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Cornhusker Economics

Carbon Farming: A Preliminary Economic Analysis of Carbon Credits for No-Till and Cover Crops

What is carbon farming?

Carbon farming refers to a carbon-sequestering change made in some farm practices in exchange for receiving payment for carbon credits. A carbon credit is essentially a certificate attesting that a specific amount of carbon dioxide has been removed from the atmosphere and sequestered for a long period. Buyers of these credits can then claim credit for carbon sequestered on their behalf by someone else, and in this way offset their own carbon emissions. Here we examine some issues related to the benefits and costs of agricultural carbon credits.

Recent press reports (Dunn 2021, Olick 2022, Plume 2021) have noted that some farmers are currently signing contracts to sequester carbon for credits that can be sold on carbon credit markets. The contracts are signed with intermediary companies that identify the quantity of carbon to be sequestered and in turn sell the credits to buyers. These carbon markets commodify agricultural carbon sequestration by allowing producers to sell agricultural carbon sequestration credits.

There are two kinds of fundamentally different carbon credit markets. Compliance markets identify sequestration that is mandated by a governmental agency. These markets are set up and operated by that agency. Voluntary carbon credit markets consist of trades between voluntary suppliers and voluntary buyers who have motives other than complying with some regulation. As demand for carbon credits grows, more intermediary companies are creating carbon credit trading platforms to connect agricultural producers to buyers. Examples of these firms include Nori, IndigoAg, and Land'O'Lakes' Truterra. Because coordination between individual buyers and producers would be costly and cumbersome, these intermediaries facilitate carbon credit transactions.

Who are the buyers and sellers in voluntary credit markets?

Voluntary buyers of carbon credits range from individuals to large corporations and may have a variety of motivations. Buyers in the voluntary market might wish to offset their emissions simply for public relations reasons, to be able to claim they are "carbon neutral". Or, the buyers might be individuals who are concerned about climate change and want to offset their own impact on the environment. Both of these types of buyers create demand for credits in the voluntary market, and they are willing to pay someone else to sequester carbon on their behalf.

Sellers in the voluntary agricultural carbon credit market are farmers who contract with an intermediary firm that pays them for adopting a new carbon-sequestering agricultural practice on an agreed-upon number of acres. Agricultural sellers in the voluntary market can increase their net revenues if they can implement the sequestration practice at a lower cost than the payment received for the carbon sequestered. The new practice could be switching from conventional tillage to no-till soil preparation or planting cover crops on land that would otherwise lay fallow during the off-season. These are the two practices we examine here.

How is carbon sequestration measured?

The most accurate way to identify changes in soil carbon content in a particular field is to physically sample and measure carbon content both before and after the change in practice. But this is prohibitively expensive. Instead, the farmer provides the intermediary firm with information about soil and management practices. The firm uses this information in conjunction with expert computer models to estimate the quantity of additional carbon that would be sequestered over a given period. These estimates of carbon sequestration are generally then verified by a third party before the transaction is logged in a third-party register that prevents the double-counting of credits. The farmer then begins the new practice, the firm begins the agreed-upon payment schedule to the farmer, and the firm sells the verified number of credits to individual or corporate consumers. Because the estimation procedures are not perfectly accurate, there remains a degree of uncertainty about the exact amount of carbon that is being sequestered in the field enrolled.

How much carbon is sequestered by adopting no-till or cover crops?

As suggested above, intermediary companies use mathematical models to predict how much soil organic carbon would be created by a particular change in practice on a particular field. We do not know what levels these models predict in general, and companies do not publicize the details of the models and data they use. So, we turn to scientific literature for experiments that measured changes in soil carbon due to adoption of no-till or cover crops. We have standardized all observations to metric tons of CO_2e (carbon dioxide equivalent)

