

2009 National Cooperative Soil Survey National Conference

Las` Cruces NM May 11

Methodologies for Digital Soil Mapping & Monitoring

Alex McBratney & Budiman Minasny

The University of Sydney
AUSTRALIA

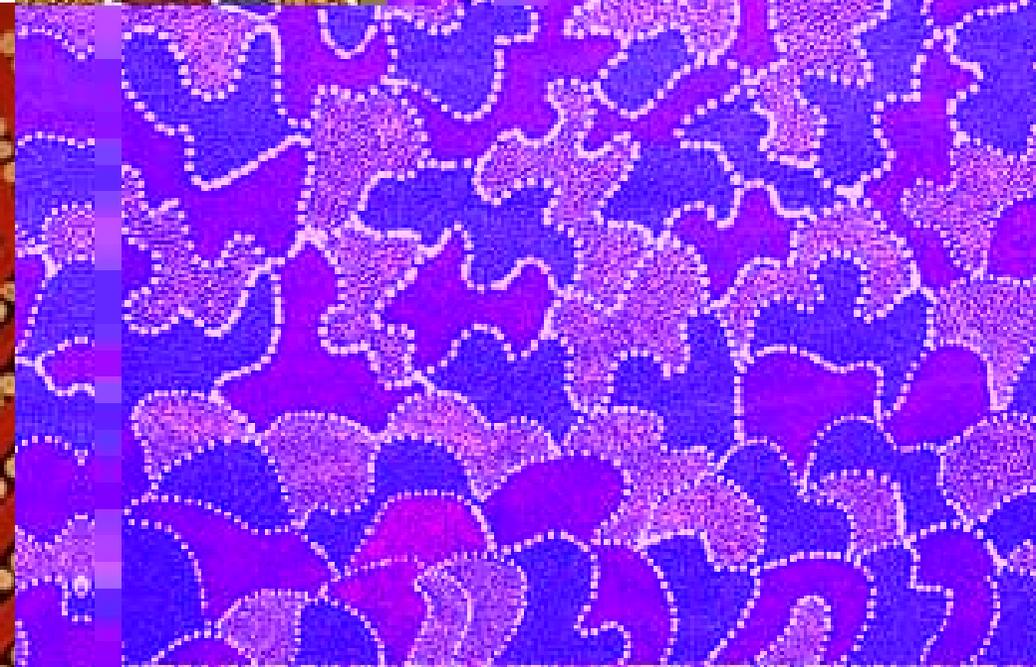
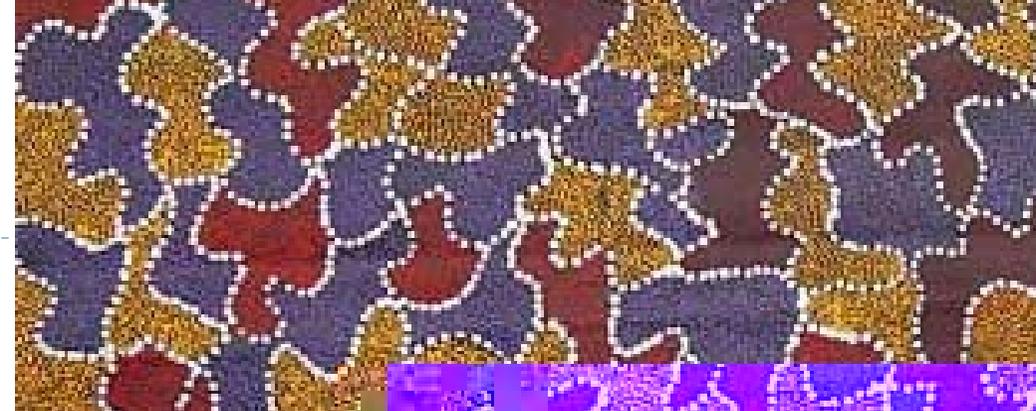




***“We know more about the movement
of celestial bodies than about the soil
underfoot.”***

- Leonardo da Vinci







-
- ▶ Digital soil mapping
 - ▶ *globalsoilmap.net* project
 - ▶ Digital soil assessment
 - ▶ Digital soil monitoring
 - ▶ (My thoughts on) opportunities for National Cooperative Soil Survey





DSM definition

- ▶ The creation and population of spatial soil information systems by numerical models inferring the spatial and temporal variations of soil types and soil properties from soil observation and knowledge and from related environmental variables
 - ▶ Lagacherie & McBratney 2007
-





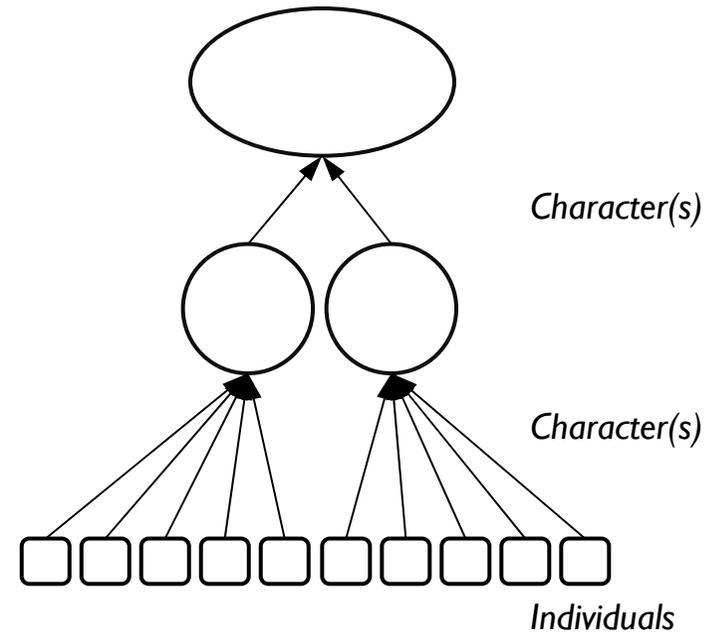
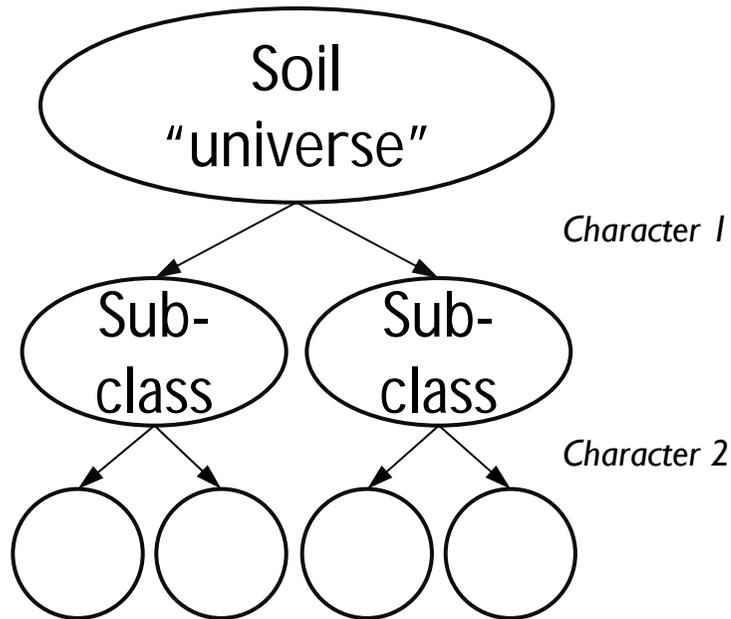
DSM resolution

- ▶ High <20 m
- ▶ **Medium 20-200 m**
- ▶ Low > 200 m





Top-down and bottom-up approaches





Top-down approaches

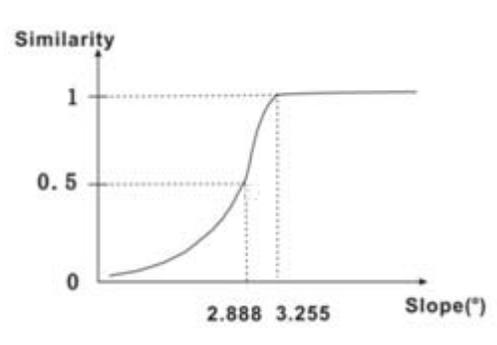
- ▶ Expert - SOLIM
- ▶ Data-based scorpan



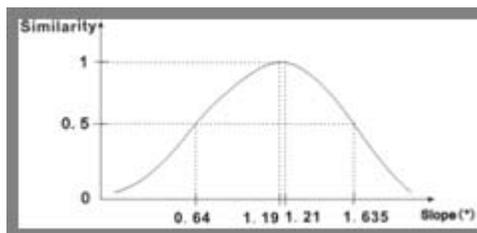


SOLIM

- ▶ a personal construct-based approach to extract the knowledge on soil-environment relationships from local soil experts and represent the knowledge as membership curves



Fuzzy membership curves with respect to slope for a toposequence: a. Mollic Bori-Udic Cambosols, b. Typic Hapli-Udic Isohumosols -1, c. Typic Bori-Udic Cambosols, d. Lithic Udi-Orthic Primosols (Zhu et al, 2009)





scorpan

$$S_{c,p} = f(s, c, o, r, p, a, n) + e$$

s: soil, other properties or prior knowledge of the soil at a point;

c: climate, climatic properties of the environment at a point;

o: organisms, vegetation or fauna or human activity;

r: topography, landscape attributes;

p: parent material, lithology;

a: age, the time factor;

n: space, relative spatial position.

