University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

USDA Forest Service / UNL Faculty Publications

U.S. Department of Agriculture: Forest Service -- National Agroforestry Center

June 2005

# Agroforestry-Working Trees for Sequestering Carbon on Ag-Lands

Michele M. Schoeneberger
*University of Nebraska - Lincoln*, mschoeneberger1@unl.edu

Follow this and additional works at: http://digitalcommons.unl.edu/usdafsfacpub

Part of the Forest Sciences Commons

Schoeneberger, Michele M., "Agroforestry-Working Trees for Sequestering Carbon on Ag-Lands" (2005). *USDA Forest Service / UNL Faculty Publications*. 11.
http://digitalcommons.unl.edu/usdafsfacpub/11

This Article is brought to you for free and open access by the U.S. Department of Agriculture: Forest Service -- National Agroforestry Center at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in USDA Forest Service / UNL Faculty Publications by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Schoeneberger, M.M. 2005. Agroforestry - Working Trees for Sequestering Carbon on Ag-Lands In: Brooks, K.N. and Ffolliot, P.F. (eds) Moving Agroforestry into the Mainstream. Proc. 9th N. Am. Agroforest. Conf., Rochester, MN. 12-15 June 2005 [CD-ROM]. Dept. Forest Resources, Univ. Minnesota, St. Paul, MN, 13 p.

# AGROFORESTRY–WORKING TREES FOR SEQUESTERING CARBON ON AG-LANDS

Michele M. Schoeneberger, USDA Forest Service, National Agroforestry Center
East Campus-UNL, Lincoln, NE

## ABSTRACT

Agroforestry is an appealing option for sequestering carbon on agricultural lands because it can sequester significant amounts of carbon while leaving the bulk of the land in agricultural production. Simultaneously, it can help landowners and society address many other issues, such as economic diversification, biodiversity, and water quality, facing these lands. Nonetheless, agroforestry remains underrecognized as a greenhouse gas mitigation option for agriculture in the US. Reasons for this include the limited information base and tools agroforestry can currently offer compared to the decade's worth of investment in agriculture and forestry, and to agroforestry's cross-cutting nature that puts it at the interface of agriculture and forestry; not strongly owned or promoted by either discipline. Agroforestry research is beginning to establish the scientific foundation required for building carbon accounting and modeling tools but more progress is needed before it is readily accepted within agricultural greenhouse gas mitigation programs and, further, incorporated into the broader scope of sustainable agricultural management. Agroforestry needs to become part of the agricultural toolbox and not viewed as something separate from it. Government policies and programs driving research direction (and investment) are being formulated with or without data in order to meet pressing needs. Enhanced communication of agroforestry's carbon cobenefit, as well as the other benefits afforded by these plantings, will help elevate agroforestry awareness within these discussions. This will be especially crucial in this interim period as deliberations on such broad sweeping natural resource programs as the 2007 Farm Bill begin.

**Keywords:** aboveground woody biomass, biomass equations, carbon credits, carbon sequestration, greenhouse gas mitigation

## INTRODUCTION

Despite US's decision to not ratify the Kyoto Protocol, society is continuing to look for viable strategies to reduce atmospheric $CO_2$, even if only as a temporary means to bank carbon until more socially and economically acceptable alternatives can be developed (Williams et al. 2005). In support of this, the Department of Energy (DOE) recently released the Interim General and Technical Guidelines for the 1605(b) Voluntary Greenhouse Gas Reporting Program (US DOE 2005). In these revised guidelines, Sections H (Agriculture) and I (Forestry) list activities, accounting rules and guidelines for the reporting of carbon, along with other GHGs, sinks and sources that can potentially be modified by shifts in our natural resource management activities. There are also indications within the US of a willingness to pay for this sequestered or "bankable" carbon. For instance, the 2002 agreement negotiated between the Pacific Northwest Direct Seed Association (PNDSA) and Entergy is for 30,000 tons of $CO_2$ offset credits to be generated via direct seeding by PNDSA members/growers over the next 10 years (KCARE 2003). It is still not clear what role carbon sequestration will ultimately play in US's climate change strategy and markets. However, the above-listed actions suggest those natural resource practices that can provide "bankable" carbon within these governmental and private frameworks will be the ones that receive additional attention as programs are formulated.

Agroforestry are *working* tree practices that are intentionally planted and managed in rural and urban landscapes. Additional details on these practices are available in papers throughout these proceedings or can be found at the USDA National Agroforestry Center website (http://www.unl.edu/nac/). These plantings represent a category of conservation/production activities that can sequester large amounts of carbon while providing a multitude of additional benefits to the landowner and society (Brandle et al. 1992; Schroeder 1994; Ruark et al. 2003; Montagnini and Nair 2004). The amount of carbon sequestered per unit area by agroforestry, as with most new tree plantings (putting trees where they have not been before, at least recently), is substantial due to the large amount of carbon sequestered in the woody biomass. However, unlike afforestation (individually large new tree plantings), agroforestry plantings do not result in a change in land use to forest. Indeed, the appeal of agroforestry as a carbon sequestering activity on agricultural lands rests in large part on its ability to sequester significant amounts of carbon on a relatively small land base (~5%) while leaving the bulk of the land in agricultural production (Ruark et al. 2003; USDA NAC 2000).

