Can Carbon Find a Home on the Range?

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As concerns over global climate change increase, there is growing interest in the potential for agricultural lands to provide ecosystem services related to carbon sequestration. Many geologic sequestration techniques remain unproven and cost prohibitive; yet, terrestrial sequestration is currently viable, both economically and environmentally (De Steigur et al. 2008). Rangelands are a major land cover in the United States, and particularly the West, accounting for nearly half of the 336 million hectares (Mha) of grazing lands in the U.S. (Schuman et al. 2002). They have received less attention in the literature as potential carbon sinks when compared to forest and crop lands. While the per acre carbon capture potential of rangelands may be less than either crop or forest lands, the scale of rangelands in the U. S. and globally suggests that total carbon sequestration on these lands can impact carbon cycles.

The Chicago Climate Exchange (CCX) has recently initiated a program allowing the trading of carbon credits[14] sequestered in rangeland soils (CCX 2009). Participation in the CCX exchange is currently voluntary, with the specific goal to reduce emissions of greenhouse gases in North America via offset programs (CCX 2009). Due to the voluntary nature of the program, carbon prices have varied greatly, experiencing a drastic drop in response to the current economic situation. As producers have entered the CCX program, uncertainties have arisen about the true costs and benefits of this program. Moreover, further complications have arisen from uncertainty about how agricultural credits will be handled by proposed cap and trade legislation. Agricultural economists must develop a better understanding of how rangeland carbon cycles are impacted by adoption of management practices. It is equally important that the incentives which would motivate producers to participate in these management practices are fully understood. This understanding will help policy makers evaluate the potential effectiveness of alternative carbon sequestration policies on rangelands ex ante.

The State of Knowledge Regarding Carbon Sequestration on Rangelands

Grazing lands occupy 37% of the total land area, or 336 million hectares (Mha), in the US, and represent about 15%[15] of the potential for US soils to sequester carbon (C) (Lal et al. 2003). Grazing lands are typically characterized by short periods of high C uptake and long periods of C balance or small losses (Svejcar et al. 2008). These types of relationships must be accounted for in any long-term economic modeling efforts.

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[14] A credit is measured as a metric ton of carbon.

[15] Lal et al. (2003) base this on grazing lands in the US having the potential to sequester Carbon in the range of 13-70 teragrams (Tg) of carbon per year, mean=42.

Rangeland soil organic carbon (SOC) sequestration rates have been estimated between 0.07 to 0.30 megagrams (Mg) C per hectare per year (Derner and Schuman 2007). Rangelands play an important role in the global C cycle. The large reservoir of sequestered C can be lost from the ecosystem with improper management; yet high rates of SOC accumulation can be attained by improving degraded rangelands. Therefore, a significant store of soil C in carbonate form in semi-arid and arid environments can act as both a sink and a source of C (Follett et al. 2001; Svejcar et al. 2008). The magnitude of soil C sequestration in rangelands depends the following: climatic trends (Derner et al. 2006), plant community (Conant et al. 2001), land management (including grazing, burning, and ecological restoration) (Follett et al. 2001) and disturbances such as recurring drought, nitrogen deposition, and climate variability (Jones and Donnelly 2004; Ingram et al. 2008; Svejcar et al. 2008).

Gaps in scientific knowledge on soil C sequestration in grazing lands are more numerous and prevalent than in crop and forest lands (Derner and Schuman 2007). However, the main considerations in SOC sequestration for grazing lands include the following: 1) in contrast to forests, the aboveground C pool is <5% of total C storage and mean residence time of the aboveground pool is only 1 to 2 years; 2) most SOC is recalcitrant, well-protected from natural disturbances, and generally resists change; 3) major pathways of SOC input are through decomposition of below-ground root biomass, surface deposition of animal feces and decaying litter from above-ground forage; and 4) large perturbations in the SOC pool occur with soil disturbances, such as through wind and water erosion following natural (e.g., extreme weather) or human-induced degradation (Follett et al. 2001). Three main drivers that control the fate of C on grazing lands are as follows: 1) long-term changes in production and quality of above- and below-ground biomass; 2) long-term changes in the global environment such as rising temperatures, altered precipitation patterns and rising CO_2 concentrations that affect plant community composition and forage quality; and 3) effects of short-term weather conditions (e.g. droughts) on net C exchange (Ciais et al. 2005; Soussana and Lüschert 2007; Ingram et al. 2008; Svejcar et al. 2008).

