Building critical SOC concentration as a major pathway for improving nutrient use efficiency in sub-Saharan Africa

By

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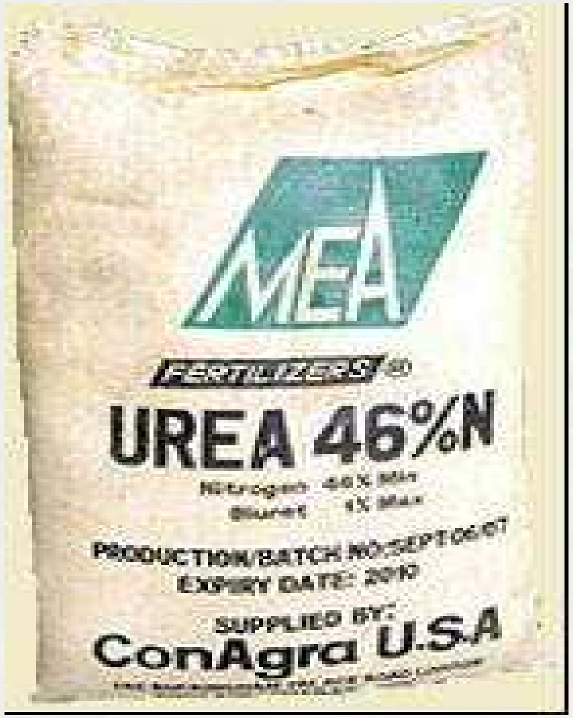


Background

- ✓ High cost of N fertilizers and low N use efficiency key challenges to yield
- ✓ Nutrient recovery efficiencies do not exceed 50%
- ✓ Measures that may result in increased nutrient use efficiency (NUE) a must
- ✓ One potential parameter that can guide N application is SOC
- ✓ It is a good indicator of soil fertility and critical SOC range for high NUE is important

Background cont'd

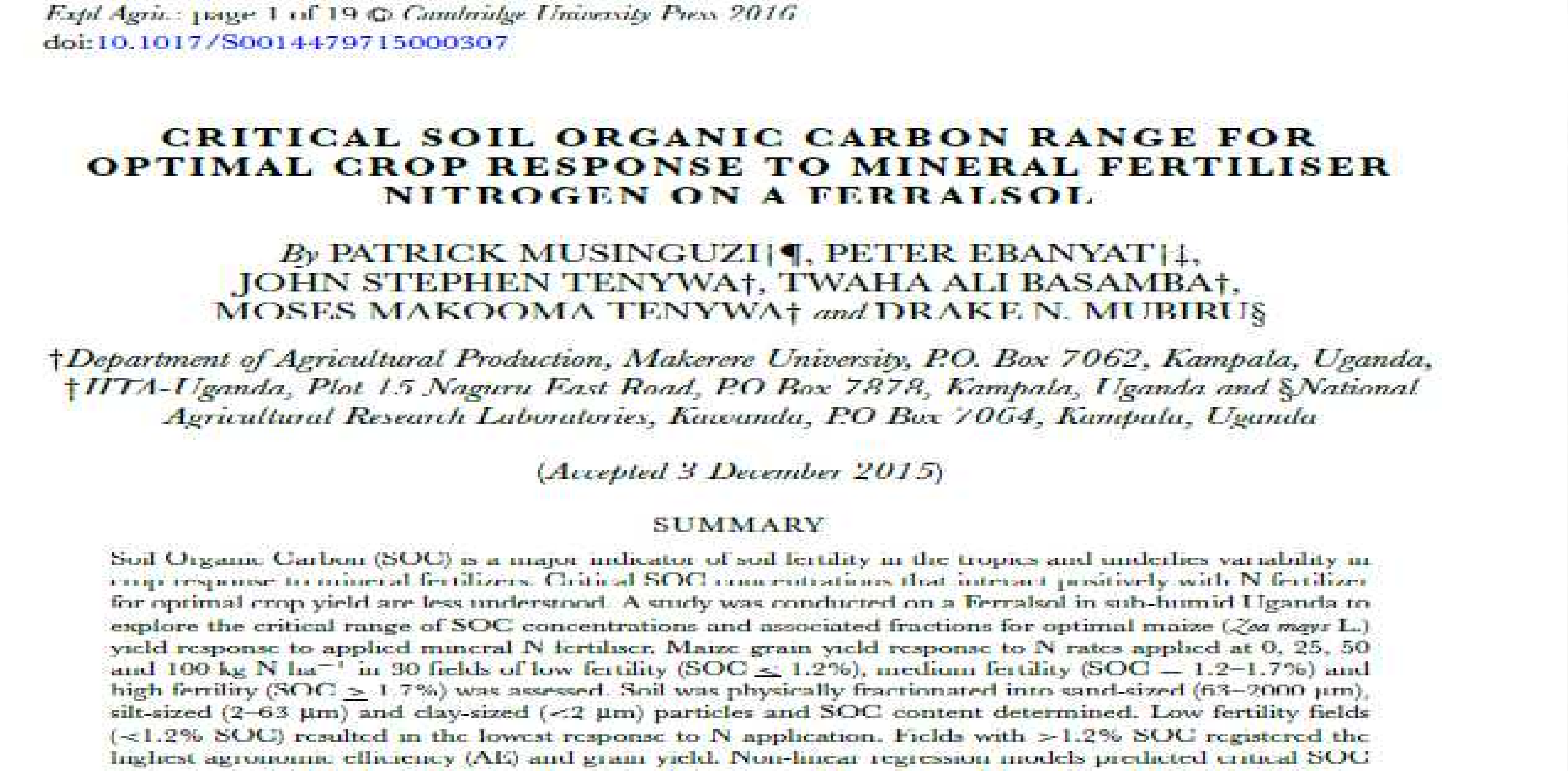
Building SOC to critical levels is envisaged to