## AGROFORESTRY–A CARBON SEQUESTERING OPTION FOR AG-LANDS

### Attractiveness of Agroforestry as a Carbon Sequestering Activity

Of the six broad categories of agroforestry practices (i.e., riparian forest buffers, windbreaks, alley cropping, silvopasture, forest farming, and special applications), several practices hold especially strong promise as carbon-sequestering activities for reporting, such as windbreaks and riparian forest buffers. These practices are established predominantly for the noncarbon ecological services they provide. In the case of windbreaks, it is for the alteration of microclimate by the planting and, in riparian forest buffers, it is for the filtering, trapping, and bioprocessing of agricultural runoff. These practices are established for the long-term investment in the benefits they provide while in place. And, once established, they are not easily or economically converted back to other practices, creating a high degree of **permanence**.

As mentioned earlier, agroforestry can give the landowner the biggest net gain of **carbon per unit land area**, generally without compromising agricultural activity. This is particularly true for windbreaks used in crop, livestock and farmstead protection. Although the carbon fixed within a single agroforestry planting is small, taken within a whole-farm context the amount can become significant (Table 1). Given the tremendous land base in agricultural production within the US that could benefit from the non-carbon services afforded by agroforestry plantings, the potential carbon that could be sequestered by agroforestry at these larger scales become noteworthy (see for example, Table 2 and USDA NAC 2000).

**Table 1.** Comparison of $CO_2$ sequestered under two management options (all no-till and no-till with windbreaks) on a hypothetical farm[a] in Saunders County, Nebraska. Values for no-till represent $CO_2$ sequestered in soil and were calculated using COMeT for first 20 years, with subsequent 10-year period rates being 50% of prior year's rate for total C (Brenner, J., pers. comm.). Values for cropland with windbreaks represent $CO_2$ sequestered in above and belowground woody biomass produced by trees and were calculated using shelterbelt-derived biomass equations (Zhou 1999) and root equations presented in Cairns et al. (1997). (adapted from Schoeneberger, M., J. Brandle, X. Zhou, and R. Straight, unpublished data).

| PRACTICE | Years | Ha | % TOTAL | MT C/ha/yr | MT $CO_2$/ha/yr | MT $CO_2$ | TOTAL MT $CO_2$ |
|---|---|---|---|---|---|---|---|
| **OPTION A: No-till** | | | | | | | |
| Cropland in no-till[b] | 1-10 | 254 | 100 | 0.32 | 1.17 | 2,972 | 2,972 |
| | 11-20 | 254 | 100 | 0.35 | 1.28 | 3,251 | 6,223 |
| | 21-30 | 254 | 100 | 0.18 | 0.66 | 1,676 | 7,899 |
| | 31-40 | 254 | 100 | 0.09 | 0.33 | 838 | 8,737 |
| | 41-50 | 254 | 100 | 0.05 | 0.18 | 466 | 9,203 |
| | | | | | | **Option A Total** | **9,203** |
| **OPTION B: No-till and Crop Windbreaks** | | | | | | | |
| Cropland in no-till[b] | 1-10 | 243 | 96 | 0.32 | 1.17 | 2,843 | 2,843 |
| | 11-20 | 241 | 95 | 0.35 | 1.28 | 3,085 | 5,928 |
| | 21-30 | 238 | 94 | 0.18 | 0.66 | 1,571 | 7,499 |
| | 31-40 | 238 | 94 | 0.09 | 0.33 | 785 | 8,284 |
| | 41-50 | 238 | 94 | 0.05 | 0.18 | 428 | 8,712 |
| | | | | | | | |
| Cropland in windbreaks | 1-10 | 11 | 4 | 0.64 | 2.36 | 260 | 260 |
| | 11-20 | 13 | 5 | 2.44 | 8.99 | 1,169 | 1,429 |
| | 21-30 | 16 | 6 | 4.69 | 17.23 | 2,757 | 4,186 |
| | 31-40 | 16 | 6 | 2.54 | 9.34 | 1,495 | 5,681 |
| | 41-50 | 16 | 6 | 2.95 | 10.84 | 1,735 | 7,416 |
| | | | | | | **Option B Total** | **16,128** |

[a]Hypothetical farm is 256 ha total: 2 ha farmstead, roads, ditches etc and 254 ha available for farming.
[b]Conventional corn/soybean rotation converted to no-till operations.

Integrating trees into working agricultural landscapes provides an **ease of measurement and monitoring** of agroforestry activities not found in other practices, which sequester less visible forms of carbon, like no-till. The aboveground woody biomass of agroforestry trees, comprising the majority of carbon sequestered in this system, is readily observed which greatly facilitates measurement, monitoring and verification. Since it represents an afforestation-like activity on agricultural lands, the baseline can be assumed to be zero. Allometric equations (that relate the tree's height and diameter to its biomass) allow nondestructive estimates to be made of the above and belowground woody stocks. Aerial photography, regardless of season, could be used to verify the continued presence of the practice. Consideration of the other carbon pools is discussed in the next section.

