Grass Carbon Allocation Potential under Different Clipping Frequency and Irrigation Amount: Implications for Mitigation and Rangeland Management

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Research Brief

Feed the Future Innovation Lab for Collaborative Research on Adapting Livestock Systems to Climate Change

TRB-09-2015 East Africa TIRI Research March 2015

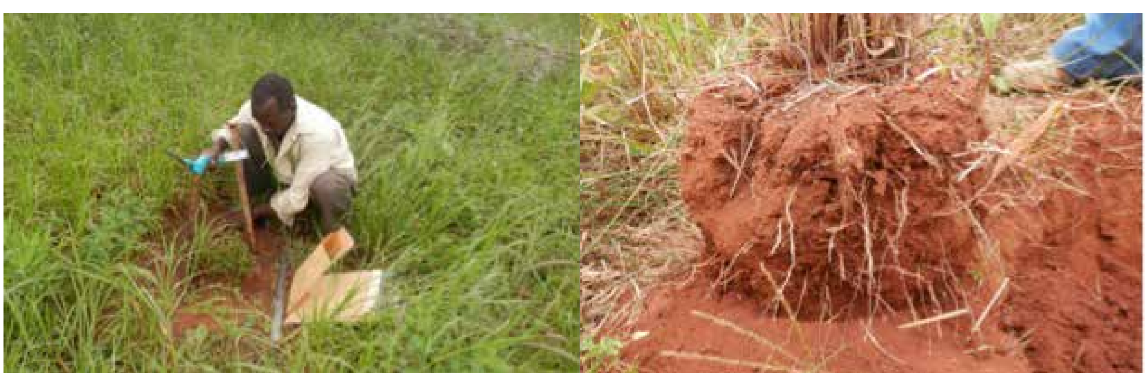
Abstract

Knowledge regarding the response of the carbon allocation potential of grasses to grazing and varying rainfall amounts has paramount importance in devising appropriate strategies for mitigation of CO_2 emissions in grazing systems. Yet, understanding how individual grasses respond to the main rangeland stressors—herbivory and drought—has been hampered by the difficulty of quantifying grass carbon (C) allocation. As a result, little experimental research has been conducted to address the effects of these two stressors on the atmospheric CO_2 mitigation potential of rangeland grasses. In this study, researchers experimentally quantified above- and below-ground C of selected native grass species in both mature grass tufts and pot and plot trials under variable irrigation amounts and clipping frequencies in the Borana rangelands of southern Ethiopia. Results indicated that above-ground grass organic carbon increased significantly by up to four times in unclipped compared to clipped grass tufts. Conversely, below-ground grass organic carbon was significantly higher in clipped compared to unclipped tufts. Analysis of the combined impact of clipping frequency and irrigation amount showed that both factors significantly influenced organic carbon content. In these irrigation scenarios, above- and below-ground organic carbon content was about three times higher in clipped than in unclipped treatments—suggesting the climate change mitigation potential of grazed grasses. It is recommended that appropriate grazing management be used to maintain the long-term carbon sequestration and storage potential of grasses amid existing herbivore pressure and increased rainfall variability due to climate change.

Grasses may mitigate increasing atmospheric CO_2 concentration

Atmospheric carbon dioxide (CO_2) is one of the most important anthropogenic greenhouse gasses driving climate change and has increased from a pre-industrial value of about 280 ppm in 1750 to 391 ppm in 2011. Although fossil fuels use is the primary source of atmospheric CO_2, changes in land use such as conversion of grasslands to croplands also make a significant contribution.

Grasslands have a high potential for atmospheric carbon (C) sequestration and storage. Grasses have a below-ground biomass component that stores absorbed C, with global grasslands showing an increased storage potential beyond that of global forests. Compared to woodlands, grasslands can store more C and can potentially sequester similar amounts of soil C as native forests. Grasses also contribute more to soil C content than legumes, further highlighting their carbon sequestration potential. The high CO_2 sequestration potential of grasses can be used to offset anthropogenic emissions and play a significant role in climate change mitigation.



Grass tufts above-and below-ground carbon determination by destructive method. (Photo credit: Samuel Tuffa Kawo.)

Herbivory and precipitation limit the carbon sequestration potential of grasses

Grasslands' ability to sequester and store a large amount of soil C is primarily controlled by two main stressors: herbivory and precipitation. Herbivory removes above-ground biomass as well as changes the below-ground C stocks of rangeland grasses. Some studies suggest that heavy grazing decreases soil carbon with little recovery following grazing cessation. Other studies show an increase in root biomass under biweekly- to heavy-grazing, and hence, higher soil-plant system C pools. However, little is known about how plant-herbivory interactions affect the overall C balance. Furthermore, climate change will result in multiple stressors on animals and plants in the coming decades. There is a likelihood of increases in both the amount of heavy precipitation and the intensity of drought in the future due to climate change. Up to now, little is understood regarding how the combination of these stresses will affect the C storage potential of grass layers.

