Forest Productivity and Carbon Dynamics: Sequestration Possibilities and Climate Change Impacts[1]

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Craig Wayson[2], Jane Southworth[3], and J.C. Randolph[2]
[2]School of Public and Environmental Affairs, Indiana University, Bloomington
[3]Department of Geography, University of Florida, Gainesville (formerly at Indiana University)

Indiana Forests and Forest Productivity

In Indiana, almost all of the forests are secondary successional: trees re-growing on land cleared in the past. These forests are highly productive, incorporating carbon into their biomass at fairly fast rates, which vary by species, site conditions such as topography, soil nutrient availability, and climate conditions, as well as forest management practices. There is some evidence from a decade-long research project in the Morgan-Monroe State Forest that forest growth rates in these successional forests may be increasing. In addition to the productivity of existing forests, there are increasing forestlands. Over the period 1967-1998, Indiana experienced a ~5% reforestation rate even while a large population increase occurred. Future forest productivity in Indiana will be influenced by a combination of climatic, ecological and economic factors. For example, over the past five years the rates of reforestation have slowed to ~1% new forestland per year, indicating that there are other land uses competing with forestlands.

Carbon cycles through terrestrial ecosystems from (1) uptake by leaves through photosynthesis to (2) growth and storage in plant tissues, then (3) into the detritus pool when the live tissue dies, and finally (4) the carbon returns to the atmosphere through decomposition. The length of time carbon spends in a terrestrial system can be a matter of days to millennia, with the speed at which carbon flows through the cycle being highly dependent on climate, especially temperature and precipitation. Terrestrial vegetation is an important part of the global carbon cycle storing ~600 Gt with about 10% cycled in and out of the pool each year. Forests are by far the largest portion (about 45%) of total terrestrial carbon stored worldwide.

Indiana's Forest Industry

Indiana has 4,654,500 acres (1,883,675 hectares) of forestland of which 85% is privately owned. Of these forests, 96% are comprised of higher valued hardwood species. Forests are important to Indiana with forestry and forest products manufacturing with a direct GDP of $2.2 billion dollars in 2006 and employing ~60,000 persons with a total economic impact of roughly $17 billion (roughly $51 for each board foot of timber processed). Timber harvested in Indiana is generally manufactured into wood products in Indiana; in 2005, for every $1 paid to the landowner for timber, $26.43 of value was added to the final product. Nationwide Indiana ranks first in the production of: wood office furniture, manufactured homes, kitchen cabinets, wooden caskets, and hardwood plywood type products. (See http://www.in.gov/dnr/forestry/files/fo-IHI_economic-impact.pdf for detailed economic information).

[1]This policy brief was written at the request of the Indiana Chapter of The Nature Conservancy and has been reviewed by that organization.

Terrestrial Carbon Sequestration

Carbon stored for long periods of time (decades to centuries) is considered sequestered. Due to reforestation and increased growth rates in terrestrial ecosystems, carbon dioxide (CO_2) is not accruing in the atmosphere at a rate equal to fossil fuel burning, which has been a factor mitigating climate change. There is evidence that, however, without a conscious effort these terrestrial carbon sinks are becoming saturated. Global reforestation rates have been slowing recently and the recent research on forest productivity at high levels of CO_2 shows that after an initial increase, productivity returns to levels at or below historic rates (e.g. Lichter *et al.*, 2008). The causes of this are unclear and much research is being done to identify the causes.

There is a large potential for terrestrial carbon sequestration in Indiana. Three principal methods to augment forest productivity and carbon sequestration rates are:

1) *Promote sound forestry management practices*. The use of best management practices (BMPs) that may include residue management, tree selection and erosion controls that can sequester carbon (Bradford *et al.*, 2009). The Indiana Division of Forestry currently has a detailed manual of BMPs for forest harvesting to which all companies logging on State lands much must conform. These practices protect soil, help return nutrients to the soil and overall, maintain the ecological productivity of the forests. Taken together, these practices ensure long-term productivity but also maintain carbon in the vegetation and soils.