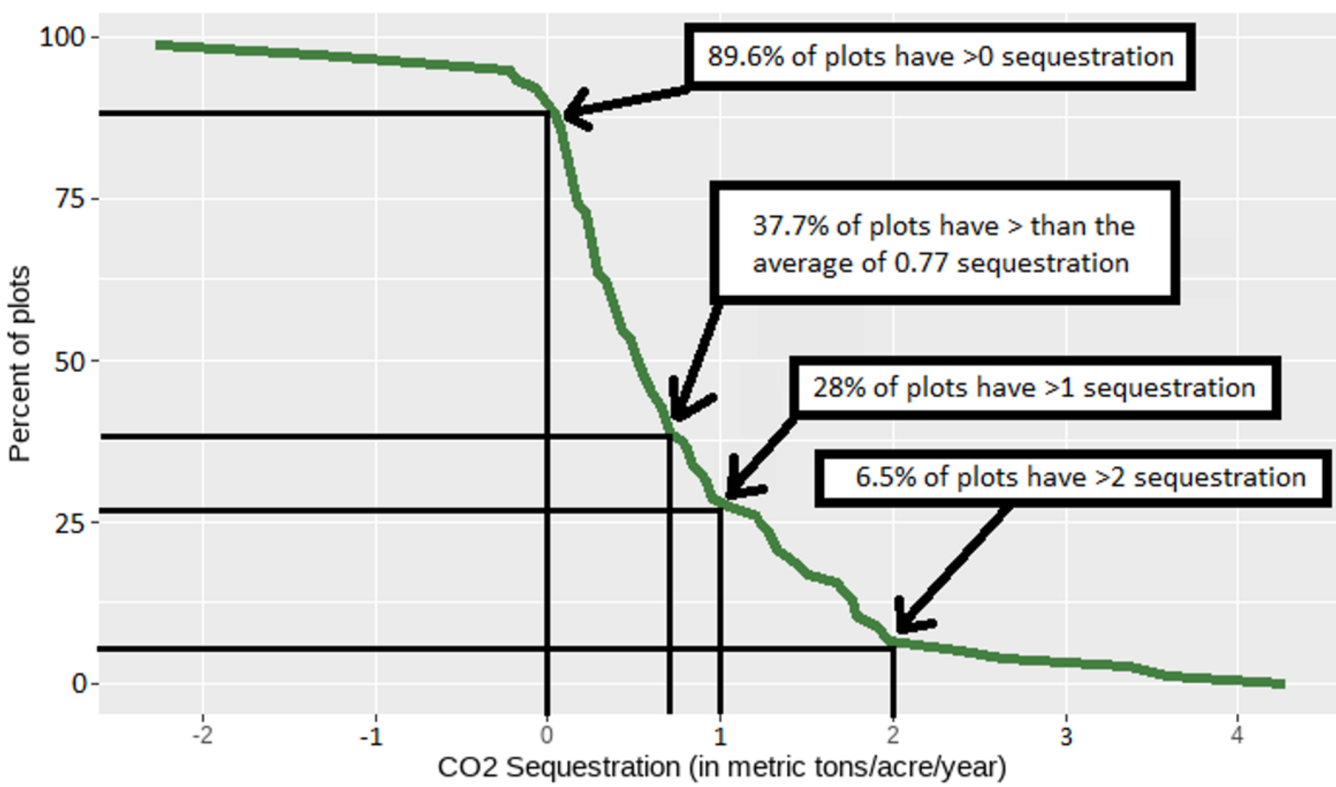

Figure 1. Percentage of no-till plots that showed carbon sequestration above the amount on the horizontal axis. Any point along the curve can be interpreted as "Y% of plots have greater than X amount of sequestration".

