climate change will have a dramatic impact on the distribution of existing forests, the dominant land use of nearly 4,000 million hectares or 30 percent of the Earth's land area. The predicted rise in the atmospheric temperature and carbon dioxide levels will favour the growth of some forests and will place severe pressure on other forests' ability to adapt and survive. Moderate increases in temperature and carbon dioxide levels can be favourable to tree growth, however, with the expected scenarios of rising temperatures, changing availability of water, and doubling of the carbon dioxide levels; it is expected that one-third of the forests worldwide will experience significant changes in species composition.

"By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by arid-land vegetation. There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America"

- IPCC Fourth Assessment Report, Working Group II

Trees are not equipped to adapt quickly to environmental changes because of their long maturation period and their inability to move from one locality to another. Species migration for trees can be as slow as a few metres per century. The predicted rise in the atmospheric temperature in North America by the end of the 21st century would result in a 150 km to 550 km shift northwards of climate boundaries for many of the existing forest ecosystems.

Subsequently, we could see extensive dieback in many forest areas as conditions become unfavourable for their growth and survival. As a consequence, the volume of dead and dying stands of trees would significantly increase the incidence of fire, insect, and disease attacks, which in turn would have an impact on many forest ecosystems. A well-known Canadian example of the devastating impact of climate change can be found in the lodgepole pine forests of British Columbia. Climate change has moderated the traditionally cold winters that kept the population of the mountain pine beetle in check. From 1993 to 2005, warm winters have allowed the beetles to multiply and destroy 8.7 million hectares of forest in Central British Columbia with serious environmental and economic consequences for over 30 communities in the affected area.

In order for existing forests to be eventually replaced with more suitable or adaptable species, the present forests must die with consequent releases of further large amounts of carbon into the atmosphere. However this could result in the disappearance of entire forest types. The introduction of species previously not present could have profound implications for forest biodiversity and wildlife populations. The new forests that would take their place would have very different species compositions, ones that match the combination of seed availability, precipitation, temperature, growing season, and soil present at the time.

4. CLIMATE CHANGE CONVENTION AND THE KYOTO PROTOCOL

In response to a growing concern and the mounting evidence of global climate change, the Framework Convention on Climate Change was adopted at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. The objective of the convention is "to stabilize atmospheric greenhouse gas concentration at a level that would prevent dangerous anthropogenic interference with the climate system." The convention is a statement of basic principles and a framework for subsequent action including the development of protocols where participating nations commit to specific actions.

CDM would allow for carbon sequestration and storage investments in reforestation and in afforestation to qualify as emission reductions credits by the investing countries. The theory is that it does not matter where the emission reductions occur in the world for the global atmosphere to benefit.

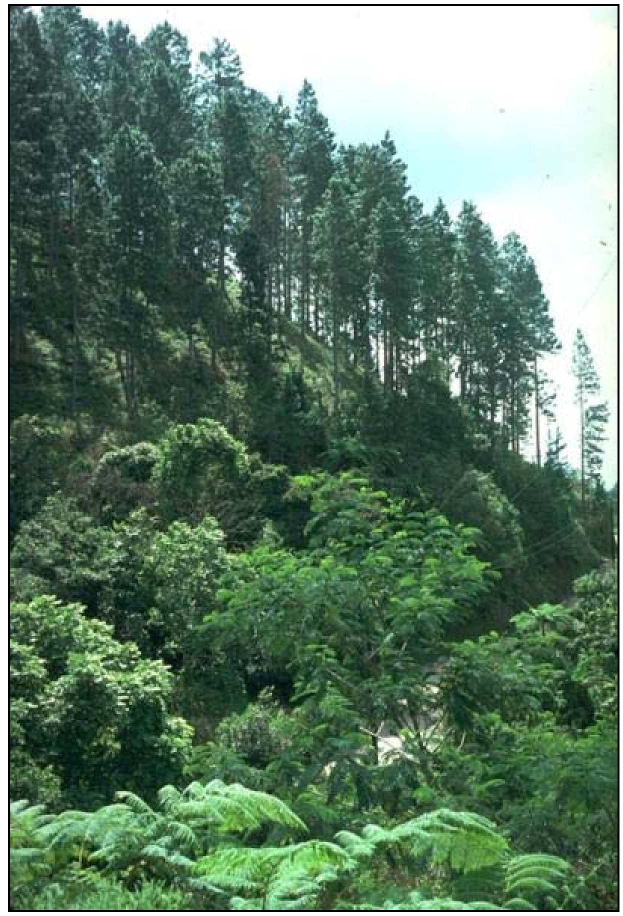
The most significant agreement to date has been the Kyoto Protocol, tabled at the December 1997 meeting of the Third Conference of Parties (COP-3) in Kyoto, Japan. The Kyoto Protocol sets legally binding commitments for emission reductions for the so-called Annex 1 countries (the developed countries and the Eastern European countries of the former Soviet Bloc) to levels relative to their 1990 levels. For the "commitment period" of 2008 - 2012, countries are meant to reduce their collective annual emissions by 5.2 percent below the 1990-benchmark levels, with allowable emissions based on each country's recent emission history. For most industrialized countries, this means reductions of 6 to 8 percent, while others with better emission records would be permitted to increase their emissions. According to the Protocol, the Non-Annex 1 countries (i.e., the developing countries) would be exempt. The Kyoto Protocol came into force on the 16th February 2005 after which time it became a legally binding instrument. As of December 2006, 168 states and regional economic integration organizations have ratified it.

