BUILDING CARBON CREDITS WITH BIOSOLIDS RECYCLING

Using biosolids is a logical way to increase soil C reserves. Add in energy recovery from digester methane, and production of fuel crops fertilized with biosolids and the $C0_2$ credits/dry ton grow.

Part II

Sally Brown and Peggy Leonard

THE total carbon (C) content in soil comprises a large portion of total sequestered carbon. However, reserves of C in agricultural and nonagricultural soils have been depleted over time. A large portion of the CO_2 in the atmosphere originated from the mineralization of soil organic carbon (Lal *et al.* 1997). Factors responsible for this include urbanization, land use changes, conventional agricultural practices, open pit mining and other activities that degrade soils. As a result of these factors, more C entered the atmosphere from soils than from fossil fuel combustion from the 1860s until the 1970s. The total C currently sequestered in soils and vegetation is estimated to be 1555 Pg C with an annual release of 53.3 Pg C from vegetation and 22.4 Pg C from soils (Lal et al., 1997). U.S. agricultural practices currently account for the release of 2.7 Tg C annually (Robinson et al., 1997).

Increasing soil C reserves, by increasing organic C concentrations in agricultural and range land soils, restoring degraded soils to productivity, or returning agricultural soils to native ecosystems have been proposed as a means to sequester C and increase the reserves (Lal et al., 1998). A survey of the potential role of agriculture in meeting the United Kingdom's C sequestration goals noted that altering agricultural practices and land use would be sufficient to achieve 50 percent of the 12.5 percent reduction required in the overall agreement with members of the European Union (Smith et al., 2000). Practices that would result in C sequestration include biosolids application, no-till farming, woodland regeneration, and bioenergy crop production.

Given that municipal biosolids contain carbon, land application of these materials has the potential to increase soil C reserves and gain additional C credits. For example, land application of biosolids to agricultural soils would provide carbon to soils in addition to credits accrued for the fertilizer value of the biosolids. However, determining the C credit or potential for biosolids carbon to increase soil carbon is not clear cut and there is currently no consensus on determining the rate of sequestration:rate of addition. Also, end use of the land and associated management practices will affect the percent of total added carbon that remains in the soil. However, soils provide a large potential sink for carbon and using biosolids is a logical way to increase soil C reserves. A review of information on factors involved in determining the potential for added C to remain in soils will be used as a guide upon which to base recommendations for King County, Washington to follow should C sequestration become a determining factor in its biosolids program.

Part I of this article evaluated the net greenhouse gas contributions of landfilling biosolids in King County versus land application in forests and on agricultural soils. That evaluation did not consider credits for carbon sequestration. Part II adds carbon credits into the calculations, and then revisits overall climate change impacts of biosolids management options in King County.

LITERATURE REVIEW

A brief literature review was done to assess data on the effect of soil amendments like biosolids on soil C content. Literature related to agronomic crops and soil restoration were reviewed.

For agronomic crops, the organic carbon content of agricultural soils decreases with increasing cultivation. For example, in a long-term study of soils in Iowa, all cultivated soils had 22 to 49 percent less carbon than adjacent fence row soils (Robinson et al., 1996). In a study looking at the effect of different tillage

Long-term studies in the Northwest with wheat cultivation suggest that biosolids addition (right), coupled with no-till farming, would be a way to maximize increases in soil carbon reserves.

and rotational practices, total C in the surface of no till treatments was >5 percent, while C in conventional till treatments was about 2 percent (Dick and Durkalsi, 1998). In long-term studies of wheat cultivation in the Northwest, researchers observed that fallowing, accompanied by incorporation of stubble, increased the rate of C mineralization and loss in dryland wheat production (Rasmussen and Albrecht, 1998). This loss was reduced when manure addition was included as part of the management practice. These results suggest that biosolids addition, coupled with no-till farming methods, would be a way to maximize increases in soil C reserves. However, increases in soil carbon following amendment addition vary by site, climate, soil type and site management (Gerzabek et al.; 2001; Khaleel et al.,1981; Rochette and Gregorich, 1998).

