The Center for Growth and Opportunity at Utah State University

Can Private Agricultural Lands Contribute to Carbon Sequestration?

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Research in Focus

Introduction

Climate change caused by carbon dioxide (CO_2) and other manmade greenhouse gases is one of the most pressing problems facing society today.[1] In total, the world emits 35 billion tons of carbon dioxide per year. These emissions have had wide-ranging effects on the climate, such as rising sea levels and more frequent extreme weather events.[2] Growing public concern has led 139 countries and over 700 corporations to make net zero emissions pledges, in which greenhouse gas emissions are lowered or offset.[3] Many of these pledges rely on the purchase of carbon offsets to reach net zero.

Carbon offsets are purchased through carbon markets where offset dealers sell credits that most often represent one ton of CO_2 reduction or sequestration. Carbon markets rely on economic principles, namely that allowing markets to incentivize CO_2 reductions will lower emissions. Most carbon offset credits today are generated by emissions reductions, in which a firm reduces its own emissions and then sells those reductions as offsets.[4] Some credits also come from sequestration projects, where CO_2 is captured from the atmosphere through either manmade or natural processes and sold as offsets.

Unfortunately, carbon markets have yet to be effective in creating large-scale reductions in CO_2. Several barriers prevent markets from working well, most notably the high cost of measurement, reporting, and verification of carbon reductions and sequestration, as well as the high initial costs of projects and lack of reliable information. The current carbon market does not provide a high enough price to incentivize large amounts of high-quality carbon reduction or sequestration projects.

Despite this, physically sequestering carbon in the natural landscape should still be pursued for its CO_2 reductions and numerous other environmental services. In particular, private agricultural lands could provide enough carbon sequestration to more than offset the emissions from food production.[5] Several different land management practices can be used to sequester carbon including reforestation, regenerative agriculture, and adaptive multi-paddock grazing, with each practice also providing co-benefits such as cleaner water, healthier soil, and improved wildlife habitat.

This paper examines some of the key approaches for sequestering carbon on private agricultural lands and the barriers that exist in carbon markets. It provides evidence that carbon payments themselves are insufficient to incentivize uptake, but that additional payments based on the co-benefits created by these land management practices may be enough to overcome the costs of implementation, including measurement, reporting, and verification.

How to Capture Carbon: Costs and Conservation

Terrestrial carbon capture, or carbon farming, is the process of using plants to sequester carbon in the soil. Through changes in land management, carbon is drawn from the atmosphere by growing plants and stored in their roots, stems, and leaves. As humans use the plants for timber, crops, or forage, much of the carbon remains underground in the roots, where they gradually decompose and improve the soil organic matter (SOM).

Increased SOM improves the fertility of the land and, depending on the region and practice, carbon can be held underground for decades or even centuries.[6] Healthier soils have several co-benefits including improved water retention, reduced soil erosion and water pollution, and improved wildlife habitat.[7]

Several agricultural land management methods can be implemented to sequester carbon. These methods rely on the principle of improving soil health by minimizing soil disturbance and improving SOM. The simplest of these methods are reforestation and afforestation. These processes either allow forests to grow back naturally or establish new forests.

Trees are the most effective plant for carbon sequestration; the world's existing forests capture 1.5 times the amount of total US carbon emissions each year.[8] In addition to having extensive root systems that store carbon, wood is 50 percent carbon by weight and any durable goods made from timber, such as homes and furniture, can be viewed as long term sequestered carbon. The timber industry is one of the only carbon sink industries in the US, capturing the equivalent of 12 percent of annual US emissions.[9]

Forest sequestration also faces challenges. Measuring carbon levels in soil requires taking a core sample that reaches the roots of the sequestering plant, which in the case of trees can be 10 or more feet below the surface. Many core samples must be taken throughout a forest, as the amount of sequestered carbon can vary across short distances.[10] In addition, the accuracy of these core samples is still questioned in the literature.[11]

Establishing a new forest can also be expensive. A Congressional Research Service review of carbon sequestration through forests found that carbon offset prices would need to be above $91 per ton to be profitable, far more than current offset prices of $3–6 per ton.[12]

In addition to creating or reestablishing forests, current timber management practices can be altered. Single stand forests, such as the vast pine forests of the Southeast, have been shown to be effective at capturing carbon and may even capture more carbon than natural forests under the right conditions.[13] Typically, mixed stand forests made up of many ages and species of trees are the best management option for environmental benefits. However, mixed stands require single tree harvesting which is more expensive and time consuming than harvesting in single stands.[14] Other practices can also be used to improve carbon sequestration, including longer rotations between harvests, harvesting timber in winter, and growing trees that are slow to mature, all of which add additional costs.[15]