By being compatible with agriculture and not converting agricultural lands to forests, use of agroforestry should not create **leakage--**carbon changes on nonproject lands (e.g., conversion of forest land elsewhere to make up for the loss of agricultural land put into agroforestry plantings). In terms of **additionality**, agroforestry assumes that agricultural land use will remain the landowner's primary intent and that agroforestry establishment will therefore sequester carbon over and beyond what would occur under the continuation of prior agricultural activities.

The "benefit" of agroforestry's **multiple cobenefits,** along with carbon sequestration, fits in well with the need to design ecologically sound GHG mitigation programs. For instance, a danger exists that if carbon credits become tradable, biodiversity could potentially be adversely impacted through massive establishments of practices that can fix massive amounts of carbon but contribute little to landscape diversity. In response to a request from the United Nations Conventions on Biological Diversity, the IPCC Technical Paper–V examined this issue regarding climate change, mitigation strategies and biodiversity (Gitay et al. 2002). This report identified agroforestry as an activity that "can sequester carbon and have beneficial effects on biodiversity because it creates more biological diverse systems than conventional agricultural lands." This ability to address both landowner and society objectives beyond carbon should translate to increased interest in planting and maintaining agroforestry plantings that were also designed to optimize carbon sequestration; adding further to its permanence.

## Accounting for Agroforestry Carbon Pools

For GHG mitigation efforts, it is the flux or difference in a carbon pool as affected by a shift in management practices that must be accounted for. For voluntary reporting programs, only those pools that can be easily, reliably and economically measured should be reported on. Not all agroforestry practices can be easily, reliably or economically measured or even estimated for carbon sequestered at this time. Looking at Figure 1, we can see that even in "simple" agroforestry practices, like windbreaks, the carbon sinks and sources are complex.

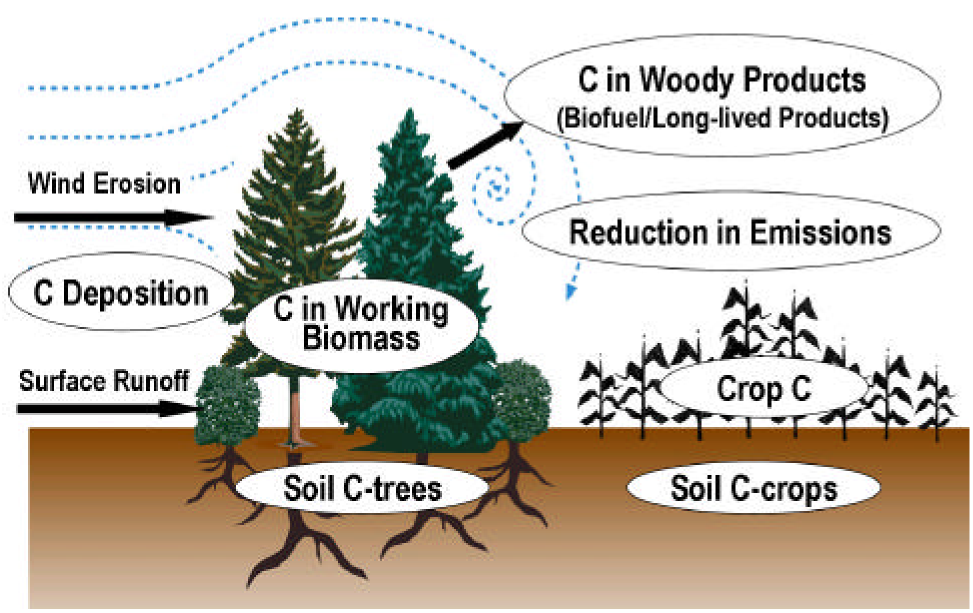


**Figure 1.** Major carbon sinks and sources in a field windbreak.

In Section I (Forestry) of the 1605(b) Technical Guides, where agroforestry is currently housed, the aggregated pools that are to be considered include:

- Live trees
- Understory vegetation
- Standing dead trees
- Down dead wood
- Forest floor
- Soil carbon
- Harvested wood mass in use and landfills
- Harvested wood mass burned for energy
- Harvested wood mass that results in emissions that is not used for energy.

An array of default tables developed for estimating these pools in forest stands throughout the US are contained in the Part I Appendix in the report (US DOE 2005) for ease in reporting. However, these default tables cannot be used for estimating carbon sequestration in agroforestry plantings. The "intensive, intentional, integrated and interactive" nature of agroforestry plantings (Gold et al. 2000) results in species combinations, use of plant materials, stocking levels, management, and, therefore, carbon flows that are quite different than in the forest stands used default value formulation.