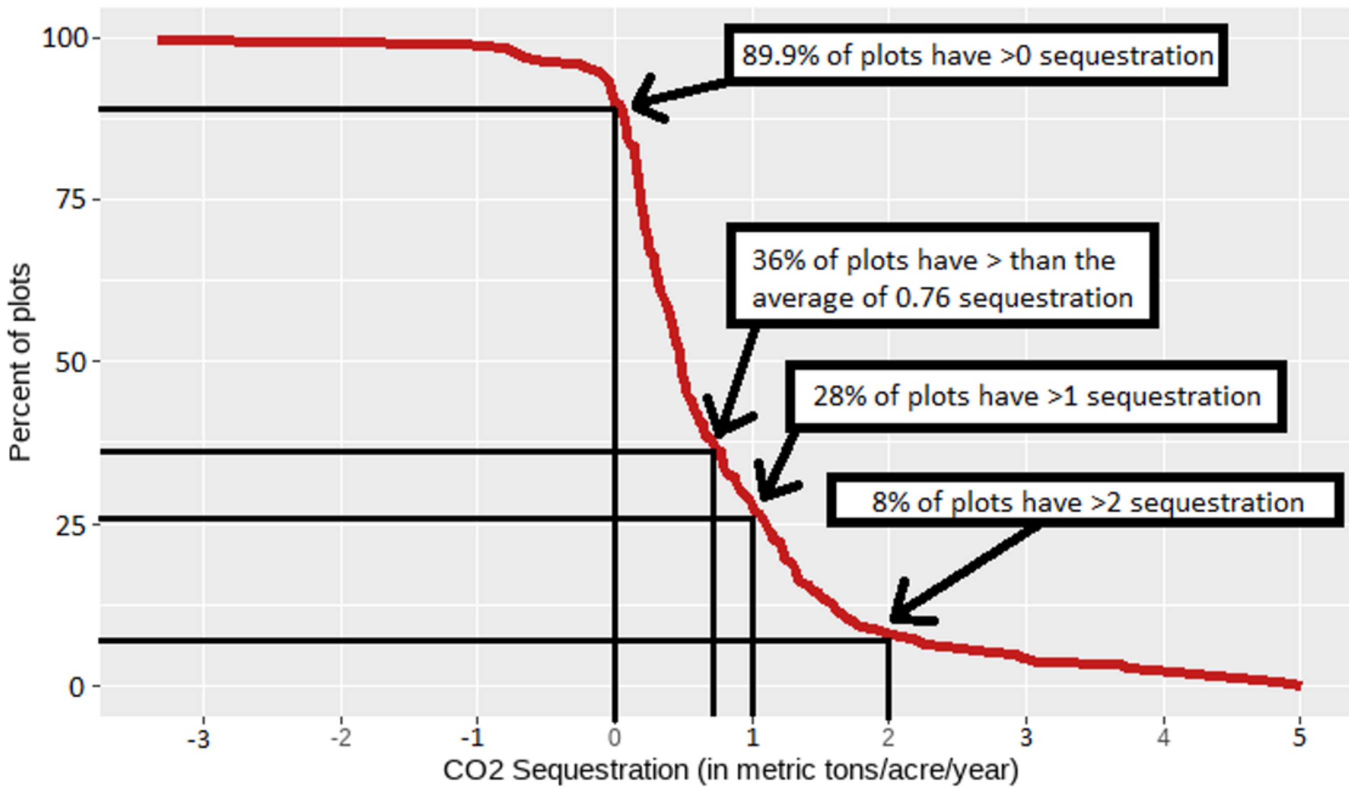

Figure 2. Percentage of cover crop plots that showed carbon sequestration above the amount on the horizontal axis. Any point along the curve can be interpreted as "Y% of plots have greater than X amount of sequestration".

as this is the most common way of discussing carbon sequestration amounts in popular literature. We found 77 multi-year experimental results measuring changes to no-till with an average carbon sequestration benefit of 0.77 metric tons of CO_2e per acre per year. We found 189 experimental results for planting cover crops, with an average sequestration benefit of 0.76 metric tons per acre per year.

But the range of outcomes around these averages was substantial for both practices. These ranges are visualized in Figures 1 and 2, where we arrange outcomes from lowest to highest sequestration (shown on the horizontal axis). The curve indicates the percent of plots that yielded sequestration above the level indicated on the horizontal axis. In Figure 1 for no-till experiments for example, the worst outcome was a plot on which no-till *decreased* soil carbon by a little more than 2 tons of CO_2e per acre. As revealed on Figure 1, 89.6% of the no-till experimental plots recorded positive carbon sequestration, while 28% of them recorded sequestration above 1 ton per acre per year. Thus, from these experimental reports we learned that the average increase of 0.77 tons sequestered per year hides a huge range of outcomes, and Figure 2 indicates a similar result from the cover crop experiments.