Another method of carbon farming is regenerative agriculture. The goal is to capture carbon by improving soil health through farming practices such as minimum or no-till, cover cropping, and crop rotation. Each of these methods improves soil fertility by either minimizing soil disturbance or actively promoting more soil organic matter.[16] If done on a large scale, regenerative agriculture has the potential to capture six to nine percent of US carbon emissions annually, enough to more than offset emissions produced by the agricultural industry.[17] These practices also improve water retention, reduce soil erosion, and limit fertilizer runoff.[18]

Despite the benefits of regenerative agriculture, only about 12.5 percent of farmers use these methods.[19] The profitability of these practices is debated in the literature. Some work indicates that fewer inputs and increased soil fertility increases profit, while other work shows reduced yields. One reason for this debate is the large overlap in organic and regenerative practitioners.[20]

Most organic farmers use regenerative and organic practices together. While there is no problem with this, regenerative agriculture allows for the use of conventional tools such as synthetic pesticides and fertilizer that organic farming prohibits. Unfortunately, this means it is difficult to gauge the true profitability of regenerative agriculture alone. There are also important differences in both crops and geography that affect the economic viability of these practices.

Despite the difficulties of showing profitability, the sale of carbon offsets may still offer another income source for farmers under the right circumstances and encourage wider adaptation.

Prospective regenerative farmers around the world must take on initial costs that can range from $3 to $130 per acre depending on the country, farm, and practice. Costs include capital expenditures in new equipment and variable costs like seed for cover crops and increased labor costs associated with learning and implementing new practices.[21] Studies that looked specifically at American agriculture found even higher costs with a minimum of $20 per acre.[22]

Regenerative farmers also must deal with carbon measurement and verification challenges similar to those faced by the timber industry. Although these might be lower because core samples are not required to go as deep, the process is still expensive and time consuming.

Rangeland covers about one-third of the US and can also be used for successful carbon sequestration. By mimicking the mob grazing patterns of wild herds, some ranchers argue they have been able to greatly improve the health of their rangeland.[23] Adaptive multi-paddock grazing (AMP), also known as holistic or intensive rotational grazing, divides the land into many paddocks through which the herd is rotated with the goal of using the herd to control invasive grasses and encourage vigorous plant growth. After sufficient grazing, the paddock is given time to recover and native plants regrow stronger than before, including in their roots. Improved root growth increases SOM and sequesters carbon underground.[24]

There is significant disagreement in the literature on the benefits of AMP grazing, with many studies finding little improvement in yields of forage or beef. However, conservation ranchers continue to swear by the practice and some analyses of landscape changes after adoption of AMP grazing show significant improvement in conservation value.[25] In spite of this, there is solid evidence that these methods do sequester additional carbon, even if they do not improve yields.[26]

Numbers on current AMP grazing practice are hard to come by, but according to the Iowa Beef Center survey only 16 percent of Iowa farmers used seven or more paddocks on their grazing land. Similarly, the Savory Institute, a nonprofit that advocates for holistic grazing, estimates that their practices are used on less than one percent of the world's rangelands.[27] Large-scale adoption of AMP grazing faces barriers like those found in the timber and crop industries, including measurement and verification difficulties, labor inputs, and high initial costs. In particular, the cost of creating paddocks can add up quickly, with costs up to $10 per acre.[28]

While landowners face significant economic barriers in establishing terrestrial carbon farming on their land, other challenges also exist. Climate politics is divisive and massive swings in government policy can occur with each new election. Concern over frequent changes in government policy is one concern pointed to by farmers.[29]

While carbon markets are largely not government controlled in the US, nations like Australia have experienced this more directly, with continual changes in government policy increasing the risk facing carbon farmers. Reliable information is also a challenge for prospective carbon farmers with limited data on carbon prices, the cost of practices, and the effect on business.[30] Once a farmer has overcome these economic barriers and invested in carbon sequestration, carbon markets present their own set of challenges.

Carbon Market Challenges

There are two main types of carbon offset markets: compliance and voluntary. Compliance markets function under government regulations that cap the amount of carbon a firm can emit and allow for the purchase of offsets and trading of carbon allowances. Voluntary markets function without government mandates and are where most companies currently purchase offsets as part of their net-zero goals. Emerging voluntary markets face a lack of regulation and oversight, allowing for both innovation and fraud. Concerns over offset market effectiveness relate to three main areas: additionality, verification, and measurement of sequestration.[31]

Additionality requires that a conservation project provide environmental value beyond what was already provided before the project. For example, selling offsets for carbon sequestered by an existing forest would not lower carbon levels.

Figuring out whether an offset project is additional, however, can be challenging. Carbon sequestration occurs all the time from normal land management practices (e.g., traditional farming, grazing, and forestry). Determining additionality requires comparing it to the hypothetical scenario where carbon offset revenue was not available.[32] In other words, if the project was not undertaken for the sole purpose of selling carbon credits, it does not provide additionality.

