2024 ENGINEERING INSTITUTION OF ZAMBIA SYMPOSIUM

Enhancing Crop Resilience Amid El Niño: Exploring Biochar Applications and Machine Learning Insights

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Avani Victoria Falls Resort,
Livingstone, Zambia

Presentation Outline

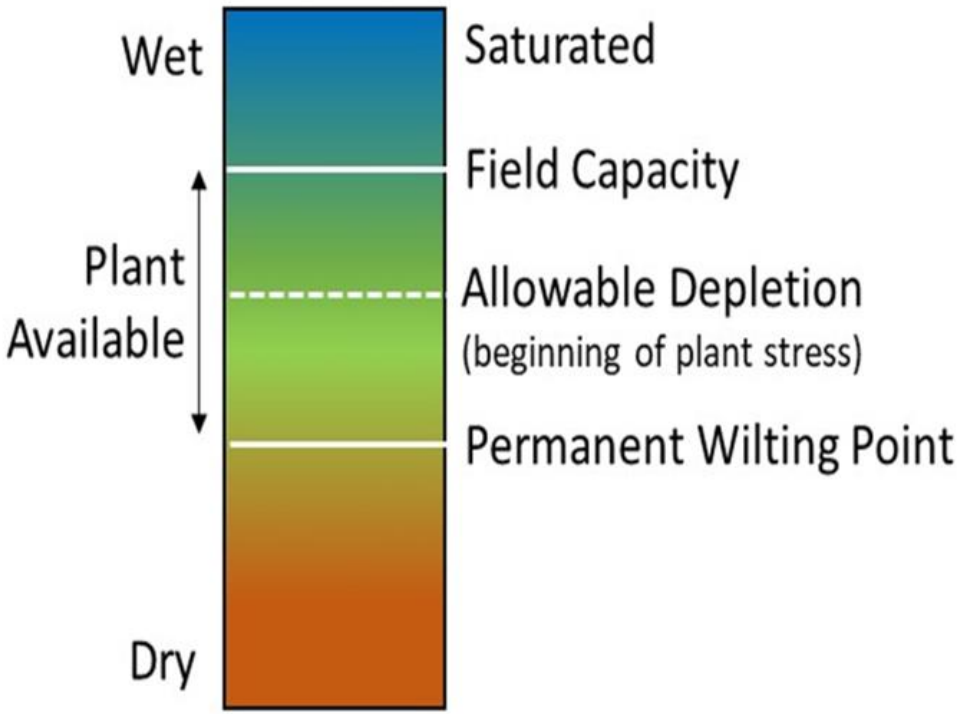
- Background
- Understanding Available Water (AW)
- Biomass Generation Status in Zambia
- Biochar and Its Uses
- Biochar as a Soil Amendment (Water Retention)
- Production Methods of Biochar
- Development of ML Tool for Analyzing Biochar Efficacy
- Model Results
- Conclusions
- Recommendations

Background

- The ripple effect of the El Nino on agriculture has been the inability to sustain plant life due to limited rainfall
- An immediate reaction to this challenge will be finding means of providing water through Irrigation
- Another important factor to consider is the soil's ability to hold water and have it available for plant growth, this is known as Available Water Capacity (AWC) of the soil
- AWC can be improved through adding soil amendments such as processed or unprocessed biomass

Soil Available Water Capacity

- **Soil Moisture Levels**



Case in point:
Effects of El Nino
(Drought 2023/24)

Biomass Residues Generation Status in Zambia

- Biomass is renewable organic material that comes from plants and animals.
- According to the FAO & MOE (2020) the country produces between 8.76 and 11.71 million tonnes of agricultural residues per year.
- Additionally, an estimated 4.59 and 6.56 million tonnes of forestry waste is generated per year (FAO & MOE, 2020).
- Uses of biomass waste for agriculture:
  - Compost production
  - Mulching
  - **Biochar production**

agro waste

forestry waste

What is Biochar?