- ✓Boost NUE
- ✓ Restore soil fertility and enhance crop productivity
- ✓Increase C sequestration for climate benefits
- ✓Enhance soil health and boost income security

Background cont'd

- ✓ Efforts in tropical soils have already attempted to establish critical SOC (Musinguzi et al., 2016)

- ✓ The critical SOC range is between **1.92-2.204%** for a Ferralsol for maize



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CRITICAL SOIL ORGANIC CARBON RANGE FOR OPTIMAL CROP RESPONSE TO MINERAL FERTILISER NITROGEN ON A FERRALSOL

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SUMMARY

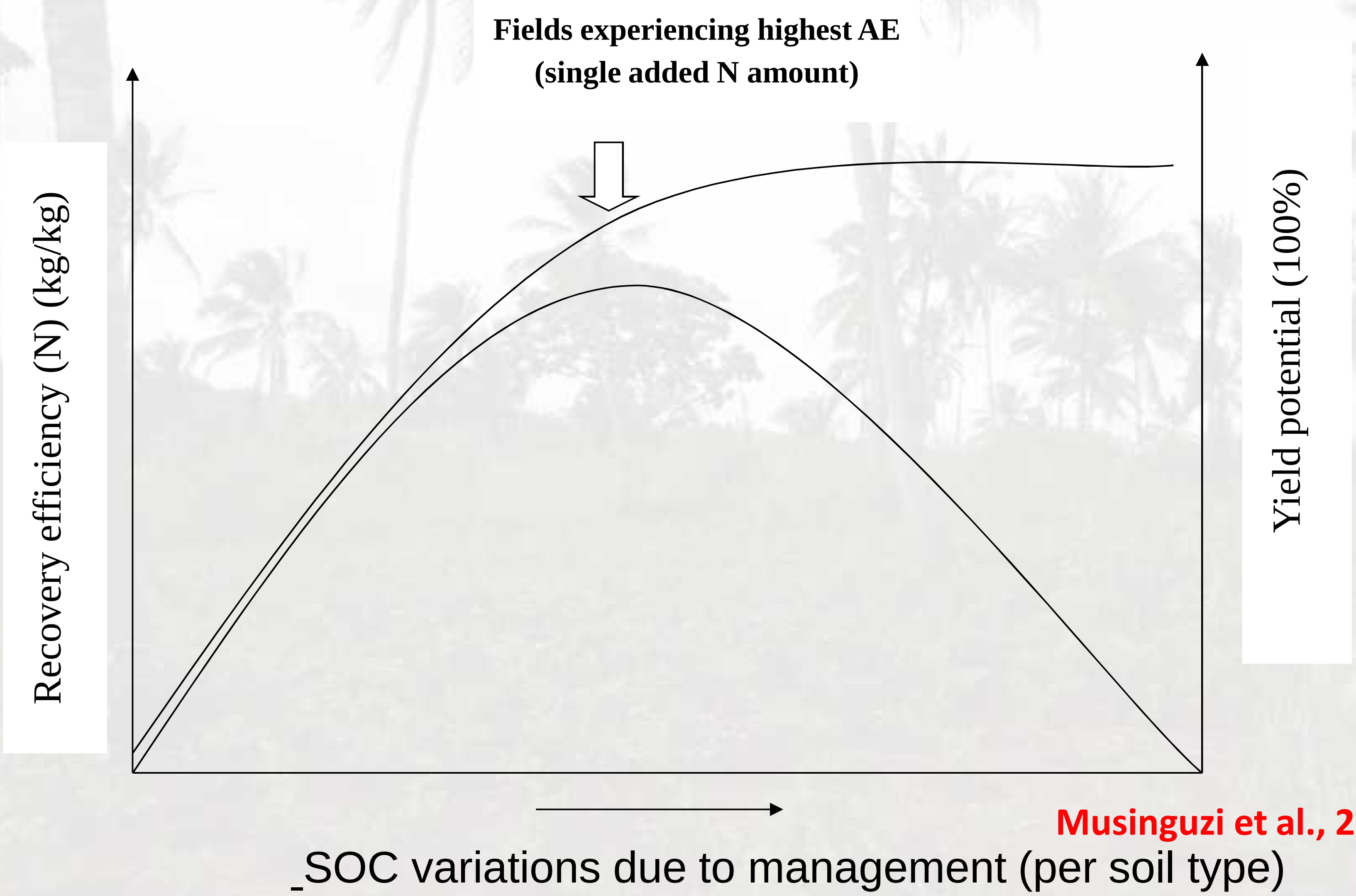
Soil Organic Carbon (SOC) is a major indicator of soil fertility in the tropics and underlies variability in crop response to mineral fertilizers. Critical SOC concentrations that interact positively with N fertilizer for optimal crop yield are less understood. A study was conducted on a Ferralsol in sub-humid Uganda to explore the critical range of SOC concentrations and associated fractions for optimal maize (*Zea mays* L.) yield response to applied mineral N fertiliser. Maize grain yield response to N rates applied at 0, 25, 50 and 100 kg N ha^{-1} in 30 fields of low fertility (SOC $\leq$ 1.2%), medium fertility (SOC = 1.2–1.7%) and high fertility (SOC $\geq$ 1.7%) was assessed. Soil was physically fractionated into sand-sized (63–2000 µm), silt-sized (2–63 µm) and clay-sized (<2 µm) particles and SOC content determined. Low fertility fields (<1.2% SOC) resulted in the lowest response to N application. Fields with >1.2% SOC registered the highest agronomic efficiency (AE) and grain yield. Non-linear regression models predicted critical SOC

The Problem

- ✓ However, it remains unknown on how SOC can be built to critical levels
- ✓ Some research have attempted to study organic materials and explore the critical SOC
- ✓ The potential of available tropical materials to restore SOC has had less attention
- ✓ This work explored the potential of available materials for SOC restoration

Photo credits: by Vanlauwe

Hypothetic critical SOC for high NUE



Fields experiencing highest AE
(single added N amount)

Musinguzi et al., 2013

Research Objective

✓To explore the potential of tropical organic inputs for SOC restoration of SSA soils

