Effects of grazing and fire on soil carbon in dry African Savanna

Ermias Betemariam
Jan de Leeuw
Keith Shepherd
Context

• **Land productivity** is key to feed the world - grasslands as “protein pools”

• **Land degradation** remains a global challenge and reducing/reversing land degradation is a development/research priority

• Soil comes to the global agenda: sustainable intensification

• Global Environmental Benefits - land degradation and soils are among the priority global benefits (GEF/UNCCD)
Extensive grassland are mostly in arid and semi-arid zones.

75 percent of eastern Africa is dominated by grasslands.
Moisture is a major limiting factor in the drylands

- Low and variable rainfall
- Sensitive to disturbances- rangeland degradation/bush encroachment

Grass lands have high SOC stocks (~12% of terrestrial SOM)
- Topsoils (1m) contain 1400-1500 Pg (or Gt, billions of tonnes) of SOC
- Three times the amount that is present in the atmosphere (ca. 800 Pg) or vegetation (ca. 550)- small change could cause large effects on climate system
- Climate change mitigation potential through C sequestration is less known (FAO, 2010).
SOC balance

- **Inputs**
  - Litter, roots, branches

- **Outputs**
  - Autotrophic respiration: roots
  - Heterotrophic respiration: CO$_2$ respiration of soil organisms that use dead plant matter as a food source
What determines the amount of SOC in a soil? - the kitchen sink analogy (Govers, 2012)

SOC sequestration = Increasing SOC stocks through the increase of inputs and/or decreasing C decomposition (M. Stocking, 2012)
Disturbance

- Climate change:
  - increase warming increase respiration rates = SOC increases
  - Warming & CO2 fertilization stimulate plant growth = SOC increases
- Tillage: increases respiration: SOC decrease
- Harvesting: reduces inputs = SOC decrease
- Land use change = SOC increase or decrease
Two decades of controlled burning did not affect soil C in Sudanian savanna-woodlands of West Africa
Fire-a necessary evil

- Fire is widely used as a management tool in tropical savanna ecosystems.
- Long-term effect on soil carbon (SOC) is poorly documented.
- Fire has the potential to alter soil carbon storage by influencing rates of net primary productivity, carbon allocation patterns, and rates of organic matter decomposition (Ojima et al., 1994).
  - Carbon allocation - SOC gain
  - Decrease input - SOC loss
The study site
Methods (cont.)
Experimental design (1992-2011)
Results

No Sig difference in SOC between burned and unburned plots
Results (cont.)

No Sig difference in SOC between burned and unburned plots
Results (cont.)

No Sig difference in SOC between burned and unburned plots
Effects of termite on SOC

- Termites contribute for an increase in SOC in savannah ecosystems
- Introduction of earth worms increased soil carbon in grasslands (Conant et al. 2001)
Three decades of livestock exclosures did not affect soil organic carbon in dry savanna in southern Ethiopian.
Rangeland degradation

- Bush encroachment following banning of burning in the 1975s

- Several efforts to reverse bush encroachment

- Controlled grazing as a strategy to enhance soil carbon sequestration
The study site

[Map of Ethiopia showing the location of Borena]
Methods

- 14 exclosures were mapped
- Pairwise sampling
Results

- No sig. difference in SOC content between closed and open sites for all age categories
• No sig. difference in SOC between closed and open plots for all age categories
Exclosures for soil and water conservation

Exclosures significantly reduce soil erosion and give more grass production.

- Exclosures have high sediment trapping capacity – Effective soil and water conservation measure (Descheemaeker et al. 2006)
Results (cont.)

- Rangeland degradation in Borena rangelands: soils matter
Results (cont.)
Some findings from Kenya

- Baringo - SOC difference between 25 years closed and open grazing lands (Vagen et al. 2007)

Figure 1.3: Reclaimed (rehabilitated) communal area (Field 1 - initiated in 1982) on the right, area without any intervention on left. (Photo: Tor-G. Vägen, November 2007)
Some findings from Kenya

Wildlife Works Carbon / Rukinga, Kenya
http://www.coderedd.org/redd-project/wildlife-works-carbon-rukinga-redd-project/
Final remarks

• Effects of fire on soil processes are highly variable and no generalized tendencies (González-Pérez, 2004)

• Exclosures are viable options to restore degraded lands

• Carbon loss by erosion

• **Target multiple benefits:** practices that sequester carbon in grasslands often enhance productivity, biodiversity, etc.

• SOC sequestration is not a commercially viable operation at present - response time decades (set realistic goals)

**Site-specific solutions**
Chivenge et al., 2007:

• increase input in course textured soils

• reduce decomposition/disturbance in light textured soils
Final remarks (cont.)

• The role of water as the primary limiting factor on productivity may be more important (Semmartin et al., 2004).

• Where to invest? (BIODEV)
  • **mineralization** rates are low (cold, moist climates) or
  • **input** rates are high (warm, wet climates)

• It is easier (and probably cheaper to preserve than to restore - drylands of Africa

• Modeling SOC is difficult - may be better described with more complex models
Thank you