Measuring and Evaluating Soil Health in Africa

Getting the best out of light

Keith D Shepherd & Ermias Betemariam

Land Health Decisions
World Agroforestry Centre (ICRAF), Nairobi, Kenya

World Agroforestry Centre

Soil-Plant Spectral Diagnostics Lab

Africa Soil Information Service
www.africasoils.net

Conference on Agricultural Productivity and the Environment

11-12 March 2015, Washington D.C.

Context

- Soil comes to the global agenda
  - Sustainable intensification took soil as a x-cutting
  - Global Environmental Benefits - land degradation and soils are among the priority global benefits (GEF/UNCCD)
  - Soil information is the weakest link in agriculture and many other sectors (Dobermann 2013)
- Increasing demand for soil data at fine spatial resolution
  - High spatial variability in soil properties- large data sets needed to reduce uncertainty
  - Soil monitoring is expensive to maintain

Land health surveillance

- Land health surveillance is the ongoing, systematic collection, analysis, & interpretation of data essential to the planning, implementation and evaluation of land management policy and practice, and application of these data to promote, protect, and restore land and ecosystem health.

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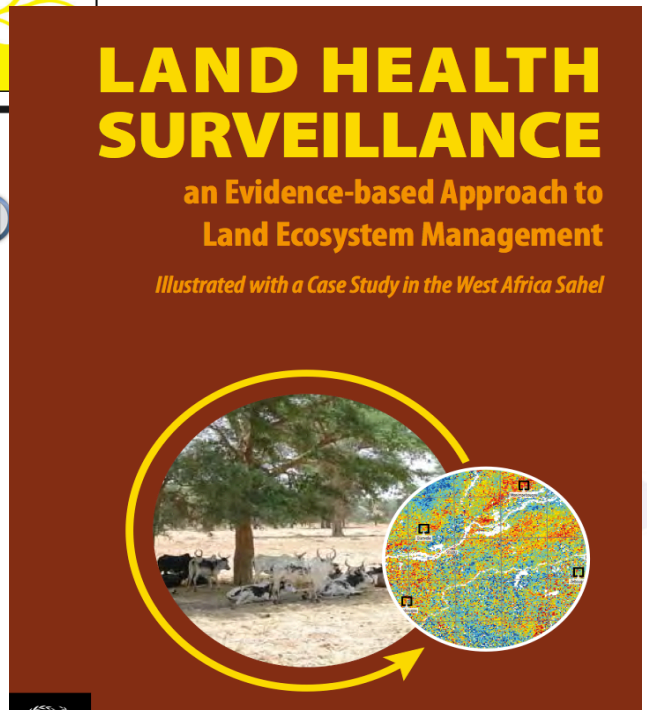
journal homepage: www.elsevier.com/locate/agsy

Land health surveillance and response: A framework for evidence-informed land management

Keith D. Shepherd [a,*], Gemma Shepherd [b], Markus G. Walsh [c]



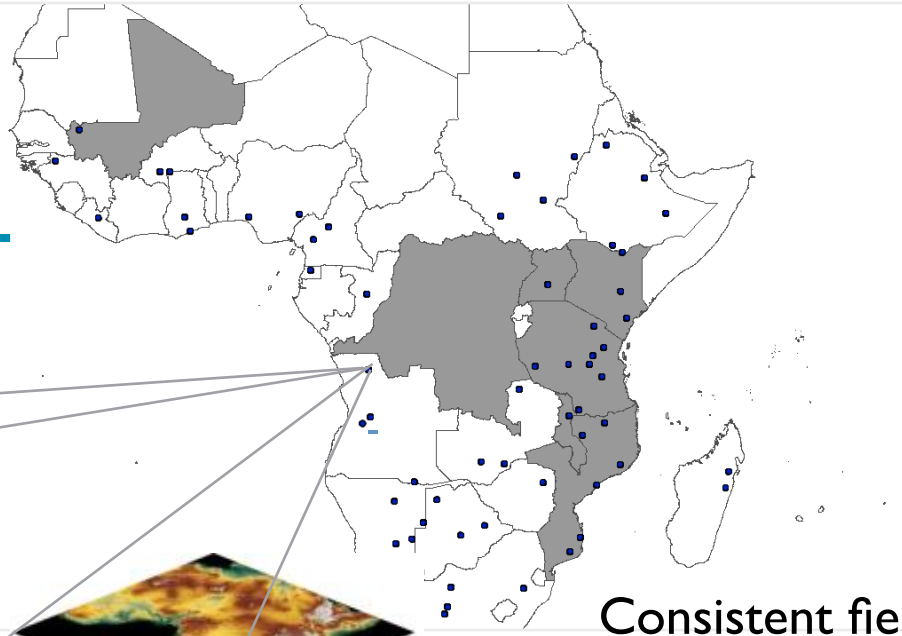
Tells us:

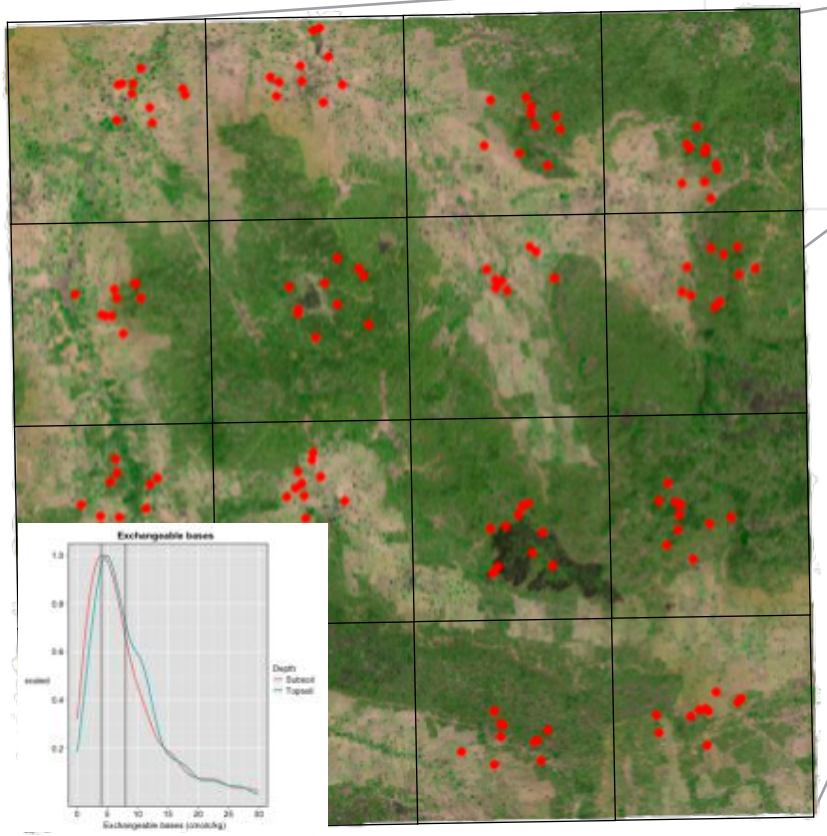
- Where land problems exist
- Whom and what they affect
- Where programmatic and prevention activities should be directed
- How well they are working

