Global Soil Mapping in a Changing World

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Acknowledgements:
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GIS Research Lab

Soil Story

My soil story

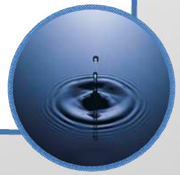
…. Your soil story

Digital Soil Mapping in a Changing World

Global climate change, land use change, population growth

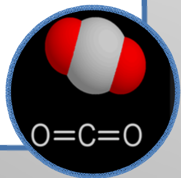
Soil Gap

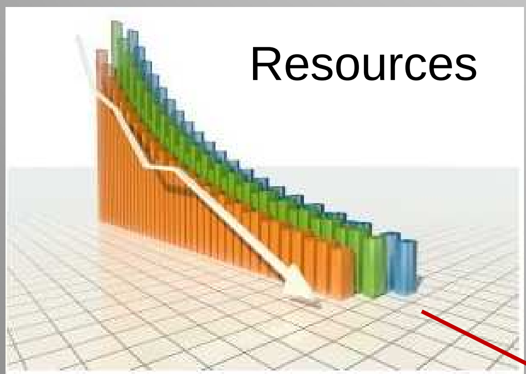
Water Gap



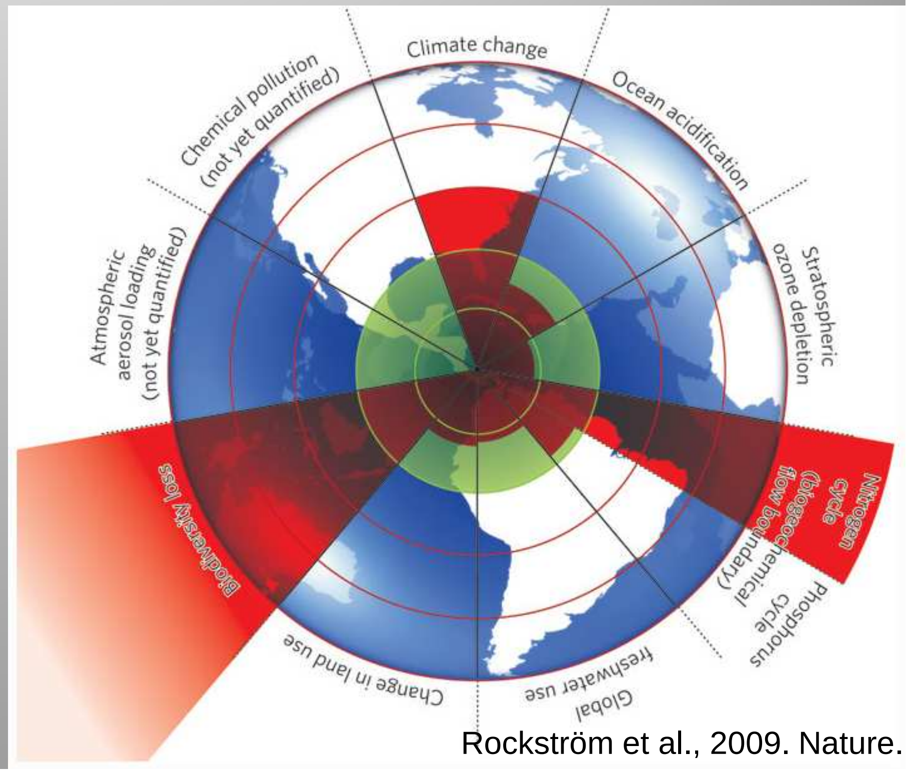
Food Gap

Soil Carbon





Sustainability



Rockström et al., 2009. Nature.

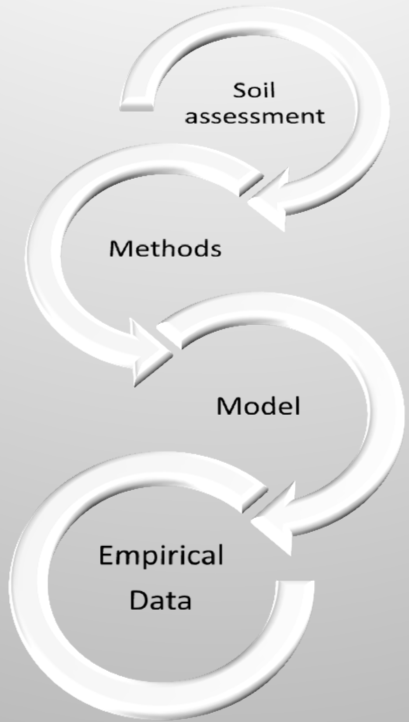
Digital Soil Mapping (DSM)

Abstraction level & complexity

High

- Sustainability
- Adaptation / mitigation potential
- Soil ecosystem services (natural capital)
- Risk / vulnerability
- Soil gaps
- Soil functions
- Soil ecosystem processes
- Soil change / evolution
- Soil properties
- Soil classes

Low



Statistical methods:
e.g. multivariate regression
Ensemble trees
Machine learning

Geostatistical methods:
e.g. kriging

Mixed/hybrid methods:
e.g. regression kriging
PTF & interpolation

Process-based methods:
e.g. simulation models

and more ….

