COLLEGE OF AGRICULTURAL, CONSUMER AND ENVIRONMENTAL SCIENCES

Carbon Sequestration on Rangelands: A Primer

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pubs.nmsu.edu • Cooperative Extension Service • Guide B-827

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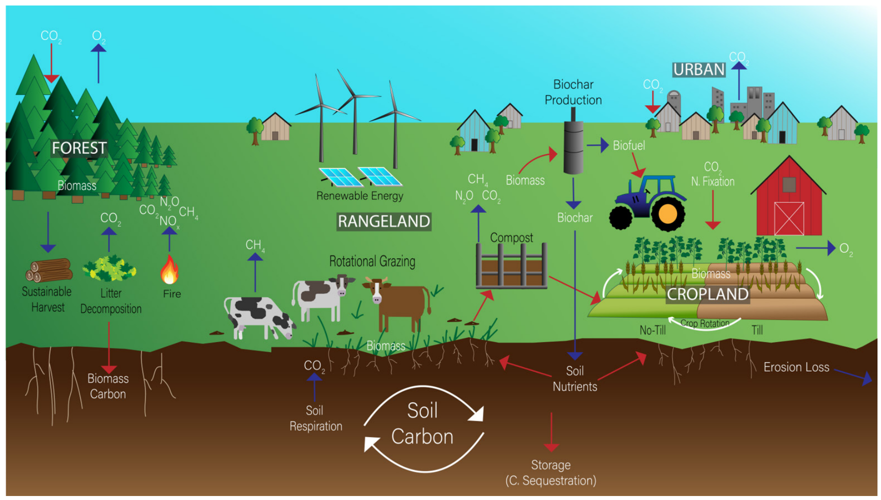

***Figure 1.* Illustrative schematic of the carbon cycle in forests, rangelands, croplands, and urban environments with potential management practices to increase carbon sequestration or reduce carbon loss. Figure created by Dr. Rajan Ghimire, NMSU.**

INTRODUCTION

Climate and environmental changes caused by greenhouse gases—and how to compensate for these changes—are increasingly popular topics. Rangelands comprise approximately 760 million acres of the contiguous United States land base and are being examined for their potential for climate change correction. Rangeland resources represent approximately 15% of the soil carbon stocks and can act as an important carbon sink, emphasizing the importance of carbon sequestration in rangeland management objectives. Additionally, there may one day be an opportunity for ranchers to capitalize on climate-friendly management practices through a carbon credit system. However, there is still much to be done before these subsidies can be implemented.

Rangeland carbon baselines are uncertain and depend on locality, vegetation, soil conditions, climatic events, and management practices. Understanding the carbon cycle and assessing current carbon levels will help ranchers be prepared when carbon credits come to fruition. Although appealing, carbon quantification and sustainable carbon farming must be considered locally before "buy-in."

THE CARBON CYCLE

Carbon is the currency of most biological systems and is constantly cycled through the earth (Figure 1). The sun's energy fuels the carbon cycle, a natural process that moves carbon from our atmosphere to the earth and back. Carbon sequestration captures, secures, and stores atmospheric carbon in plants, soils,

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and oceans. The opposite process is carbon emission, where carbon is emitted through actions like soil respiration and the burning of fuels. A balance between sequestration and emission, known as carbon flux, provides ideal conditions for life on Earth. Eighty percent of all carbon is stored as inactive, deep within the earth and oceans. The earth contains five times more actively cycling carbon than the atmosphere.

Humans have the innate ability to access and utilize carbon resources for their benefit. One such resource is deeply sequestered fossil carbon (fossil fuels). The advent of the industrial era has made humans reliant on fossil fuels. When fossil fuels are burned, carbon dioxide (CO2) is emitted, creating an atmospheric carbon blanket that traps the sun's heat. Climate change is thought to result from carbon being emitted faster than it can be sequestered.

Carbon ranching is the process of implementing a series of land management practices designed to either increase carbon stocks or reduce the loss of biogenic carbon through plant, soil, animal, and microbial processes. Focusing on rangeland management strategies to address carbon sequestration is one way ranchers can positively alter the rangeland-carbon cycle.