http://www.unep.org/dewa/Portals/67/pdf/LHS_Report_lowres.pdf

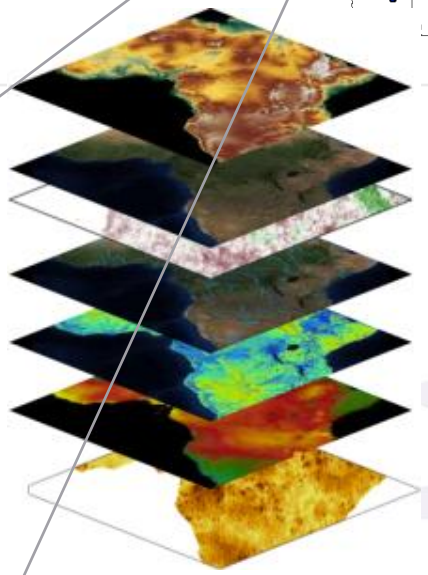
Africa Soil Information Service

Sentinel sites
Randomized sampling schemes





Prevalence, Risk factors, Digital mapping

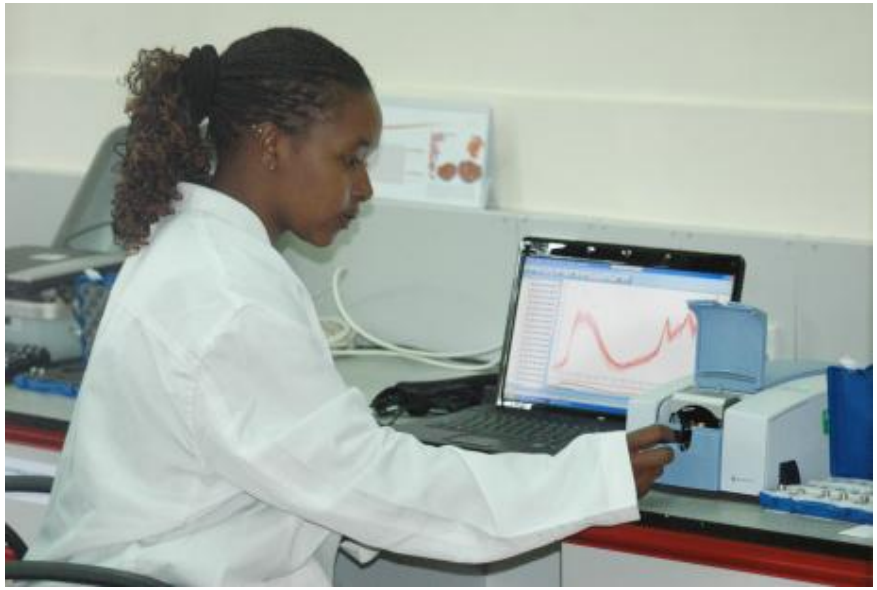


Coupling with covariates (e.g. remote sensing)