The best management practices (BMP) for sequestering C on croplands and the related economic consequences of those practices have been the subject of a growing research literature (see for example, Antle et al. 2002a; Antle et al. 2002b; Antle et al. 2001a; Antle et al. 2001b). Relatively little research exists related to rangeland C sequestration. Research suggests there are several management practices that can improve the amount of C sequestered on rangelands (Derner and Schuman 2007; Mortenson et al. 2004; Schuman et al. 2002). Campbell et al. (2004) investigate the costs of storing C on Wyoming rangelands by means of inter-seeding *falcata* alfalfa, better utilization of rangeland by implementing mineral or water placement, and sagebrush thinning on a central Wyoming ranch. Based on secondary data the authors conclude that Wyoming ranchers could potentially compete with crop and forest lands for sequestering C on a cost per unit basis. Schuman et al. (2001) suggest that the adoption of BMP such as proper stocking rates, adaptive management and destocking during drought conditions on poorly managed rangelands (113 Mha), could result in sequestration of 11 Tg C per year. Continuation of these BMP on the remaining rangelands would avoid losses of 43 Tg C per year. Many rangelands are nitrogen (N) deficient. N additions, through interseeding of legumes, can increase both forage production and C sequestration (Mortenson et al. 2004, 2005). Additional research is needed to determine how introduction of perennial legumes affects C and N cycling in rangelands. N additions in labile, legume-based organic materials may increase turnover rates and help mineralize stored SOC (Wedin and Tilman 1996). Soil organic C sequestration rates decrease with longevity of the management practice

(Derner and Schuman 2007), indicating that ecosystems reach a 'steady-state.' Additional changes in inputs would be required to sequester additional C (Conant et al. 2001, 2003; Swift 2001).

Relevant Issues for Economic Analyses of Carbon Sequestration on Rangelands

The above literature suggests the need for economic analyses of alternative management practices. The heterogeneity of rangelands offers a further research challenge. Actual rates of sequestration are likely to vary, complicating any land-scale modeling efforts aimed at estimating potential carbon storage. The CCX program treats rates of carbon sequestration as fixed across large eco-regions as long as stocking is 'moderate'. There is little evidence that the CCX estimates of sequestration potential provide accurate information about actual storage potential, especially across various management practices.

Some range livestock producers in Wyoming and the West have enrolled in the CCX program while others have expressed potential interest in enrollment. The CCX requires a minimum of 10,000 tons of CO_2 in order to register to trade credits in the market, requiring most producers to use an aggregator in order to trade. Aggregators act as market intermediaries to pool credits from many producers to deliver the minimum amount required for participation. The services of the aggregator require payment (usually 8-10% of the value of credits they sell) creating additional costs to producers contemplating program enrollment. Enrollees in the program are responsible for paying registration and trading fees ($0.15 and $0.05 per credit respectively) as well as verification fees (between $0.10 and $0.12 per credit) (Ribera et al. 2009).

The CCX requires a 5-year contract to be allowed to sell carbon credits. If a producer discontinues the practices required for enrollment, they are required to re-pay previously earned credits. Producers must also have a grazing management plan, including a drought contingency plan, and must register each pasture with a Farm Service Agency (FSA) number separately (Agragate 2009).