In a study that is the most pertinent for King County, Cogger (personal communication) compared plots treated — continuously for 10 years — with 360 lb N (fertilizer) per year versus plots receiving 9 dry tons/year of biosolids. Control plots received no fertilizer or biosolids. The plots were maintained in continuous fescue with no-till as the management practice. Grass was cut throughout the study and removed from the plots. Soil organic matter (consisting of carbon, hydrogen and oxygen) in the biosolids amended plots averaged 2.9 percent, with the N amended and control treatments averaging 2.4 percent and 2.3 percent respectively.

For restoration, addition of high rates of amendments have been shown to increase soil functionality as well as both below and above ground C pools (Alverez et al., 1999; Brown et al., 2003; Cox and Whelan, 2000;Fierro et al., 1999; Sopper, 1993). Above ground C pools refer to increased permanent plant cover on a restoration site. The soils at disturbed sites where biosolids are used for restoration are generally deficient in organic carbon. This is because many of these sites are former mine sites where the topsoil has been lost in the excavation process. For all of the studies cited, amendment addition in the form of biosolids increased soil C over unamended soils. However, soil carbon in relation to the total amount of carbon that was added decreased over time in some studies and increased in others. As these are restored ecosystems, it is not known if the rate of change will stabilize over time. In one study of two coal mined lands reclaimed with biosolids, total organic C remained elevated in restored versus undisturbed soils for at least 21 years following amendment addition (Malik and Scullion, 1998). However, it is likely that, over an extended period, it will be similar to total carbon concentrations in neighboring undisturbed ecosystems. The total carbon in soils in undisturbed systems can be used to estimate C sequestration potential in this type of scenario.

Soil organic matter in the biosolids amended plots averaged 2.9 percent, with the N amended and control treatments averaging 2.4 percent and 2.3 percent respectively.

APPLICATION TO KING COUNTY PROGRAM

This brief review of available literature on the ability of soils to sequester carbon and the potential implications for biosolids use on land suggests that it is possible to figure C credits in addition to fertilizer credits for the King County program. However, due to the range of factors that affect how much of the added C remains in the soil, it is difficult to determine what percent of the added C can be counted. Some assumptions for King County can be made to make this calculation easier: 1) Application to forest and range land will result in higher C accumulations; and 2) Applications to dry land wheat with conventional tillage will result in reduced to no C accumulations.

If the data from Craig Cogger (Washington State University, personal communication) is used as a basis for a calculation, soil C increased by 0.5 percent over other fertilizer treatments after receiving approximately 90 dry tons of biosolids per acre over a ten year span. This application rate is in excess of what is generally used to meet the N needs of a crop. If you assume a similar rate of organic carbon increase but with a 5 dry ton per acre application rate, that could account for an annual increase of 0.025 percent in soil C reserves. On a per hectare basis, the total weight of the soil in the top 15 cm would equal 2000 Mg ha^{-1} (Brady and Weil). Each annual application of biosolids would then increase the soil C reserves by 1Mg C ha^{-1}. The potential C credits for increasing soil C is much greater than the C credits for fertilizer application (0.39 Mg C per ha).

King County is working with Emerald Ranches in Sunnyside, Washington to test the feasibility of growing canola fertilized with biosolids for production of biodiesel. Reuben Fernandez (right) of Emerald Ranches evaluates crop response.

The data from Cogger is based on applications on the east side of the Cascades where rainfall is generally sufficient for plant growth. In addition, it is from plots that received annual applications of biosolids. In order to reduce the uncertainty in this estimate, it would be necessary to collect soil samples from long-term biosolids application sites and neighboring areas that have not received biosolids. The difference in total C in these soils, combined with an application history, would make this more of a quantitative value and less of a crude estimate. It is likely that the rate of C accumulation will vary based on the location, land use, management practice and frequency of application. Many of the sites in the King County program receive biosolids applications every several years versus annually. Analyzing those sites, therefore, would also provide information on whether C accumulation still occurs under varied conditions.

MANAGING BIOSOLIDS TO ACCRUE C CREDITS

The literature also suggests that there are ways that King County can direct its biosolids program to increase carbon sequestration in soils. These include using biosolids to grow biofuels, restoration of disturbed soils and compost production. By using biosolids to grow alternative fuels, King County would gain fertilizer credits, as well as credits for the fuel produced. Using biosolids for soil restoration also appears to be a straightforward means to increase soil carbon as well as above ground carbon reserves.

