COMET-VR: AN ONLINE TOOL FOR ESTIMATING CARBON STORAGE IN AGROFORESTRY PRACTICES

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ABSTRACT

The CarbOn Management Evaluation Tool for Voluntary Reporting (COMET-VR) is an online tool developed by the USDA Natural Resources Conservation Service and Colorado State University to estimate carbon sequestration in farm and rangeland soils under user-specified management scenarios. Development is underway to expand the capabilities of COMET-VR so users will be able to estimate changes over time in carbon storage (CS) in above- and below-ground components of agroforestry practices. Individual tree biomass is calculated using diameter-based allometric equations generalized for species groups. The Century soil carbon model, linked to COMET-VR, is used to estimate CS flux in soil. Estimates of biomass growth and therefore reportable CS flux over the next 10 years are based on inventory data from both windbreak and forest plots in different regions of the conterminous US. The tool output will be an estimate of the annual change in CS suitable for use in voluntary greenhouse gas reporting. It will also allow users to compare potential CS in agroforestry and other agricultural practices.

Key Words: carbon sequestration, biomass, allometric equations, soil carbon, greenhouse gas reporting

INTRODUCTION

Agroforestry practices contribute to the storage of carbon in temperate-zone agricultural landscapes while maintaining food and forage production (Brandle et al. 1992, Montagnini and Nair 2004, Oelbermann et al. 2004). Planting and maintaining woody plants on farm and rangelands dominated by annual vegetation can significantly increase carbon storage (CS) in both soils and vegetation.

Practical methods have recently been developed to estimate CS on cropland, pasture and forests. Examples of carbon accounting methods for forest stands include the use of look-up tables generalized by forest type and region (Smith et al. 2006), computerized models of tree biomass growth that reflect stand conditions and silvicultural practices (e.g., the carbon submodel of Forest Vegetation Simulator, http://www.fs.fed.us/fmsc/fvs/index.shtml), and periodic direct measurement of the structural components of forests in which carbon is stored (Brown et al. 2004).

For crop and rangelands in the conterminous US, the online CarbOn Management Evaluation Tool for Voluntary Reporting (COMET-VR) enables landowners to rapidly estimate potential CS in agricultural soils under various land management practices. It uses the Century Soil Organic Matter model, a generalized biogeochemical ecosystem model that simulates changes in soil carbon, nitrogen and other elements (Parton et al. 1993). COMET-VR is designed to comply with the requirements for voluntary reporting of carbon emissions under the US Dept. of Energy's 1605(b) program (US Dept. of Energy 2006b). It is publicly available at www.cometvr.colostate.edu.

Since agroforestry by definition includes elements of both agricultural and forest landscapes, an appropriate carbon accounting system will include methods from both land uses. This paper describes the development of methods for estimating changes in CS in agroforestry practices that will be incorporated into COMET-VR.

METHODOLOGY

The agroforestry extension of COMET-VR will enable users to estimate CS in the most common temperate-zone practices. These include both row-type practices, i.e., Alley Cropping and Windbreaks, and forest-like practices, i.e., Silvopasture, Riparian Forest Buffers, Multi-Story Cropping (also known as Forest Farming) and Farm Woodlots. In keeping with the design criteria for COMET-VR, the agroforestry extension is designed for relative ease of use, national-scale (conterminous US) applicability, and reasonable estimation across a wide range of site factors.

CS occurs within various pools in agroforestry systems depending on their structure and management, including live trees, standing and down dead trees, understory shrubs, annual crops, leaf litter, and soil. However, most of the change in CS occurs as result of growth, and thus biomass accumulation, of live trees. Other pools such as down deadwood, understory and litter change relatively slowly (Smith et al. 2006). Technical guidelines for reporting of greenhouse gases from agroforestry projects recommend measuring and monitoring of carbon in the live tree (above and below-ground) and soil pools (US DOE 2006a).

Tree Biomass Baseline Estimation

Before users can begin the COMET-VR tool, they must first perform an inventory of the standing live trees within the parcel(s) of land for which they wish to estimate CS. Users must divide their land into more or less uniform, contiguous parcels for the purposes of sampling and CS estimation. Basic inventory information required are the tree species present, average diameter at breast height (DBH) of the sampled trees, and the estimated number of trees of that species on the parcel. For landowners who do not already have inventory data available, two different sampling methods will be described in the online help files at the COMET-VR website. They are strip sampling within row segments, for linear plantings such as windbreaks and alley cropping, and fixed area plots for forest-like agroforestry types (NRCS 2004). Landowners in some states growing certain commercial species, e.g. Douglas-fir in the Northwest or loblolly pine in the Southeast, have the option to specify the site productivity of their parcel, if known.

Once the COMET-VR tool is accessed online, the user will first be asked to enter some general information about the parcel they're reporting, including state, county, and parcel size. From user inputs of state and county, the parcel's location at two regional scales will be identified: Major Land Resource Area (MLRA) and the larger-scale Land Resource Region (LRR) (NRCS 2006a).

Users will then be asked a series of questions leading to a description of conditions and a history of land management on the parcel:

1. The predominant soil texture of the parcel, and whether or not the soil is hydric.
2. The land management applied during four time periods (pre-1970's, 1970 to mid-1990's, mid-1990's to current year, and next 10 years) from choices of irrigated and dryland crop rotations that are common in the MLRA of the parcel being assessed, plus generic agroforestry practices.
3. For the time periods from 1970 and later, the intensity of tillage utilized, e.g. intensive, reduced or no-till.