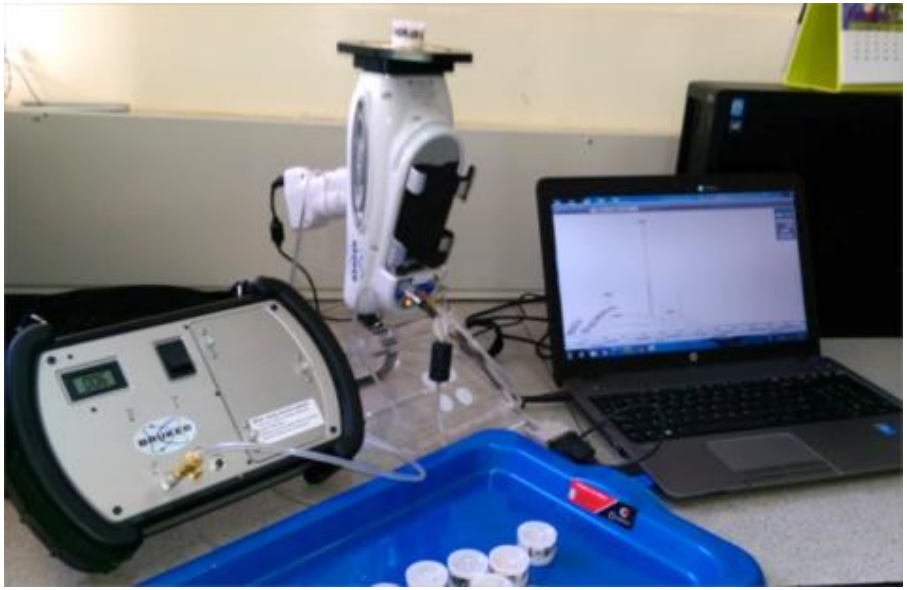
Consistent field protocol

Soil spectroscopy

All you need for soil and plant analysis



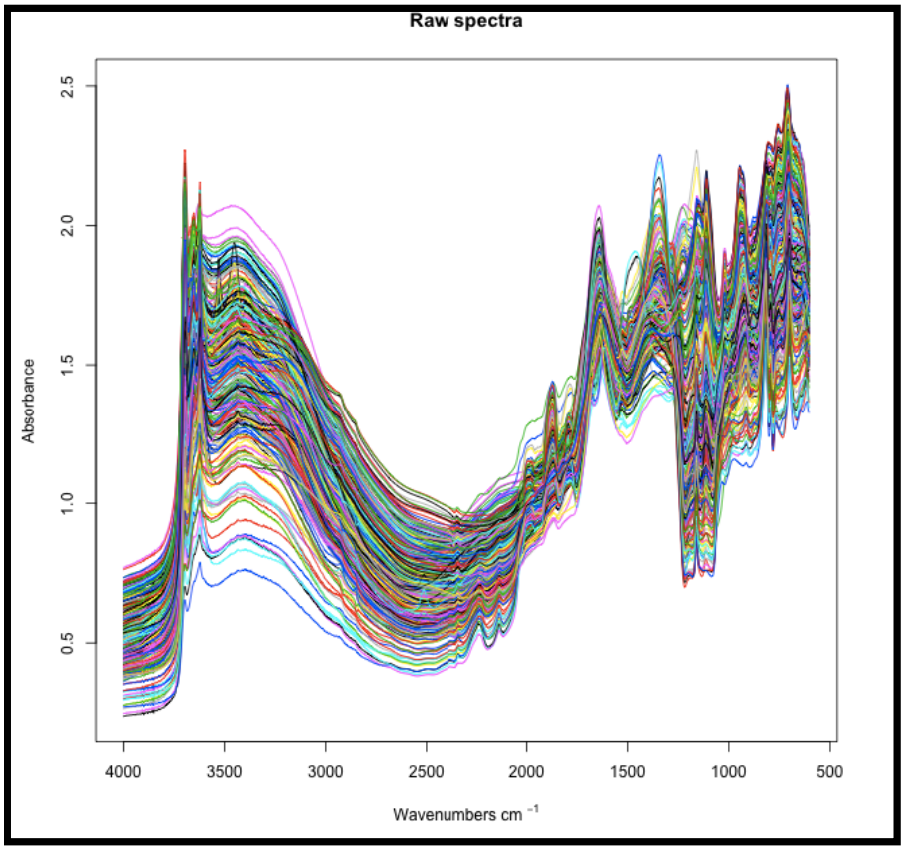
Mid-infrared spectrometer



Handheld XRF analyser

Solar power box

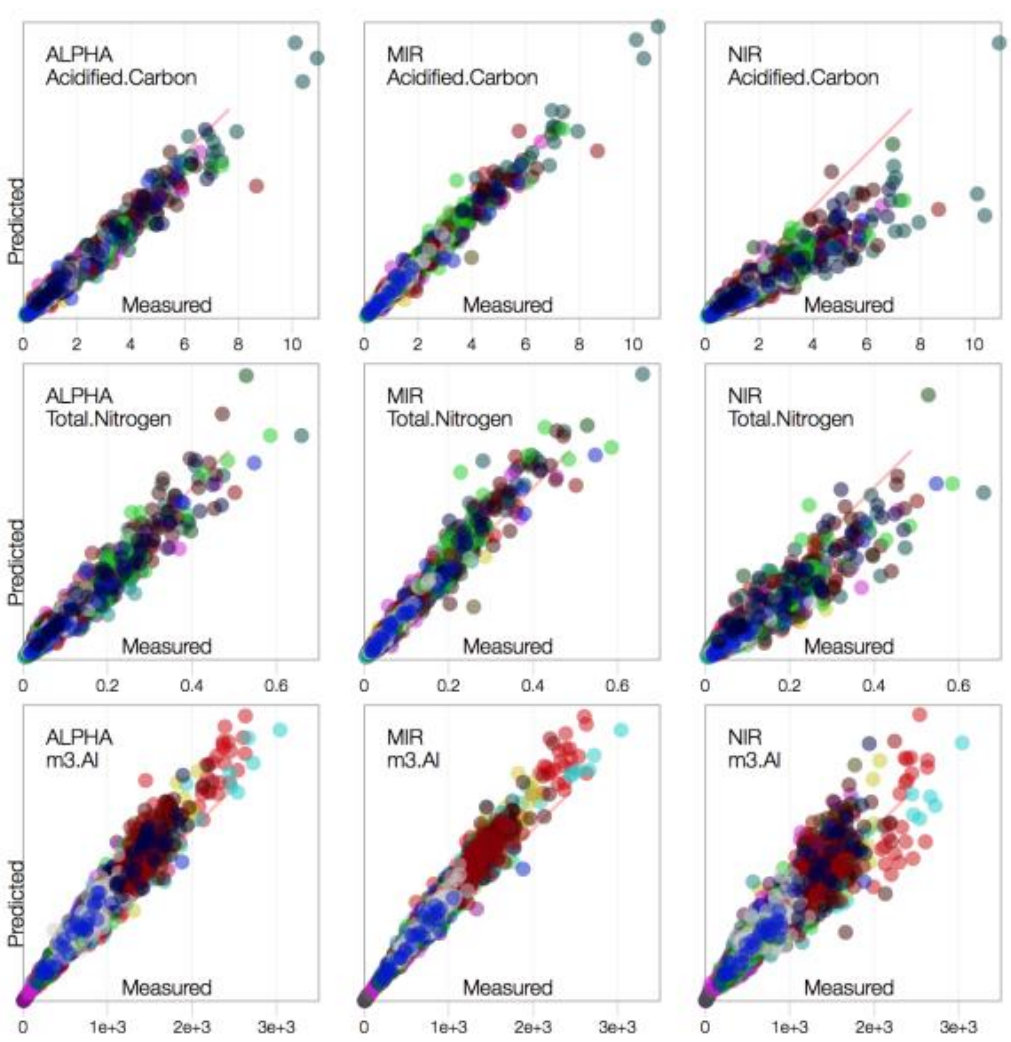
Spectral shape relates to basic soil properties



- Mineral composition
- Iron oxides
- Organic matter
- Water (hydration, hygroscopic, free)
- Carbonates
- Soluble salts
- Particle size distribution

➔ Functional properties

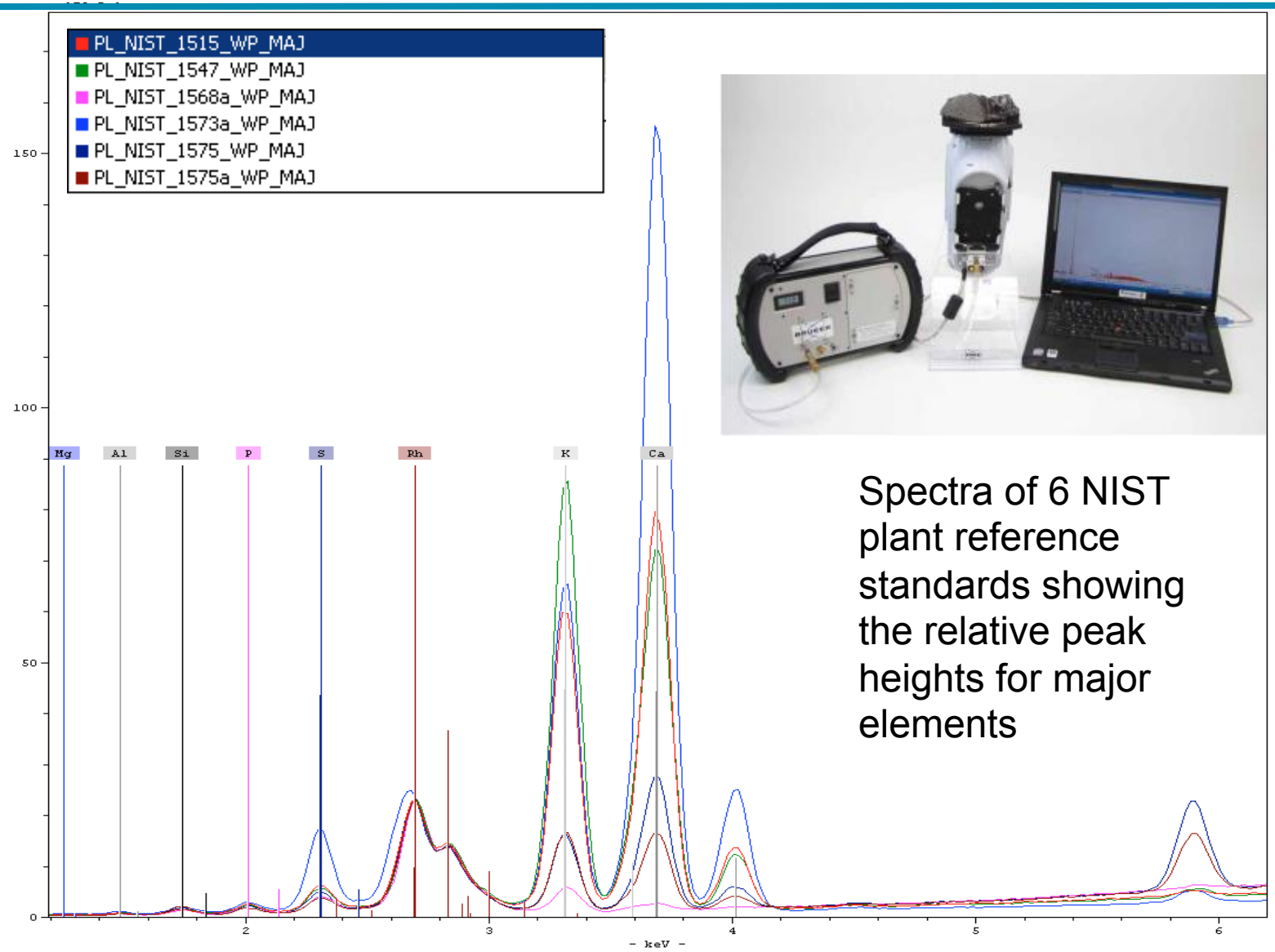
On-line Spectral Prediction Engine
Bayesian Additive Regression Trees



- *Angola*
- *Botswana*
- *Burkina Faso*
- *Cameroon*
- *Ethiopia*
- *Ghana*
- *Guinea*
- *Kenya*
- *Madagascar*
- *Malawi*
- *Mali*
- *Mozambique*
- *Niger*
- *Nigeria*
- *SAfrica*
- *Tanzania*
- *Uganda*
- *Zambia*
- *Zimbambwe*