Materials and methods

Study sites for critical SOC building approaches

- Action sites-Tropical soils of Uganda, East Africa

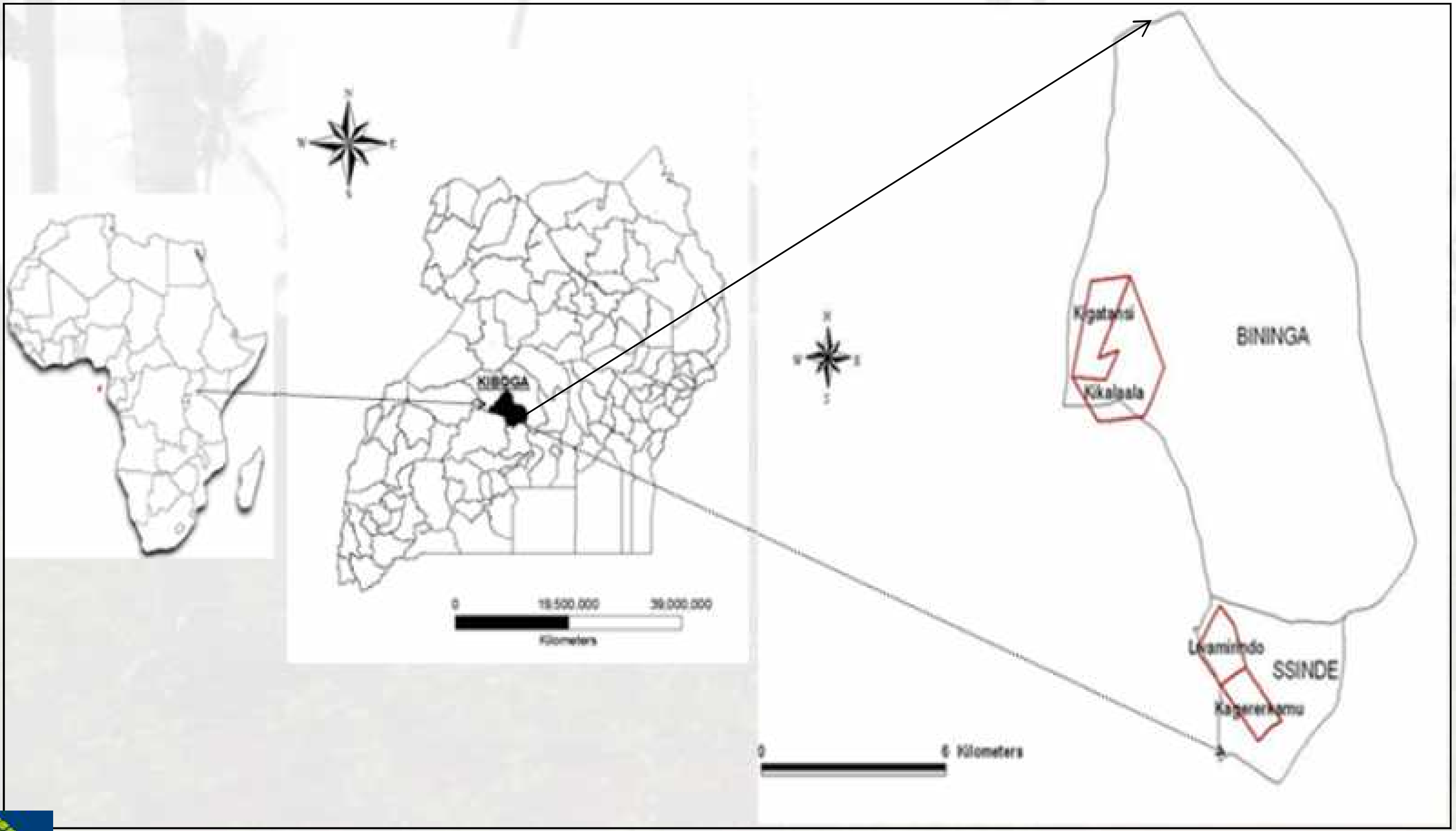


Figure 1. Central Uganda, East Africa region

Materials and methods (contd)

