Soil carbon monitoring program for ranches in dryland ecosystems

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Abstract

Implementation of ranching practices that lead to greater soil carbon sequestration has become increasingly important due to rising atmospheric CO_2 levels. Sustainable ranching practices are suggested to improve soil health and sequester more carbon in the soil. However, there is a paucity of measured data from replicated on-farm studies to support this premise. Thus, we developed a soil carbon monitoring program for a ranch located in the state of Oregon. Our monitoring program is focused on measuring the net carbon budget and the soil carbon sequestration totals. To achieve this goal, we combined field-sampling data with the COMET-Farm model. A total of 21 sites were sampled over a two-year period from 2020-2022. Soil was sampled at 0-20cm and 20-60cm depth for soil organic carbon (SOC), nitrogen (N) and standing plant biomass. SOC from the top 20cm increased (P <0.05) from 32.70 ton/ha in spring 2020, to 40.44 ton/ha in spring of 2022. Total soil carbon sampled during the fall of 2020 increased (P=0.02) from 29.31 ton/ha to 42.69 ton/ha in fall of 2021. Carbon pool at 60cm depth was more stable and mostly remained unchanged (P >0.05). The COMET model revealed that the ranch operations are avoiding an estimate of 8880 tons of emissions of CO_2 equivalents per year. The results indicated that the monitored ranch is functioning as a carbon sink. Our next step is to implement the monitoring program on the other ranches participating on this study. Rangelands have high potential to sequester carbon if managed properly, which offers added value to products or commodities produced on rangelands.

Introduction

Rangelands are considered as critical ecosystems for multiple goods and services including water holding capacity, recreation, wildlife habitat and soil carbon sequestration (Derner and Schuman, 2007). In recent years, soil carbon sequestration has become increasingly important as the rises in atmospheric CO_2 from fossil fuel combustion and land use changes require a different approach to mitigate the effects of global warming (Lal, 2004). For an ecosystem to become a carbon sink, sustainable management practices such as minimum/no till farming, integration of cover crops in rotations, adaptive grazing management and optimized nitrogen management are essential (Wezel et al. 2014). Practices that improve soil carbon sequestration also improve ecosystem soil structure, nutrient cycling, and reduce soil erosion (Derner and Schuman, 2007). Thus, soil carbon sequestration is deemed an excellent indicator of sustainable land management.

Measuring carbon sequestration is particularly difficult in rangelands because of their vast expanses and difficult access. Their natural vegetation makes them best suitable for low-cost animal grazing (Papachristou et al. 2005). However, livestock production has been scrutinized from its environmental impact standpoint in semi-arid environments (Johnson et al. 1996; Lassey, 2008; Pinares-Patiño 2013). This led to land managers to adopt more sustainable ranching practices to reduce their carbon footprint. However, there is still a need for more research to develop proper carbon policies and develop advisory tools and practices for land managers (Derner and Schuman, 2007). Therefore, there is a critical need to develop soil carbon monitoring programs to better understand soil carbon sequestration in rangelands, and to assist the decision making to implement novel management practices to benefit soil carbon sequestration. Here, we conducted a soil carbon monitoring study for a sheep ranch in eastern Oregon that had 20 years of recorded sustainable ranching practices to see how soil carbon sequestration changes over time. Our objectives are to determine the ranch net carbon budget and the soil organic carbon sequestration totals.

Methods

The study area is in Wasco County, Oregon. The ranch has an acreage of 32,323 acres, all private deeded with a diverse agricultural operation, primarily raising cattle (cow/calves) and sheep (ewes/lambs), combined with hay and grain production. The ecosystem is composed by open shrub- sagebrush steppe grasslands with the presence of juniper in the drainage slopes and bottoms of the canyons. Management practices primarily focused on minimum tillage in dryland crop production, incorporation of forage legumes in crop rotations, restoration of riparian areas, off stream water development, wildlife conservation areas, etc.

Soil was sampled in spring and fall seasons from 2020 to 2022. Soil was collected using a 2-inch bucket auger (Forestry suppliers, Jackson, MS). A total of 21 representative sites were selected for sampling based on land use, soil type and vegetation. Five soils samples were collected at each sampling point (replications), then mixed into one single sample per site. Soil was collected at 0 to 20 cm depth, and at 20 to 60 cm at each fifth sampling point. Soil samples were sent to the Soil Health Laboratory at Oregon State University, Corvallis, OR, USA for soil carbon and nitrogen content analysis as well as bulk density estimates. Bulk density was estimated in the lab after the sample was oven-dried at 105°C for 48 h and weighed, then bulk density was calculated as the ratio of the mass of oven-dried soil sample to a given volume (g cm^{-3}). The soil carbon mass per area (Mg C ha^{-1}) was computed with the formula: Soil C (Mg ha^{-1}) = BD (g cm-3) x C % x d (cm). Where: d = soil depth (cm), BD = bulk density in g cm 3, and C % = percentage carbon content of the sample. Then, the soil carbon mass per area was transformed into tons / hectare.