It is indisputable that all countries have the right to develop and offer their citizens a better future, and it is only just that the industrialized countries that have generated most of the greenhouse gases pay most of the cost of any remedial measures. However, excluding any country, particularly the emerging economies of Asia, from meeting the emission reduction targets is a major shortcoming of the Kyoto Protocol. China and India, for example, have emissions that exceed those of many of the industrialized nations and those emissions are accelerating annually.

The protocol identifies three possible "flexibility mechanisms" for countries to meet emission reduction targets: joint implementation, a clean development mechanism (CDM), and emission trading. Of particular interest to North-South cooperation is the CDM that would allow Annex 1 countries to receive emissions credits by implementing projects in non-Annex 1 countries that reduce emissions. CDM would allow for carbon sequestration and storage investments in reforestation and in afforestation to qualify as certified emission reductions credits by the investing countries. The theory behind this market-based mechanism is that it does not matter where the emission reductions occur in the world for the global atmosphere to benefit. For example, a French energy utility could obtain certified emission reduction credits for France by establishing a tree plantation in Zambia as a carbon sink.

Afforestation and reforestation projects under CDM can only be carried out in countries that have ratified the Protocol and only on lands that were not forested for at least 50 years (afforestation) or were converted to other uses before 1990. Assisted natural regeneration, plantations, agroforestry, and urban forests qualify; however, enrichment plantings in disturbed forests do not. To qualify, project must undertake baseline studies of the carbon stock, involve local stakeholders in the design, ensure that the project contributes to sustainable development, and be adequately monitored. Once the project has been verified, certified emission reductions credits can be issued. Carbon forests also have to pass the tests of "additionality" and "leakage." Additionality means that the emission reductions attributed to the carbon forest must be new and in addition to those that would have occurred anyway. Leakage, on the other hand, refers to the requirement that the reduction does not cause an equivalent emission elsewhere.

"Sink enhancement" interventions related to improving the management of the existing forest resource and compensation for "avoided deforestation" are under consideration as part of CDM but have not been agreed to as yet. A recent initiative holds promise of rewarding countries that reduce their rates of deforestation. The World Bank, in a response to developing countries that felt their efforts at reducing deforestation were not being recognized, has proposed the creation of the Forest Carbon Partnership Facility (FCPF). The FCPF would be a framework to reduce emissions from deforestation and degradation through innovative policies and incentives. It would consist of a preparatory or "readiness" phase to build the capacities of developing countries to participate in the future incentives programs. Capacity building could include updating forest resource and carbon emissions information, developing methodologies for monitoring emission reductions, designing strategies and payment channels, and institutional strengthening. This would be followed by a "carbon finance" phase in which pilot incentive programs for reducing deforestation and forest degradation would be implemented and evaluated. It is hoped that the international community will agree on a realistic, workable mechanism that will recognize all aspects of forests and trees contributions to moderating atmospheric change. It is important that actions that are taken to reduce emissions from deforestation be eligible for CDM credits. Protecting and conserving and existing forest would be much more cost-effective than investing in reforestation or afforestation projects.