For both practices, about 10% of plots resulted in negative changes in soil carbon, and it would not make sense for buyers to pay for changing practices on those sites. Nor would it make sense to pay for changing practices on any site for which the cost exceeds the benefits.

What are the costs and benefits of sequestering a ton of CO_2e by changing farm practices?

Costs:

The cost of changing to no-till or adopting cover crops will vary from farm to farm, depending on equipment already owned, farm characteristics and other circumstances. However, land grant university experts have generated crop budgets that we can use as cost estimates. We found 6 such budgets for no-till with an average implementation cost of $16.67 per acre per year, but ranging from $8.17 to $23.75. Based on the average rate of sequestration, this implies that the cost of carbon dioxide equivalent sequestered would range from $10.61 to $30.84 per ton with an overall average of $21.98 as recorded in the middle row of column 5 of Table 1.

We found 8 budgets for cover crops with an average implementation cost of $44.84 per acre per year, ranging from $21.51 to $69.11. Based on the average rate of sequestration from cover crops, the average cost of carbon dioxide sequestered would be $28.30 to $90.93 per ton with an overall average of $59.68. The large range in cover crop cost estimates is due to the type of seed used. The cheapest budgets were for planting cereal rye, while the more expensive budgets used hairy vetch and other more expensive seeds. Here we consider only the carbon benefits of cover crops, ignoring whether the more expensive seeds provide additional benefits to farmers.

Benefits:

We do not have information to determine the value that voluntary buyers place on credits. Clearly, buyers have revealed a willingness to pay that is at least as great as the market value, currently around $15-20/ton. However, apart from the private value those buyers receive, there is a social benefit to the entire world society of re-