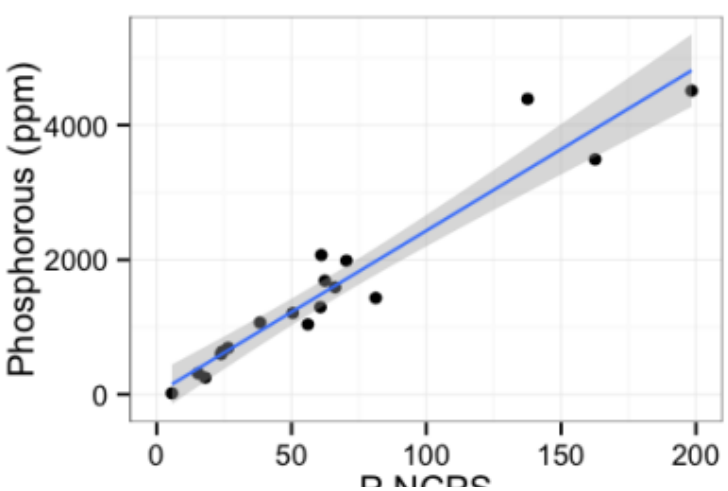
Jiehua Chen & William Wu Columbia University

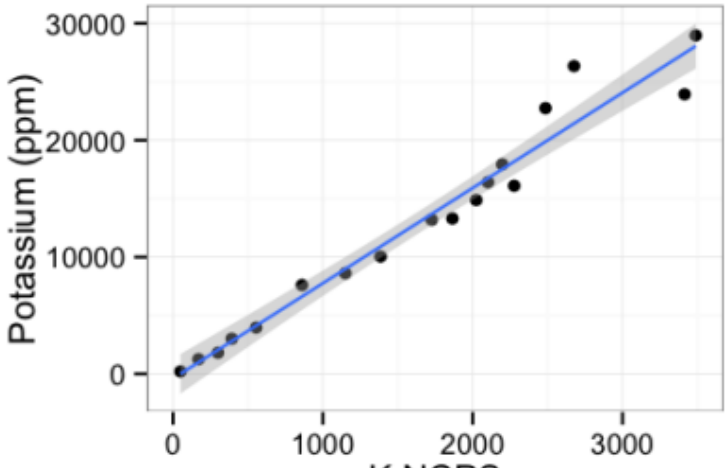
HHXRF counts atoms

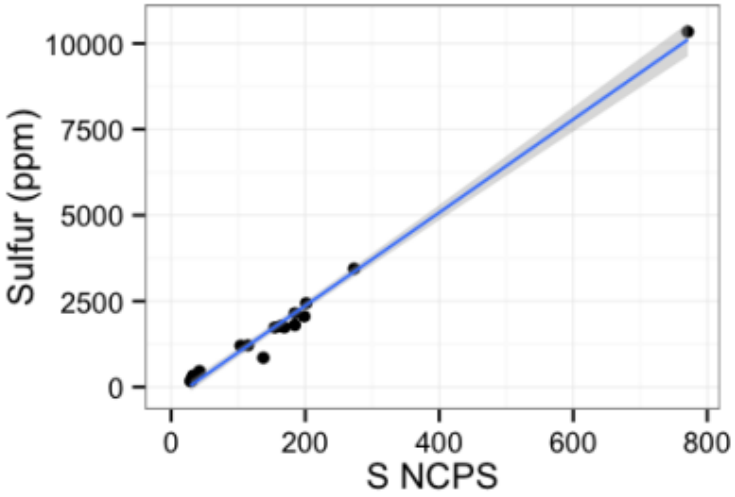


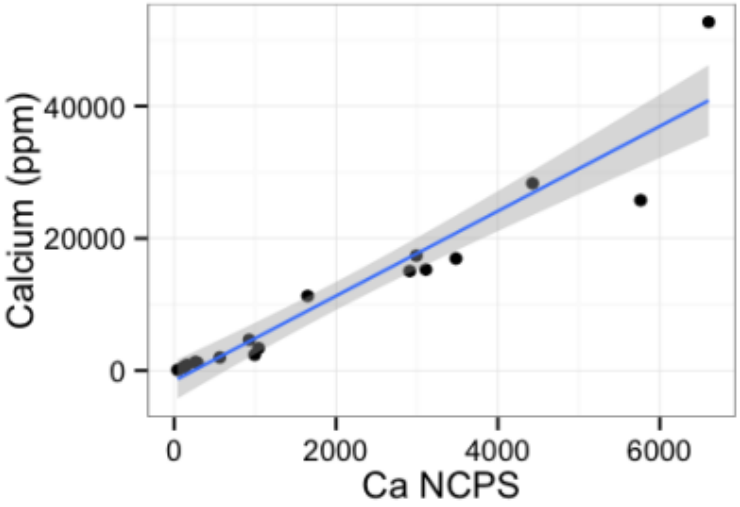
Spectra of 6 NIST plant reference standards showing the relative peak heights for major elements

HHXRF Calibration – plants

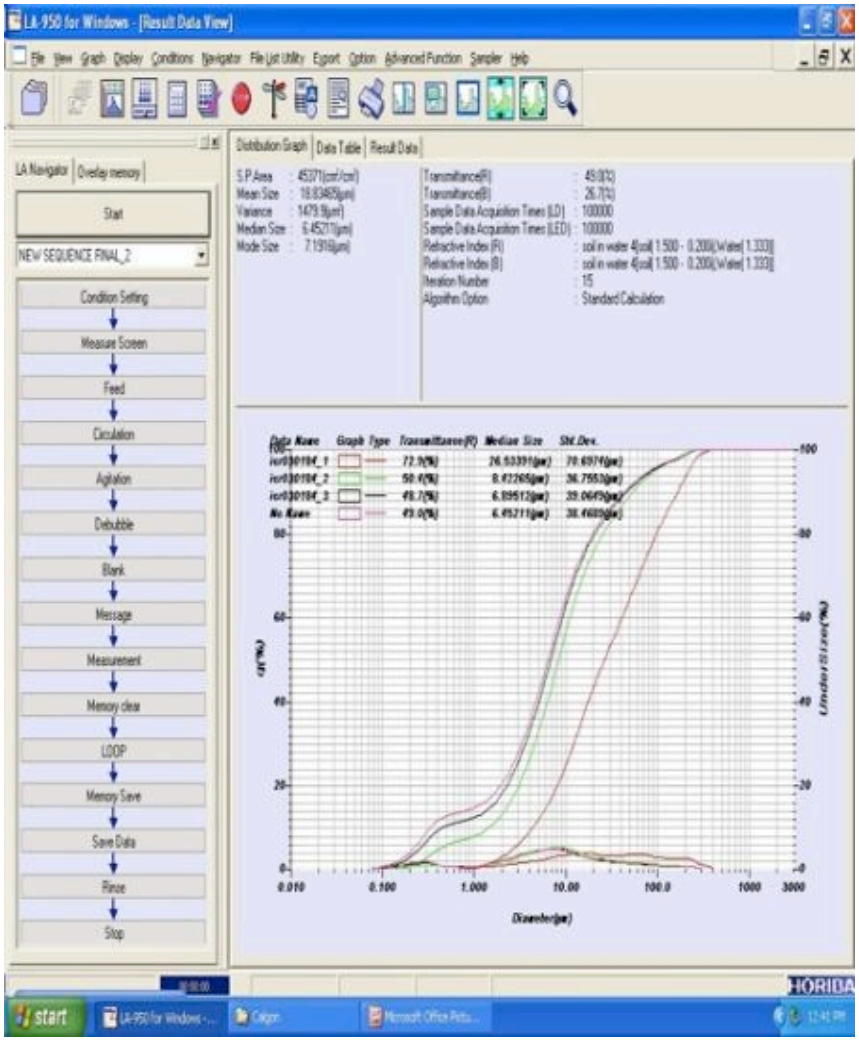








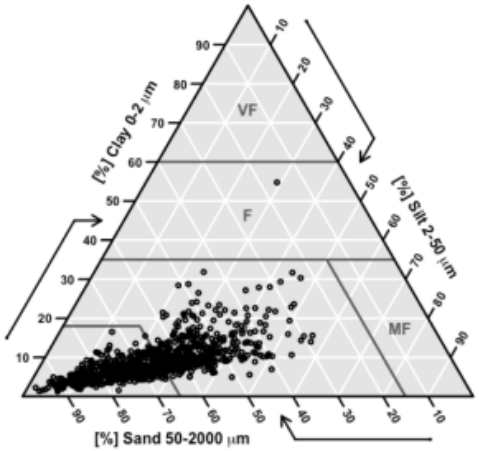
Laser diffraction particle size analysis