The technology to establish fast-growing plantations exists, as does the global expertise for establishing them (3)

The specific mechanics of how many the instruments would work have not yet been completely defined and there is still some uncertainty about which forestry-related practices will eventually qualify under the Protocol. Guidelines describing what constitutes good "carbon forestry" practices and how they relate to the ongoing definition of criteria and indicators for sustainable forest management will have to be agreed upon. The procedures for certifying and monitoring "carbon forests" will have to be adopted and they will have to be compatible with the prevailing timber certification standards of organizations like the Forest Stewardship Council.

5. FOREST'S ROLE IN MITIGATING CLIMATE CHANGE

There are three broad categories of forest-related interventions that will help stabilize greenhouse gas emissions: managing the existing forest resource better, expanding the area of forest cover, and using woodfuels as a substitute for fossil fuels. These interventions do not necessarily fall within the framework of the Kyoto Protocol, but they could make major environmental and socio-economic contributions to the countries where they are undertaken.

While trees have an enormous potential to sequester and store large volumes of carbon, they will be undergoing considerable stress as they try to adapt to the changing climate. In fact, millions of hectares of forests will be dying as a consequence and will be, themselves, sources of carbon emissions. Obviously, this could limit their sequestration capacity and their contribution to mitigating climate change. How this will play out in the coming decades is not known. Managing the existing forest resource better involves introducing improved forest management and harvesting policies and technologies to improve the existing forests' capacity for carbon sequestration and storage. This can be accomplished by making investments that minimize the loss of forest area to deforestation, that maintain or improve tree growth, that minimize soil disturbance and residual stand damage during timber harvesting, and that ensure quick and satisfactory regeneration of new forests. It could also include adopting socially acceptable programs of forest protection or joint management; improving the management of parks and protected areas; ensuring satisfactory natural regeneration of harvested forests and forests damaged by fire, insects, and disease; improving forest fire suppression and management capabilities; adopting reduced-impact logging practices; and minimizing the negative environmental impact of road construction and maintenance. In short, it means practising sustainable forest management. Given that the overwhelming majority of tropical forests are not sustainably managed, there is tremendous scope for improvement.

Although sustainable forest management should be the goal of all countries with forest cover, there are difficulties with including the better management of natural forests in any internationally recognized program to obtain carbon credits. In developing countries, and to a lesser extent in developed countries, the financial and human resources needed to adequately monitor forest management simply do not exist. Forests are normally the responsibility of government and governments do not, at the present time, have the budgets and staff to manage the forests by today's modest standards, let alone to take on the monitoring of forest management for carbon sequestration and storage. To be effective, monitoring would require a new, innovative program that would require massive injections of money and qualified personnel. Furthermore, there is no satisfactory baseline data available in most countries that could be used as the yardstick to measure future management. Without this initial information, it would be impossible to do the monitoring, even if the funds and staff were available. Unlike the management of natural forests, new plantations would be comparatively easier to monitor. Verification could be carried out using aerial photography and satellite imagery with appropriate levels of ground sampling to confirm tree survival and growth. The methodologies are still being developed, however, they would include measuring the physical parameters of the subject area, the collection of pre-project baseline information, assessing leakage and additionality, and measuring the growth and yield of the new forest.