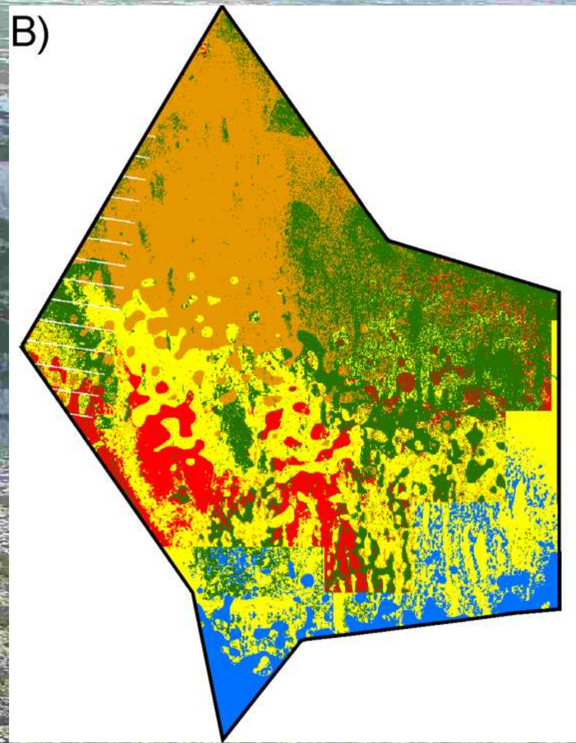
What is the Purpose of Digital Soil Mapping?

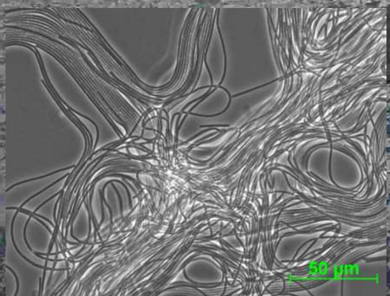
(1) Intrinsic knowledge: “just for the sake of knowing” (create maps)

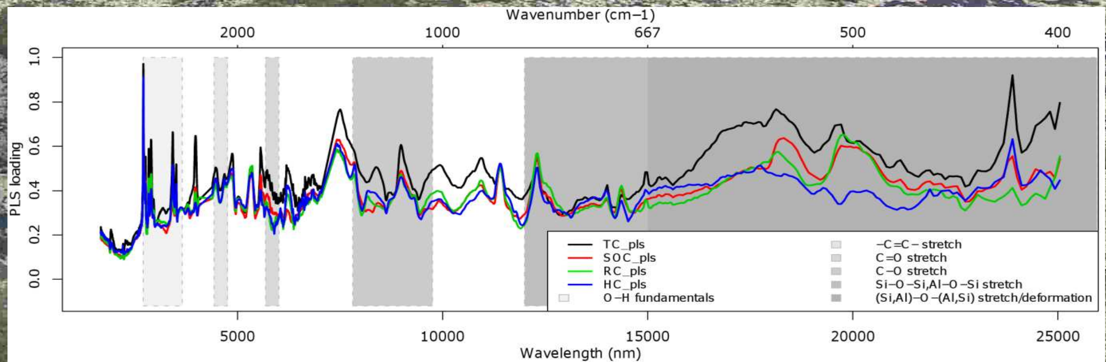
(2) Extrinsic knowledge: To address societal, complex, global issues; a changing world w/ uncertainty; we co-create soil ecosystems