▶ **e:** autocorrelated random spatial variation



scorpan

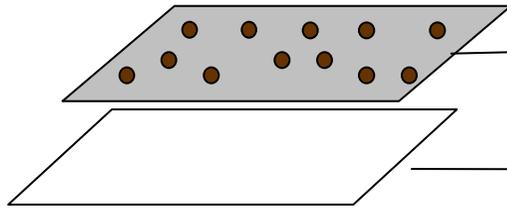
$$\mathbf{S}_{c,p} = f(s, c, o, r, p, \mathbf{h}, a, n) + e$$





scorpan -classes

Soil Classes



$$S_c = f(s, c, o, r, p, a, n) \longrightarrow$$

scorpan layers



f - *Decision trees,*
Random forests,
Neural networks,
Etc..
Krige the residuals



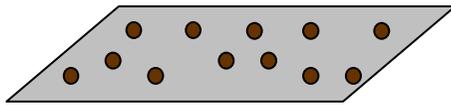




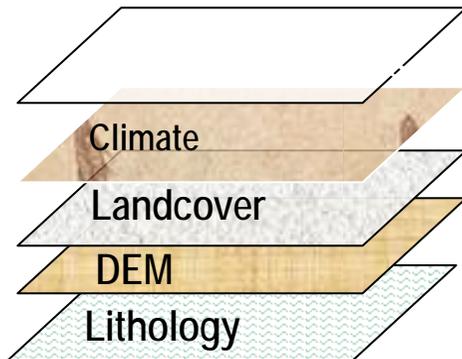


scorpan - properties

Soil observations



scorpan layers



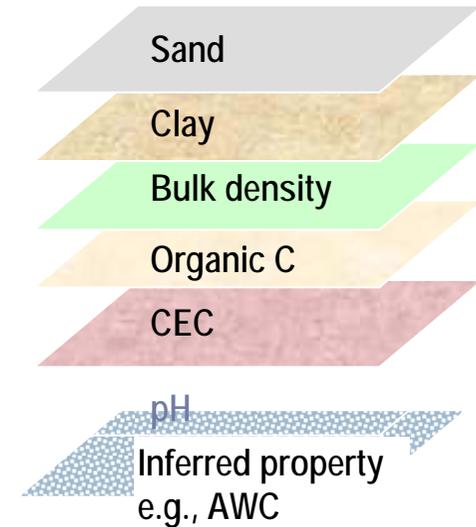
$$S_p = f(s, c, o, r, p, a, n) + e$$

f - *Linear regression,*
Regression trees,
Random forests,
Neural networks,

Etc..

Krige residuals (e)

Master
variables





scorpan properties - the continuous layer model

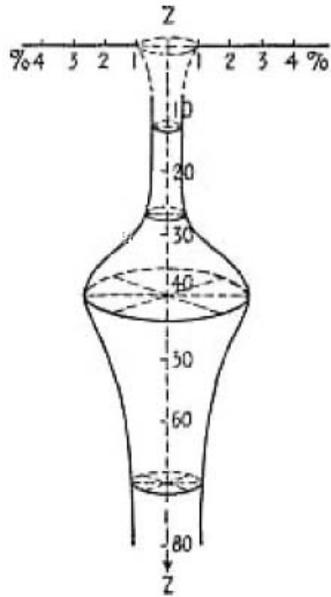


FIG. 6.—Illustration of a soil indicatrix. Colloidal Al_2O_3 of a podsol profile on level topography.

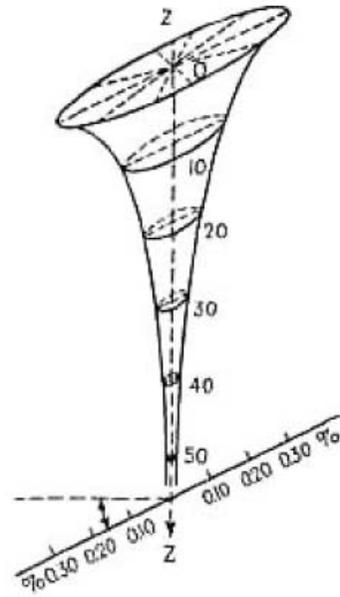
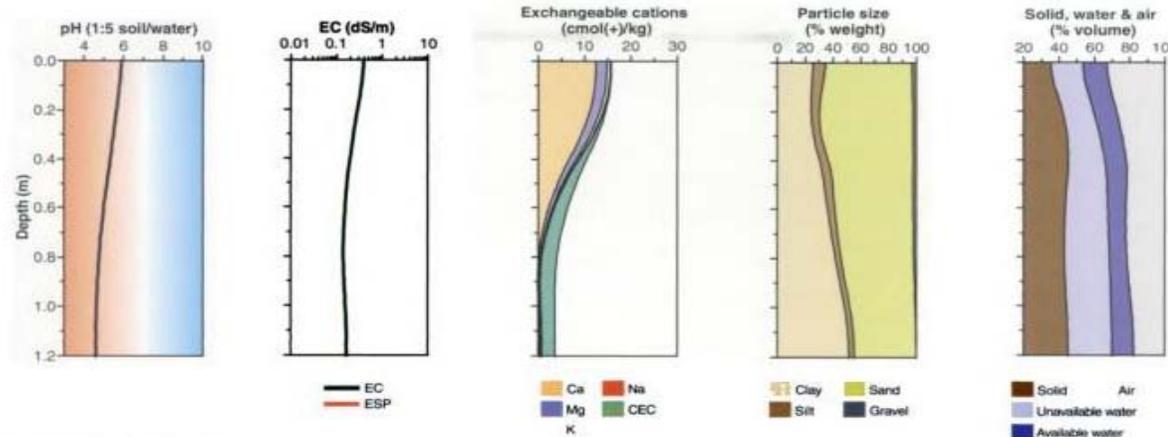


FIG. 7.—Illustration of a soil indicatrix. Total nitrogen of a prairie soil profile on a slope of $26^{\circ}34'$ or 50 per cent.

DE6: Melanic-Acidic, Dystrophic, Brown Dermosol

Key profile properties



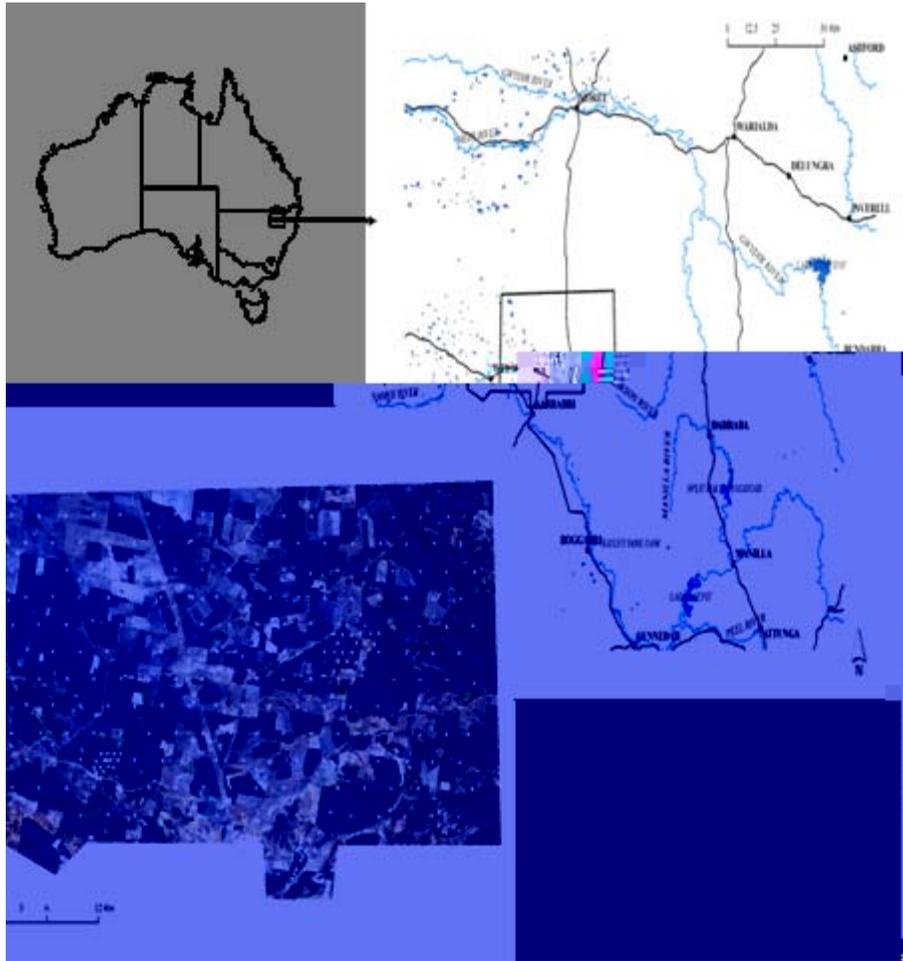


Equal-area spline

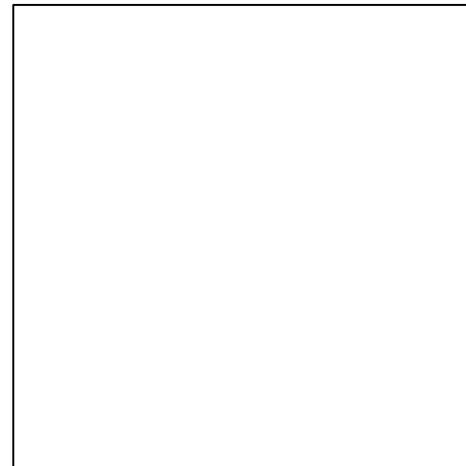
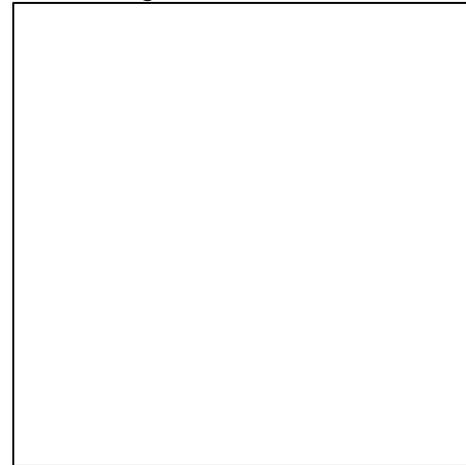