To understand the effects of clipping on carbon sequestration potential of grasses, researchers tested the effects of clipping frequency on mature grass tufts of already established grasses and newly established grasses of the same species (*Cenchrus ciliaris* and *Chloris gayana*) in the Borana rangelands of Ethiopia. In the first of two experiments, researchers evaluated grasses at three research sites under natural rainfall conditions with *C. ciliaris* grown at two test sites and *C. gayana* at one. In the second experiment, researchers established seedlings of the two grass species and transplanted them to evaluate how the combination of clipping frequency and irrigation would influence carbon sequestration potential of these grasses in pots and plots. For the latter experiment, rainwater was harvested during the rainy season and stored for later application during the dry season.

Clipping frequencies negatively affect the carbon sequestration potential of mature grasses

For the first experiment, researchers selected a total of 95 similarly-sized tufts of the two grass species at the three research sites. At the first location, 35 cages were set up above *C. ciliaris* tufts to prevent grazing in an otherwise grazed area. Here, in seven replications, four clipping frequencies (weekly, biweekly, monthly, or no clipping) were used to simulate grazing pressure. Adjacent, caged tufts of similar size were grazed by cattle on a weekly basis and observed to capture variations that would occur due to different stimulating effects of grazing and clipping. At the second location, *C. gayana* tufts were dominant and researchers used three clipping frequencies (weekly, biweekly, and no clipping) with ten replications each. At location three, *C. ciliaris* was dominant and the same ten-replications of three clipping frequencies were applied. Locations two and three were completely fenced off from any domestic and wild grazers, though grasses here had been hand clipped at the end of the rainy season for hay making since 2008 and 2001, respectively.

Results of the trials indicated that above ground organic carbon (OC) was significantly higher in the unclipped compared to the clipped treatments. The below-ground OC stock was not significantly different for treatments at locations two and three for *C. gayana* and *C. ciliaris*, which may be attributable to the grasses developed root systems' low growth rate.

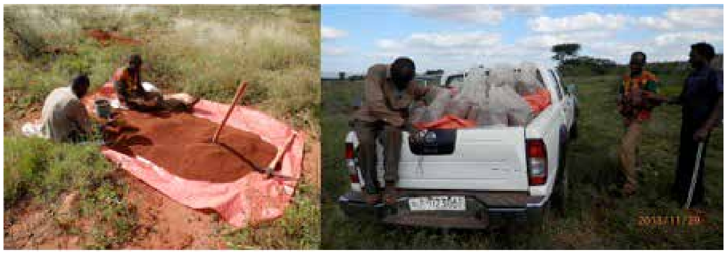
The significantly higher above-ground OC in unclipped compared to clipped treatments indicated that grazing might play a significant role in reducing the carbon sequestering potential of established grasses due to loss of photosynthetic plant tissue. On the other hand, these already established grasses exhibited enhanced below-ground OC under clipping and weekly grazing compared to the unclipped control grasses in location one. Researchers found that weekly grazing and clipping had the same effect, suggesting that clipping can appropriately simulate the impact of grazing on grass C sequestration potential.

Clipping frequencies positively affect the carbon sequestration potential of young grasses

For the second experiment, the rainwater collected during the rainy season was used for dry season irrigation treatment as a second variable in addition to clipping frequencies. Irrigation resembled the conditions of a typically wet April—the main growing season of the two focus grass species. The average April rainfall (158.8 mm) of 30 years (1984-2013) was divided by the average number of rainy days (~15 days) for this month, and then used for calculating the volume of water to be added as average rainfall treatment. From this calculation two additional scenarios of a 5% rainfall increase and 30% rainfall decrease were derived as additional treatment variables.

Both grass species were grown in pots and plots, grouped in blocks, and subjected to a random combination of one of four clipping frequencies (weekly, biweekly, monthly, or no clipping) and one of three irrigation amounts (average rainfall, 5% increased rainfall, or 30% decreased rainfall). The increased and decreased rainfall amounts were used to simulate increased rainfall and drought due to climate change, respectively. Soils for each block were mixed and sieved before the

Seedling establishment on seedbed (a) and transplantation to pots (b) and plots (c) (Photo credit: Samuel Tuffa Kawo).



Soil sieving, mixing and transporting for pot experiment. (Photo credit: Samuel Tuffa Kawo.)

experiment to remove roots and other debris and remixed to increase soil homogeneity within a block. All clippings were done at 10 cm above the soil surface with the resulting material oven-dried at 60° for 48 hours before weighing. At the end of the experiment, all above-ground clipping parts were harvested, dried, and weighed and summed for each clipping to obtain total weight.

For below-ground C assessment, roots of the grasses were excavated at the end of the clipping period. To remove fine roots from the soil, all roots were collected with soil and soaked in water, washed, and strained through small mesh sieves. The washed roots were oven dried at 60°C for 48 hours. The C content of above-and below-ground biomass was calculated based on the comprehensive standard that the C content of most plant tissues is in the range of 45-50%.