- ✓ Typical Ferralitic soils of different SOC (low SOC and high SOC)

Materials and methods (cont'd)

- ✓ **Building SOC approach**

- ✓SOC building based on theoretical model projections

- ✓Applied the elemental C for materials to estimate SOC restoration capacity

- ✓ The exponential model decay constant (k) (day^{-1}) applied for selected materials

- ✓ The half-life was used as a reference for accumulative application of organic materials

- ✓Frequency of organic material addition depended on half-life, quality **(other factors constant)**


Sesbania Sesban

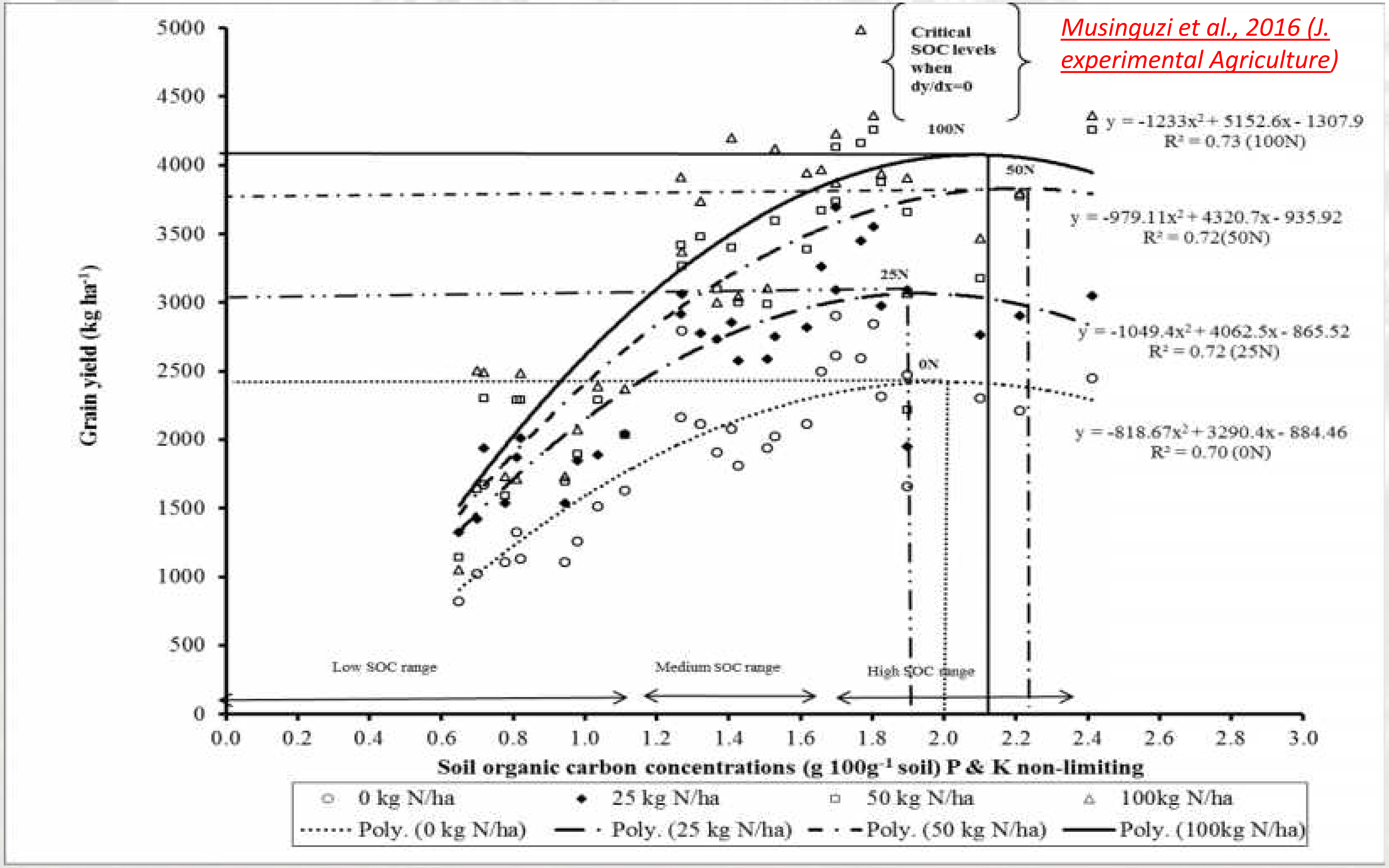

Mucuna pruriens


compost


Bio char

Materials and methods (cont'd)