Whole profile mapping

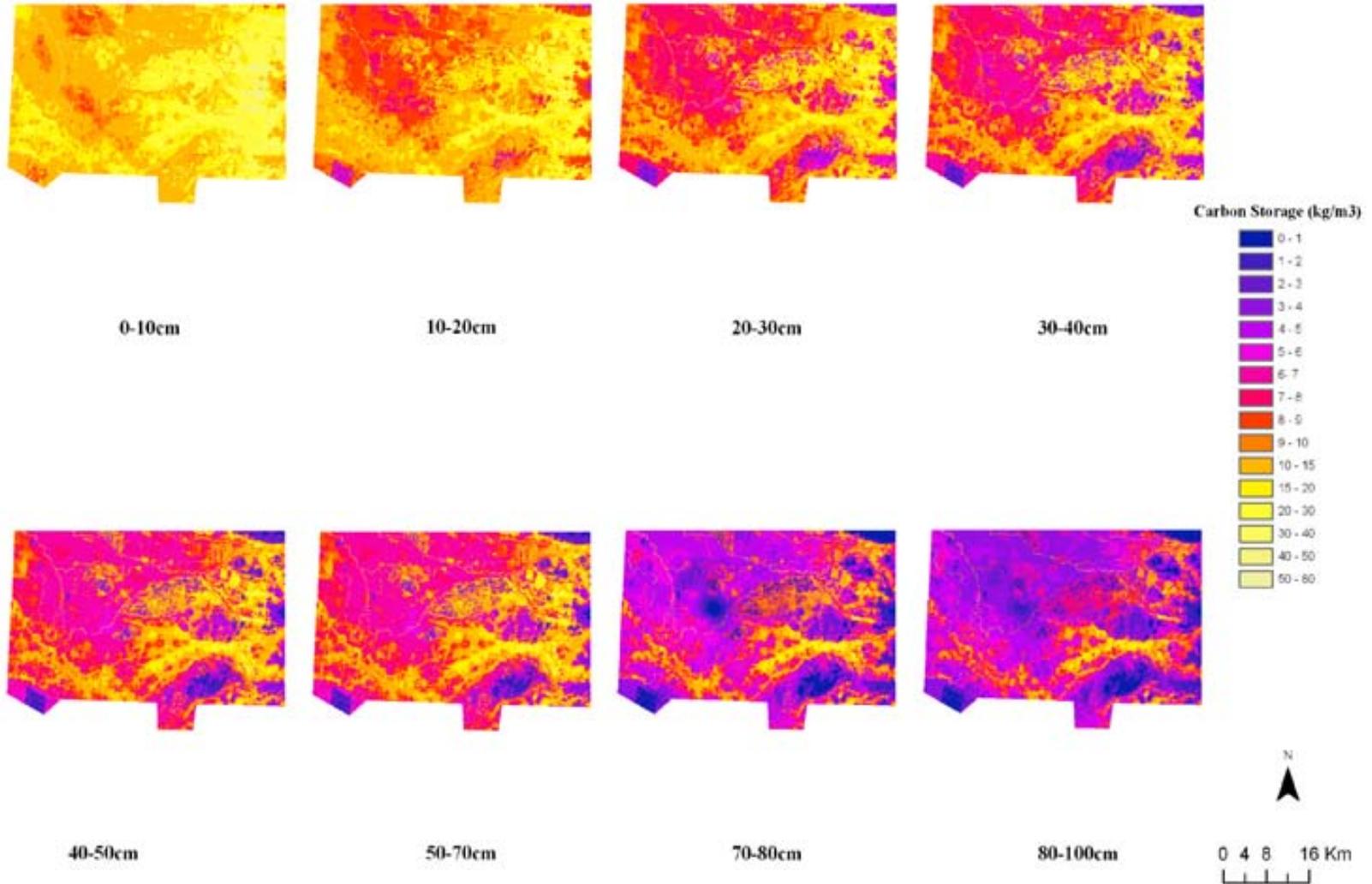


Clay content

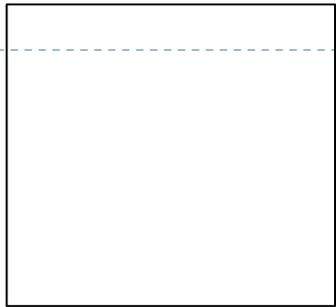
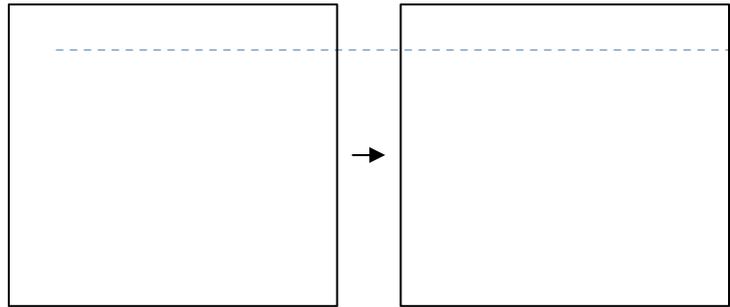




Profile Soil C prediction



Carbon Storage

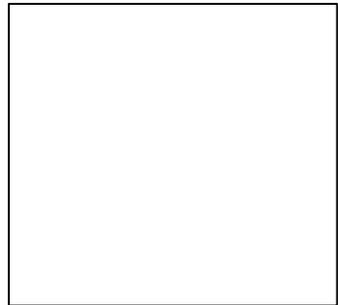


• **Environmental factors:**
Elevation, slope, altitude above channel network, stream power index, potassium, bands #3, #4 and #5 and band ratios 3/7 and 5/7



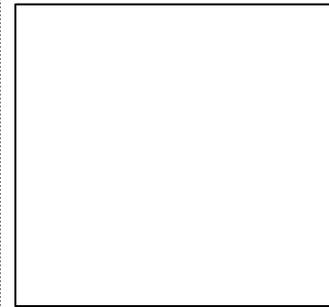
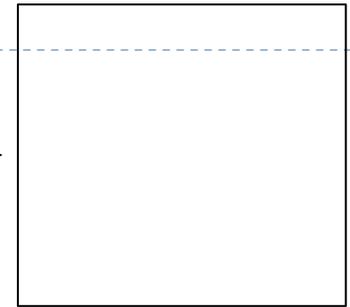
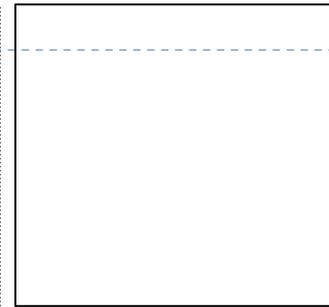
• **Fit of model:** R^2 ranged between 50-78%- best predictions 20-100cm

• Adequate fit of predicted spline functions with raw profile data in most



Fitted splines of raw data

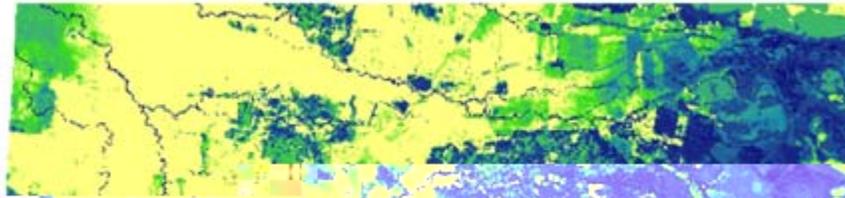
Fitted splines of model estimates



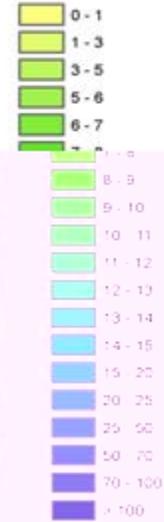
Fitted splines of raw data

Fitted splines of model estimates

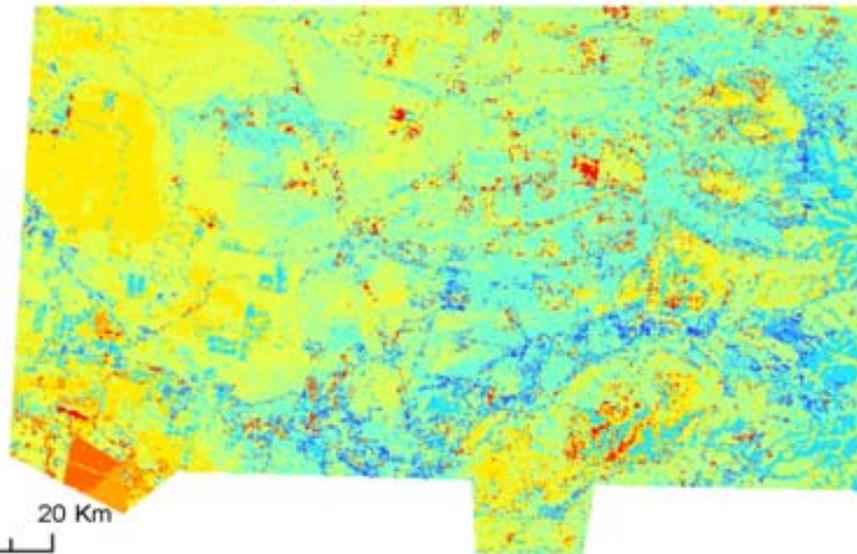




Depth (cm)



