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Modelling soil organic carbon at multiple depths in woody encroached grasslands using integrated remotely sensed data

Sfundo Mthiyane
PhD Candidate
University of KwaZulu Natal

science, technology & innovation
Department: Science, Technology and Innovation
REPUBLIC OF SOUTH AFRICA

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Background

Woody Encroachment

- The global transformation of mesic grasslands into woody-dominated ecosystems has significantly increased over the past century
- Common documented drivers are fire suppression, overgrazing, nutrients availability, climate change and global carbon dioxide enrichment

Impacts

- Reduces the quantity of productive grazing landscapes for wild herbivores and livestock
- Reduces the frequency and intensity of grazing and fire, which are key factors maintaining grassland diversity
- Pronounced impact on below ground nitrogen and carbon pools (Soil Organic Carbon) in grasslands

Background

Benefits of SOC

- Provide various ecological services such as regulating the climate, improving water quality, and supporting biodiversity
- Improve soil structure, retain water, and provide plant nutrients, characteristics critical for increasing the resilience of soils towards droughts and floods
- A decline in SOC can trigger a loss of soil quality and productivity

Knowledge gap

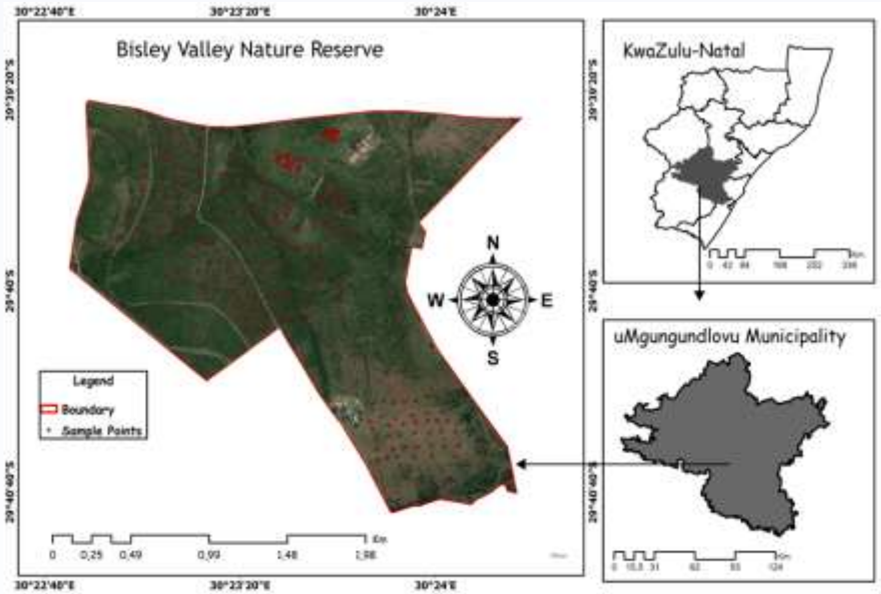
- SOC is expected to be higher in deeper soils of woody vegetated landscapes due to higher root litter and decomposition
- Contradictions on whether woody encroachment increases or decreases SOC concentration
- Environmental factors that include historical land-use patterns and soil biophysical attributes
- Most studies that have investigated SOC in deeper soils of woody encroached grasslands have typically utilized traditional methods that rely on field-based observation that are expensive, labour demanding and time consuming
- Advancements in satellite technology and data storage have tremendously revolutionized SOC stocks modelling

Aim & Objectives

- ❑Estimate SOC at various depths (30 cm, 60 cm, and 100 cm) in a woody-encroached grassland by integrating Sentinel-1 (S1), Sentinel-2 (S2), PlanetScope (PS) satellite imagery, and topographic variables.
- ❑The study coupled random forest and remotely sensed data to model SOC distribution at different soil depths of Bisley Nature Reserve affected by a proliferation of woody vegetation on a grassland.
- ❑The study also evaluated the spatial distribution of SOC from a wood encroached to a pristine grassland.

Study Site

- The study area is located at Bisley Valley Nature Reserve (29° 39' 53'' S; 30° 23' 32'' E), Pietermaritzburg, South Africa
- The area is highly invaded by woody trees and thus minimizing the dominance of pure grasses.
- Although woody trees dominate most of the landscapes, there are few areas dominated by pure grasses in the reserve.