There has been little research to date showing how costs of enrollment and compliance compare to the stream of revenues received from selling credits in the current CCX Rangeland Soil Carbon Offset program. Such information would help producers determine whether the program provides sufficient incentives to adopt the practices necessary to meet program requirements. Current net per acre payment levels may not be very attractive to local producers. Current per acre sequestration rates under the CCX program range from as low as 0.12 credits per acre in the Northwestern Wheat and Range Region, Rocky Mountain Range and Forest Region and Northern Great Plains Spring Wheat Region to as high as 0.27 credits per acre in the Western Great Plains Range and Irrigated Region[16]. The highest carbon prices received to date has been $7.40 per credit in August 2008, which translates to per acre payments ranging from $0.68 to $1.64 across the differing regions. However, since 2003, the average price of carbon has been only $2.47 per credit, and this price translates to per acre payments of only $0.14 to $0.45 across the differing regions.[17] If cap and trade legislation is

[16] These credit rats are based on rangeland in a "Non-Degraded" state per CCX regulations (CCX 2009). Map of Land Resource Regions is available at: http://www.chicagoclimateexchange.com/docs/offsets/CCX_Rangeland_Soil_Carbon.pdf.

[17] Closing carbon credit prices are available at http://www.chicagoclimatex.com/market/data/summary.jsf. Per acre payments were calculated by the authors based on representative contract fees and costs from Agragate (2009) including a 10% aggregator fee, $0.10 per acre verification fee, and $0.20 per credit CCX trading cost.

enacted, the increase in carbon prices could raise payment levels to $8 to $11 per acre on rangelands (Ribera et al. 2009), which may make program enrollment more attractive to producers.

Ranchers are faced with the opportunity of adding a carbon credit enterprise to their existing operations. It is important operators understand how this new enterprise will impact the existing livestock enterprise. Some proposed management practices, such as reduced stocking rates, would likely have a direct impact on the livestock enterprise; however, other management practices, such as legume seeding, could create a positive externality for the livestock enterprise. Knowledge regarding these interactions, and the impact on profitability of alternative management practices, will be important for producers evaluating program participation.

If policy makers want to encourage sequestration on rangelands then it will be important to understand producers' attitudes toward carbon sequestration and alternative management practices. Relatively little research related to preferences of agricultural landowners to provide carbon sequestration as an ecosystem service has been published. Stavins (1999) used a revealed preference model of land use change to indicate costs associated with current policy instruments to sequester carbon are sensitive to land quality. Lubowski et al. (2006) used a similar approach to conclude policies impacting forestation or deforestation need to be evaluated in regards to sensitivity of total sequestration. Shaikh et al. (2007) survey agricultural landowners in western Canada regarding preferences for participating in a tree-planting program. They elicit willingness to accept (WTA) values from a discrete choice random utility model regarding compensation for landowners associated with tree planting compared to the resulting carbon sequestration benefits. They conclude that estimates of WTA are less than forgone returns from agricultural activities, but that the average costs of creating carbon credits exceed their projected value under the CO_2 trading scheme. Olenick et al. (2005) conducted a survey of western Texas landowners to investigate perceptions related to provision of ecosystem services from rangelands and found that respondents disapproved of programs that would encourage the proliferation of woody plants in an attempt to increase carbon sequestration. While these publications offer some insights into producers' preferences regarding carbon sequestration, more research targeted at rangeland production systems and alternative management practices would be beneficial.

Discussion

Research on the economic implications of rangeland carbon sequestration is in its infancy. There is much that economists can contribute to decision making for both landowners and policy makers. Modeling efforts that incorporate the long-term dynamic nature of the carbon cycle to capture the costs and benefits of engaging in carbon sequestering activities will help policy makers and landowners. These costs and benefits must include both the direct costs associated with program enrollment and the induced costs and benefits associated with changes in linked enterprises such as livestock production activities. Analyses should address policy impacts on individual producers as well as the potential for large-scale land-use changes. This will require knowledge of producer preferences for management practice adoption, individual benefits and costs, and the incorporation of contract and or price risk. While the state of knowledge regarding actual sequestration rates on rangelands is currently limited, economists can play a crucial role in leading multi-disciplinary research focused on management practices that show potential for producer adoption. Results from these types of research efforts will be helpful to both land managers and policy makers when evaluating whether carbon can find a "home on the range."

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