Depth at which soil
C < 1%



Depth (cm)



Depth at which
AWC = 100 mm





A wee bit on sampling

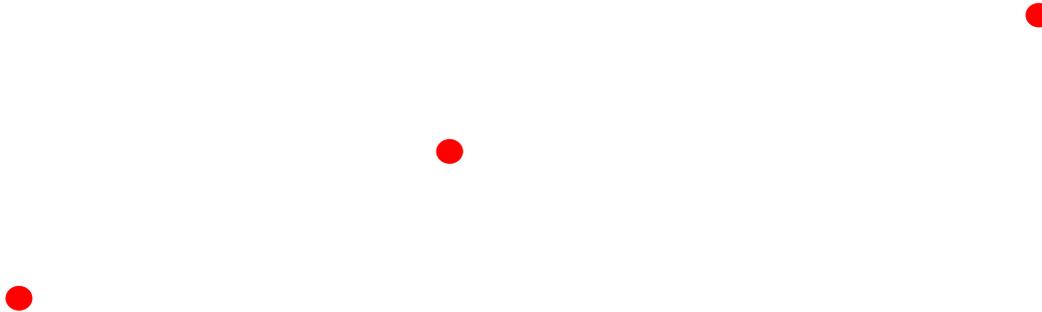
- ▶ 1/3 of the samples used for corroboration/validation/certainty estimation