Field Data Collection

- Employed a purposive sampling strategy to establish three transects that were 622 m long measured from a pristine grassland to a woody encroached grassland
- At each transect, a total of 40 plots (15m² each) were established
- Within each plot, 1x1 meter square quadrant was placed every 15 m, and three soil samples collected per quadrant at different soil depths
- As a result, a total of 40 soil samples were collected for each depth (30 cm, 60 cm and 100 cm) using a handheld MAC AFRIC 68 CC EARTH Auger Drill
- Additionally, through utilizing the Trimble Handheld Global Positioning System with a sub meter accuracy, Global Position System (GPS) locations for each plot were recorded
- A total of 360 soil samples were collected and subsequently dispatched to the laboratory for further investigations

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Image Acquisition and Preprocessing

- A combination of radar (SAR), Sentinel 2 and PS satellite images
- PlanetScope(https://www.planet.com/markets/education-and-research/)
- SAR & S2(https://dataspace.copernicus.eu/)
- The Ground Range Detected (GRD) format SAR image of interferometric wide swath mode was pre-processed with ESA’s Sentinel-1 Toolbox in the software SNAP (version 6.4.5)
- Georeferencing, Thermal noise, Terrain Correction, etc.
- Topographic residuals were extracted from a SRTM Digital Elevation Model (DEM) image with 30 m spatial resolution acquired from Earth Explore online platform. Using ArcGIS pro (version 3.0)
- Elevation, Aspect, Slope, and Topographic Wetness Index (TWI)
- Random Forest

Index	Formula	Reference
Normalized Difference Vegetation Index (NDVI)	(B8-B4)/(B8 + B4)	(Rouse et al., 1974)
Green Normalized Difference Vegetation Index (GNDVI)	(B9-B3)/(B9 + B3)	(Ahamed et al., 2011)
Red-Edge 1	(Red-Edge/Red)	(Cloutis et al., 1996)
Radar Vegetation Index (RVI)	(8*VH)/ (HH + VV + 2*VH)	(Kim et al., 2011)
Modified Soil Adjusted Vegetation Index (MSAVI)	29 + 1–1*()/2	(Wu et al., 2007)

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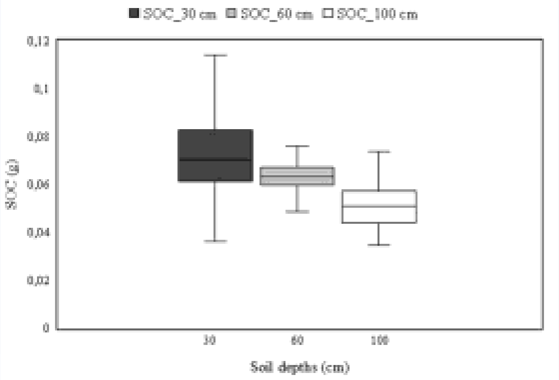
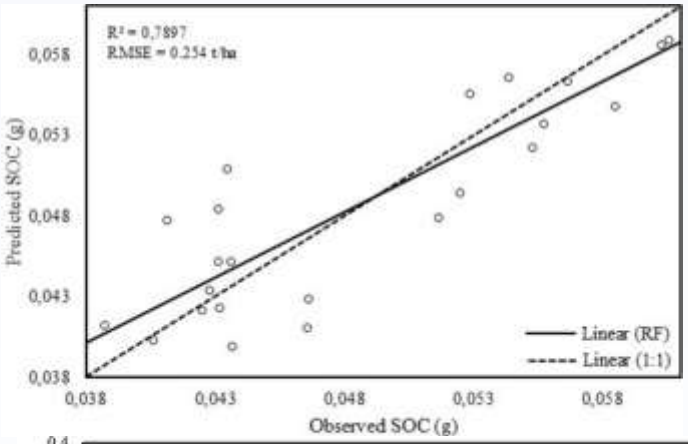
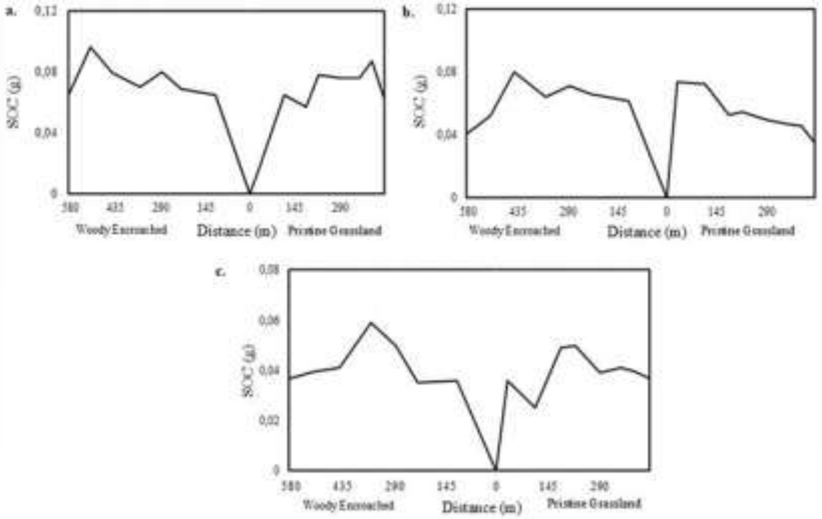
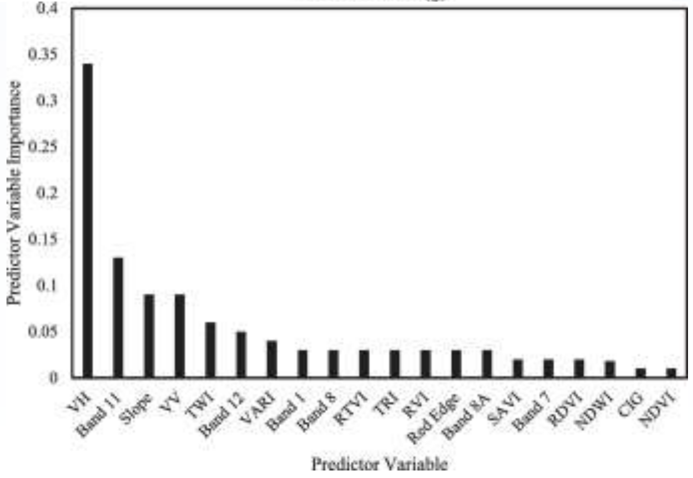
Results