- Biochar is defined as a **carbon-rich material** produced during pyrolysis.
- Pyrolysis: thermal-chemical decomposition of materials at elevated temperatures in limited amount or absence of oxygen

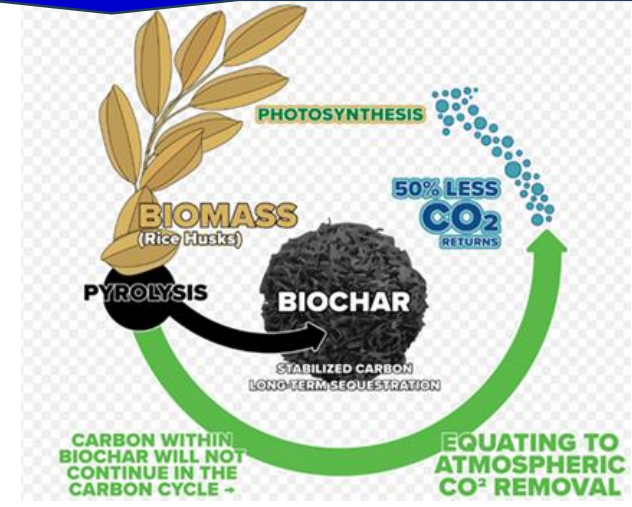
"Black Gold"

Uses of Biochar

Soil Amendment

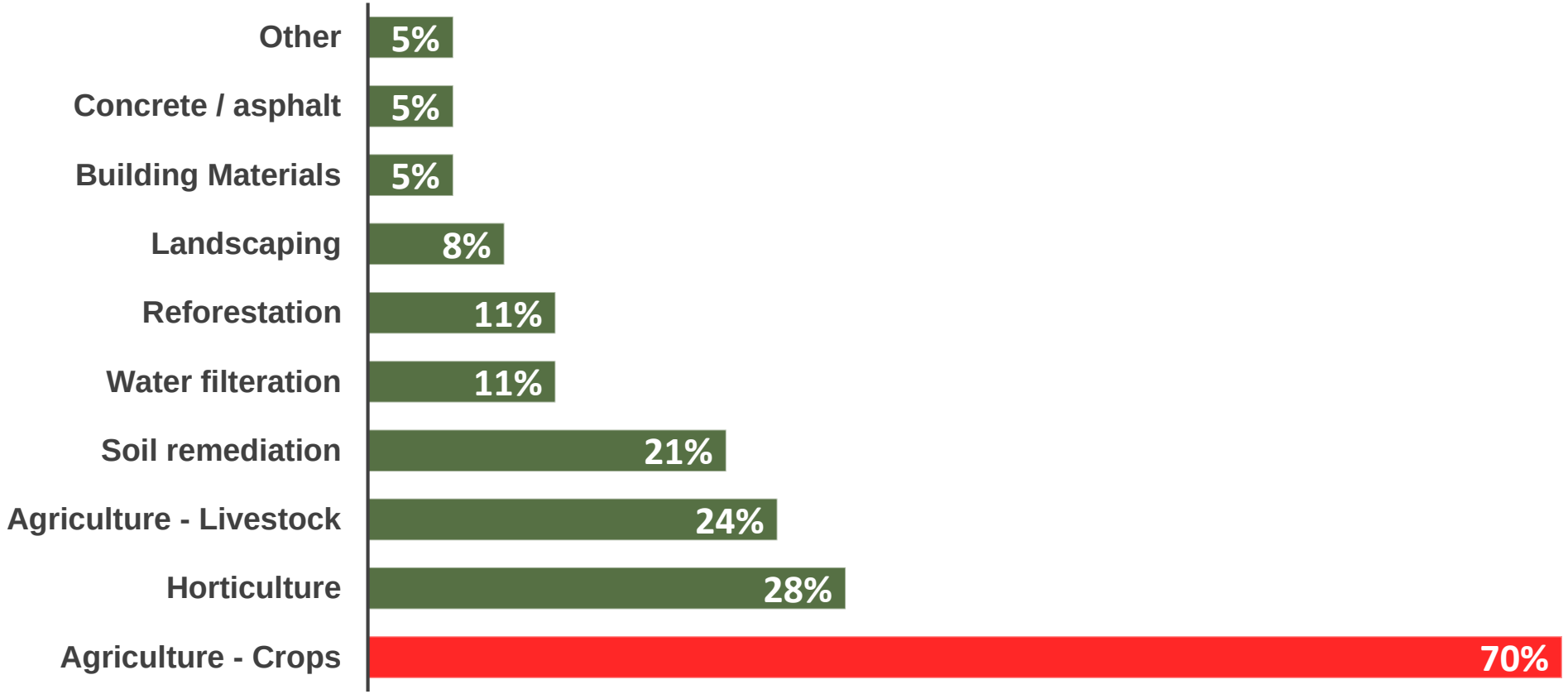
Biochar Briquettes (Fuel)