- ▶ Random catena sampling
- ▶ Latin hypercube sampling



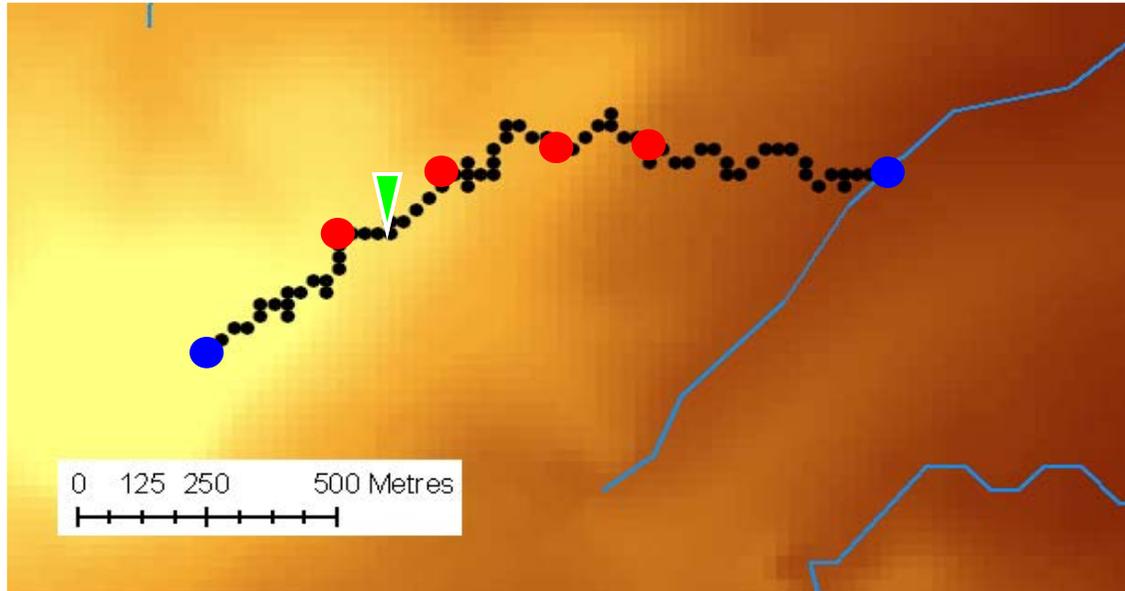


k th-order random toposequences

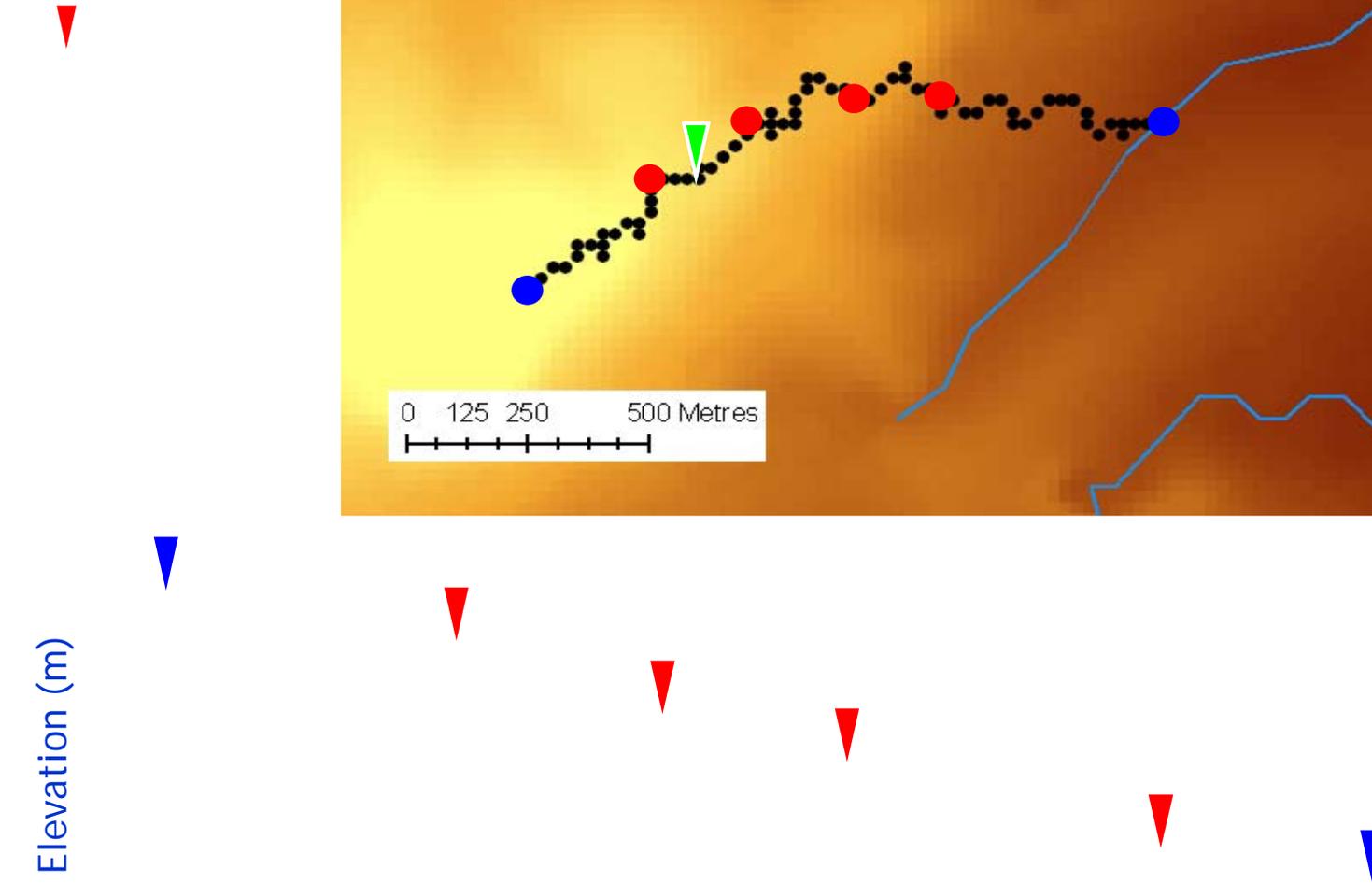




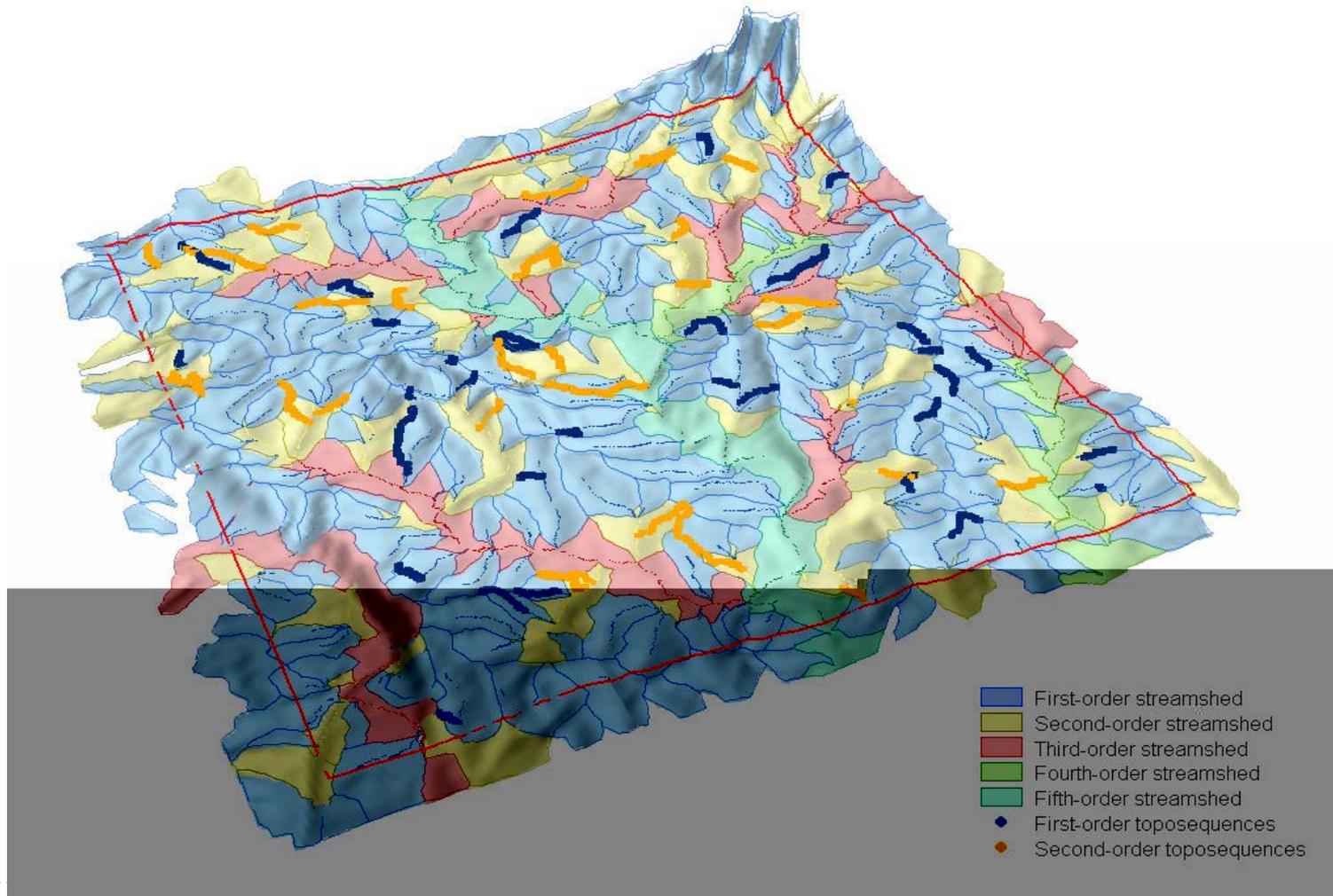
kth-order random toposequences



Elevation (m)



k th-order random toposequences

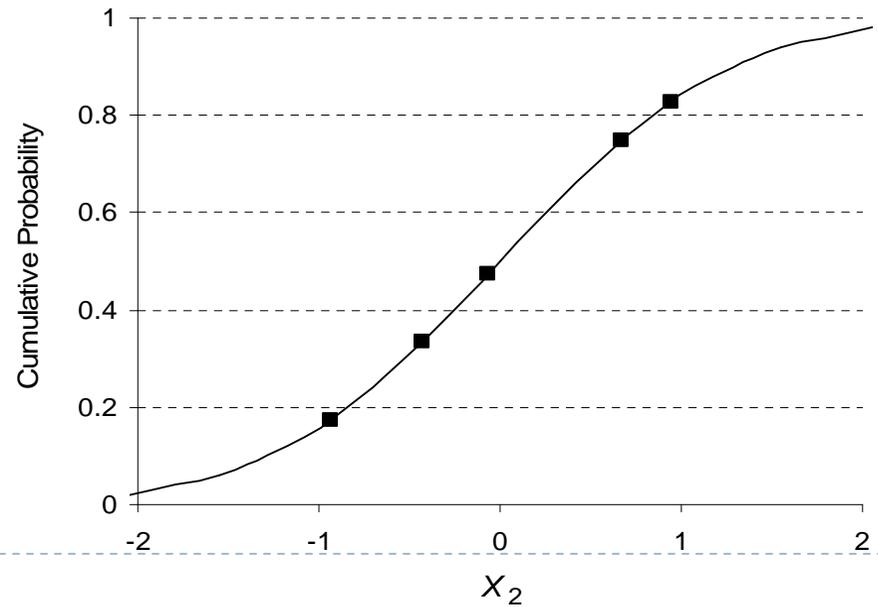
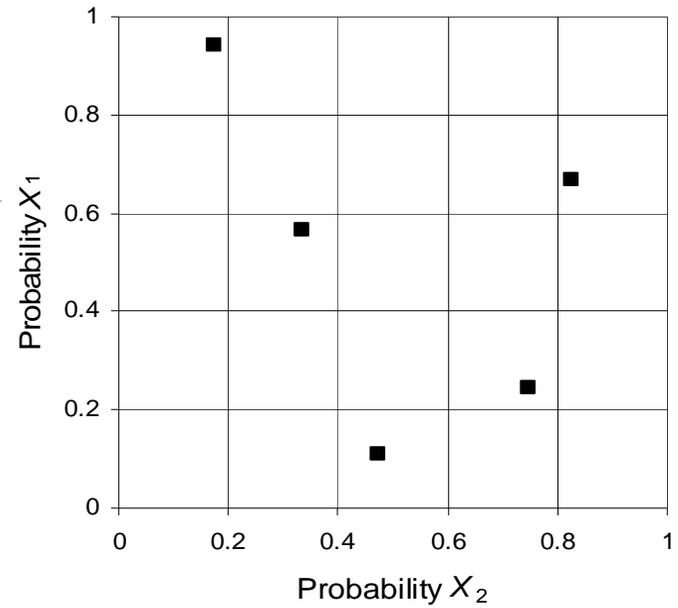
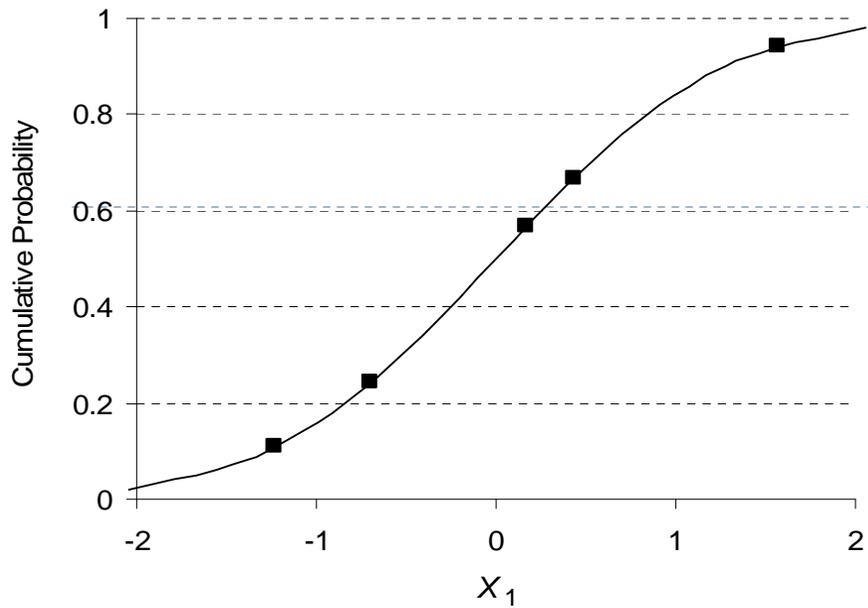




Latin Hypercube Sampling

- ▶ Designed for the scorpan model

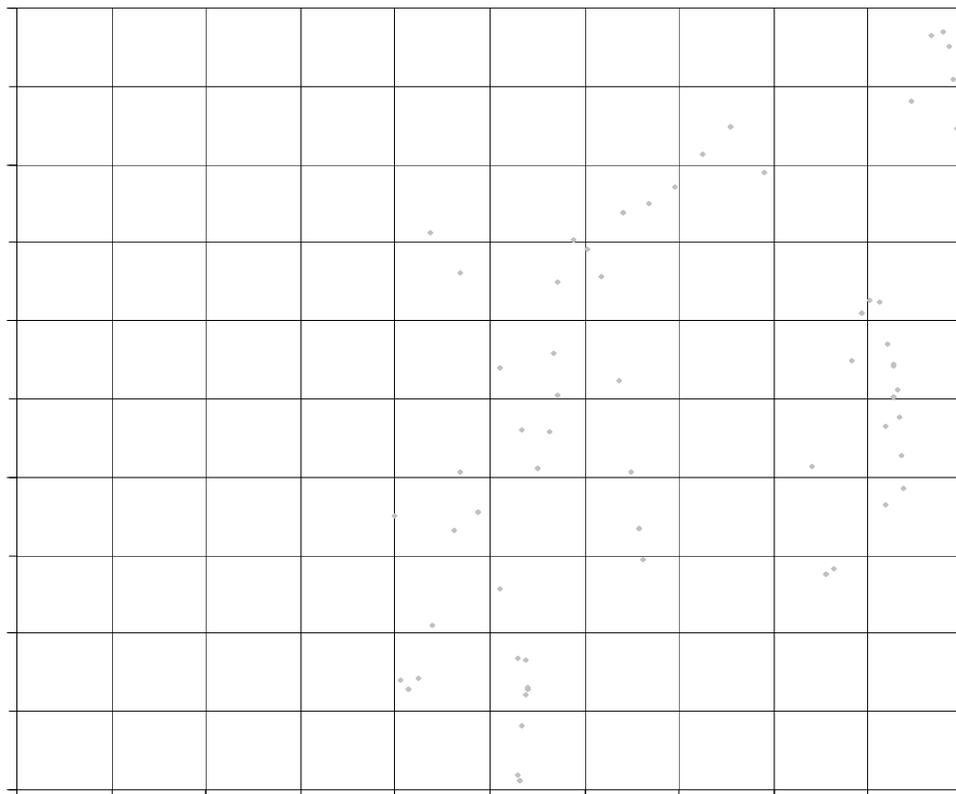




Latin Hypercube Sampling

A random sampling procedure that ensures a full coverage of the range of each variable by maximally stratifying the marginal distribution









-
- ▶ Land cover
 - ▶ CTI
 - ▶ Gamma`K
 - ▶ 300 soil profiles





Bottom-Up Soil Mapping

- ▶ A more radical approach suitable for special purposes
- ▶ In this case defining `digital terroir`