All these inputs are then transmitted by COMET-VR to the Century model which estimates the annual change in soil carbon over the next 10 years. The soil flux value is added to estimated CS flux in live trees in the final step (see below).

The next step will be to calculate the biomass of live trees on the parcel at the present (baseline) year. The user is asked to supply the information collected from their inventory sample. Based on this input, COMET-VR then calculates individual tree biomass using a series of diameter-based allometric equations developed by the US Forest Service (Jenkins et al 2003). They predict total above- and below-ground dry weight biomass of individual trees from DBH for all US tree species divided into ten different groups by genera, and are designed to be used at the national scale over all sites, slopes, aspects, elevations, etc.

Tree Growth and Carbon Flux

Once the baseline biomass is estimated for an average tree of each species present, the next step will be to predict how much that tree will likely grow over the next 10 years in the geographic region where the parcel is located. Inventory data collected from sample plots both in forest stands (US Forest Service, Forest Inventory and Analysis, http://fia.fs.fed.us) and windbreaks (NRCS Ecological Site Inventory, http://esis.sc.egov.usda.gov/Welcome/ pgFSWelcome.aspx) in all 48 conterminous states were accessed online. Unpublished data including diameter re-measurements of individual trees were also obtained directly from USFS FIA.

From the state FIA files, data were selected for trees for which DBH was remeasured at two points in time. For each species with sufficient observations, coefficients were calculated for nonlinear regressions of the average relative diameter increment versus initial diameter, using the method described in Lessard (2001). For selected commercial species in some states, coefficients were also derived by site productivity class. For the state ESI data files, coefficients were calculated for nonlinear regressions of age versus DBH for each species under both irrigated and non-irrigated conditions, using the Chapman-Richards growth model (Richards 1959). Where observations for species were insufficient at the state level, data were combined by LRR and those regional values were used instead. Equation coefficients developed from FIA data were used to predict the growth of tree species in forest-like agroforestry practices while those derived from ESI data were used for row-type plantings.

Average diameter growth calculated from FIA data, and the correlations of age versus diameter from ESI data, were used to predict future diameter at 10 years beyond present by species and location. Using the predicted DBH at 10 years, individual tree biomass was again calculated using the equations from Jenkins (2003). The difference between baseline and future individual tree biomass is the predicted growth increment for a particular species and location.

The final calculation step is to expand the estimated 10-year biomass growth of an individual tree by the number of trees in that species over the whole parcel. Predicted growth values for all species present are summed to give a total biomass flux for the parcel. This value is converted to carbon assuming a factor of 50% of dry-weight biomass. The annual soil carbon flux predicted by Century is then added to the total. The final result reported to the user is the annual change in carbon mass (and CO_2 equivalent) for the parcel. An uncertainty value will also be reported for soil CS estimated by Century. However, due to the scarcity of long-term, well-documented agroforestry experiments, uncertainty values will not be estimated for carbon flux in live tree biomass.

DISCUSSION

COMET-VR is a first attempt to develop a carbon accounting system for agroforestry practices in the US based on detailed user inputs. The intended audience includes private landowners, farmers, ranchers, non-industrial private forest owners, NRCS field staff, and technical service providers. Public release of agroforestry extension of COMET-VR is expected in 2008. It will be available at same URL (see above).

Because it is based on allometric equations and growth projections derived from regional datasets, the estimates produced by COMET-VR are generalized for a site-specific location.

More accurate accounting of biomass growth, and thus carbon flux, would require more site-based information, e.g. site index or localized growth curve formulae. This would be possible only for those species and locations where large inventory plot datasets are available.

The allometric equations from Jenkins (2003) were originally derived from data collected in forest stands where stocking levels were likely higher than would be found in agroforestry practices. Therefore, it is possible that the use of forest-derived biomass equations may underestimate biomass in more open-grown agroforests. Recent studies involving destructive sampling of trees growing in windbreaks in the Great Plains suggest that forest-derived equations may underestimate biomass of individual trees by at least 22% (Zhou, X., Brandle, J.R., Schoeneberger, M.M., Awada, T. and Mize, C.W. unpublished data). Since similar studies have not been performed in other locations, it is not possible at present to correct the values calculated using the forest-derived biomass equations. Comparison of results using allometric equations with data from destructive biomass sampling of trees growing in agroforestry practices, e.g. Zhou et al. (2007), will help improve the accuracy of COMET-VR.

We expect the agroforestry extension of COMET-VR to be used for a variety of purposes. It will be used under the DOE 1605(b) program for voluntary reporting. Some landowners received support for testing COMET-VR under the Conservation Security Program during the past year (NRCS 2006b). It is possible that other conservation provisions of the forthcoming Farm Bill in the US will encourage farmers to monitor carbon fluxes in conservation practices such as agroforestry with COMET-VR.

If it is accredited for such use, COMET-VR could also be used to monitor and report CS in agroforestry practices which are established as carbon offset projects under contracts with state programs (e.g., Regional Greenhouse Gas Initiative, http://www.rggi.org) or private companies (e.g., Chicago Climate Exchange [CCX], http://www.chicagoclimatex.com). For example, some private organizations, acting as aggregators of forestry carbon offset projects for CCX, are currently offering contracts for new riparian buffers and other widely-spaced (<625 stems ha) tree plantings (e.g. Iowa Farm Bureau, http://www.iowafarmbureau.com/carbon). The availability of an accredited, user-friendly tool for CS estimation will help landowners wishing to enroll their agroforestry plantings as small-scale carbon offset projects.

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