ASSESSING CARBON FLUX ON RANGELANDS

Rangelands are defined as uncultivated lands of natural plant cultivars that provide food, fiber, and ecosystem services (Society for Range Management, 1998; Holechek, 2011). Eighty percent of New Mexico is classified as rangeland and comprises grasslands, shrublands, and forestlands. Carbon sequestration is not a complex process; it removes carbon dioxide from the atmosphere and stores it in stable organic forms that enhance soil health and promote plant growth. Nevertheless, rangelands are highly dynamic, with variability between plant species, land management, soil composition, and climatic conditions at both the local and landscape levels. Quantifying carbon sequestration in such a dynamic system is where the complexity lies. Multiple variables and processes must be considered to adequately assess and quantify the resulting carbon flux.

Plant species

Grasslands are considered a more reliable resource for carbon sequestration than shrublands or forests due to greater belowground carbon allocation (Lorenz & Rattan, 2018; Li et al., 2018; Viglizzo et al., 2019). For instance, when a wildfire occurs on grasslands, belowground carbon often remains unchanged, whereas when a forest burns, large amounts of the aboveground carbon are released back into the atmosphere, changing the landscape from a carbon sink (sequestering) to a carbon source (emitter). Predictive modeling showed that carbon fluxes are context-dependent and can be altered by climate change. For example, when extreme environmental conditions persist (e.g., increases in temperature and reduced precipitation), grasslands provide substantially more carbon sequestration than forests (Dass et al., 2018). However, under the same prevailing conditions, woody plants can capitalize on increased atmospheric CO2 and rising temperatures to expand and encroach (Archer et al., 2017), making grasslands harder to sustain. Because vegetation types vary widely at the landscape level, establishing a carbon baseline for potential increases in carbon sequestration needs to be done locally.

Grazing management

Livestock grazing is the primary use of rangelands. These lands have the potential to sequester 2.3 to 7.3 billion metric tons of carbon dioxide (CO2) equivalents per year (Bai & Cotrufo, 2022). This would help offset approximately 3.3 % of U.S. CO2 emissions from fossil fuels and enhance rangeland soil quality. Lack of sequestration is thought to be due to the removal of aboveground plant material through grazing. However, well-managed grazing (i.e., removal of less than 40 percent plant parts using light to conservative grazing) has been shown to increase above and belowground plant production, nutrient cycling through animal excrements, acceleration of plant litter decomposition, and increased incorporation of decadent material into the soil through trampling (Derner & Schuman, 2007; Shuman et al., 1999; Holechek et al., 2020). These ideas paint an appealing picture in favor of grazing management and carbon sequestration, but overall, research findings show a large variability of results and have been inconclusive. While some studies have found increases in soil organic matter (SOC) from grazing, others found no change or even decreases in SOC (Piñeiro et al., 2010; Derner et al., 2019). The lack of direct consideration of carbon sequestration in grazing management decisions is likely due to many of the uncertainties associated with site-specific effects and climatic variables, again emphasizing the need for conducting carbon assessments at the local level.

Soil composition

Soils hold over three times as much carbon as the atmosphere (Lehmann & Joseph, 2009), more carbon than the atmosphere and terrestrial plant mass combined. Further, every ton of carbon stored in the soil removes or retains 3.67 tons of CO2 from the atmosphere. Most of this sequestered carbon (SOC) lies within the top 6 inches of the soil layer, and it is no coincidence that this is where 70 percent of plant roots exist (Gill et al., 1999). Approximately 50 percent of all soil organic matter - discomposing plant roots,, litter, and microbial biomass ¬- is made up of SOC. Annual grasses have a shallower root system and quicker lifespan, contributing less to soil carbon than perennial grasses (Yang et al., 2019). Soil type and texture also influence potential carbon storage. For instance, finer-textured soils (i.e., clay) tend to have a higher organic carbon content than coarse-textured soils (i.e., sand), thereby influencing soil carbon sequestration directly (Ingram & Fernandes, 2001). It is thought that soils richer in clay or silt produce smaller aggregates that protect SOC from excessive microbial degradation and loss. Soil samples at differing layers at the local scale are needed to properly assess carbon storage and potential sequestration along the soil profile.