Growth and carbon allocation patterns in agroforestry trees reflect the more "open-grown" or "edge forest" conditions created by agroforestry arrangements. The majority of woody biomass equations available for developing carbon estimates were derived from forest stands and, not unexpectedly, found to underestimate woody biomass in agroforestry plantings (Zhou 1999). Since agroforestry cannot be estimated using these default tables, the degree of difficulty to report increases. In order to be appealing, voluntary reporting and even carbon credit accounting for markets will need to focus only on those pools within agroforestry practices which can then be easily, reliably, and economically measured and estimated. The final number reported will be conservative (underestimated) but at least is one that reliably represents the majority of carbon sequestered in these systems and provides some recognition these plantings make in regards to carbon sequestration. A brief discussion regarding the estimation of these pools in agroforestry plantings are as follows:

- **Aboveground woody biomass:** This component represents the most easily and reliably reported pool in agroforestry plantings and captures the majority of carbon sequestered by this system.
- **Belowground woody biomass:** This highly variable and sampling intensive/expensive pool is best estimated using available equations, such as reported by Cairns et al. (1997).
- **Understory vegetation:** This pool is assumed to be too small, too variable, and too labor intensive for inclusion in estimates at this time.
- **Litter/Forest Floor/Dead Wood:** Since most agroforestry practices involve the planting of new trees, carbon flux is this group of pools will be relatively low until trees become mature.
- **Soil Carbon:** Most discussions regarding agricultural carbon sequestration center on the soil pool, more specifically as it is affected by different levels of conservation tillage operations (for example, see Section H in the 1605[b] Technical Guides [US DOE 2005]). This pool and the potential levels of storage are substantial. Nonetheless, the utility of trying to estimate

this pool in agroforestry systems is questionable. Looking at data from afforestation studies, such as Paul et al. (2002), we can assume that carbon sequestered in soils under agroforestry from biomass turnover will be greater than under conventional agricultural operations. However, getting a handle on what that number is will be difficult. Soil carbon in agroforestry systems is from sequestered sources (e.g., biomass turnover) and external sources deposited within the plantings (e.g., wind or surface runoff [see Figure 1]). The nature of both sources creates high spatial variability (see Sharrow and Ismail 2004) that is not easily, reliably or economically captured. So while we know carbon is sequestered in this system, measurement of this pool is best suited for purposes research rather than reporting (see presentation by Sauer in these proceedings; Sharrow and Ismail 2004; Thevathasan and Gordon 2005) and not for voluntary reporting programs. Interestingly, in regards to this pool and agroforestry, Sampson (1995) pointed out that the best investments in new carbon storage will be tree planting in northern temperate soils that have been cropped and therefore have a higher capacity for sequestering new carbon.

Although not be covered in this paper, the additional GHG mitigation impacts afforded by agroforestry plantings beyond just sequestering carbon need to be acknowledged. The indirect benefits derived from crop and farmstead windbreaks increased crop production, reduced wind erosion, and increased efficiency in agricultural production leading to reductions in use of fuel (which then leads directly to reduction in emissions from the combustion process), fertilizer and pesticide (Brandle et al. 1992).

## AGROFORESTRY–THE UNACCOUNTED AGRICULTURAL OPTION IN GHG MITIGATION PROGRAMS

If agroforestry is such an attractive carbon sequestering option for agricultural lands, why does it remain underrecognized in carbon sequestration efforts? Part of the answer rests on the very reason agroforestry works—benefits are derived from having an *ecological* foot in both agriculture and forestry (Olson et al. 2000). But having an ecological foot in both worlds has not translated into necessarily having a strong *political* foothold in either one.

On one hand, agroforestry is thought of as “afforestation” as it adds new trees where trees have not been before or recently (putting it in the forestry camp) but by definition, the *size* of agroforestry plantings does not qualify it as “forest land” (putting it in the agricultural camp). Perry et al. (2005) noted that agroforestry and other *working tree* practices were not explicitly accounted for “by either of the of the two primary national natural resource inventory programs;” the Forest Inventory Analysis (FIA) program of the USDA Forest Service and the Natural Resources Inventory of the USDA Natural Resources Conservation Service (NRCS). By default, these plantings do not then get included in other reporting efforts that provide input into policy and program discussion. In this instance, one of the more important ones is the joint agriculture and forestry GHG inventory.