- ✓ **Basis for SOC building in the tropics**



Musinguzi et al., 2016 (J. experimental Agriculture)

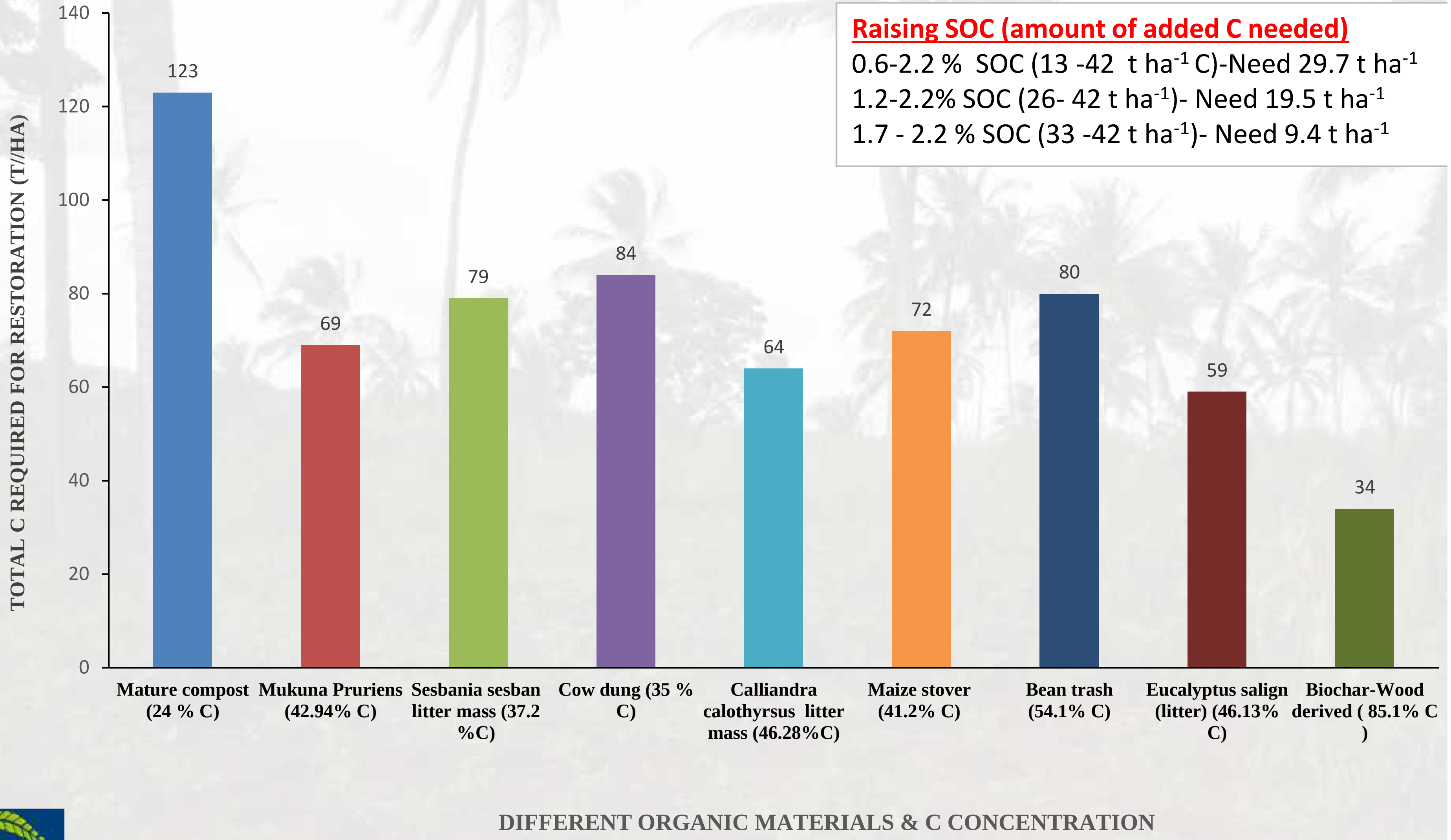
Figure 2. Non-linear model fitting of maize grain yield response to added nitrogen fertilizer under soils of different SOC ranges in a Ferralsol in Uga