Carbon Sequestration



Uses of Biochar Cont'd

Existing End -Use markets



Source: International Biochar Initiative – Global Market Report (2023)

Use of Biochar as a Soil amendment for Water Retention

- Hansen, et al. (2016) found that soil amendment with biochar increased AWC by **17–42%**, irrespective of soil type.
  - How? Biochar increases soil porosity, thereby enhancing the soil's ability to absorb and retain water similar to a “sponge”
- Application rate ranging from 3 t/ha to more than 10 t/ha depending on the **soil types**
- AWC increment results in **less demand for water application** and a direct **enhancement on crop yield**, with yields improvement ranging from **5% to 100%** (Ding, et al., 2016)

Biochar as a Soil Amendment for Water Retention cont'd

4 t BC/ha | **Control (Without BC)** | **4 t BC/ha**

Source: International Biochar Initiative (2022)

Production Methods of Biochar

- Technologies appropriate for biochar production in Zambia

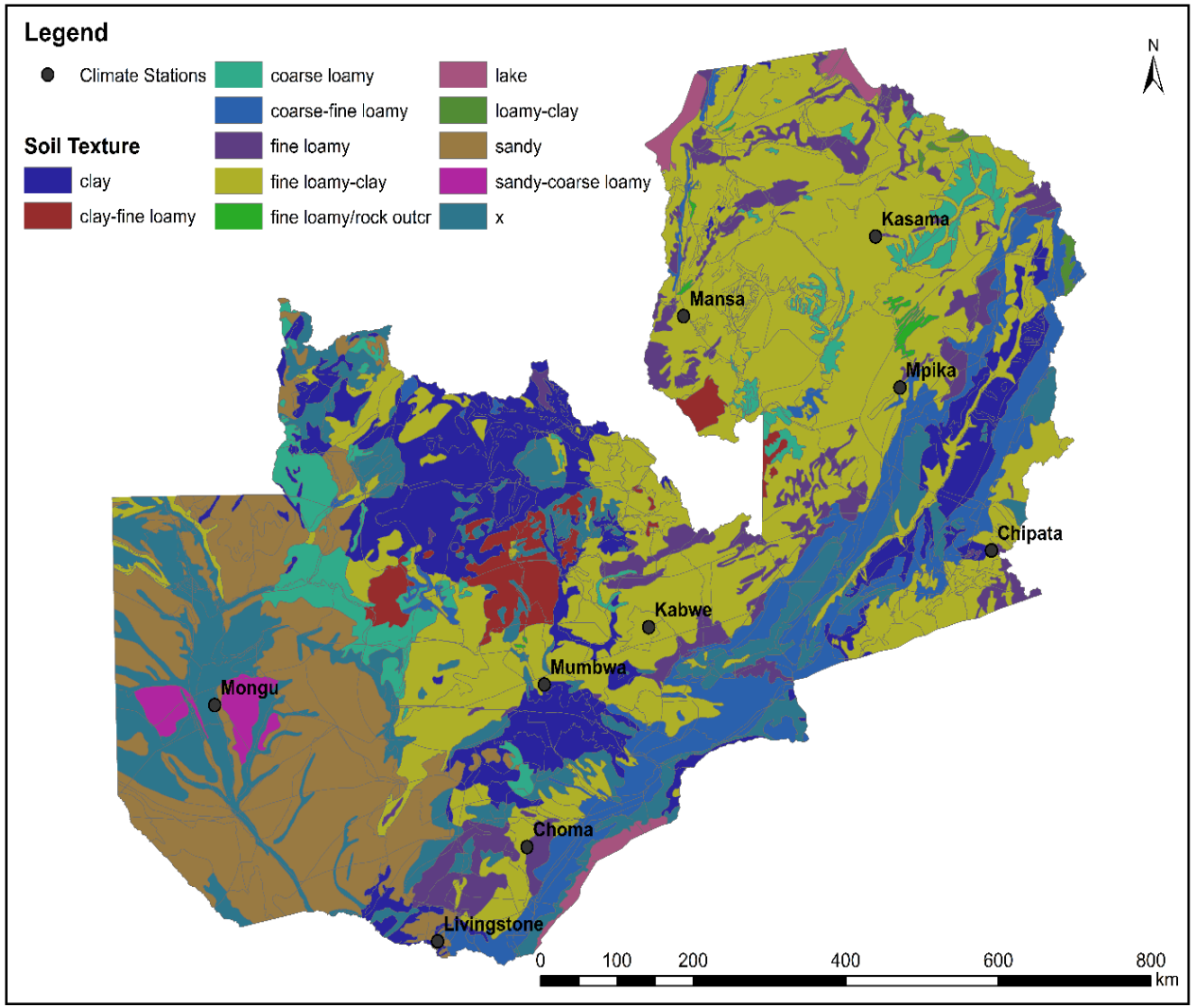
TLUD Gasifiers

Retort

Kon-Tiki Kilns

Drum Kilns

Development of ML Tool :Methodology



Data Collected

Dependent Variable	Source	Independent Variables	Source
Maize Crop Yields (1976 – 2023) from 9 towns	Central Statistics of Zambia	Rainfall (mm/year, 1976 – 2023)	TAMSAT (https://data.tamsat.org.uk/)
		Crop Evapotranspiration (ETo, mm/year, 1976 – 2023)	TAMSAT (https://data.tamsat.org.uk/)
		Available Water Capacity (AWC, Vol %)	(Kalumba, Dondeyne, et al., 2022; Kalumba et al., 2022)

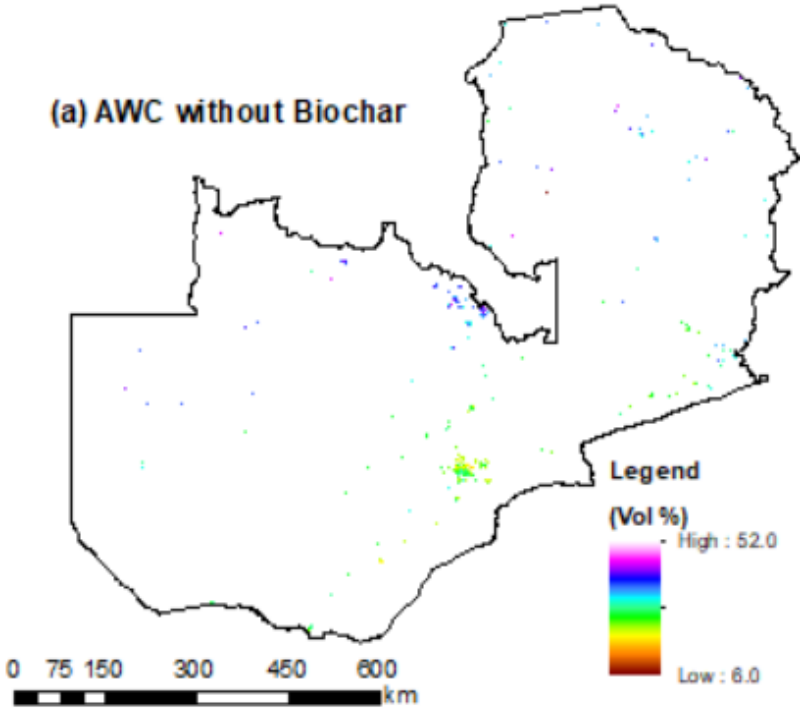
Tools used: Using R software, 4 Machine Learning (ML) Models were Tested, Gradient Boosted Regression Trees(BRT) model was used for Scenario analysis as best performing model