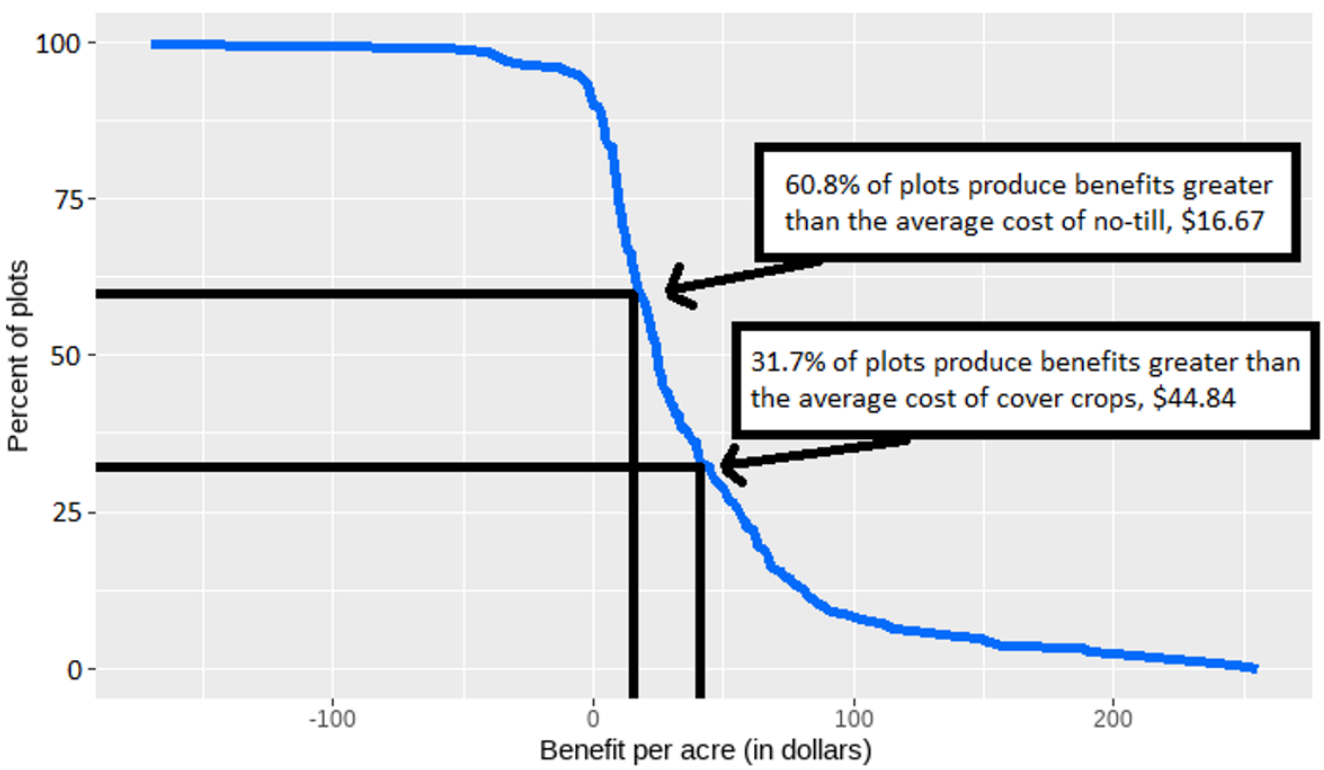

Figure 3. Percentage of plots that showed benefits above the amount on the horizontal axis. Any point along the curve can be interpreted as "Y% of plots produce greater than X amount of benefit".

ducing atmospheric carbon because it reduces future damages from climate change. Thus, any action we can take to slow or reverse climate change is socially valuable. The present value (discounted) of future costs to society of an additional ton of CO_2 emitted today is known as the *social cost of carbon*. Here we will use this value as the benefit achieved by the sequestration of carbon. Because we recognize that buyers of credits may experience private benefits in addition to this social benefit, we consider the social cost of carbon to be a lower-bound estimate of total benefit.

The federal government maintains estimates of the social cost of carbon (Executive Order 13990), based on academic studies of likely additional damages in the future due to an additional ton of emissions today. The 2021 estimate of the social cost of carbon by Interagency Working Group on Social Cost of Greenhouse Gases is $51 per metric ton of CO_2. This is a reasonable number for us to use as an estimate of the social benefits of carbon sequestration because it is the damage avoided by sequestering, rather than emitting, a ton of CO_2.

Table 1: Average costs and benefits expected by practice and enrollment criterion.

Outcome	No-till		Cover crops	
	Enroll only fields with carbon benefit greater than cost	**Enroll all fields**	**Enroll only fields with carbon benefit greater than cost**	**Enroll all fields**
Fraction of fields enrolled	60.8%	100%	31.7%	100%
Average sequestration (tons CO_2e per acre enrolled)	1.21	0.77	1.85	0.76
Average cost per acre enrolled ($ per acre)	$16.67	$16.67	$44.84	$44.84
Expected cost of sequestration ($ per ton CO_2e)	$13.80	$21.98	$24.18	$59.68
Social benefit of sequestration ($ per ton CO_2e)	$51.00	$51.00	$51.00	$51.00
Expected net benefit of sequestration ($ per ton CO_2e)	$37.20	$29.02	$26.82	-$8.68

We note that the average cost of sequestering CO_2 via no-till is about $21.98 per ton (see above), well below the $51 benefit, while the average cost via cover crops, $59.68 per ton, is higher than the $51 benefit.

Net benefits:

We visualize in Figure 3 the range of social benefits of no-till and cover crops in Figures 1 and 2 by simply multiplying the horizontal axis (tons per acre) by $51 per ton. (Because the distribution of sequestration outcomes is nearly identical for the two practices, we just present the distribution for cover crops.) We can now see that the benefits exceed the average cost of no-till on about 60.8% of experimental plots, while benefits exceed the average cost of cover crops on only 31.7% of plots.

If these experimental plots do represent the distribution of outcomes on farm fields, it would make economic sense for society to enroll and reimburse only the top 60.8% of fields for no-till, and only the top 31.7% of cover crop fields. If we were able to know ahead of time exactly which of the experimental plots reflect the outcome for a given farm field, we could implement this "perfect information" policy and enroll only individual fields with positive net benefits. For the 60.8% of fields that would be enrolled for no-till, the average sequestration would be 1.21 tons per acre with an average value of $61.71 per acre, or $13.80 per ton sequestered. On the other hand, for a policy of open enrollment of all fields for no-till, the cost per ton sequestered rises to $21.98, still well below the social benefit of $51.00 (see second and third columns of Table 1).

