

## Chapter 23

# PROJECTED LAND-USE CHANGE FOR THE EASTERN PANAMA CANAL WATERSHED AND ITS POTENTIAL IMPACT

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**Abstract:** Human occupation of the Panama Canal Watershed has affected its land cover for the past century. A rule-based model was developed and applied to estimate changes in land use and subsequent carbon emissions over the next twenty years in the Eastern Panama Canal Watershed (EPCW). Projections show that the highest percent change in land use for the 'new-road' scenario compared to the 'business-as-usual' scenario is for urban areas, and the greatest cause of carbon emission is from deforestation. Thus, the most effective way to reduce carbon emissions to the atmosphere in the EPCW is by reducing deforestation. In addition to affecting carbon emissions, reducing deforestation would also protect the soil and water resources of the EPCW, which has important implications for the long-term sustainable operation of the Panama Canal.

**Key words:** Panama; carbon baselines; carbon benefits; land-cover change; regional analyses; spatial projections; tropical deforestation;

## 1. INTRODUCTION

Completion of the Panama Canal in 1914 led to recognition of the importance of the Panama Canal Watershed that supplies the millions of gallons of water required for each ship to pass through the Canal, as well as providing potable water to the major urban centers of Panama City and Colón. Today, the watershed is home to some 30% of the people living in Panama. The watershed supports suburban life as well as agriculture, ranching, and forestry (Heckadon-Moreno, 2005, this volume). In addition,

the Panama Canal Watershed is widely acclaimed for its ecological importance (Condit *et al.*, 2001; Perez *et al.*, 2005, this volume).

At the end of 1999, the United States turned over operation of the Panama Canal to Panama. The Autoridad del Canal de Panama (ACP) (formerly Panama Canal Commission - PCC) is now responsible for permitting land-use changes in the watershed that affect water resources. Portions of the watershed are undergoing rapid changes in land use. There is concern about the compatibility of urban and economic development with hydrological needs and concomitant requirements for conservation of the watershed (Condit *et al.*, 2001). Human activities such as those in the Eastern Panama Canal Watershed (EPCW) can affect future ecological resources, and thus the carbon storage potential. The analysis presented here is designed to project land-cover change through 2020 under 'business-as-usual' and 'new-road development' scenarios. This analysis provides a projected baseline to identify where opportunities exist for implementing potential projects to generate potential carbon benefits.

The storage of carbon has become a newly-recognized value of forests as concern increases over rising levels of atmospheric concentrations of carbon dioxide (Bloomfield *et al.*, 2000; Gitay *et al.*, 2001). To participate in the potential market for carbon credits based on changes in the use and management of the land, a country needs to identify opportunities and implement land-use based emissions reductions or sequestration projects. A key requirement of land-based carbon projects as articulated in the Kyoto Protocol (Article 12, also known as the 'Clean Development Mechanism') is that any activity developed for generating carbon benefits must be additional to business-as-usual baseline. A projection of the business-as-usual scenario of land-use change along with the resulting changes in carbon stocks on the land can be used to demonstrate this baseline requirement (*e.g.*, Brown *et al.*, 2000).

## **2. BACKGROUND**

### **2.1 The Environment of the EPCW**

The Eastern Panama Canal Watershed (EPCW), the focus of this analysis, contains 339,638 ha of largely forested land. This eastern portion of the basin is the historic watershed, but the legal watershed was defined more expansively in 1999. Forests currently cover 158,000 hectares (54%) of the EPCW. Most of the remaining area is pasture, agriculture, or scrubland. Some of the forest has been lost to establish urban areas. In the rural communities, forest land is being converted into agriculture land using fires

to prepare a site for planting. However, because of the poor soil quality, some of these agricultural areas are reconverted to pasture land. Between the 1980's and 1998, satellite imagery shows that 1.7% to 3% of forests per year changed to pasture, agriculture, or scrubby vegetation, and 0.2% per year changed to urban areas (PCWMP, 1999).