Bottom-Up Summary

Create and define soil layer classes



Layer classes

Created and defined soil series classes

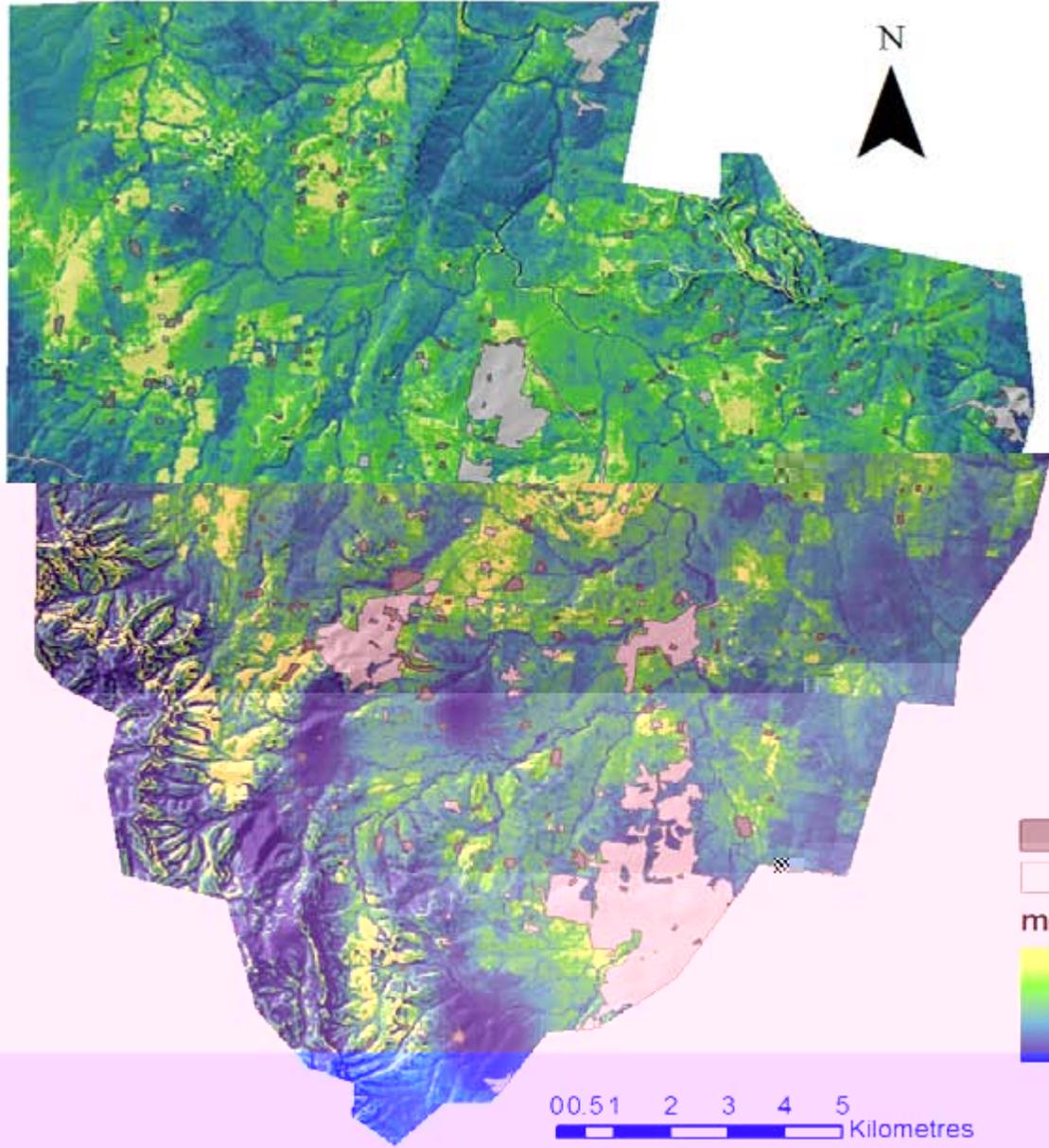
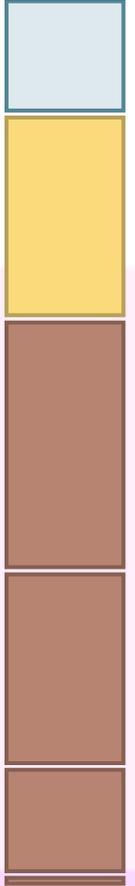


Series classes

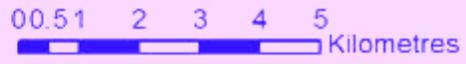
Created and defined soil mapping units



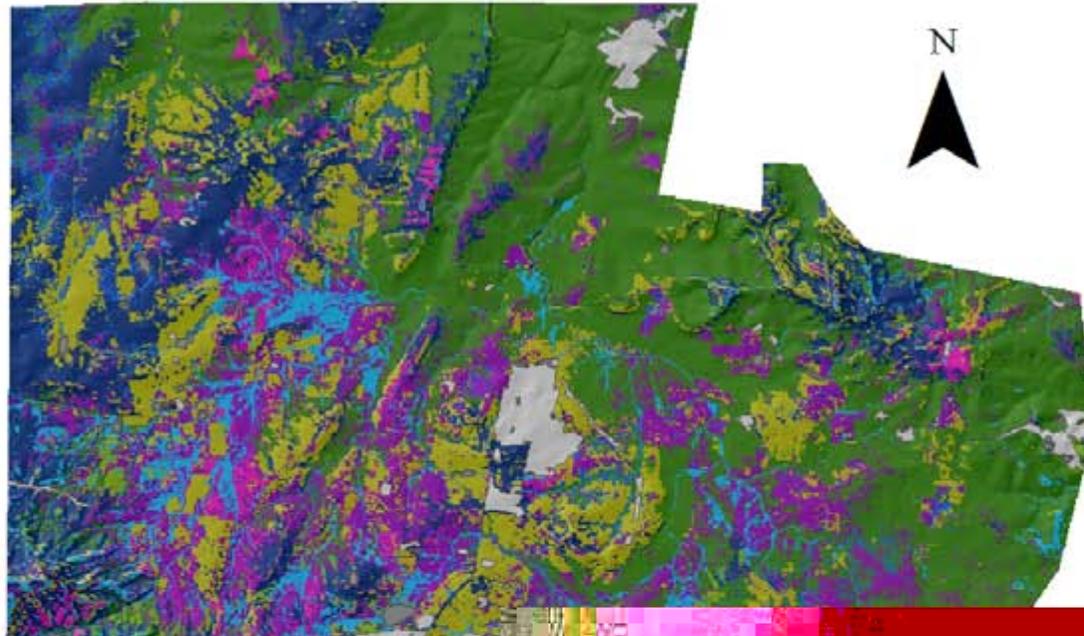
S5



Map

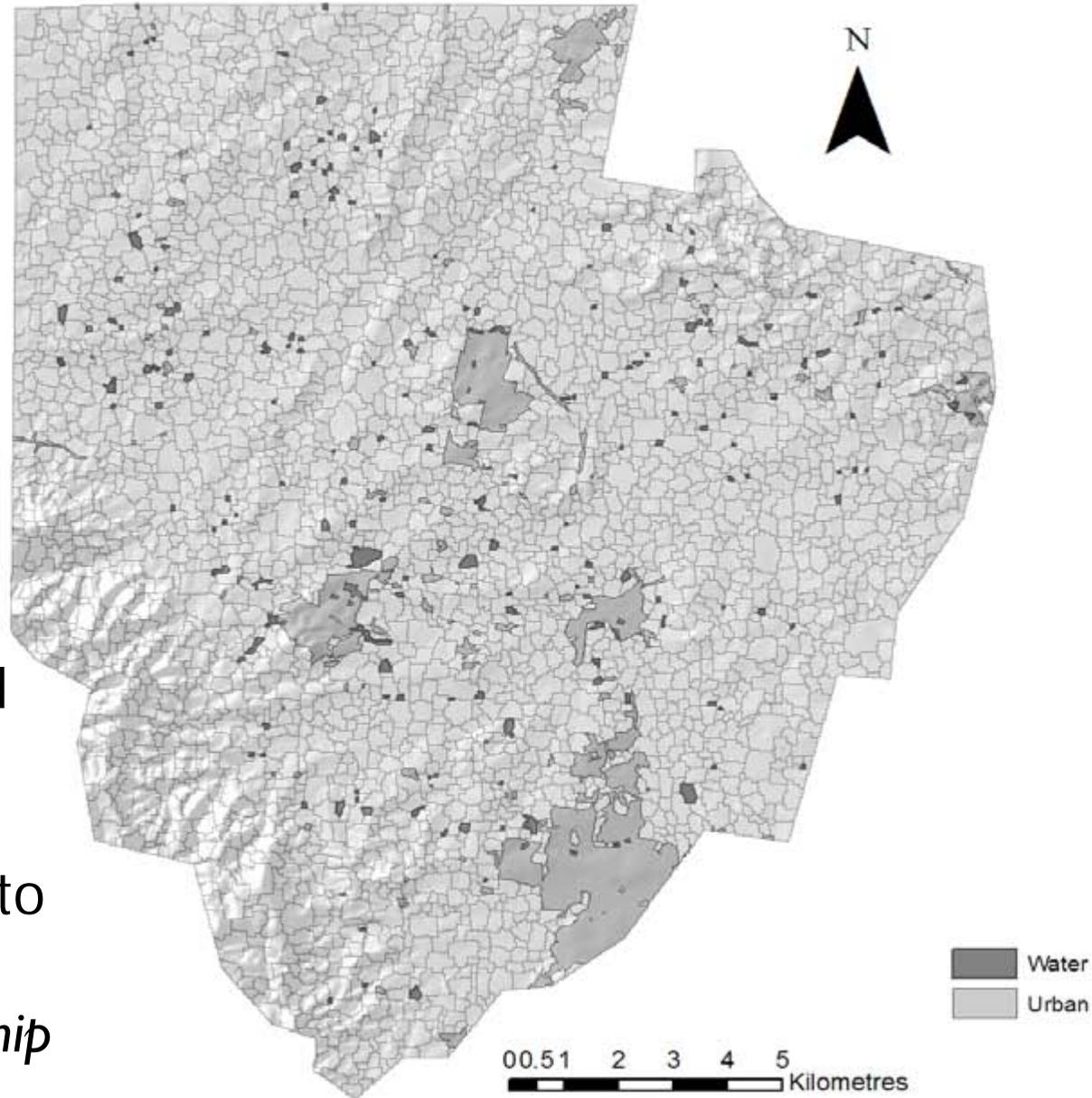


Membership (series 5)