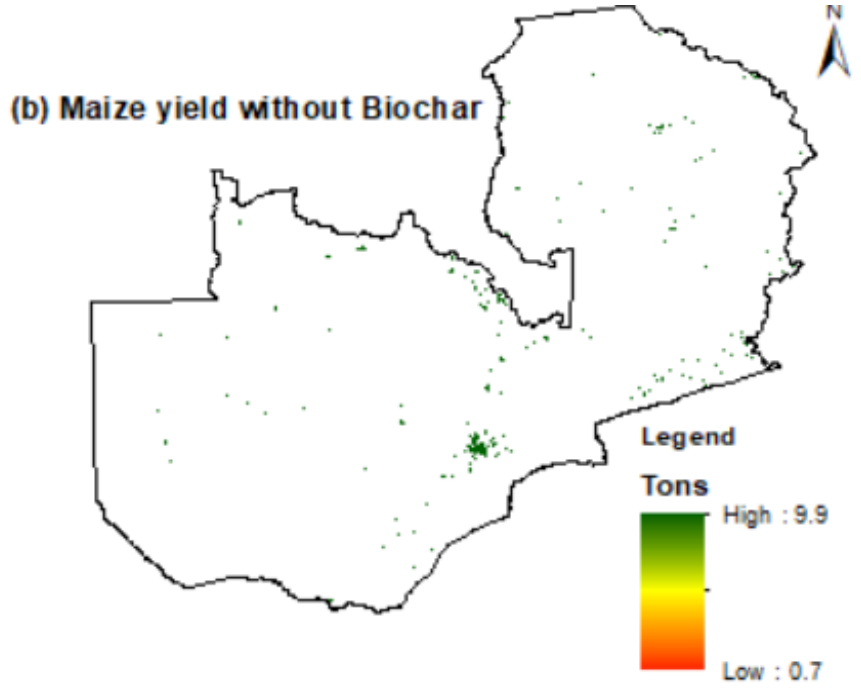
Methodology – Scenario Analysis

Baseline – Analysis (Add 0 Vol % to the AWC (without Biochar)

Scenario – Analysis (Add 28.5 Vol % to the (Edeh, 2020) AWC (with Biochar)