The issues of measurement and verification come from the difficulty and costs associated with measuring carbon. Not all offsets are created equal, and buyers want high-quality offsets that will last for long periods of time and reduce greenhouse gases. Ensuring this requires intensive tests to establish baseline carbon levels and continued monitoring to ensure that the project sequesters carbon. Due in part to this complexity and associated costs, investors have been wary of carbon farming and sequestration on agricultural lands.[33] In total, only two percent of all carbon sequestration projects come from agriculture.[34]

This is due in large part to the high transaction costs associated with carbon farming. Accurate soil carbon testing requires large numbers of samples from a single property as the amount of carbon sequestered can vary greatly even over a single farm. In addition, direct soil tests are not always simple and may require expensive equipment depending on the type of sequestration practice and the depth of the roots.[35]

Even though direct soil tests are the most accurate method, there is disagreement over their precision in the literature, which disincentivizes both investors and landowners from participating.[36] In total, transaction costs—which also include insurance and regulatory approval—add up quickly and can make up anywhere from 25–75 percent of the total cost of a sequestration project. One analysis suggests up to 270 percent of anticipated income from offset sales goes to transaction costs.[37]

The current structure and requirements of carbon markets are likely insufficient to meet the challenges of large-scale carbon farming. In the future, carbon offsets may become more valuable and encourage investors to take on the higher costs and risks associated with carbon farming, but until then, terrestrial carbon sequestration will require additional incentives to be viable.

Valuing Co-Benefits as a Solution

Carbon farming faces many barriers, but capturing the value of its co-benefits through incentives beyond carbon markets may help overcome those barriers. The literature on co-benefits points to important non-market values for many conservation activities, including reduced soil erosion and degradation, cleaner water, and better wildlife habitat.[38] In effect, the seller of a carbon offset is generating a positive externality. Thus, the price offered for carbon is lower than the true value of the practice, given its external benefits.

This market failure could be addressed by including co-benefits in offset prices or by creating and expanding markets that trade each co-benefit separately. While including the value of these co-benefits in payments to farmers would incentivize more uptake of carbon farming, measuring co-benefits is often as difficult as measuring carbon.

One option is expanded government support for carbon farming. Because the effects of conservation practices are complex and the benefits wide ranging, this may be the simplest option. American agriculture is already supported by the US government. Farmers received about $22 billion in subsidies in 2019 through a wide array of programs frequently adjusted to encourage different outcomes in the industry.[39] Moreover, programs such as the Conservation Reserve Program (CRP) and Environmental Quality Incentives Program (EQIP), offer billions more to farmers each year. Utilizing some of these dollars to support more carbon farming, is one option for policymakers to consider.

In 2021, the Biden administration supported more regenerative agriculture through increased spending in a cover cropping program as well as an initiative to quantify climate effects of the CRP.[40] The Senate also passed a bipartisan bill the same year to support carbon farming through the creation of a USDA advisory board that will recommend methods of overcoming measurement and verification challenges.[41]

Policy changes like these are good but remain in the early stages. One easier option may be the use of a certification program, like the USDA certified organic, to allow farmers to sell "carbon neutral" products at a premium. This type of certification could help cover the high costs of establishing carbon farming practices.

Farmers are also concerned about the lack of reliable information and the USDA and state extension offices can help overcome this barrier by providing information through its agents. Local extension agents are some of the most trusted government officials in agriculture and would be an excellent way of disseminating these practices to the industry.[42]

Some states, such as Iowa, have already started using their extension programs for just this purpose.[43] Research shows that farmers may even be more interested in the co-benefits of carbon sequestration for the health of their land than possible income from carbon markets. Simply providing free and reliable information through extension offices may be enough to encourage more farmers to take on carbon farming practices for their own sake and without the added income from offset sales.[44]

Innovation is needed to overcome the main issues in carbon farming: the difficulties and costs of measurement and verification. Fortunately, some current carbon offset traders are attempting to solve this problem through innovative technological solutions, including the use of machine learning models that can better estimate sequestered carbon.[45] Current research is also working to improve the accuracy of other methods of estimation, such as eddy covariance, which measures infrared light reflection from soil, as well as carbon budgeting, which predicts soil carbon levels based on pre-measured sequestration capacity of individual plants and land management practices.[46]

More research is needed in these areas, but combining different estimation methods with effective computer models may help reduce verification costs.

Conclusion

Agriculture has latent potential to contribute to lowering greenhouse gas levels, but current incentives do not allow for large-scale implementation. To change this, the best options will be to either value the co-benefit environmental services in a market or use government dollars to help lower initial and transaction costs.

Although carbon farming cannot solve climate change by itself, it is a key piece of the carbon emissions puzzle. The adoption of carbon farming practices would also increase the conservation value of millions of acres of agricultural land and the environmental sustainability of the nation's food system.

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