In many GHG reports, agroforestry practices are absent in the lists and tables of potential mitigation activities. For instance, the report on potential management practices to reduce carbon dioxide emissions from New Zealand agriculture did not include agroforestry within the mitigation options it listed (Clark et al. 2001). Further it discounted the utility of grazing as a GHG mitigation strategy. The report noted that since "managing grazing land to increase carbon storage requires a larger portion of the carbon fixed in photosynthesis to be returned to the soil, that this was not an economically viable carbon sequestering option since it means reduced product output relative to inputs." Unfortunately, statements in executive summaries like this are the take-home message used in formulation of policies and programs. Silvopasture would have provided a management alternative suitable GHG mitigation (Sharrow and Ismail 2004) and which could be quite profitable for the landowner, carbon aside. The November 2000 World Resource Institute Climate Notes tackled the issue of Kyoto protocol intent and impact on economic well being of farmers (Faeth and Greenhalgh 2000). Although agroforestry would have fit well with the four elements they laid out for a climate strategy for US agriculture, the practice that a reader would leave with was no-till. The pervasiveness of no-till/absence of agroforestry in agriculture assessments may be (1) a reflection having had experts in that were more from the traditional center of the discipline and (2) then fallout from these original reports that have elevated these more traditional based activities so that they are now the only alternatives being carried along in the later phases of development and delivery. Surprisingly in the IPCC Technical Paper 1–Technologies, policies and measures for mitigating climate change, agroforestry was included as a mitigation activity in both the forestry and agricultural sections; a result of having used information generated by a group of scientists that included one knowledgeable of agroforestry (Watson et al. 1996). What this indicates is that if agroforestry is brought to the discussion table its potential seems to be acknowledged and the activity is included in the process. A more active approach to elevating the awareness of agroforestry may be more appropriate than assuming this is simply accomplished by publishing our science.

Another factor contributing to the absence of agroforestry in GHG efforts may be the limited amount of data and therefore scientific understanding and tools agroforestry has at this time compared to the wealth of information produced from decades of investment and efforts that agronomy and forestry can draw. While practiced for many centuries, agroforestry is still a relatively new science. The impact of scientific foundation in terms of models, default tables, and tools and what activities are more readily accepted is evident in the 1605(b) Technical Guide (US DOE 2005). However, this should not exclude promising but lesser-known technologies from still being considered in the formulation of agricultural programs to address GHGs.

## Agroforestry: An Agricultural or a Forestry Carbon Sequestration Activity?

Natural resource activities for GHG mitigation tend to be categorized by the land use they are applied. In the case of agroforestry, where it is applied versus the "home" science base creates confusion in regards to ownership and endorsement. Agroforestry is a tree-based activity (that requires forestry knowledge) but which is used on agricultural lands (therefore also requiring knowledge of agronomy). The implications of this in regards to perception or "awareness" by potential users may be (1) agroforestry, by definition of size, will never be a big activity within the forest land use mitigation strategies so therefore will not be promoted within their strategic efforts, (2) that those working within agriculture land use will not be looking to Forestry Land Use activities to glean their "agricultural" opportunities, and (3) that agroforestry practices that fully integrate the tree/crop component throughout the whole farm, such as silvopasture and alleycropping, may not be picked up by either group, despite their excellent carbon sequestering/production capabilities.

The organization of headings in Section 7.2 in the IPCC Technical paper–V (Section 7.2.1. Potential Impacts of Agroforestry; Section 7.2.2. Potential Impacts of Forest Management; Section 7.2.3. Potential Impacts of Agricultural Sector Mitigation Activities; and Section 7.2.4. Potential Impacts of Grassland and Grazing land Management) (Gitay et al. 2002), further adds to this confusion in that one could get the perception that agroforestry is a land management option separate from forestry and agriculture (and grazing) rather than a suite of practices of which at least one has application in each of these (e.g., forest→ forest farming; agriculture→ windbreaks; and grazing → silvopasture).

Chapter 1, Part H of the Technical Guidelines of the 1605(b) Voluntary GHG Reporting document provides "guidance on identifying and quantifying emissions and sequestration from agricultural sources and sinks." Agroforestry is acknowledged in this agricultural section, albeit too briefly for someone to really get a grasp on the many practices and opportunities for their application in agricultural lands. Entities engaged in agroforestry activities are referred to Section I (Forestry). The dominant carbon activity promoted in Section H for agriculture is soil tillage and cropping operations as it impacts soil carbon. Considering the massive land base on which agricultural operations can impact the soil carbon status, it make sense that "entities that engage in cropping practices or grazing land management can estimate and report the carbon dioxide emissions and sequestration associated with those activities." This and other GHG reports will serve not only as a guideline for reporting activities that an entity is already engaged, but will also be influential in influencing what future practices are then adopted, it becomes very important to clarify agroforestry's role is within the agricultural guidelines.

## Agroforestry as Part of a Whole-farm GHG Accounting System

By not being housed within the land-use sector that a practice, like agroforestry, is applied significantly reduces the likelihood of incorporation in more whole-farm policy and program discussions, like carbon credits and cost-share programs. Tools that estimate carbon sequestered on the farm from several activities not only provide a more whole-farm accounting but are also instrumental in evaluating different types and combinations of activities within a whole-farm operation. Enabling side-by-side comparisons to be made between available types and combinations of activities, these tools can be extremely influential in terms of endorsement, promotion and adoption of these different practices. A good example is the CarbOn management Evaluation Tool for Voluntary Reporting (COMET VR) recently released by the USDA NRCS (USDA NRCS 2005) and included in Section H of the 1605(b) technical guides (US DOE 2005). This tool provides an estimate of carbon flux in mineral soils on cultivated lands. The tool also provides data (e.g., N-fertilizer use and fuel consumption) that can be used in reporting for other GHG sources. By changing management operation inputs, entities can easily compare different scenarios. Unfortunately, this tool currently does not include agroforestry among its management options.