Expanding the area of forest cover by establishing tree plantations, agroforestry plantings, or analog forests enlarges the capacity of the terrestrial carbon sink. (4)

Expanding the area of forest cover by establishing tree plantations, agroforestry plantings, or analog forests enlarges the capacity of the terrestrial carbon sink. Trees are composed of approximately 50 percent carbon, which they extract from the atmosphere during photosynthesis. The rate of carbon sequestration is depends on the growth characteristics of the species, the conditions for growth where the tree is planted, and the density of the tree's wood. It is greatest in the younger stages of tree growth, from 20 to 50 years. Growth rates on commercial plantations in the tropics have been improving steadily as the results of tree improvement research have been applied. The technology to establish fast-growing plantations exists, as does the global expertise for establishing them. Growth rates of more than 30 cubic metres/hectare/year are now commonplace for intensive industrial pulp plantations in the tropics and FAO estimates that there are over 4 million hectares of tree plantations established every year in developing countries. Globally, intensive plantation management is being employed to meet industrial roundwood needs and can be called upon to grow more trees and grow them faster for carbon sequestration objectives. Estimates of the area of land available for planting varies greatly, but it is probably from 300 to 400 million hectares in developing countries (although much of that area is abandoned farming and grazing land subject to serious investment and socio-cultural constraints). Obviously, an opportunity exists to combine proven technologies, technical expertise, and available land to expand the area of tree plantations. However, if the funds were made available to invest in such massive plantation programs, there would be a need to strengthen the managerial and technical capacities in tropical countries that implement them.

On another front, agroforestry plantings and analog forestry offer some scope for carbon sequestration. Some agroforestry systems hold considerable potential for improving carbon sequestration and storage in both the soil and the biomass. Long rotation systems that use trees for windbreaks, border plantings, and overstory shade can sequester carbon for many decades. Of lesser importance are short rotation agroforestry systems like improved fallows or hedgerow intercropping unless the wood is used as fuelwood in substitution for fossil fuels. Analog forests attempt to reverse the loss of forest cover by planting trees and lesser plants on deforested lands, recreating the structure and functions of the original forest. In this way, they offer the opportunity to expand forest cover, sequester carbon during the growing phase, and to provide long-term carbon storage when mature.

Urban tree planting also offers the advantages of reducing greenhouse gas build-up by sequestering carbon, by providing shade that reduces energy consumption for air conditioning in summer, and by providing shelter that reduces heating system emissions in winter. Tree planting, by whatever method, has a broad-based appeal in many societies and brings with it many benefits beyond the sequestration of atmospheric carbon. Whatever type of tree planting approach is used, the carbon storage value of the wood depends very much on its end use. Fast-growing wood used for wood pulp has a relatively low storage value because the end product is short-lived. On the other hand, slower-growing wood used for lumber or furniture can store carbon for many decades. The Working Group II of the IPCC, in its fourth assessment report, anticipates the commercial use of new tree improvement technologies to increase biomass productivity and carbon sequestration before 2030.

Forest-related mitigation options can be designed and implemented to be compatible with adaptation, and can have substantial co-benefits in terms of employment, income generation, biodiversity and watershed conservation, renewable energy supply and poverty alleviation

- IPCC, WG III

Expanding the use of woodfuels as substitutes for fossil fuels is the third important role that forests can play. Globally, woodfuels (firewood and charcoal) account for over 55 percent of all wood harvested. In developing countries, four times as much wood is cut to meet energy needs than for industrial purposes. FAO estimates that while fuelwood and charcoal's overall contribution to the developing world's energy budget is about 15 percent, they supply more than 70 percent of the total energy requirements for over 30 countries. Biomass fuels, unlike fossil fuels, are considered to be "carbon-neutral," the assumption being that the resulting emissions will be compensated for by the absorption of an equivalent amount of carbon in the regrowth of the fuelwood on sustainably managed woodlots. For example, if fuelwood plantations are managed sustainably and replanted after harvesting, there will be no net emissions because the carbon will be captured by photosynthesis of the new plantation. If energy consumption shifts from fossil fuels to fuelwood, there is a net gain in emission reductions. This requires that the forests and woodlands from which the fuelwood was collected are not being deforested and converted to other land uses. They must be allowed to naturally regenerate, coppice, or be planted after harvest. In many developing countries, this is a real challenge.

In developing countries, the continued or expanded use of woodfuels has potentially important impacts -- both positive and negative -- for women and children. Woodfuel is a relatively cheap energy source. It is collected outside the market economy and, therefore does not place a demand on the limited financial resources of the less privileged groups in society. Money that is not needed to meet domestic energy needs can then freed up for other urgent necessities. Village or household woodlots can relieve the time consuming burden of firewood collection. It should be noted that there are serious health problems related to the smoke of wood-based fuels if there is inadequate ventilation or inefficient stoves are used.