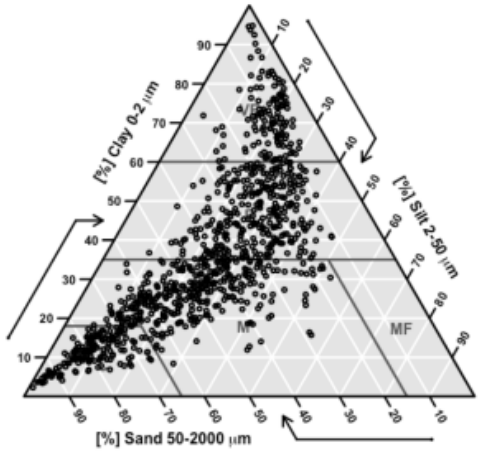
Susceptibility to water and wind erosion

Laser diffraction particle size analysis

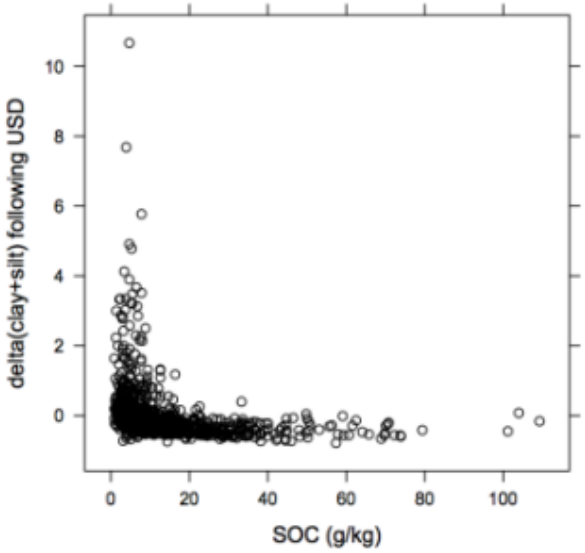
Topsoils dispersed in water



Topsoils dispersed in water & ultra-sonified 4 min



Analysis by
Markus Walsh



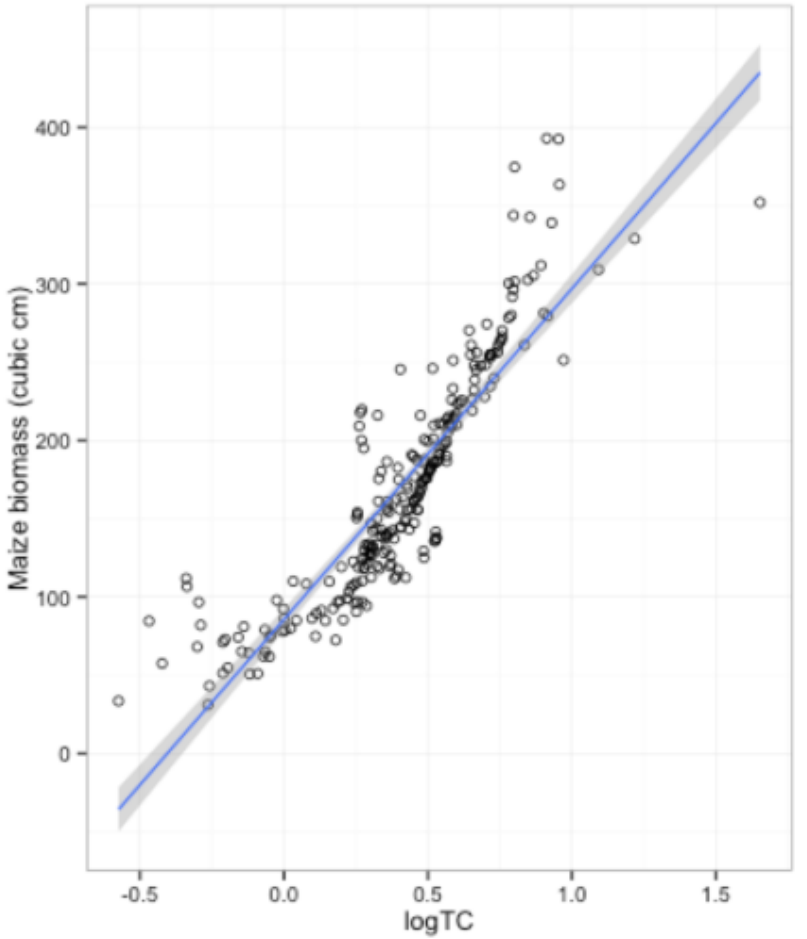
Best predictors of yield and yield response

AfSIS yield response trials, 3 sentinel sites in Malawi and Tanzania; 41 fields, 2 seasons (Kihara et al):

- MIR predicted 70% of variation in maize control yields and 63% of response to P
- Yield and yield responses to NPK correlated with soil total C, N and pH