The COMET-Farm model, a web greenhouse gas accounting system was used to estimate the ranch net carbon budget. Historical, baseline and future scenario management data was input for all the ranch allotments. This model estimates how many greenhouse gas emissions are avoided (or released) based on the past and current management and how future management can influence such emissions. Since COMET-Farm is designed for crop farm operations, we adjusted our scenario to simulate grazing by creating parcels with constant perennial grass cover without any type of management except for grazing. Each parcel was less than 1100 acres in size, larger parcels had to be subdivided and managed as individual units.

Data was analysed using a non-parametric Wilcoxon-test as parts of the dataset did not follow the assumptions of normality and to compare means between years.

Results and Discussion

Soil carbon

Sustainable farming practices are expected to increase soil organic carbon sequestration (Luo et al., 2010). The monitored ranch in this study has 20+ years of recorded sustainable management practices. We found that soil carbon sampled at 20 cm depth during Fall of 2021 was greater (P=0.02) compared to the carbon sampled at the beginning of our study in Fall of 2020 (Figure 1). Soil carbon sampled at 40-60 cm depth in the Fall of 2020 also tended to be greater (P= 0.08) compared to the Fall of 2021. Carbon sampled during spring of 2020 and 2021 were not statistically different (P= 0.30), but soil carbon sampled in spring of 2022 was greater (P= 0.05) than soil carbon sampled in 2020 and greater (P= 0.01) than soil carbon sampled in 2021. These fluctuations in soil carbon also follow the precipitation patterns in which dry years are expected to minimize soil carbon sequestration as a reduction in plant production. Soil carbon sampled at 40-60cm was similar (P= 0.84) in Spring 2020 and Spring 2021. However, soil carbon sampled in 2022 was greater (P= 0.01) than soil carbon sampled in 2021. On average, soil organic carbon was estimated to have increased from 32.70 ton/ha in spring of 2020 to 40.44 ton/ha in spring of 2022. Overall, for the entire operations this represents an increase from 423,463 tons/ha to 523,657 tons/ha in soil carbon between 2020 and 2022.

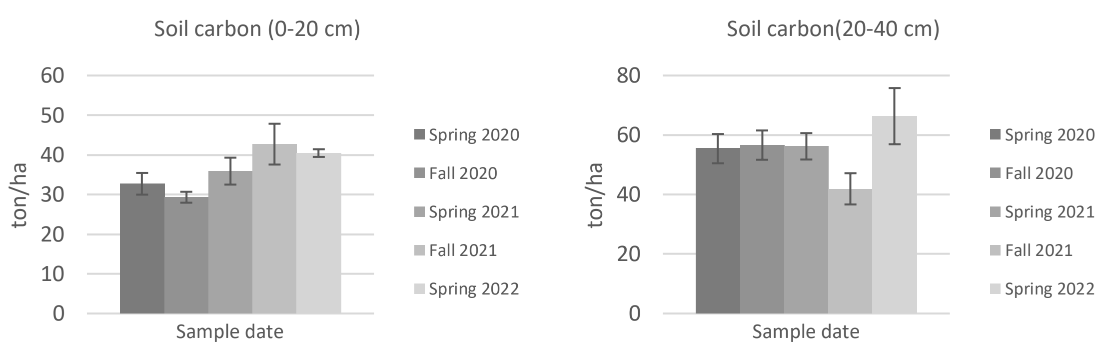

Figure 1. Soil organic carbon concentrations (ton/ha) at two (0-20 and 60 cm) soil depths.
Data are means ± standard error.

The COMET model estimated that the entire operations across 32,000 acres are avoiding 8880 tons of emissions of CO_2 equivalents per year. We also found that without sustainable management practices the ranch will avoid an estimate of 7,360 tons of CO_2 equivalents per year. This proves the potential of rangelands to sequester carbon (Derner and Schuman, 2007). However, aside from soil carbon we detected that the levels of nitrogen in soils remained mostly unchanged across the ranch. Therefore, the development of additional practices such as incorporation of legumes in the rangelands might further enhance the rangelands' ability to sequester and store carbon.

Conclusions and/or Implications

More research and monitoring programs are needed on multiple areas to better understand the drivers of carbon sequestration. This ranch had a long-term recorded history of sustainable ranching practices that provided a unique opportunity to evaluate the system's carbon totals and estimate its carbon budget. An adequate carbon monitoring program requires several years of data collection to detect trends in carbon sequestration or estimate the system's equilibrium. Therefore, we still need more years of soil sampling and evaluation of alternative management options. The ability to incorporate novel technologies such as digital modelling provides extra opportunities to understand the effect of our management actions in the system over time. In the meantime, this monitoring program provides valuable information and evidence that sustainable ranching has a beneficial impact on soil carbon sequestration. Our findings and experience will be used to expand this monitoring program into other 8 sheep ranches located in Colorado, Utah, Nevada, and California.

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