Despite the benefits they can offer, woodfuels have serious limitations. First, woodfuel plantations have not been established widely because it has not been economic to do so. While plantations are a viable source of wood for more valuable products such as pulp fibre or solid wood products, low-value woodfuel cannot usually cover the plantation establishment and maintenance costs. Second, there are no technologies available, at present, which permit woodfuels to be used as economic energy sources for large power requirements such as those needed for small cities or industries. Research and development, aided by "carbon taxes" on petroleum products, could provide the incentive for their development but currently they are not used to any degree, anywhere in the world. Can forest plantations in developing countries be feasible options for carbon offset projects?

6. CARBON TRADING MARKETS

What is the potential carbon trading market for forestry-related investments? At the present time, no one really knows. Will investors be willing to consider forestry investments and if so, on what scale of investment? If it is assumed that 80 million tonnes of carbon or 10 percent of the total emission reduction commitment of the Kyoto Protocol will be addressed through forestry investments and that the likely market value will be $20 per tonne of sequestered carbon, this would create a market of $1.6 billion.

There are still unanswered questions about the role of forests in carbon trading markets. The sequestration of carbon by forests must be quantifiable and be in addition to that which would have occurred anyway. How this will be measured is still unknown. Also unknown is the nature of the costs and benefits to participating countries. Information concerning the primary costs and benefits of the new forest practices to be employed as well as the secondary costs (i.e., plantations' impoverishment of biodiversity) and benefits (i.e., job creation or soil conservation) is imprecise. There is also still considerable uncertainty about investor interests and priorities in forest-related carbon trading projects. Having both political and economic stability in the countries to be invested will be key to attracting partners. It is important that a scientifically acceptable methodology be developed and agreed upon for measuring emissions reduction. Only in this way will there be a viable carbon trading market established.

Research is needed to provide the information for sound policy decisions. Specific information needs include collecting better baseline data, improving methodologies for assessment and monitoring, compiling and disseminating forest-specific information on potential technological and social innovations, and analyzing the constraints to adaptation and change.

Are carbon sequestration and multiple use forestry compatible? There are concerns that the growing interest in forests' role in carbon sequestration might overshadow the hard-won gains in recognizing the important multipurpose roles they play. The monetary value of sequestration and storage has the potential to dwarf the more modest economic returns that come from timber, non-wood forest products, water, biodiversity and other environmental services and put at risk the recent advances in respecting traditional forest values of indigenous peoples.

Globally, woodfuels (firewood and charcoal) account for over 55 percent of all wood harvested. (5)

Whatever the agreed-upon interventions eventually are, they must be environmentally sustainable, economically viable, technologically feasible, and socially adaptable in the countries where they are developed. Under the right circumstances of secure land and tree tenure, acceptable pricing of carbon credits, low forest establishment and maintenance costs through the use of appropriate technologies, low management and monitoring costs through cluster programming, good growth and sequestration results, and equitable benefit sharing with local stakeholders; forestry options for carbon sequestration and storage can be attractive investment alternatives that provide society many external socio-economic and environmental benefits.

7. INTERNATIONAL COOPERATION

For many years, CIDA has collaborated with the governments of developing countries and with non-governmental organizations on projects for improving forest management. In recent years, projects have been undertaken in Cameroon, Senegal, Cuba, Nicaragua, Indonesia, and East Timor. CIDA also supports the programs implemented by the multilateral organizations like the World Bank, the regional development banks, and the agencies of the United Nations.

Canada Climate Change Development Fund funded forest-related projects that promote activities in developing countries that address the causes and effects of climate change while at the same time contributing to sustainable development and poverty reduction. The Forest Resources Management for Carbon Sequestration (FORMACS) Project in Indonesia, the Community-Based Natural Resource Management for Carbon Sequestration Project in East Timor, and the Climate Change, Forests and Peatlands Project in Indonesia are recent examples.