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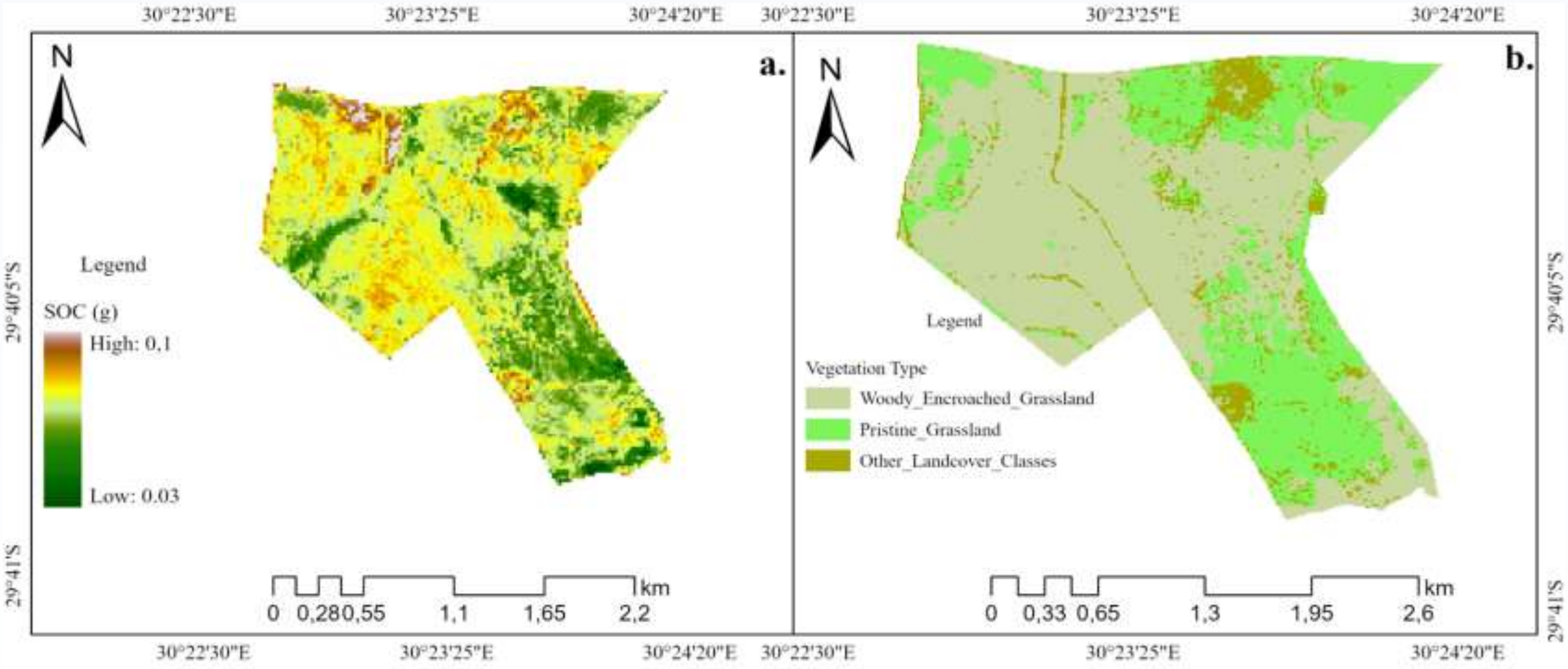

Conclusion

- The study established that integration of spectral information with vegetation indices provide valuable information for monitoring SOC distribution in woody encroached grasslands
- We conclude that freely and accessible SAR and PlanetScope data and topographic factors provide more opportunities to quantify SOC stocks in grasslands
- The study is beneficial to reserve supervisors and policymakers to make informed decisions on conserving the nature reserve
- The methodology presented by the study is a cost-effective and time-efficient procedure of monitoring SOC distribution across woody encroached grasslands.
- Reserve managers can use the insights of the study to establish effective land management patterns to preserve and maintain SOC pool

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