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RESEARCH BRIEF
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Assessing the Potential of Biochar to Restore Degraded Lands

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RESEARCH BACKGROUND

Climate change threatens ecosystems and human well-being, primarily through food insecurity, land degradation, and biodiversity loss. The geographical ranges of many species are likely to be altered by changes in precipitation and temperature, with some being driven to extinction. Understanding the impacts of and risks of climate change on both natural and human systems is crucial for comprehending the climate emergency. Due to their distinct adaptation needs, developing countries are more vulnerable to extreme climate events.

Climate change and land degradation are interlinked processes with similar causes and consequences. While climate change can accelerate the process of land degradation, land degradation can also accelerate the process and impacts of climate change. Given the urgency presented by the need for productive land to increase food production and conserve biodiversity, there is an urgent need to address land degradation, especially in the sub-Saharan African region.

This study aimed to uncover the potential of using biochar, a product of the thermochemical decomposition of biomass, to restore severely degraded land. For this purpose, field trials were conducted to explore the effects of biochar on soil properties and plant growth. After six months, the collected data was analysed to investigate how soil properties changed after biochar application.

PROJECT SUMMARY

This study aimed to investigate the potential of biochar, a product of the thermochemical decomposition of biomass, to restore severely degraded land. Field trials were conducted to assess the effects of biochar on soil properties and plant growth over six months.

KEY FINDINGS

- **Soil bulk density decreased over time**, although the differences among treatments were not statistically significant. There were no significant changes in total carbon, nitrogen, potassium, calcium, magnesium, sodium, pH, and phosphorus, except for a slight but significant increase in soil pH in biochar-treated plots.

- While plant species diversity increased over time, **biochar treatment did not significantly affect germination rates or plant biomass within six months**. However, biochar-treated plots showed higher diversity, indicating favourable conditions for germination and establishment.

- The study concludes that **biochar has potential for climate change mitigation and land restoration**. Future research should include different environmental conditions, biochar types, and longer-term studies to better understand biochar's impact on soil properties and plant growth.

METHODS AND MATERIALS

STUDY SITE DESCRIPTION

The study was conducted at Lapalala Wilderness Reserve (LWR) in the Waterberg District. Lapalala covers 36 000 ha of land and is part of the upper catchment of the Palala River which drains into the Limpopo River (Kearney *et al.*, 2008). The area falls within the summer rainfall region with an overall estimated rainfall of 500mm and a mean annual evapotranspiraion of 2200 mm - 2400 mm (Lalapalala Wilderness Masterplan, 2004). Mean minimum and maximum monthly temperatures are 2 °C and 20 °C in July, and 14 °C and 30 °C in Janua 22

The ancient acid sandstones of the Kransberg Subgroup primarily underlie LWR and the topography of the area is mountainous, with high-lying areas in the north and south and deep valleys or gorges concomitant with the rivers that run through the reserve. Vegetation belongs to the savanna biome and the area is home to a high diversity if wildlife, many of which are threatened. LWR's land use is diverse, with a historic emphasis on cattle and tobacco farming and ecotourism plays an important role in the local socio-economic wellbeing of the area.

PROBLEM STATEMENT

Land degradation threatens ecosystems, biodiversity, and development worldwide. Climate change can accelerate the impacts of land degradation, and nearly all the drivers of land degradation are exacerbated by climate change.

Ecological restoration is crucial but often insufficient due to scale and competing land use demands and the inability to address greenhouse gas emissions. Biochar offers a promising solution by enhancing soil quality and vegetation growth, especially in severely degraded areas like in the Waterberg District, Limpopo Province, South Africa, the Sneeuberg uplands in the eastern Karoo, South Africa, and the Swartland in the Western Cape Province, South Africa.

Biochar's ability to amend soil and sequester carbon long-term makes it a valuable tool in combating land degradation. This study aimed to investigate the use of biochar as a means to restore degraded land.