Extractable nutrients vs soil buffer capacity

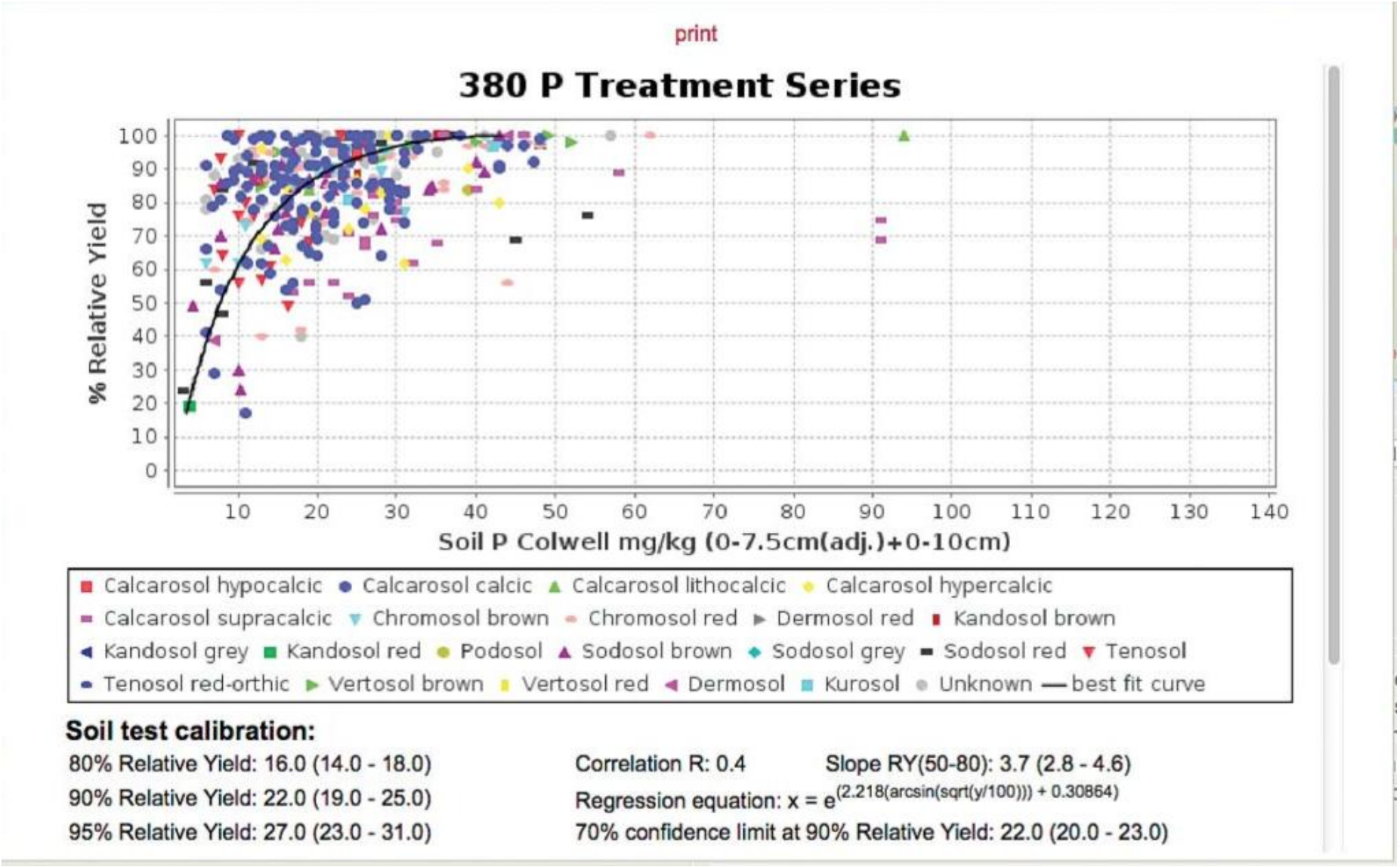
MIR gives mineralogy, P sorption, organic P, intermediate K pools



Maize biovolume vs soil carbon

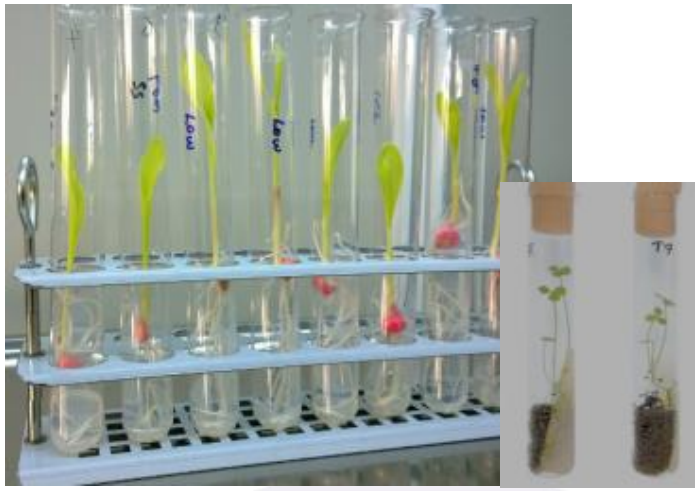
No other soil properties significant (Ichami et al)

Calibrating crop response to soil tests



Plant Environment Facility

Plant growth bioassays in test tubes for high throughput diagnosis of soil macro and micronutrient deficiencies.



Soil carbon measurement planning tool

World Agroforestry Centre

Home | About us | Calculator | About CO_2 | Publications and Links | Contacts

Measurement and Monitoring Soil Carbon

- Guide
- Why measure soil carbon?
- What will the protocol deliver?
- How much will it cost?
- Sampling
- Field work
- Lab work
- Data analysis
- Present and use of the results
- Glossary

Google Search

worldagroforestry.org only

A Protocol for Measurement and Monitoring Soil Carbon Stocks in Tropical Landscapes

This protocol has been developed over a number of years through various projects and is currently being refined in the context of the Africa Soils Information Service (AfSIS: www.africasoils.net), funded by the Bill & Melinda Gates Foundation and the Alliance for a Green Revolution in Africa (AGRA), and the Carbon Benefits Project: Modeling, Measurement and Monitoring, funded by the Global Environment Facility (GEF) of the United Nations Environment Program (UNEP).

This document was developed through a grant to the World Wildlife Fund from the Global Environment Facility and implemented by the United Nations Environment Program

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Jiehua Chen and Andrew Sila.

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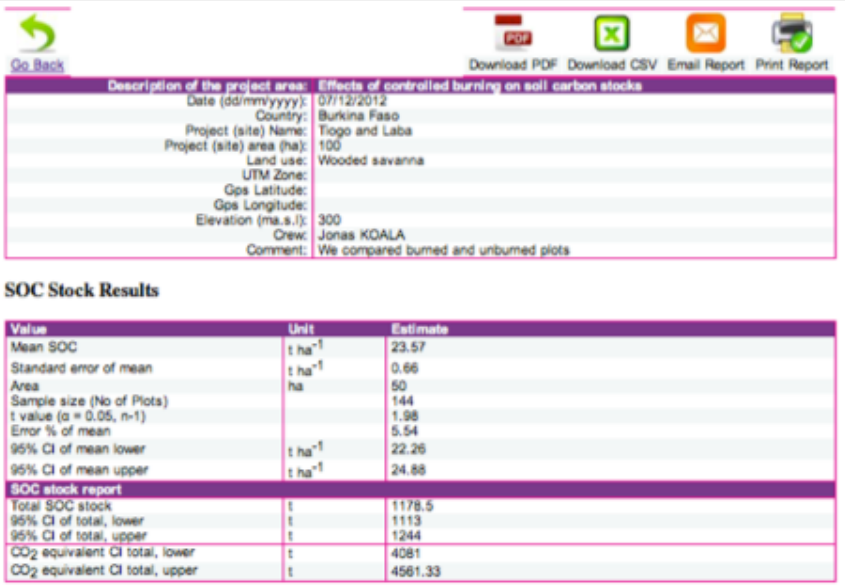
landscapes. Version 1.1. World Agroforestry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Description of the project area:	Effects of controlled burning on soil carbon stocks
Date (dd/mm/yyyy):	07/12/2012
Country:	Burkina Faso
Project (site) Name:	Tiogo and Laba
Project (site) area (ha):	100
Land use:	Wooded savanna
UTM Zone:	
Gps Latitude:	
Gps Longitude:	
Elevation (m.s.l):	300
Crew:	Jonas KOALA
Comment:	We compared burned and unburned plots

SOC Stock Results

Value	Unit	Estimate
Mean SOC	t ha^{-1}	23.57
Standard error of mean	t ha^{-1}	0.66
Area	ha	50
Sample size (No of Plots)		144
t value (α = 0.05, n-1)		1.98
Error % of mean		5.54
95% CI of mean lower	t ha^{-1}	22.26
95% CI of mean upper	t ha^{-1}	24.88
SOC stock report		
Total SOC stock	t	1178.5
95% CI of total, lower	t	1113
95% CI of total, upper	t	1244
CO_2 equivalent CI total, lower	t	4081
CO_2 equivalent CI total, upper	t	4561.33

Africa Spectral Lab Network

IAMM, Mozambique

AfSIS, Sotuba, Mali

AfSIS, Salien, Tanzania

AfSIS, Chitedze, Malawi

CNLS, Nairobi, Kenya

ATA, Addis Ababa, Ethiopia (6)