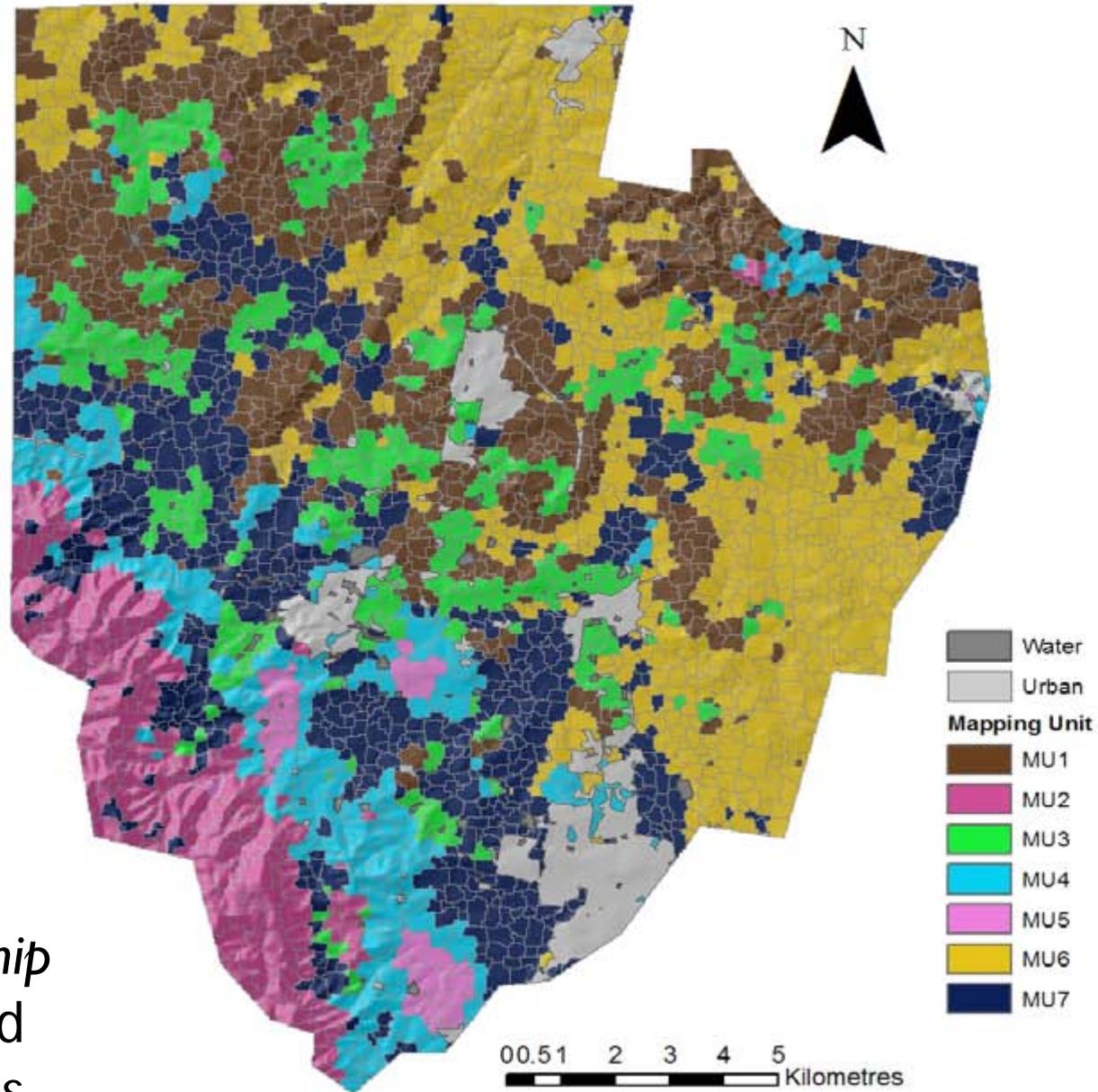


Map of predicted soil series according to *highest membership*

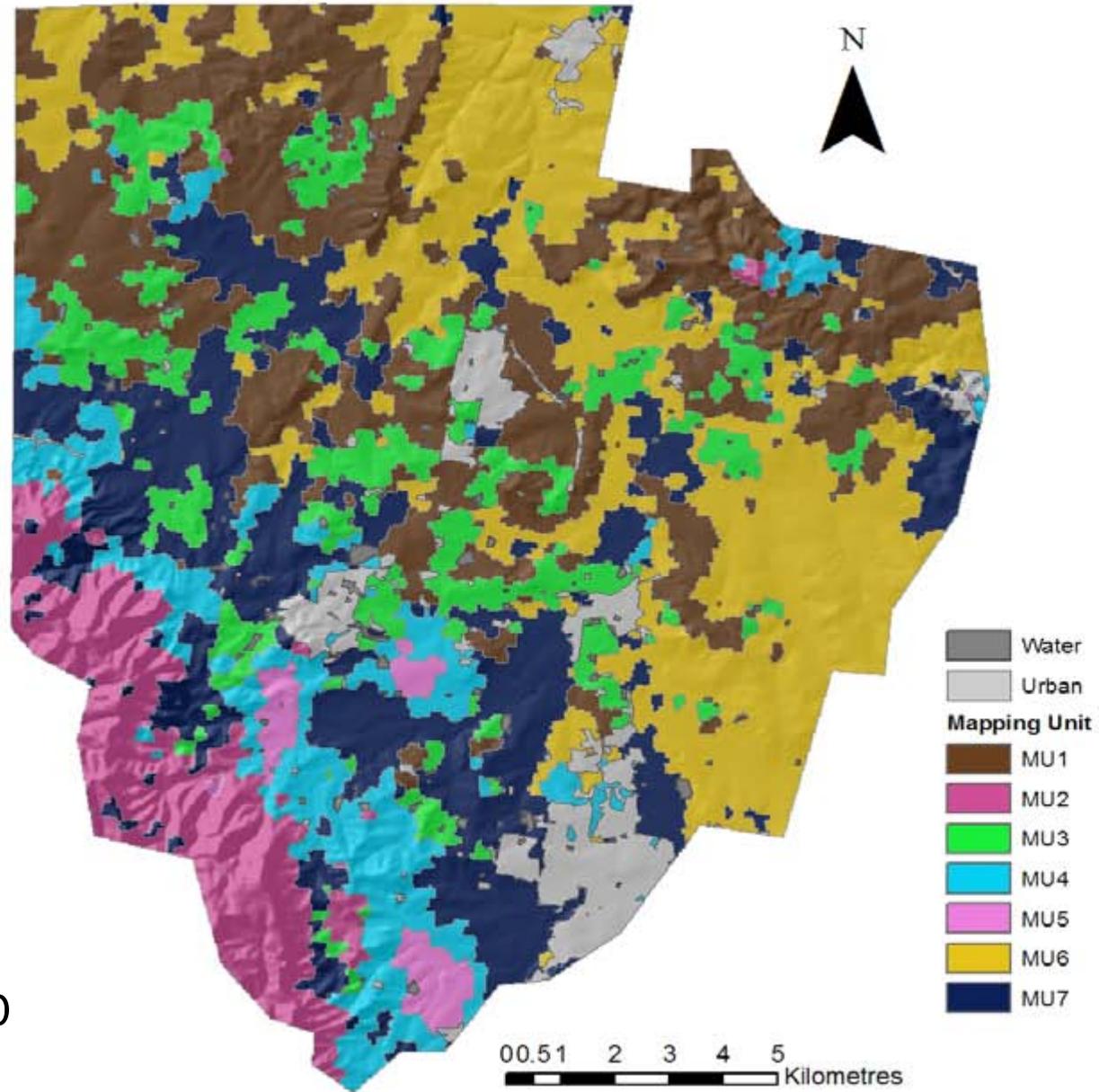
0 0.5 1 2 3 4 5 Kilometres



Object-oriented
segmentation
algorithm to
segment map into
parcels with
*similar membership
pattern*



Parcels with
*similar membership
pattern*, coloured
by map unit class



Coalesced map
unit polygons



globalsoilmap.net project



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News

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[Download the brochure](#)
[GlobalSoilMap.net in the news](#)

The project was officially launched 17th February, New York, USA
[presentations](#) [programme](#)
[speaker biographies](#) [outcome](#)



The African part of *GlobalSoilMap.net* was launched on 13th January 2009 in Nairobi. Read [here](#) the press coverage www.africasoils.net

"Let there be no mistake about the significance of this wonderful project"
Kofi Annan

"Soil mapping is one of the pillars to the challenge of sustainable development"
Jeffrey Sachs
17th February 2009

There is a need for accurate, up-to-date and spatially referenced soil information. This need has been expressed by the modelling community, land users, and policy and decision makers. This need coincides with a enormous leap in technologies that allow for accurately collecting and predicting soil properties.