2) *Manage forests for more than timber resources*. Forests are generally currently managed to produce timber at maximum sustainable yields. With changes in harvest regimes (e.g. increasing harvest rotation times) forests could also be managed for carbon sequestration yields. Under a cap-and trade system this carbon could be sold on the market, much like timber. Varying carbon and timber prices would drive management decisions and provide a free-market tool to promote C sequestration. With its 4.5 million acres of forest (about 20% of Indiana's total land area) Indiana has potential to leverage its forestland to sequester carbon. While the system, on whole, has many advantages, it does rely heavily on the assumption that carbon credits will be priced in such a way to encourage C sequestration but not so high as to drastically reduce timber harvesting and the forest products industry consequently. Also, timber is a tangible, easily measureable product; carbon is not so. Carbon markets utilize estimates C sequestration rates to generate the amount of carbon available for sale but this method is time forward, meaning they *project* C sequestration rather than sell a product already in existence. While this concept is not new (i.e., the futures market for many agricultural products), the time frame in which this market operates is not annual, but decadal. Projecting further into the future is inherently more risky.

3) *Promote afforestation*. Afforestation can result from either planting trees or encouraging forest succession in areas where, in some longer time frame, forests did not exist previously. While it does not make economic sense to plant forests on agriculturally productive lands, Indiana is estimated to have 3-5 million acres of marginally productive agricultural lands (~18% of all agricultural lands). These are lands with marginal soils as defined by the USDA National Resource Conservation Service. While these lands may not be most suitable for row crops and high quality pasture, they are capable of sustaining forests. Afforestation has many benefits as it could provide better economic opportunities for the current landowners. Presumably, these lands are being utilized for agriculture over timber due to slightly higher economic benefits. With a cap and trade system, there may be enough value added to this land use by selling carbon credits to surpass this threshold and promote the conversion of these lands to forest. Foresting these lands will decrease erosion, improve water quality and begin to replace

soil nutrients and carbon. Niu and Duiker (2006) discuss further the potential for afforestation in the Midwest.

Indiana's capacity for geological C sequestration far surpasses that of terrestrial sequestration in forests and terrestrial sequestration cannot fully meet Indiana's offset requirements based on any of the main greenhouse gas legislation scenarios. However, terrestrial sequestration is a useful tool with many side-benefits. Geological sequestration requires technological inputs. Also, geological sequestration is only feasible with use from point sources, which account for about half of Indiana's greenhouse gas production.

Climate Change

Most models of climate change based on General Circulation Models (GCMs, e.g., the Hadley Center model: HadCM3) have predicted a long-term increase in temperatures (maximum, minimum and mean) for the Midwest, with the magnitude of the increase depending on global energy scenarios, as presented by the IPCC, but ranging from around 3-10° C for 2050 predictions. Early precipitation predictions however, were less consistent, with some predicting increased rainfall (e.g., HadCM2) and others a general decrease (e.g., CCM1). Recent regional modeling by Purdue University using the widely-accepted HadCM3 and other updated models downscaled to a regional scale suggests that slightly increased precipitation is most likely, especially in the winter and spring seasons. However, with the increase in precipitation, an increase in intense storms is also expected. Rain will tend to run off more, and infiltrate soils less, leading to drier soils, particularly in summer, despite the increase in annual rainfall. The best estimate for our region is then, in effect, "hotter, drier summers" and "warmer, wetter winters," coupled with an increase in extreme storm events and increase in the intensity and frequency of heat waves (Diffenbaugh *et al.* 2005).

Climate Change Effects on Forest Productivity and Carbon Cycling

Given the above scenario, in 2050-2100 carbon cycling in Indiana's forests will not be favored. Warmer and drier summers will limit productivity of most of the forest stands, decreasing carbon sequestration. The water stresses placed in the trees during critical summer months will rates lower rates of photosynthesis, decreasing carbon uptake. Exacerbating this reduced carbon uptake will be greater carbon losses in the system during the warmer, wetter winters. These losses will lower soil carbon stocks.

The overall effects would lead to increased mean harvest times of forests under management, whether these are natural or planted with consequent reductions in timber volumes. There would be less carbon sequestered and, therefore, loss of potential carbon credits/offsets at a time when most current climate change reduction plans are most stringent. Also, the economic impacts would be large with the level of value-added forest product manufacturing in Indiana. It is estimated that for each board foot of timber in lost production would equate to $51 of lost economic benefits to Indiana.

Indiana has advantages in its forestlands, with a large capacity to help meet carbon targets through the use of best management practices when harvesting, managing forests for carbon sequestration and promoting afforestation on marginal lands. In doing so, other benefits external environmental and economic benefits are realized.

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