CNRA, Abidjan, Cote D' Ivoire

KARI, Nairobi, Kenya

ICRAF, Yaounde, Cameroon

IAR&T, Obafemi Awolowo University, Ibadan, Nigeria

IAR, Zaria, Nigeria

FMARD, Nigeria

IITA, Ibadan, Nigeria

IITA, Yaounde, Cameroon

SARI, Salien, Tanzania

CNLS, Nairobi, Kenya

SoilCares, Kenya

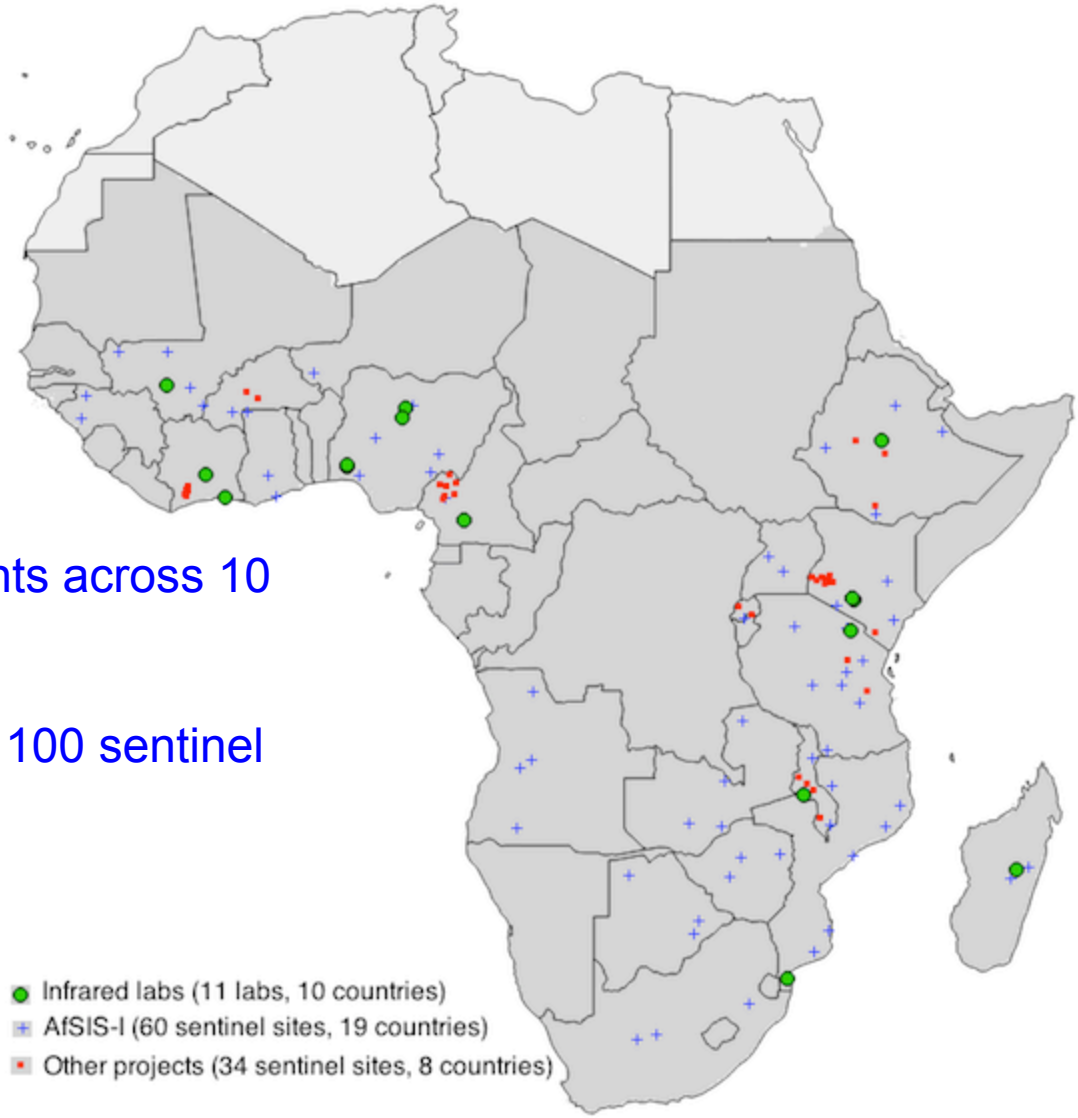
IISS, Bhopal, India

Soil-Plant Spectroscopy Support Group

Land Health Projects in Africa

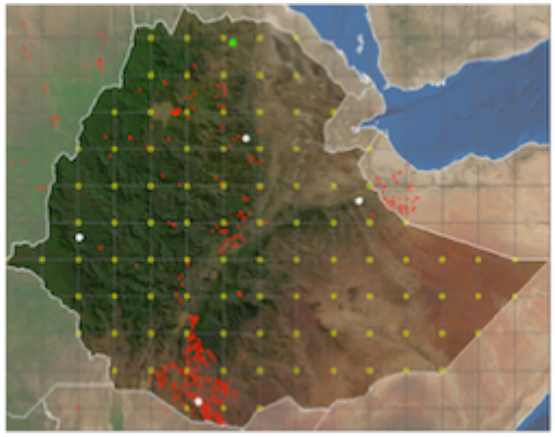
We support 27 spectral instruments across 10 countries across Africa

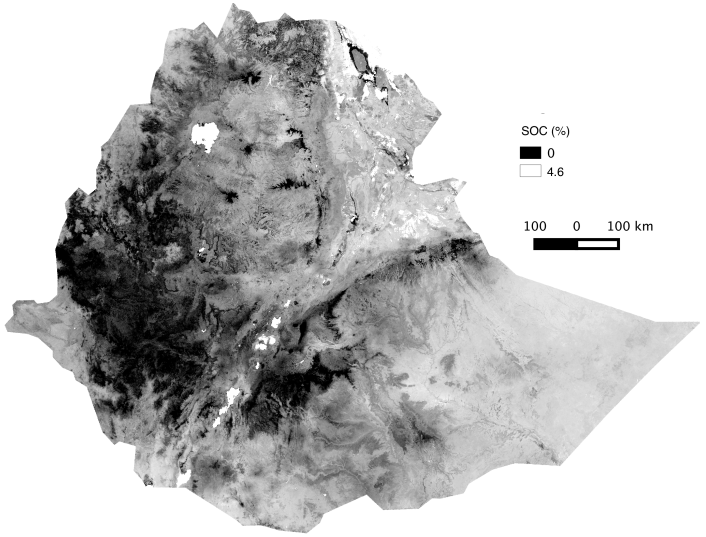
Land health data from more than 100 sentinel sites across Africa



Land health projects: National scale

From AfSIS to EthioSIS





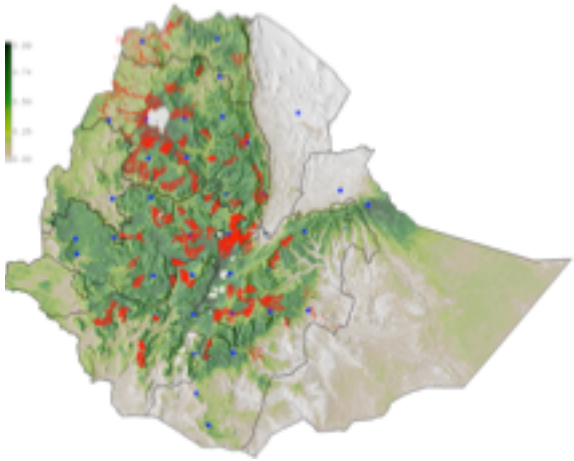
Probability topsoil pH < 5.5 ... very acid soils