We have formed a consortium that aims to make a new digital soil map of the world using state-of-the-art and emerging technologies for soil mapping and predicting soil properties at fine resolution. This new global soil map will be supplemented by interpretation and functionality options that aim to assist better decisions in a range of global issues like food production and hunger eradication, climate change, and environmental degradation. This is an initiative of the [Digital Soil Mapping](#) Working Group of the International Union of Soil Sciences [IUSS](#)

In November 2008, an \$18 million grant has been obtained from the Bill & Melinda Gates foundation and the Alliance for a Green Revolution in Africa (AGRA) to map most parts in Sub-Sahara Africa, and make all Sub-Saharan Africa data available. From this grant there are also funds for coordinating global efforts and for the establishment of a global consortium. Several institutions have assumed a leading role in this effort.



Initially a legacy based approach

Define an area of interest

Assemble environmental covariates

Which soil data are available?

Assign quality of soil data and coverage in the covariate space

Detailed soil maps with legends and Soil Point data

Full Cover?

Yes

No

Soil maps:
-Spatially weighted mean
-Spatial disaggregation
Soil data:
- *scorpan* kriging

Extrapolation from reference areas:
-Soil maps
-Soil point data

Soil Point data

scorpan kriging

Detailed soil maps with legends

Full Cover?

Yes

No

-Spatially weighted mean
-Spatial disaggregation

Extrapolation from reference areas
Spatially weighted mean

Almost no data

Homosoil

DIGITAL SOIL ASSESSMENT









Soil inference systems

- ▶ Linked pedotransfer functions
- ▶ SINFERS2 soil inference engine software
- ▶ MIR reflectance spectra very useful

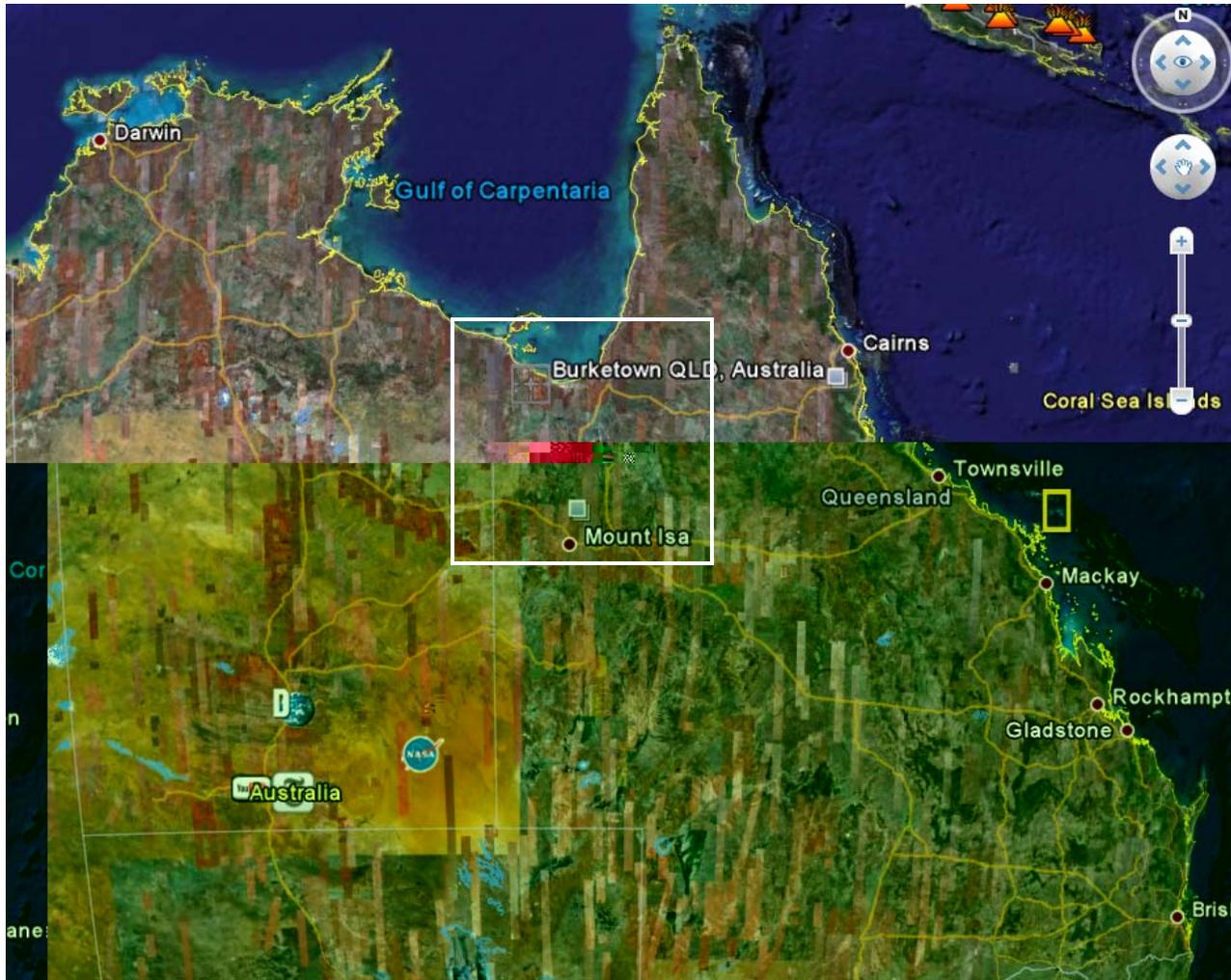


DIGITAL SOIL MONITORING



- ▶ Stratification using the scorpan covariates suggests appropriate monitoring locations
- ▶ Latin hypercube sampling
- ▶ Fuzzy k means stratification





Monitoring in the Gulf Country Queensland





▶ QLD DNR&W



Fuzzy k-means of
The environmental layers
 $k = 50$





Siteses were constrained to be located within 1.5 km from roads





BY WAY OF CONCLUSION



DSMM OPPORTUNITIES FOR National Cooperative Soil Survey



- ▶ Remote and Range Lands
 - ▶ Updating $s = f(s' \text{ corpan})$
 - ▶ Globalsoilmap.net
 - ▶ Value-adding MLRA soil survey process
20m resolution continuous layer model
-





Some key points

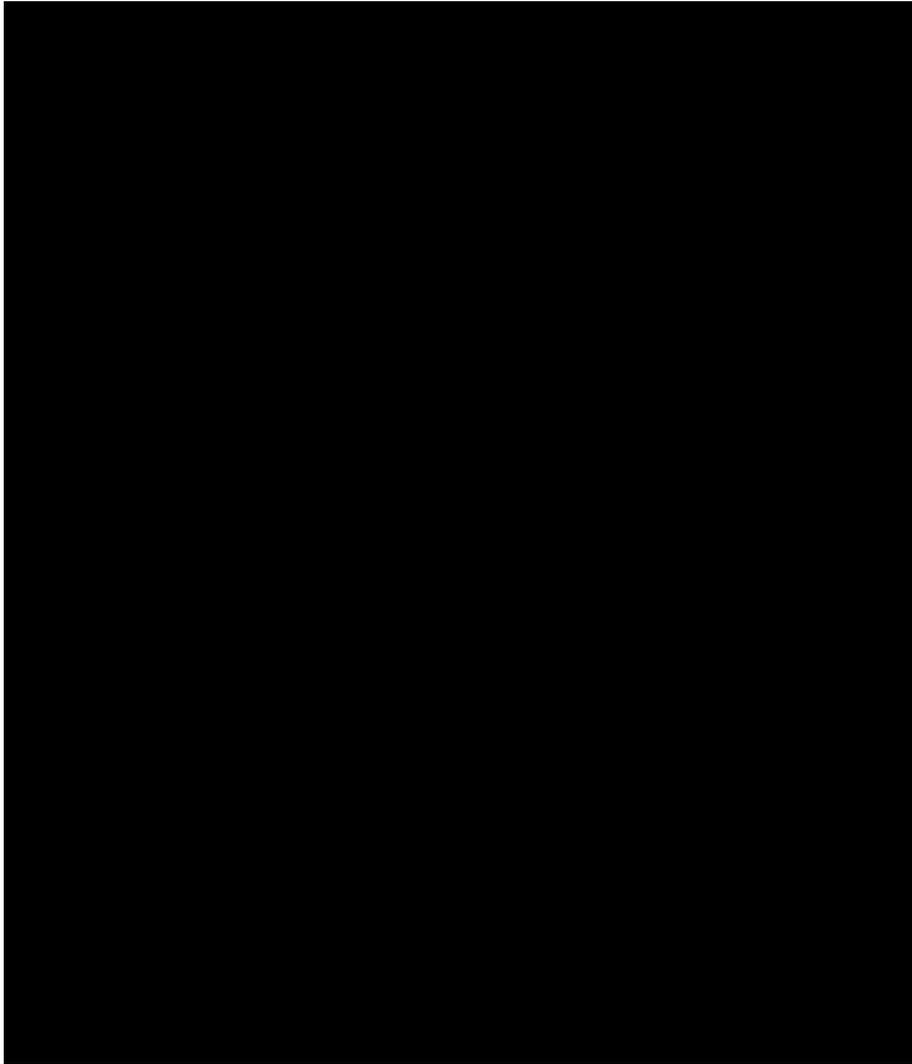
- ▶ Scorpan model
- ▶ Latin hypercube sampling
- ▶ MIR and gamma radiometrics useful technologies
- ▶ All lead to huge value-adding opportunities







Southern Hemisphere pedology



Australia is a cultured country



Cheers!



One soil

There was once

Only one soil

In all our worlds

For me it was

A cryptopodzolic brown earth

In a Scots pine forest

On the Balmoral estate

Why did we need

To find another

And yet another?

David van der Linden