As an exercise to see what numbers a farmer might be looking at if he/she were to put in some agroforestry practices, carbon sequestration estimates were made over a 50-year period for a hypothetical farm in Saunders County, Nebraska, under two different combinations of GHG mitigations activities (see Table 1). COMET was used to estimate carbon sequestered in soil for the farmland under no-till operations. Shelterbelt-derived biomass equations were used to estimate the carbon sequestered in the above and belowground woody biomass produced in the windbreaks. The windbreaks were designed for purposes other than carbon (i.e., to provide enhanced crop protection and production, soil protection, and potentially other recreational and income opportunities through enhanced wildlife habitat) and comprised on an average 5% of the farmland during the 50-year period. Since there are many other carbon accumulating activities in windbreak systems not accounted for here (Figure 1), the numbers presented for the windbreaks are conservative (underestimate), and as discussed earlier represent the majority of the captured carbon and are also the most easily, reliably and economically measured and monitored. Comparing the values obtained under two farming scenarios shows that Option B (no-till + windbreaks) not only might net the farmer more carbon (~75% more in this hypothetical exercise) but also create a more beneficial farming strategy for the landowner and society. Efforts are being initiated to investigate how simple agroforestry activities might be easily incorporated into COMET VR as a means for comparing potentials of management scenarios in the near term, with a longer term effort directed at being able to incorporate some of the other promising but structurally complex agroforestry practices (e.g., alley cropping) (J. Brenner, USDA NRCS, pers. comm.).

Not having the ability to include agroforestry in these types of comparative exercises, from farm- to national-scale, will contribute heavily to continued underrecognition, underutilization, and underfunding of agroforestry. The Carbon Sequestration Advisory Committee in Nebraska was established to provide state-level GHG recommendations to the 2000 Session of the Nebraska Unicameral (NE DNR 2001). Typical of the problem identified in the preceding sections, the original committee members were dominantly from agriculture with no agroforestry expertise represented at the table. The four major recommendations ultimately made in this report were: (1) maintain a Carbon Sequestration Committee to respond to changing conditions, (2) provide additional funding for basic research relevant to Nebraska, (3) provide funding to support a carbon sequestration pilot project in Nebraska, and (4) develop a state GHG inventory. Since the committee evaluated activities in terms of their potential in Nebraska, their backgrounds or expertise would determine what made it into the process, it was fortunate that agroforestry and agroforestry expertise were later included. Despite the perception of Nebraska being a treeless expanse of land, the potential for carbon sequestration by agroforestry practices, implemented for objectives <u>other than carbon,</u> is significantly large. The development of Table 2 has proven very useful in illustrating agroforestry's potential for GHG mitigation in Nebraska and beyond; serving as a simple but very powerful communication tool as we wait for more detailed scientific information to be generated

**Table 2.** Agroforestry potential to store carbon on Nebraska farmland. Storage values are calculated at 20 and 40 years following planting. (Developed by USDA National Agroforestry Center for the report: "*Carbon Sequestration, Greenhouse Gas Emissions, and Nebraska Agriculture–Background and Potential*" to the Nebraska Unicameral [NE DNR 2001])

| **Agroforestry practice** | **Stored $CO_2$ / land unit at age 20** ***metric tons (MT)*** | **$CO_2$ storage potential for Nebraska** ***million metric tons (MMT)*** | |
|---|---|---|---|
| | | ***20 years*** | ***40 years*** |
| Field windbreak<br>(planted on 5% of cropland) | 36 - 72 MT /mile<br>*(20 ft width, 0.4 mi. = 1 ac.)* | 11.7 - 23.4 | 23.4 - 46.8 |
| Living snow fence<br>(high priority roadways) | 162 - 324 MT/mile<br>*(50 ft width)* | 5.4 - 10.8 | 10.8 - 21.6 |
| Riparian forest buffer | 426 - 852 MT /mile<br>*(100 ft width, each side stream)* | 9.2 - 18.4 | 18.4 - 36.8 |
| Pivot irrigation corners<br>-pivots below 23 inch annual precipitation<br>-all corner pivots | 352 - 704 MT/pivot<br>*(4 corners, each 6 acres)*<br>" " | 6.6 - 13.2<br>15.1 - 30.2 | 13.2 - 26.4<br>30.2 - 60.4 |
| **TOTAL** | | **41.4 - 82.8** | **82.8 - 165.6** |

## AGROFORESTRY IN FUTURE GHG MITIGATION STRATEGIES
### Win-Win Agroforestry-based Carbon Sequestration Opportunities

While US recognition of agroforestry as a carbon sequestering activity is lagging, there is a growing interest in it in countries that have not only ratified the Kyoto Protocol but are also facing many other ecological problems on their private working lands. On November 22, 2004, the $CO^2$ Group Limited announced its contract with Origin Energy, a leading Australian energy company, to supply carbon credit through to 2012 ($CO^2$ Group Limited 2004). The agreement, considered the largest in Australia to-date and valued at up to $20 million, is reportedly also the first carbon sink deal of its type under an emissions trading system anywhere in the world. These credits will be generated by up to 6,500 hectares of eucalyptus plantations to be established in western New South Wales as tree plantings integrated with cereal cropping agricultural systems. The plantings will be in place for more than 100 years, sequestering carbon along with providing "significant environmental benefits including mitigation of dry land salinity, enhanced biodiversity, soil conservation, water catchment protection, and significant employment opportunities in regional NSW."