Climate conditions

Long-term studies have found that carbon sequestration is influenced more by uncontrollable variables such as precipitation and temperature than by human-controlled variables (Derner et al., 2019; Ingram & Fernandes, 2001). For instance, the Great Plains exhibited short periods of high soil carbon accrual followed by long periods of very little soil carbon loss when normal precipitation occurred (Svejcar et al., 2008). Drought was found to reduce this sequestration and loss timeframe. Thus, in the arid southwest, increases in soil carbon sequestration by conservative management practices are likely offset by low precipitation and frequent droughts. Although climatic events cannot be controlled, precipitation can be measured to determine whether carbon stocks and balances are either positive, negative, or neutral at the local scale.

CARBON CREDITS

Increasing rangeland carbon sequestration has the potential to provide additional income for good management practices on ranches and farms. There are talks of creating a 'carbon bank' that would allow corporations to buy carbon credits to offset carbon emissions. Several farm, food, forestry, and environmental groups have pushed the idea of providing early adoptees a higher monetary incentive and lead the way for others in practices that improve soil carbon and advance agriculture's ability to become a solution to climate change. Although there are currently no private credit markets or carbon payment programs specific for rangelands, several emergent initiatives are being hashed out for consideration.

Many technical and regulatory barriers must be overcome at the federal level before instrumentation and implementation. Some environmentalists have voiced concern that even if regulatory hurdles are addressed, providing carbon credits will not be enough to promote a sustainable carbon balance and overcome current greenhouse gas emissions. No matter their concern, it is a starting point for assessing rangeland carbon flux and whether a particular area can promote good carbon management.

Baselines must be established before a 'carbon bank' can be established. Carbon sequestration needs to be assessed at the local scale and simplified to a level where producers can feasibly achieve measurable carbon capture. There is concern that some areas of rangeland will benefit from carbon management while leaving other lackluster areas out. A uniform and equal carbon opportunity plan must be employed based on carbon sequestration potential rather than quantity captured.

For those that may not have prime carbon sequestration rangelands, affording the cost of implementing environmentally beneficial measures without some financial assistance may be difficult. Funding opportunities need to be provided, like the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service's Conservation Stewardship Program (NRCS CSP), which covers the cost of implementing specific conservation measures and allows an avenue for carbon management.

Carbon credits can potentially provide extra income to private ranches, but currently, there are many unknowns. One of which is whether rangelands can provide enough carbon sequestration to offset ongoing climate change effects. Starting now to assess carbon flux on individual rangelands will establish baseline information, setting the stage for additional income if carbon credits become a reality.

WHERE TO START

The first step land managers can take is to begin assessing and recording their own rangeland conditions to estimate current carbon levels and establish a baseline for potential carbon sequestration. Pastures should be looked at for their likelihood of increased vegetation quality and abundance, both above and below ground. Managers should also consider monitoring grazing intensity to document the effects on root biomass, correlating precipitation to vegetation response, and evaluating the economics and potential for soil improvements. Ideally, assessments should be done in the context of establishing a carbon baseline for future sequestration opportunities.

Further, farming and ranching operations should look into conservation programs that have historically been and are currently being offered by the USDA. The Soil Bank (Title 1 of the Agricultural Act 1956) and NRCS CSP programs are the most widely known. These programs reward land managers who implement beneficial rangeland monitoring and grazing programs. Several conservation practices that are thought to improve soil conditions and sequester carbon have been identified by NRCS. These practices also provide other benefits in relation to water retention, hydrological function, biodiversity, and resilience. Ranchers interested in exploring possible government programs regarding carbon sequestration should consult with the USDA-NRCS, USDA Farm Service Agency, and the NMSU Cooperative Extension Service to keep informed of any programs that may reward them for implementing specific conservation practices.

Finally, the USDA is putting tools in place to help assess carbon flux on personal operations. The tools, called COMET-Farm (https://comet-farm.com/) for Ag farming and COMET-Planner (http://comet-planner.com/) for Ag ranching, provides a modeling framework to evaluate local land management practices and climate effects on carbon sequestration and mitigation of greenhouse gases. It can be used as a sole source, inputting personal data to generate reports, or as a template or guide for carbon sequestration management options. This is only one avenue currently available, and more will likely be developed in the coming years.

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