There is great concern about the status of the forests in the watershed. LANDSAT Thematic Mapper images have been used to document that forests decreased by 43% between 1974 and 1991, from 275,549 ha to 157,063 ha. Tarté (1999) reports the rate of deforestation in 1999 as 573 ha/yr. Thus, the rate of annual clearing has declined from the 24-year average of 4,937 ha/yr. In 2002, 34% of the 375,000 ha of the EPCW was under some kind of protection, such as being maintained as a national park. Furthermore, the regional land-use plan provided by Panamanian Law 21 in 1997 mandates expansion of the protected area to 40% of the EPCW. Of the forest remaining in the EPCW in 2002, almost 69% were in protected areas, most of which had been established since 1980, when political decisions were made to preserve parts of the watershed by setting them aside in national parks and other protected areas. Most of the protected forests in national parks are primary, while those adjacent to the Panama Canal are secondary.

Commercial timber plantations began to be established in abundance in the watershed in 1998. As early as 1993, a series of Forestry-Incentive Laws were enacted, leading to cultivation of timber-yielding tree species. Tax deductions are allowed during the first five years of forest investments for plantations. The Interoceanic Region Authority (Autoridad de la Región Interoceánica, ARI) donates land-use rights to the private sector for reforestation of degraded lands to reduce erosion and sedimentation. However, in the absence of requirements to monitor these reforestation projects, management of some plantations will likely be abandoned. Anecdotal evidence suggests that some mature secondary forests were cut and replanted as plantations to receive tax deductions under the Forestry Incentives Law.

Historic sediment data suggests that deforestation in the EPCW is likely a source of excess sediment (PCWMP, 1999). However, the increasing protection and recovery of the forests is related to a gradual but constant decrease in soil erosion and rates of sedimentation in the rivers and lakes. Nevertheless, the quality of water is deteriorating (PCWMP, 1999). This decline is largely associated with the 1947 opening of the Trans-Isthmian Highway between the cities of Panama and Colón (Heckadon-Moreno, 2005, this volume). Much agricultural, industrial, and urban development occurs along the highway.

Vegetation regrowth is increasing on cattle farms. This reversion likely results from conservation and reforestation policies of the National Bank of Panama, as required by Panamanian Law 21. The regional land-use plan provided by Law 21 establishes a goal of reduction of cattle farms in the EPCW from 127,000 to 7,000 hectares by the year 2025. This plan will cause a dramatic transformation of land-use in the EPCW. Already tax incentives seem to have curtailed the expansion of cattle pastures that had occurred since the 1950's. Furthermore, the plan discourages population growth in the EPCW, although current policies of the Ministry of Housing do allow construction in two communities (Chilibre and Las Cumbres) within the EPCW.

## 2.2 Changes in the Human Population

Between 1950 and 1990, the population in the EPCW increased five-fold, from *c.* 22,000 to *c.* 113,000 that undoubtedly contributed to the need for more transportation routes (Tarté, 1999; PCWMP, 1999). By 1998, the estimated population was 142,000 (PCWMP, 1999). In recent decades, the annual population growth rate in the EPCW ranged from a high value of 4.5% for the period 1960 to 1970 to a low of 3.7% for 1970-80 (Prieto *et al.*, 1999). The rate of increase for 1980 to 1990 for the EPCW was 3.8%, compared to a 2.6% population increase for all of Panama (Prieto *et al.*, 1999). Geometric projections from 1990 using a 3.8% rate of growth indicate that population in the EPCW will increase to *c.* 407,000 people in 2020 with 24% of the growth in Colón and 76% of the growth in the province of Panama (Prieto *et al.*, 1999). There is a growing human population within the protected areas. For example, 2,712 people lived within the borders of Chagres National Park in 1990, with continued population pressure from outside the park likely to induce greater population growth within the park (Prieto *et al.*, 1999). The new Law 21 and Law 19 give the ACP the responsibility to regulate anything that might impact the hydrological resources of the watershed; however, no mechanisms exist for population control.

## 3. METHODOLOGY

A rule-based model has been developed to project land-cover dynamics in the EPCW that assumes current land-cover trends will continue into the future. The rules are described in detail in Dale *et al.* (2003) and include enforcement of environmental protection in the parks or other protected areas over the next 20 years. The projections map patterns of deforestation

and reforestation based on current land-cover patterns, distance from permanent roads and population centers, population growth, and past land-use trends. Some factors that can exert pressure on the environment are not part of the current model (*e.g.*, economic and technology changes). The new-road scenario includes the establishment of the new bridge across the Panama Canal and completion of the Trans-Isthmian highway between Panama City and Colón. This analysis focused on projecting the effects that land use may have upon land-cover change and carbon storage in the EPCW.