Results

	Selected organic material (% C content; References)	Equivalent organic material to restore C (t ha^{-1}) in fields of lowest SOC to the critical 2.2% level			Resource quality classes by Palm et al., 2001	Exponential model decay constant (k) day^{-1}	Estimated half life	Frequency and quantities required for restoration
		<0.6% to 2.2%SOC	1.2% to 2.2% SOC	1.7% to 2.2% SOC				
1	Mature compost (24 % C, Kimani & Lekasi et al., 2004)	123.8 - 81.6	81.6 - 39.3	39.3	Class I (High N, low lignin and PP*)	0.019	36	65 t ha^{-1} (applied 10 times)
2	Mukuna Pruriens (42.94% C Dauda et al., 2006)	69.2-45.6	45.6-21.9	22	Class I (High N, low lignin and PP*)	0.023	30	36.5 t ha^{-1} (12 times applied)
3	Cow dung (35 % C, Lekasi et al., 2001)	84.90 - 56	55.93-27	27	Class II (High N, high lignin, low PP)	0.011	63	
4	Sesbania sesban litter (37.2% C Palm et al., 2001)	79.9-52.6	52.6-25.4	25.4	Quality class I (High N, low lignin and PP*)	0.042	17	_
5	Calliandra calothyrsus litter mass (46.28% Palm et al., 2001)	64.2-42.3	42.3-20.3	20.3	Class II (High N, high PP*, low lignin)	0.012	58	_
6	Maize stover (41.2% C Palm et al., 2001)	72.1-47.5	47.5-22.9	22.9	Class III (Low N, low lignin)	0.0093	75	39t ha^{-1} (5 times a year)
7	Bean trash (54.1% C, TSBF database, 1997)	79.9-52.6	52.6-25.4	25.4	Not classified	0.021	33	29 t ha^{-1} (11 times)
8	Eucalyptus salign (litter) (46.13% C, Palm et al., 2001	59.5-39.2	39.2-18.9	18.9	Class IV (Low N, high lignin)	0.0072	96	35 t ha^{-1} (4 times ayear)
	Biochar-Wood derived (85.1% C)	34.9-23	23-11	11	Not classified	0.004	173	19 t ha^{-1} (applied 2

Results (cont'd)

- ✓ **Equivalent quantity of organic materials to restore SOC (0.6 to 2.2% SOC/13 -42 t ha^{-1} in 0-15 cm layer**