Results


(a) AWC without Biochar
Legend
(Vol %)
High : 52.0
Low : 6.0
0 75 150 300 450 600
km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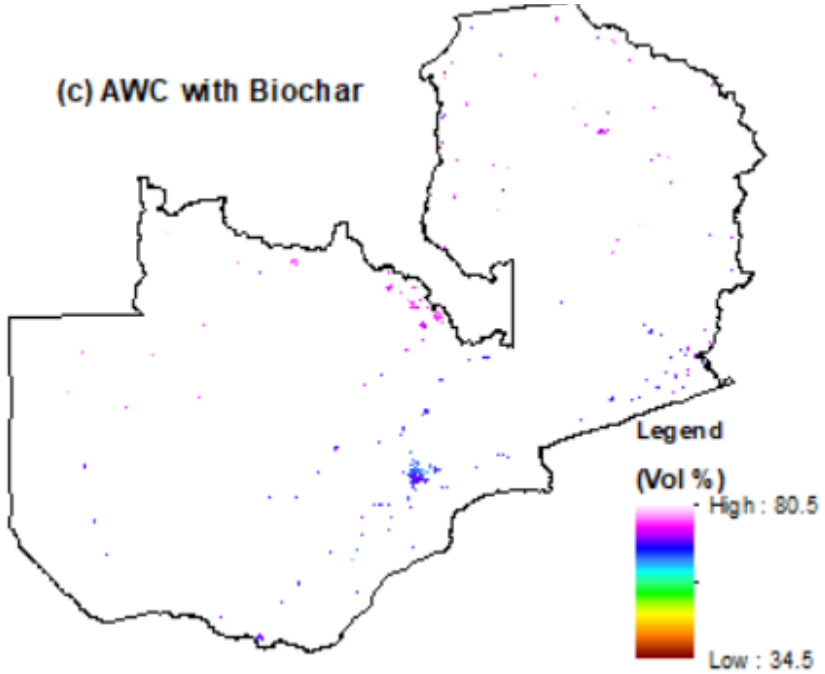
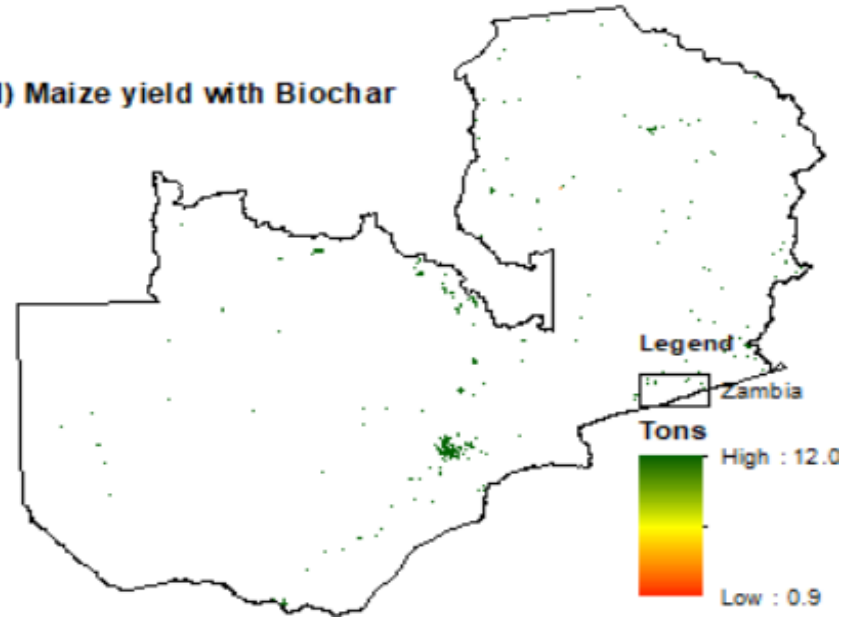
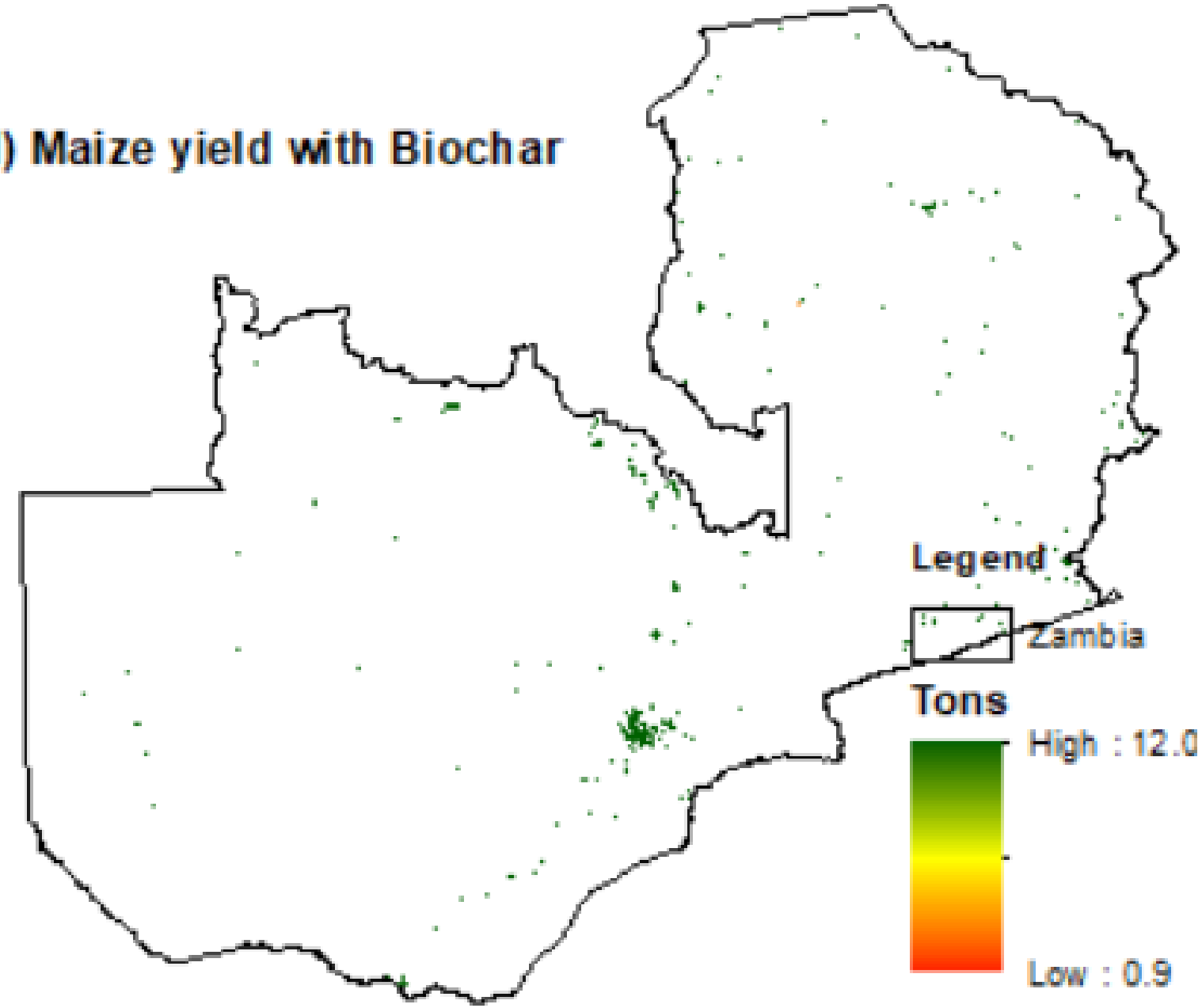
(b) Maize yield without Biochar
Legend
Tons
High : 9.9
Low : 0.7


(c) AWC with Biochar
Legend
(Vol %)
High : 80.5
Low : 34.5


(d) Maize yield with Biochar
Legend
Zambia
Tons
High : 12.0
Low : 0.9

Results

With enhanced AWC by 28.5 Vol % because of Biochar addition, yield improvements of up to 20% were predicted



Conclusions

- The importance of available water to crops and biochar's role in improving water retention is underscored in this study.
- On average, maize crop yields increased by about 20% due to the addition of biochar and the subsequent increase in AWC.
- Other benefits of adding Biochar to soils include increased nutrient retention, improved soil fertility, enhanced soil structure, and carbon sequestration.
- The BRT model demonstrated the best performance and strong predictive crop yield capabilities.

Recommendations

- Farmers should consider using biochar to improve soil water retention and crop yields.
- Conduct further research into tailored biochar application rates and methods for diverse soil types to optimize its benefits.
- Training farmers in biochar production and utilization to enhance crop productivity.
- Researching the potential generation of carbon credit revenue through carbon sequestration using biochar in Zambia.

The End

THANK YOU FOR YOUR ATTENTION.