## 4. RESULTS AND DISCUSSION

### 4.1 Land-Cover Change Projections

The projections result in major land-cover changes within the EPCW over the next 20 years for the urban areas, plantations, and the lands in pasture, agriculture, or scrub. The forest area gradually declines. Most of the land-cover change occurs where the majority of the roads and communities are located (Heckadon-Moreno, 4004, this volume). Most (80%) of the land that becomes urban derives from the pasture/agriculture/scrub category. At the same time, there is a consistent loss of native forest land that ultimately ends up as plantations.

Under the 'new-road' scenario, the greatest land-cover changes occur near the new highway (see Fig. 1B of Chapter 1), but there are relatively few differences in this case as compared to the 'business-as-usual' case. The greatest difference in land-cover changes for the two projections is the increase in urban lands and decline in plantations and pasture/agriculture/scrub for the new-road scenario (Fig. 1).

These projections of land-cover changes can contribute to an understanding of a variety of environmental issues. The model could provide a basis for estimating carbon stocks (Dale *et al.*, 2003) and for analyzing how different management practices of the land influence changes in carbon stocks. The analysis of different management practices requires spatially-explicit information on the distribution of ownership and better understanding of how different types of agricultural owners clear and farm the land, information that is now being collected. The model could also be used to analyze how management of the protected areas would influence land-cover change and carbon stocks. The effectiveness of various conservation measures and approaches could also be evaluated.

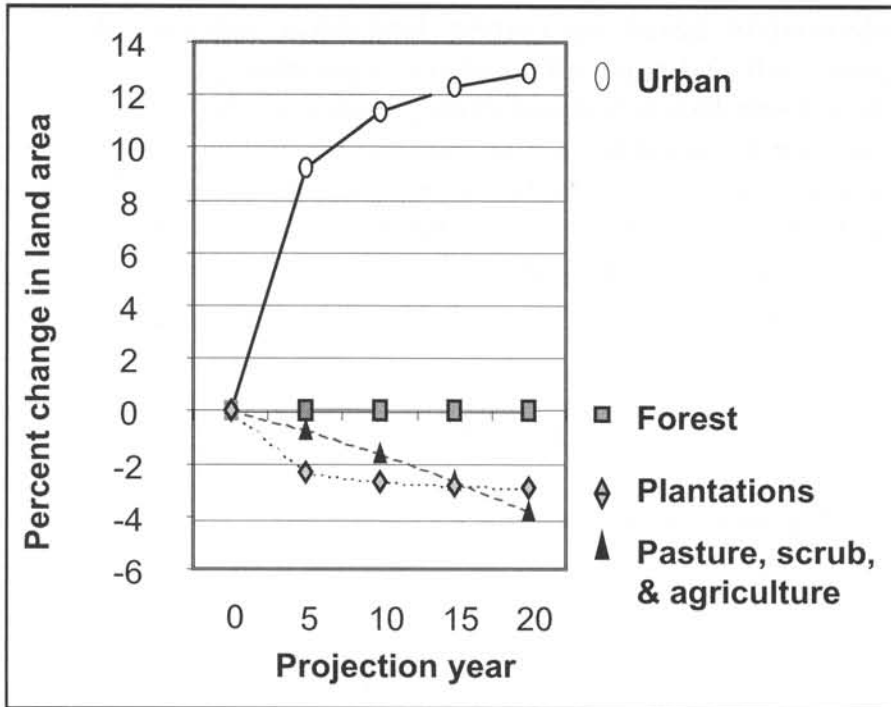


Figure 1. Change in percent land cover for the business-as usual scenario compared to the new-road scenario for the major land cover categories in the EPCW.

## 4.2 Changes in Carbon Stocks

The projected areas of each land-cover type for the two scenarios were combined with the carbon density data as described in Dale *et al.* (2003) to project the change in carbon stocks—decreases in carbon stocks are counted as emissions and increases in carbon stocks as removals (carbon sequestered). For the ‘business-as-usual’ scenario, carbon emissions from deforestation gradually decline over the 20-year period, from about 160,000 tons/yr during the first five years to about 130,000 tons/yr during the last five years (Fig. 2). Carbon emissions from deforestation could be lower if secondary forests were preferentially cleared over mature forests because the secondary forests have lower carbon stocks. Clearly, better identification of secondary forests and their land cover and carbon dynamics would decrease the uncertainty of the carbon emissions presented here.