Biofuels: Fuels made directly from plant materials are known as biofuels. Examples include methane, ethanol and biodiesel. Biodiesel is diesel fuel made by treating vegetable oils with alcohol and a base such as lye. It is suitable for use in all diesel engines. The King County Biosolids Program is cooperating with Emerald Ranches in Sunnyside, Washington to test the feasibility of growing canola (a high oil seed crop) with biosolids as a fertilizer source for production of biodiesel. This project is partially funded through a grant from the USDA Small Business and Innovative Research program. In the proposal for this project, a potential yield of 225 gallons of biodiesel was calculated. Based on a CO_2 equivalent of 21.6 lbs of CO_2 per gallon of diesel, growing canola for biodiesel would result in a net CO_2 credit of 2.2 Mg C per acre. This does not take into account the energy requirements for harvesting and processing the canola to manufacture biodiesel. The credit would be in addition to the fertilizer value of the biosolids. If no-till management were used, the potential to increase soil C reserves also adds to the C credits.

Restoration: For many disturbed sites, the total soil organic matter has been severely reduced. Examples of sites include gravel pits, logging roads, and hard rock mining sites or tailings repositories. Here, C reserves in the soil would be increased by several percent from a single application of biosolids. For example, at the Bunker Hill mining site in Idaho, amendment addition increased above ground plant biomass from near zero in the control plots to 4 to 6 Mg C ha^{-1} in the treated plots (Brown et al, 2003). Percent C in the surface averaged 13 percent across all treatments two years after amendment addition compared with 0.4 percent in the untreated soils. It is likely that this value will decrease over time as soil microorganisms decompose a portion of the added organic matter. However, the potential to sequester C, both in the soils and in plant biomass, is clear. If biosolids application for restoration increased soil C content by 2 percent, the credit would be 40 Mg C ha^{-1}.

Many restoration sites are allowed to remain as wilderness areas where the above ground vegetation isn't harvested and losses are limited to grazing. This would also increase biomass production and C sequestration potential. At these sites, fertilizer credits also could be taken. It is also possible that additional credits could be taken if biosolids are mixed with other high C residuals prior to application.

Composting: Composting stabilizes the organic matter in biosolids. A large portion of the biosolids compost in King County is used for landscaping and home garden use. A portion is also used for road restoration. It is not clear how to calculate the carbon balance associated with composting. If one considers that the C in the compost is stable and will not be mineralized over time, it is possible to look at the C in compost in relation to the initial C concentration in biosolids to determine the C credit. These credits would be comparable to the C credits for soil C accumulation. Biosolids is generally cocomposted with a carbon rich residual. This is done to stabilize the N in the biosolids and as a result, the finished compost has a negligible fertilizer value and is used primarily as a soil conditioner.

For King County, composting of biosolids is done in static piles (mixed with sawdust in a 3:1 sawdust to biosolids ratio by volume). At the end of the composting process, the volume reduction of the mixture is about 40 percent (Chuck Henry, personal communication). The majority of the compost is used locally by landscapers with a small portion used for logging road restoration. For the purposes of this report, we will only consider the carbon value of the material. The nutrient content will not be taken into account. We also will assume that all material is used locally, so that transportation carbon costs are negligible. In addition, as the compost is produced in static piles, the energy costs for production are very small. For a more accurate assessment of the C balance for compost produced using aerated static piles, an estimate of the energy costs for composting would be recommended.

If one considers that the volume reduction of the overall mixture is 40 percent and the inorganic matter component of the biosolids is 50 percent, then the reduction in the total organic component of the biosolids would be 80 percent. This translates into 20 percent of the initial organic matter in the biosolids remaining after the composting process. For a dry ton of biosolids, 500 kg of organic matter would be reduced to 100 kg. For each dry ton of biosolids that is composted in King County, one can take a CO_2 credit of 220 kg. In 2001, King County composted about 3,100 wet tons of biosolids or two percent of total output. This increased in 2002 to five percent of the total output. Accounting for the percent solids and inorganic matter in the biosolids, composting would give a 122 Mt CO_2 credit in 2001, and a 240 Mt CO_2 credit in 2002.