Other innovative programs that target massive afforestation of marginal farmlands as one GHG tactic might prove to be fertile grounds for incorporating agroforestry plantings that combine carbon sequestration with production objectives. For example, the Emissions/Biodiversity Exchange Project (EBEX21) was initiated in 2001 by the Manaaki Whenua Landcare Research Institute as a means to "catalyze business action on energy efficiency and GHG emissions, while promoting the restoration of New Zealand's native biodiversity" (Landcare Research NZ,2005). Targeting areas, such as the one million hectares of New Zealand's marginal hill farmland, the project would help promote conversion of these lands to indigenous forest in a "process that would enable landowners to enter 'Kyoto' carbon trading markets." This approach—land use shift from agriculture to forests—however, may be a serious barrier to adoption by private landowners. On the other hand, strategic use of agroforestry practices within these landscapes could fix carbon, address biodiversity concerns along with soil and water issues, provide alternative income, and create a more diversified farm-forestry system that would set better with those already engaged in agricultural pursuits (Schirmer 2002). As other countries that have ratified the Kyoto Protocol gear up, we are likely to see even more examples of contracts and agreements like this coming on line.

## On the Horizon………..

Currently, many of the programs providing support for agroforestry practices come from the Farm Bill (see USDA NAC 2003). Beginning with the 2002 Farm Bill, there has been a growing awareness for the need to shift from commodity subsidies to more conservation and international trade (Becker 2001). Continued pressure to better align with the World Trade Organization would suggest a continued and perhaps stronger push in that direction in the 2007 Farm Bill. In the World Resources Institute report "A Climate and Environmental Strategy for U.S. Agriculture," the authors felt that "policies could be developed that would help farm income, enhance the environment, and also reduce agricultural GHG emissions, while cutting soil erosion and nutrient pollution" (Faeth and Greenhalgh 2000). To accomplish this, one of their recommendations was to shift subsidies from farm income to support programs that would help farmers reduce environmental problems caused by agricultural activities. Unfortunately, while the language fits what agroforestry can deliver, agroforestry was not one of the many activities discussed. Recognition is slowly increasing of the roles agroforestry and other *working tree* plantings can play in addressing national water quality concerns. Now it is just a matter to show policy and program makers that while these plantings protect water quality they will also be sequestering significant amounts of carbon, and as well as providing other amenities being demanded from these lands, such as wildlife and income diversification. Discussions are beginning on the 2007 Farm Bill. This may well be a time to investigate the value of substituting commodity subsidies with tree planting subsidies (McCarl and MacCalloway 1995) that promote agroforestry. Communicating this and other potentials of agroforestry, along with the continued progress in our scientific understanding, will be needed as the discussions that will be formulating our climate change and environmental strategies begin.

## REFERENCES

Becker, E. 2001. Administration seeks to shift farm policy from subsidies. *The New York Times* 20 September 2001.

Brandle, J. R., T. D. Wardle, and G. F. Bratton. 2002. Opportunities to increase tree plantings in shelterbelts and the potential impacts on carbon storage and conservation. In *Forests and Global Change*, eds., Sampson, R. N., and D. Hairs, 1(9)157-175. Washington, D.C.: American Forests.

Cairns, M., S. Brown, E. Helmer, and G. Baumgardner. 1997. Root biomass allocation in the world's upland forests. *Oecologia* 111:1-11.

Clark, H., C. de Klein, and P. Newton. 2001. Potential management practices and technologies to reduce nitrous oxide, methane and carbon dioxide emission from New Zealand agriculture. New Zealand: Ministry of Agriculture and Forestry. 85 p. [On-line]. Available: http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/climate/green-house-gas-migration/ghg-mitigation.pdf (verified 18 Apr 2005)

CO2 Group Limited. 2004. Group Limited announces ground breaking carbon credit sale. Media Release. ANNOUNCEMENT 78. 22 November 2004. [On-line]. Available: http://www.co2australia.com.au/documents/CO2ASXMediaRelease22-11-04.pdf

Faeth, P., and S. Greenhalgh. 2000. A climate and environmental strategy for U.S. agriculture. World Resources Climate Notes: November 2000.