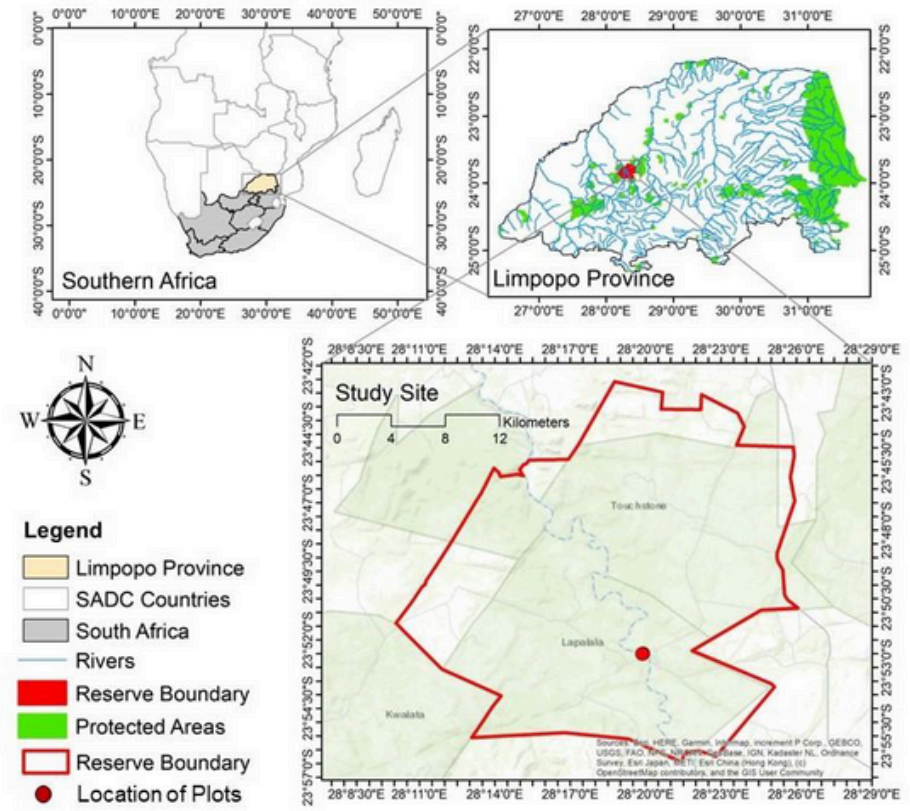

Figure 2. The location of the study area in LWR in the Waterberg District, Limpopo Province, South Africa.

EXPERIMENTAL SETUP AND DATA COLLECTION

The experiment uses a randomised block design with four plots of different treatments in each of five blocks. There was a total of four treatments: control without biochar and fertilizer (Cnf), control with fertilizer (Cf), biochar with fertilizer (Bf), and biochar without fertilizer (Bnf). There were five replicates (Blocks) for each treatment, totaling 20 plots. The following factors were analysed: above-ground and below-ground biomass, soil bulk density, and species composition.

RESULTS

- **Soil bulk density:** Biochar treatments had the lowest soil bulk density with no significant differences. Only time had a significant effect on soil bulk density.
- **Soil chemical properties:** Biochar had a significant effect on Total C whereas the effect of fertiliser on total C was not significant nor was the combination of biochar and fertiliser. Treatments did not significantly effect Total N, K, Ca or P however biochar increased Na levels significantly. The combination of fertiliser and biochar did not influence pH however, when added individually, their effects were significant.
- **Biomass:** None of the treatments significantly affected plant biomass
- **Carbon stock:** Biochar treatment had the highest carbon stock while the carbon stock and the differences were non-significant across all treatments.
- **Species richness evenness and diversity:** Species richness increased from 14 in month three to 16 in month six (pooled species richness), with the biochar treatment having the lowest species richness in both months. At month three none of the treatments had a significant effect on the species eveness and at month six, only biochar had a significant effect on species eveness.
- **Species composition:** There was no significant difference in species composition across treatments.
- **Cluster analysis:** None of the blocks clustered together at month three while at month six, block A clusters with block B and block C with block D. Block E was found in both clusters.

DISCUSSION

SOIL BULK DENSITY

Soil bulk density decreased over time, but the differences among treatments were not statistically significant. Previous studies, noted decreases in soil bulk density with higher biochar concentrations. The type of biochar, application rate, and duration of the experiment likely influenced the outcomes. Similar studies also reported varied results based on these factors.

SOIL CHEMICAL PROPERTIES

There were no significant changes observed in Total C, Total N, N, K, Ca, Mg, Na, pH, and P. In contrast, significant increases in Total C were reported by Faye et al. (2021) with biochar and manure applications over six years. A slight but notable increase in soil pH in biochar-treated plots was also observed, consistent with findings by Novak et al. (2009). This pH increase has the potential to enhance long-term plant productivity, although no significant biomass changes were detected within six months. The lack of significant effects on Total N may be attributed to rapid plant uptake or retention facilitated by biochar, as noted in other studies.

PLANT GROWTH

Plant species diversity increased from month three to six, likely due to seed dispersal and soil seed bank. Germination rates varied among species but were not affected by biochar or fertilizer. These findings align with Van de Voorde et al. (2014) and Gundale et al. (2016), who reported no significant impact of biochar on germination or vegetation cover. However, Jeffrey et al. (2022) observed higher legume cover in biochar-treated plots.

PLANT BIOMASS AND CARBON STOCK

Biochar treatment did not significantly affect biomass within six months, possibly due to low application rates or insufficient duration. Previous studies (Faye *et al*., 2021; Major *et al.*, 2010; Yan *et al*., 2022) with longer durations found positive effects on plant growth, suggesting that longer-term studies are needed. Wang *et al*. (2021) reported inconsistent effects of biochar on crop productivity across different application rates.

SPECIES RICHNESS, DIVERSITY, AND COMPOSITION

Species richness increased over time but was unaffected by treatments. Simpson's diversity index increased from month three to six, with biochar plots showing higher diversity despite similar species richness. This suggests that biochar may have fostered favorable conditions for germination and establishment. Differences in evenness at month six indicated potential impacts of biochar on seed dispersal and environmental conditions. Species composition remained consistent across treatments, with several species becoming established by month six.

CONCLUSION

Although not significant in this study, biochar still holds much potential to help in the fight against climate change and subsequent land degradation. Experiments should also be established in different study areas with varying environmental conditions (i.e., climate, soil, geography, and vegetation). Future studies should also include a methodical appreciation of different biochar types and manipulative experiments that identify the interactions between biochar, soil properties, and soil fauna and flora.

RECOMMENDATIONS

- Studies that extend over longer periods are needed (+2 years).
- Future studies must consider applying larger amounts of biochar made from different feedstock materials to assess their effects on soil, plant growth, and carbon sequestration.
- Using unpalatable grass species for restoration purposes to prevent grazing by animals when conducting field trials.

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