Some examples of international cooperation projects in the forest sector that would contribute to mitigating climate change include:

- Collaborating on reforestation and afforestation projects for carbon sequestration and storage
- Building capacities to develop appropriate technologies to avoid deforestation

- Supporting community-based organizations in the management of their forest resources
- Assessing and monitoring the extent and change of forest resources
- Advising on the development and implementation of national standards for climate-related projects
- Managing parks and protected areas for carbon storage
- Promoting sustainable agriculture projects as alternatives to deforestation
- Minimizing forest damage by adopting appropriate harvesting methods
- Reducing emissions from forest industries, in both woodlands and manufacturing sectors
- Supporting public education on the economic and environmental impacts of climate change
- Promoting efficiencies in the use of biomass fuels

Forest-related interventions can have numerous positive spin-off effects apart from carbon sequestration and storage: improved supply of wood products, better management of protected areas, increased agricultural production through agroforestry, creation of employment opportunities in rural areas, and improved environmental management. As a consequence, there needs to be a greater integration of climate change initiatives with other ongoing sustainable development programs, particularly with those aimed at the conservation of biodiversity, sustainable forest management, and control of deforestation. Such programs would make a very positive contribution to reducing the vulnerability of existing forest to climate change. With financial resources to address these issues becoming increasingly scarce, it should be the he highest priority of donors and recipient countries alike to adopt an effective coordination mechanism to avoid waste and duplication.

8. CONCLUSIONS

There are constraints to enhancing forestry's role in mitigating global climate change. Many of these constraints can be addressed through the coordinated efforts of development assistance programs with each donor agency focussing on its comparative advantage to assist developing countries. Constraints include weak governmental and non-governmental institutions; inadequate higher education, training, and research; demand for basic human needs of local populations; pressure for additional agricultural land and consequent deforestation; high cost of plantation establishment and maintenance; and ecological issues related to planting monocultures, reducing biodiversity, and the effect of using agrochemicals in tree plantations. Given the appropriate policy framework and sensitivity to the social, cultural, economic, and environmental conditions, these constraints can be successfully overcome. Will policy-makers and decision-takers have the courage to take the difficult measures to turn the situation around? How serious will the impact of climate change have to be for action to be taken on the scale necessary to be effective? These are important questions that are yet to be answered.

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Forest-related investments for mitigating climate change must be viewed as a complement, not a substitute, to a global effort to reduce fossil fuel emissions in both developed and developing countries. The major challenge is clearly to improve the efficiency in the use of coal and petroleum-based fuels for energy generation for industry, manufacturing, transportation, and the heating /cooling of buildings. Hard choices must be made to reduce the use of these fuels. These could include the elimination of subsidies to energy-inefficient, polluting industries, tax credits to "green" consumers, an increase in petroleum taxes, and incentives to research and development of alternative energy sources such as wind or solar power and the fuel-cell technology.

To have any chance of long-term success, carbon forests must have the support of the governments, the local communities, and the populace at large of the countries where they are established. They must be convinced that the forests are in their long-term interests. This means that be involved in the not only in the conceptualization, planning, and implementation, but that they also have meaningful roles and responsibilities to play and have a just share in the benefits derived. Carbon forests must be an integral part of the country's overall development plans.

Trees and forests should be looked upon as "temporary" carbon sinks that can assist in reversing the deterioration of our atmosphere until the time that truly "clean" technologies are available on a large scale. Carbon forests can help cleanse the atmosphere of the accumulated emissions of the last 200 years, but full recovery will require centuries of much reduced emissions and greatly enhanced sequestration and storage. Our successful adaptation to inevitable climate change will depend on our willingness and ability to adopt new technologies, change our consumption patterns, adopt appropriate institutional arrangements, and secure financing for mitigation initiatives.

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Photos:
(1) source: U.S. Department of Commerce. National Oceanic & Atmospheric Administration; http://www.katrina.noaa.gov/images/katrina-08-28-2005.jpg
(2) source: World Population Balance, http://www.worldpopulationbalance.org/pop/stats-us.php
(3) source: FAO; photographer: Susan Braatz; reference number: FO-0878
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