Gold, M. A., W. J. Rietveld, H. E. Garrett, and R. F. Fisher. 2000. Agroforestry nomenclature, concepts and practices for the USA. In *North American Agroforestry: An Integrated Science and practice,* eds., Garrett. H. E. et al., 63-77. Madison, WI: American Society of Agronomy, Inc.

Gitay, H., A. Suarez, R. Watson, and D. J. Dokken, eds. 2002. Climate change and biodiversity - IPCC Technical Paper V. Intergovernmental Panel on Climate Change. [On-line] Available at: (http://www.ipcc.ch/pub/tpbiodiv.pdf). (verified 5 Apr 2005).

KCARE Environmental News. 2003. Soil carbon and climate change news. # 26. October 31, 2003. [On-line] Available at: (http://www.oznet.ksu.edu/ctec/newsletter/ 10_31_03.htm). (verified 10 Apr 2005).

Landcare Research New Zealand. 2005. EBEX21 Project. [On-line]. Available: http://www.ebex21.co.nz/html/WhatIsEbex21.aspx?Flash=false (verified 25 Apr 2005).

McCarl, B., and J. Mac Callaway. 1995. Carbon sequestration through tree planting on agricultural lands. In *Soil management and greenhouse effect. Advances in Soil Science*, eds., Lal, R. et al, 27:329-338. Boca Raton, LA: CRC, Lewis Publishers.

Nebraska Department of Natural Resources. 2001. Carbon sequestration, carbon emissions, and Nebraska–background and potential. A report relating the requirements of LB 957 of the 2000 Session of the Nebraska Unicameral and containing the recommendations of the Carbon Sequestration Advisory Committee. December 1, 2001.

Perry, C. H., C. R. Woodall, V. Lessard, and M. M. Schoeneberger. 2005. Towards the accounting of *working trees*. In *Proceedings of the ninth North American agroforestry conference,*12-15 June 2005, Rochester, MN. St. Paul, MN: University of Minnesota, CINRAM.

Ruark, G., M. Schoeneberger, and P. K. Nair. 2003. Agroforestry–helping to achieve sustainable forest management. In *The Role of Planted Forests in Sustainable Forest Management: Reports and Papers of the UNFF Intersessional Experts Meeting*, 240-253; 25-27 March

2003, Wellington, NZ (ISBN-0478-07758-0). [On-line]. Available: http://www.maf.govt.nz/mafnet/unff-planted-forestry-meeting/conference-papers/roles-for-agroforestry.htm. (verified 5 Apr 2005).

Sampson, R. N. 1995. The role of forest management in affecting soil carbon: policy considerations. In *Soil management and greenhouse effect. Advances in Soil Science*, eds. Lal, R. et al., 28:339-350. Boca Raton, LA: CRC, Lewis Publishers.

Schroeder, P. 1994. Carbon storage benefits of agroforestry systems. *Agroforestry Systems* 27:89-97.

Sharrow, S. H., and S. Ismail. 2004. Carbon and nitrogen stores in agroforests, tree plantations, and pastures in western Oregon, USA. *Agroforestry Systems* 60:123-130.

Thevathasan, N. V., and A. M. Gordon. 2005. Alley cropping could help Canada meet Kyoto protocol commitments. *The Temperate Agroforester* 13(2). [On-line]. Available: http://www.aftaweb.org/readcurrent.php. (verified 20 Apr 2005)

USDA National Agroforestry Center. 2000. Working trees for carbon: Windbreaks in the U.S. USDA Forest Service and Natural Resources Conservation Service, Lincoln, NE. [Online]. Available: http://www.unl.edu/nac/brochures/wbcarbon/ wbcarbon.pdf (verified 15 Apr 2005).

USDA National Agroforestry Center. 2003. Incentives for agroforestry: 2002 Farm Bill. Inside Agroforestry [Online]. Available: www.unl.edu/nac/ia/winter03/winter03.pdf (verified 20 Apr 2005).

USDA NRCS. 2005. COMET VR–CarbOn management evaluation tool for voluntary reporting. USDA Natural Resources Conservation Service. [On-line]. Available: http://www.cometvr.colostate.edu/. (verified 27 Apr 2005).

US DOE. 2005. Draft technical guidelines. Voluntary reporting of greenhouse gases 1605(b) program. March 2005. [On-line]. Available: http://www.pi/energy.gov/pdf/library/DraftTechnicalGuideliensMar21.pdf (verified 22 April 2005).

Watson, R. T., C. M. Zinyowera, and R. H. Moss. 1996. Technologies, policies and measures for mitigating climate change. IPCC Technical Paper I. Intergovernmental Panel on Climate Change. [On-line] Available at: (http://www.gcrio.org/ipcc/techrepI/index.html). (verified 5 Apr 2005).

Williams, J. R., J. M. Peterson, and S. Mooney. 2005. The value of carbon credits: is there a final answer. *Journal of Soil and Water Conservation* 60:36A-40A

Zhou, X. 1999. On the three-dimensional aerodynamic structure of shelterbelts. PhD. Dissertation. University of Nebraska, Lincoln, NE.