The expansion and growth of plantations removes about 24,000 tons C/yr initially to 205,000 tons C/yr at the end of the 20-yr period (Fig. 2). The carbon balance for the EPCW represents a net source of carbon to the atmosphere, as the emissions from deforestation and conversion to agriculture/pasture/scrub lands exceed the removals by the growing and

expanding plantations. The business-as-usual scenario results in net carbon emissions of 606,000 tons C over the whole 20-yr period.

The 'new-road' scenario and the various assumptions for carbon densities resulted in higher net emissions of carbon (676,000 tons C over the 20-yr period) than the 'business-as-usual' scenarios. The emissions from deforestation for the new-road scenarios were only slightly higher than those for the business-as-usual scenarios; most of the increase in net emissions was caused by a reduction in the area converted to plantations.

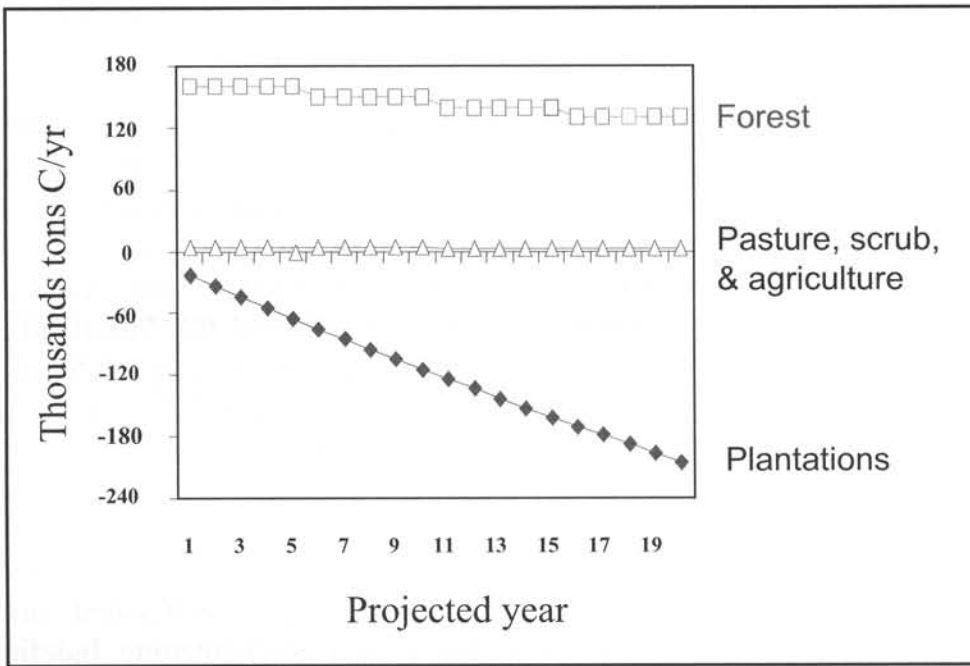


Figure 2. Changes in C emissions over time for three land-cover categories under the 'business-as-usual' scenario for the EPCW.

## 5. CONCLUSIONS

The small changes on forested land result in the largest source of carbon emissions in the EPCW. Thus, the most effective way to reduce carbon emissions is by reducing deforestation. The effect of forest removal is large because about half of the biomass in trees is carbon. Loss of mature forests contributes more to carbon emissions to the atmosphere than does the loss of secondary forest because mature forests typically contain many large trees and more carbon than trees that are smaller in size and that dominate secondary forests (Brown and Lugo, 1992; Brown *et al.*, 1997). However,

under the current framework of the Clean Development Mechanism (CDM), only carbon benefits arising from reforestation are allowed.

Even after 20 years, carbon gained by reforestation in the EPCW is insufficient to offset the carbon emissions from the ongoing small rate of deforestation. The up-to-20 years of growth and carbon accumulation in the plantations scenario is inadequate to offset the high carbon stocks of established forests that were removed. However, planting larger areas to plantations than occurs in the 'business-as-usual' scenario would cause more carbon to be stored.

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