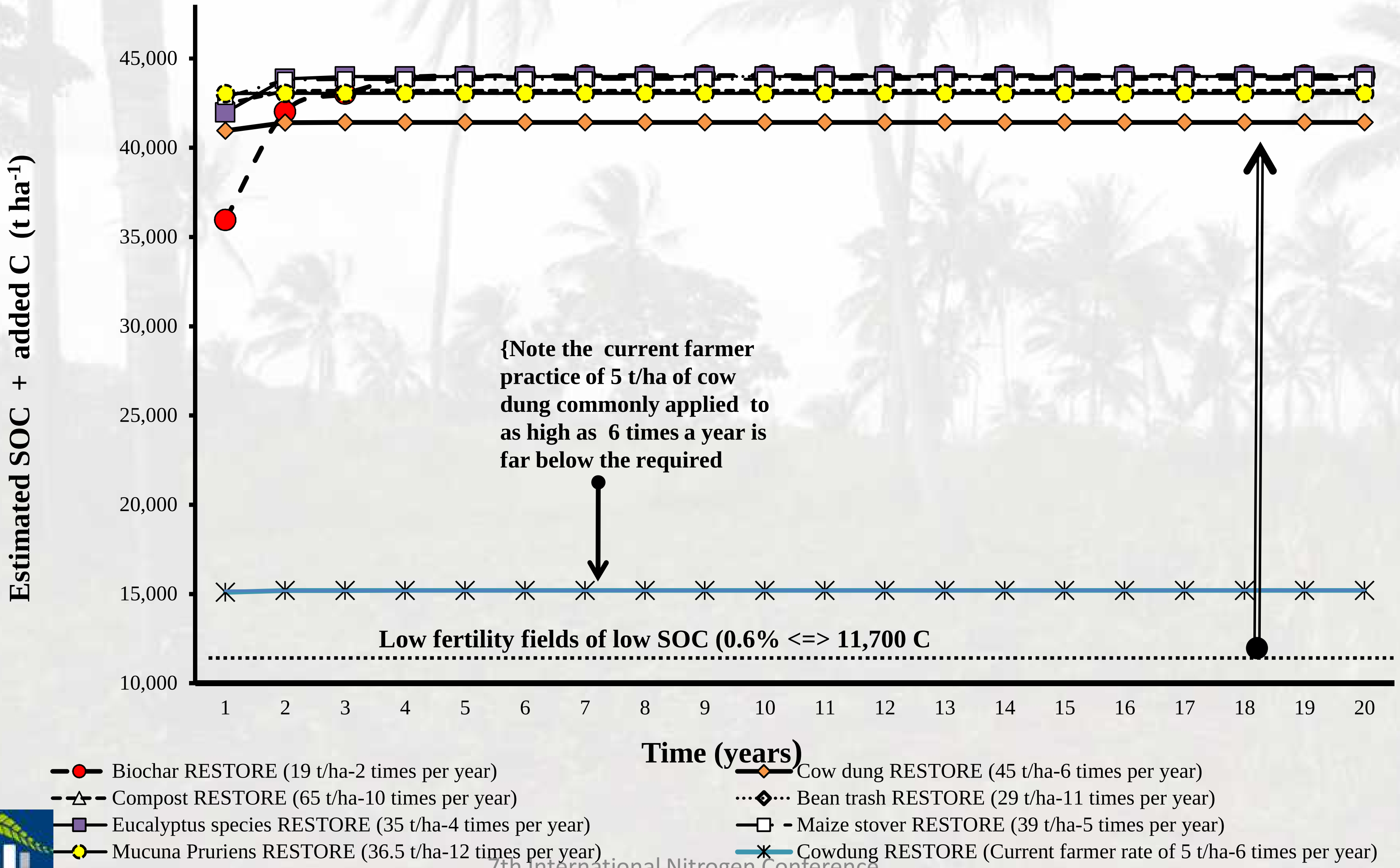


Raising SOC (amount of added C needed)

0.6-2.2 % SOC (13 -42 t ha^{-1} C)-Need 29.7 t ha^{-1}
1.2-2.2% SOC (26- 42 t ha^{-1})- Need 19.5 t ha^{-1}
1.7 - 2.2 % SOC (33 -42 t ha^{-1})- Need 9.4 t ha^{-1}

Results (Cont'd)

- ✓ Frequencies and quantity of organic materials for SOC restoration in 20 years



Conclusion and recommendations

Conclusion

- ✓ Organic materials have to be applied continuously in reasonable quantities to register unit changes in SOC
- ✓ Applications as high as 10 to 12 times in a year for compost, bean-trash and *mucuna pruriens,* and as low as 2 times for biochar needed to raise SOC from 0.6 to 2.2%
- ✓ Building SOC is a major pathway for improving NUE in the tropical soils

Recommendations

- ✓ Engaging different stakeholders such as researchers, policy makers and farmers to improve material availability, material quality and use
- ✓ Long-term research studies needed to validate the theoretical underpinnings demonstrated in this work
- ✓ Economic implications need to be considered so as to make sound judgment for future use in SOC restoration efforts

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