FUEL CELL FOR DIGESTER GAS

At one of their treatment plants, King County installed a methane collection system in combination with their anaerobic digester. Gas collected from the digester is used to fulfill a portion of the energy requirements for operating the treatment

Figure 1. How it adds up (CO_2 debit/credit per ton biosolids)

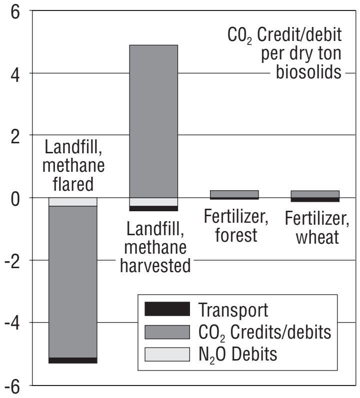
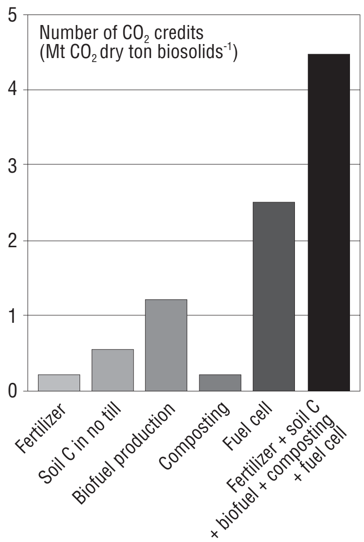


Figure 2. Carbon credits/dry ton of biosolids when fertilizer value, soil carbon and energy production are combined



plant. The digester gas supplies methane, which provides a hydrogen source for a fuel cell power plant. The energy from the one megawatt fuel cell supplies a portion of the power required to operate the treatment plant.

By collecting methane at the treatment plant, energy credits from the biosolids can be gained for methane production without losing the credits for fertilizer value of the biosolids or credits associated with other beneficial use practices. An estimate of the reduction in greenhouse gas as a result of the fuel cell put savings for one year at 1830 Mg of CO_2.

Figure 1 summarizes the data reported in Part I — essentially the $C0_2$ credit or debit of King County biosolids management options analyzed in last month's article. If King County's biosolids were being landfilled at this time (which they aren't) — and if all the methane from that landfill were captured for energy — this would be a great management practice from a CO_2/global warming/carbon sequestration perspective. Figure 1 also shows the net bonus for both fertilizer end uses (agriculture and forests). That credit pales in comparison with the amount of CO_2 that could be saved by using the energy value of the biosolids.

The problem with this carbon credit/biosolids management scenario is that all of the other values in biosolids are not available when it is landfilled. Figure 2 plots the $C0_2$ credits when all of the associated values of biosolids are added together. This includes fertilizer, soil carbon (no till land management), biofuel production, composting, and fuel cells powered by digester gas. Combined, that is equal to about 4.5 $C0_2$ credits per dry ton of biosolids — just about equal to the credit from landfilling with methane capture and energy recovery.

CONCLUSIONS

For King County, Washington and for biosolids programs across the country, beneficial use of biosolids offers an opportunity for municipalities to gain credits for greenhouse gas reductions. The most straightforward credits can be realized by calculating the energy savings associated with using biosolids as a fertilizer. However, substantial additional savings can accrue when the energy associated with anaerobic decomposition of the biosolids is harvested. This can occur at the treatment plant in a system where the methane generated during anaerobic digestion is harvested. It can also occur in a landfill, where landfill gas is collected and used for energy.

However, landfilling biosolids eliminates other carbon credits that can be gained through targeted beneficial use. Approaches to maximize carbon credits with biosolids include using biosolids to increase soil carbon reserves or to grow energy crops such as oil seed crops for biodiesel. By developing a biosolids program with global warming as a consideration, maximum carbon credits can be realized. It is important to note that the benefits associated with use of biosolids for carbon sequestration are in addition to other, well-recognized benefits of land application of biosolids. ■

A methane collection system was installed in combination with an anaerobic digester at a King County wastewater treatment plant. The methane provides a hydrogen source for a fuel cell power plant (right), which in turn provides power to operate the treatment facility.

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Landfilling biosolids eliminates other carbon credits that can be gained through targeted beneficial use.

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