Under perfect information for a cover crop program, the average sequestration for the 31.7% of fields enrolled would be 1.85 tons per acre, resulting in an average cost of $24.18 per ton, well below the social benefit. But a program enrolling all cover crops fields would bring in so many fields with adverse outcomes that the average sequestration cost rises to $59.61 per ton, above the social benefit of $51.

How does uncertainty about actual sequestration impact the market?

A perfect information policy, enrolling only the fields for which benefits exceed costs, is not achievable. This is because when a given field is offered for enrollment, there is no way to perfectly identify which of the experimental plots represents that particular field. But it is nonetheless useful to consider this hypothetical result, which we refer to as a perfect information policy.

But if we have no information at all about each prospective field and simply enroll them all, many adverse fields will be reimbursed, bringing the cost per ton sequestered up by 60% in the case of no-till and 88% for the case of cover crops.

Clearly, if we have some imperfect but useful information about each field before enrollment, that information should allow a program that would result in costs per ton somewhere between the perfect information and no-information outcomes we have described. The carbon sequestration models used by intermediary firms to predict sequestration on applicants' fields provide useful information for this purpose and should therefore result in an average cost of sequestering a ton of carbon somewhere between the two extremes we have calculated above with no information ($59.68 for cover crops) and with perfect information ($24.18 for cover crops). It is well beyond the scope of our study to attempt to identify what the average costs might be using intermediary firms' proprietary carbon models.

Because of this information uncertainty about the amount actually sequestered, a carbon credit will be worth less to purchasers (and to society) than if they could be certain how much carbon will be sequestered as a result of their purchase. There are additional uncertainties created by performance failures, for example, the practice might not be continued in the same way for the agreed-upon duration. Intermediaries can monitor and enforce performance to some degree, but not perfectly. Some intermediaries attempt to reduce performance uncertainty for buyers by purchasing more credits than they sell, providing a reserve of credits that they can use to substitute for credits purchased that prove later to have sequestered less than contracted.

Are there any possible benefits of government intervention in the voluntary carbon market?

It has been suggested that a government program could stabilize or provide a price floor for the voluntary credit market, with a government agency becoming a buyer. This would be similar to past farm programs that have had the objective of stabilizing and/or supporting market prices for farm commodities. Those programs, however, were problematic in that the minimum price became a political issue, with agricultural interests generally pressing for high prices and politicians representing taxpayers generally pressing for low prices. When support prices have exceeded market price, burdensome surpluses of the commodities have built up. However, for carbon credits, consider that the government becomes the buyer of last resort, reimbursing farmers for carbon sequestered at $51 per ton. "Surpluses" of credits would no doubt arise, consisting of carbon sequestered in excess of the amount that voluntary buyers want to purchase at $51. These surpluses would not require any government costs to maintain as had been the case for commodity surpluses, nor would the government ever need to sell them. The surpluses would constitute a "bank" of sequestered carbon, all of which was generated at an average cost below the social cost of carbon. Because the benefits of sequestration are universally enjoyed by all, the result of these banked government credits are a net social benefit and might help meet US decarbonization goals or pledges in the future.

Summary

Based on experimental data about the amount of carbon sequestered and estimated implementation costs, our preliminary results show that the average cost of sequestering carbon via no-till (about $22 per ton of CO_2e) appears to be much lower than the $51 per ton social value of sequestering that ton. In contrast, our preliminary results show that the average costs of sequestration via adoption of cover crops is much higher, about $60 per ton. Depending on how accurate soil carbon models are in predicting sequestration on individual fields to qualify them for enrollment, reimbursement costs for planting cover crops could well result in average net social benefit (this is certainly the case for some fields.)

One implication of these results is that if the government were to establish a program to reimburse all farmers for implementing no-till, the social benefits would exceed the estimated average cost of sequestration. But any program to reimburse farmers for adopting cover crops would only be beneficial if carbon models provide sufficient accuracy in predicting which fields to enroll.

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