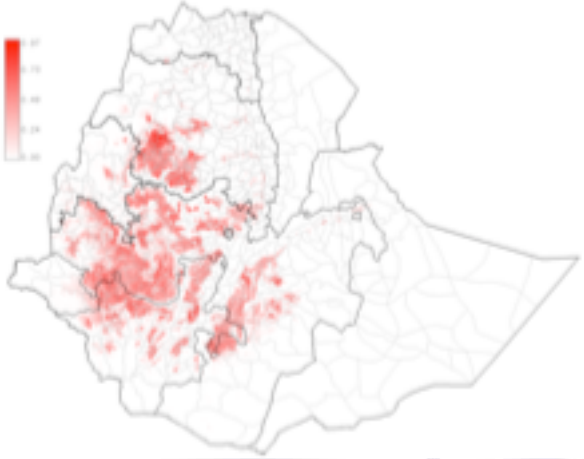
+

Probability of observing cultivation

=

Current lime requirement ? ~ min [prob(pH < 5.5), prob(cult)]





(Walsh, 2013)

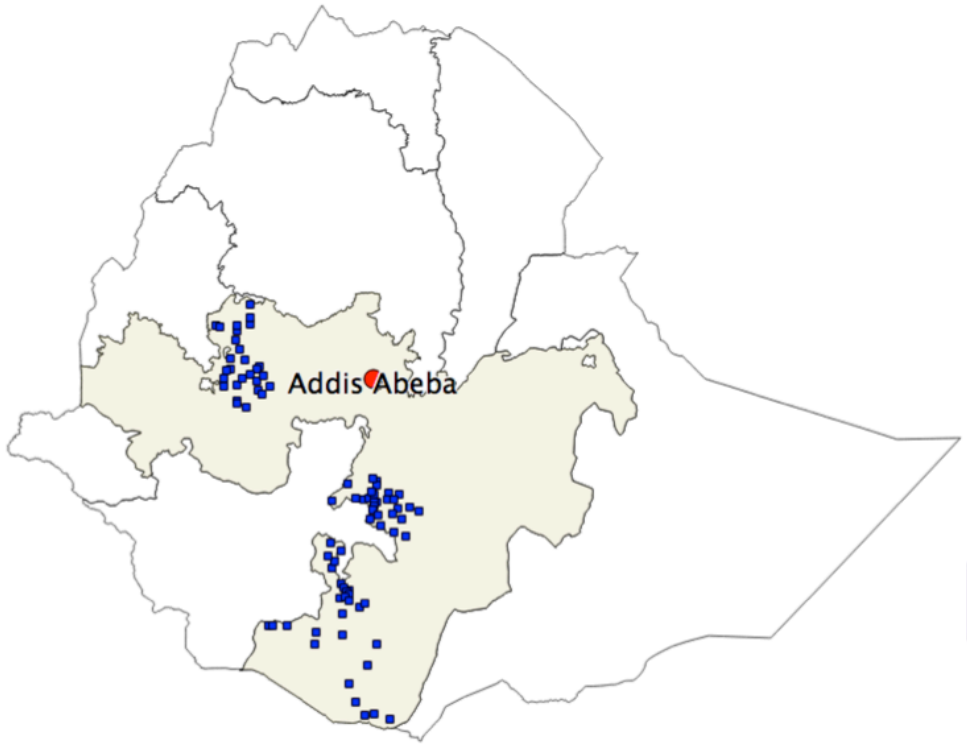
Living Standards Measurement Study-LSMS-IMS

Improve measurements of agricultural productivity through methodological validation and research

Low cost MIR soil testing for smallholder farmers

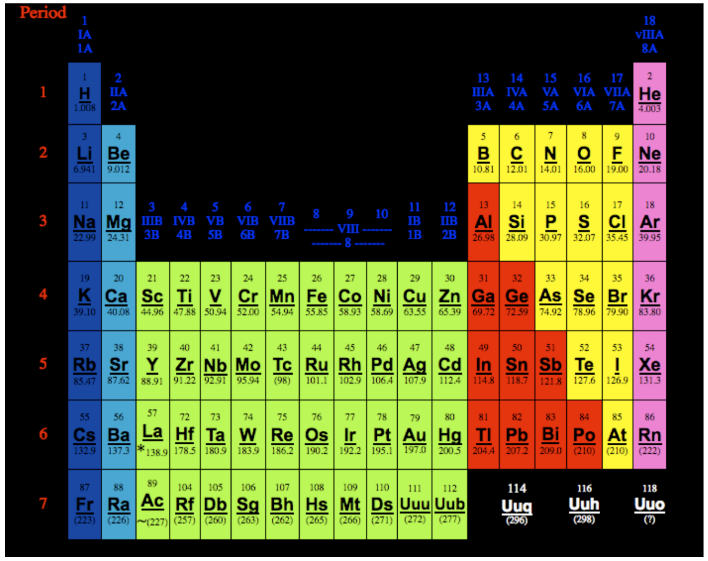
Mobile phones for quick soil screening- being tested

Jeff Herrick (USDA-ARS)

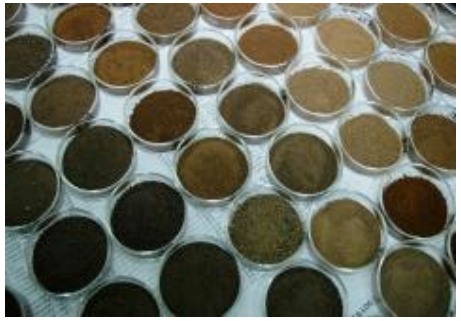


Improving Ag. statistics:
World Statistics Congress 2015

MTT-Finland
FoodAfrica
Soil Micronutrients



Evidence-based micronutrient management



Healthy soils

Healthy crops

Healthy livestock

Healthy people

Trees for food security

Characterize land health constraints and assessing Agroforestry intervention outcomes

Rwanda

Ethiopia

Purpose of measurement
Improve decisions!

- Information has no value unless it has the potential to change a decision (Ron Howard)
- Purpose of measurement is to reduce decision uncertainty
- Measurements = observations that quantitatively reduce uncertainty (Doug Hubbard)
- Making sense out of measurements:
  - Know the decision we are trying to make
  - Know the current state of uncertainty (our priors) – model the decision uncertainties
  - Measure where it matters and only enough to make a sound decision

Stochastic Impact Evaluation

- Identify the decision
- Model the uncertainties with stakeholders, experts
- Measure where it matters and only enough to improve intervention decision
- Monitor, evaluate, adjust, update

  - Applied Information Economics (Hubbard, 2014)
  - Decision Analysis
  - Complex systems management

Decision case – Groundwater supply to Wajir town

Different distributions of costs and benefits for different stakeholder groups – revealed large implementation risks – led to project rethink and redesign
(Luedeling, de Leeuw, et al. Frontier in Environmental Science (in press))

Finally…

- More research on cost-effective measurement tools
- Decision before measurement?
- Develop national capacities, networking and partnership
  - web services are needed
- Baselines are established for important soil properties across Africa
- Soil spectroscopy filling the data gaps- at National, Regional & Global levels
- Enable decision makers have clear understanding of soil status and trends (digital soil mapping)

Global Change Biology (2014), doi: 10.1111/gcb.12632

EDITORIAL COMMENTARY

Soil spectroscopy: an opportunity to be seized

MARCO NOCITA[1,2], ANTOINE STEVENS[2], BAS VAN WESEMAEL[2], DAVID J. BROWN[3], KEITH D. SHEPHERD[4], ERICK TOWETT[4], RONALD VARGAS[5] and LUCA MONTANARELLA[1]


Thank you
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