Contrary to the findings of mature tufts, in the plot and pot experiments, a higher above- and below-ground organic carbon was seen for clipped rather than non-clipped grasses. This suggests that controlled grazing can be used to enhance carbon stocks of newly-established pasture whereas overgrazing or resting do not provide such positive effects. The positive response of freshly reseeded grasses to defoliation as compared to pre-established grasses may be attributable to the greater photosynthetic capacity of young grasses over old grasses. The results suggest that a rangeland's age may play a significant role in the mitigation potential of a pasture and may be used to dictate management strategies enhancing the C sequestration potential of grasses.

Low rainfall strongly diminishes grass C allocation

Results from the potted grasses in the second experiment showed that a decrease of 30% rainfall significantly reduced both above- and below-ground OC. In contrast, the plotted grasses showed no statistically significant difference between irrigation amounts in both grass species for above- or below-ground OC. For both potted and plotted grasses, grass C allocation was strongly diminished under both conditions of low rainfall and additional grazing pressures.

The lower irrigation values that reduced above- and below-ground OC of both potted grass species suggests that the 30% and greater decreases in rainfall predicted for eastern African regions will lead to lower C in both the shoots and roots of pasture grasses. Hence, current practices that defer grazing during drought may have no value in promoting grass C allocation as decreased rainfall may be override its effects.

Interactive effects of clipping and irrigation on carbon sequestration potential of grasses

There were significant interactions between clipping and irrigation factors for below-ground organic carbon in *C. gayana*. At lower clipping frequencies, the below-ground OC significantly improved under increased and average rainfall regimes. At decreased rainfall, lower clipping frequencies did not enhance below-ground OC.

The interactions between clipping and irrigation for below-ground OC suggested that lower grazing pressure can enhance below-ground C under average rainfall, but not under low rainfall conditions. Drought induced changes in morphological, physiological, and biochemical aspects of the plant likely resulted from low CO_2 assimilation rates. In particular, grazing had no effect during drought conditions when plant productivity is zero. Rainfall in the Borana plateau and entire east-African region is predicted to increase with overall high variability and longer drought intervals due to climate change. Therefore, future work should focus on mitigating the integrated effects of rainfall and grazing to conserve the more than 90% of organic grassland carbon stored in grass roots.

Proper management of grasslands has the potential to mitigate increasing atmospheric CO_2

A review of the study results suggests that mitigation of atmospheric CO_2 by grasslands can be achieved—but only with proper management strategies. The results of grass carbon stock allocation in young and old grasses under different grazing pressure and rainfall showed significant changes under treatment. Under natural conditions, grazing significantly hampered above-ground C allocation for older grasses with established root systems. In contrast, biweekly and monthly simulated grazing stimulated above- and below-ground C in newly established grasses. Additionally, the irrigation studies showed that the C sequestering and storage potential of grasses is limited by existing herbivore pressure when rainfall is sufficient. Such results suggest a need for tailored management and utilization of a resting period when rainfall is sufficient when developing strategies to increase C sequestration by various grasslands.

Unless appropriate grazing management is in place, highly variable rainfall will override the potentially positive effects of grazing during the course of climate change. If rainfall is predictable or controllable through irrigation, appropriate management of grazing lands can greatly enhance the C sequestration potential and use of Ethiopian rangelands as CO_2 sinks. In conclusion, it is recommended that the long-term practiced enclosure in the Borana should be clipped monthly and biweekly clipped or grazed when the pasture is newly established to enhance overall C sequestration potential of the rangeland.

"If rainfall is predictable or controllable through irrigation, appropriate management of grazing lands can greatly enhance the Carbon sequestration potential and use of Ethiopian rangelands as CO_2 sinks."

Further Reading

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TIRI, Targeted Investment for Research Impact, identifies early-career researchers who are interested in tackling livestock production problems through innovative approaches and fresh perspectives. This small-grant program is open to early-career researchers (five or fewer years into research career) in any discipline, from student to professor, and from any organization that is engaged in applied research on livestock production in South Asia and East Africa — colleges and universities, government research centers or laboratories, or non-profit organizations.

Proposals are selected based on their potential to make livestock production systems more resilient to increasing climate variability and severity. At the end of one year, TIRI scholars are expected to demonstrate concrete outcomes and real potential for future impact. The 10 selected East Africa TIRI scholars and the 18 selected Nepal TIRI scholars are addressing research problems on various livestock and climate research themes.

Feed the Future Innovation Lab for Collaborative Research on Adapting Livestock Systems to Climate Change is dedicated to catalyzing and coordinating research that improves the livelihoods of livestock producers affected by climate change by reducing vulnerability and increasing adaptive capacity.

This publication was made possible through support provided by the Bureau for Economic Growth, Agriculture, and Trade, U.S. Agency for International Development, under the terms of Grant No. EEM-A-00-10-00001. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development or the U.S. government.

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