Global – regional – local scales

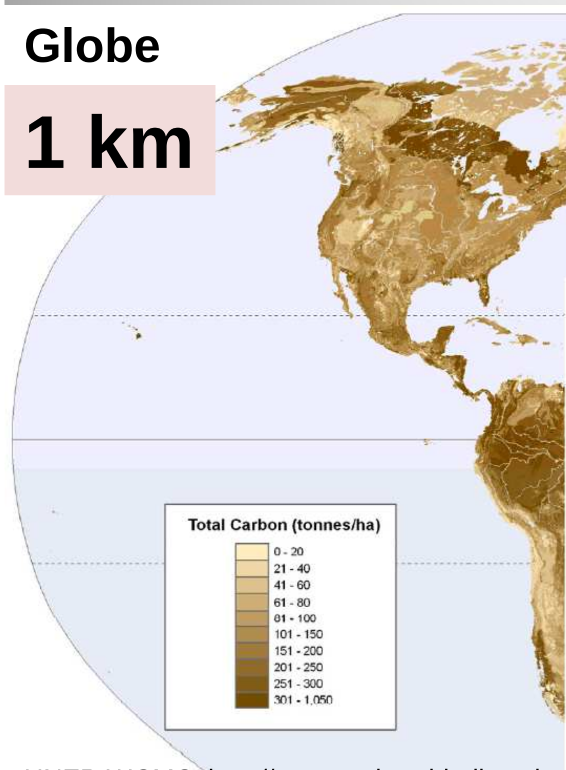
Multiple Soils Perspectives



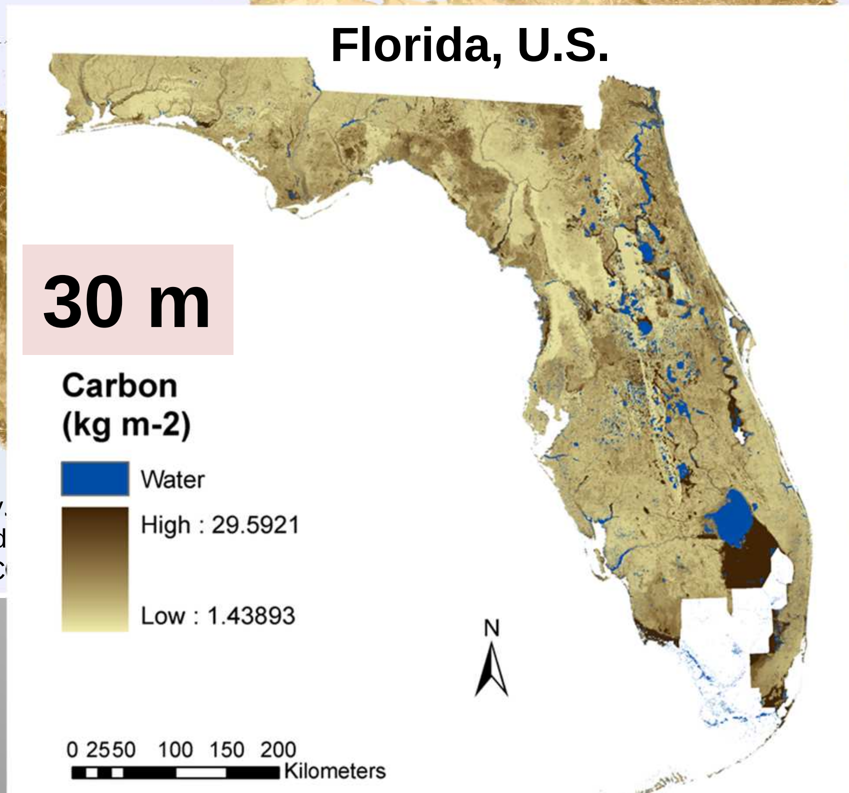




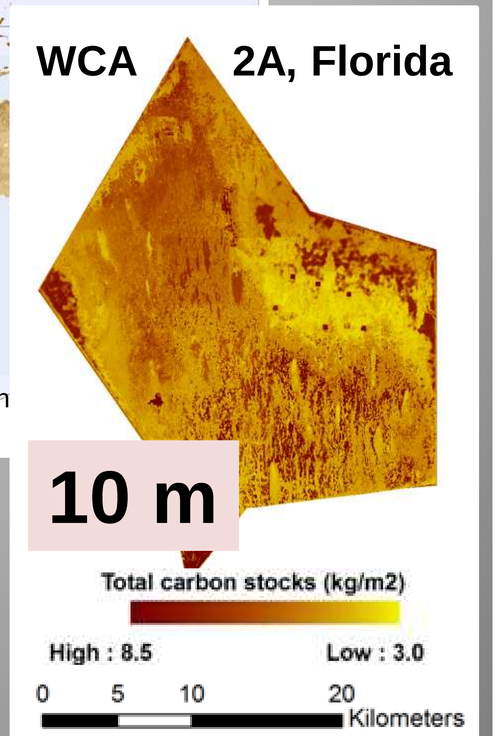
Estimates of Carbon Stocks



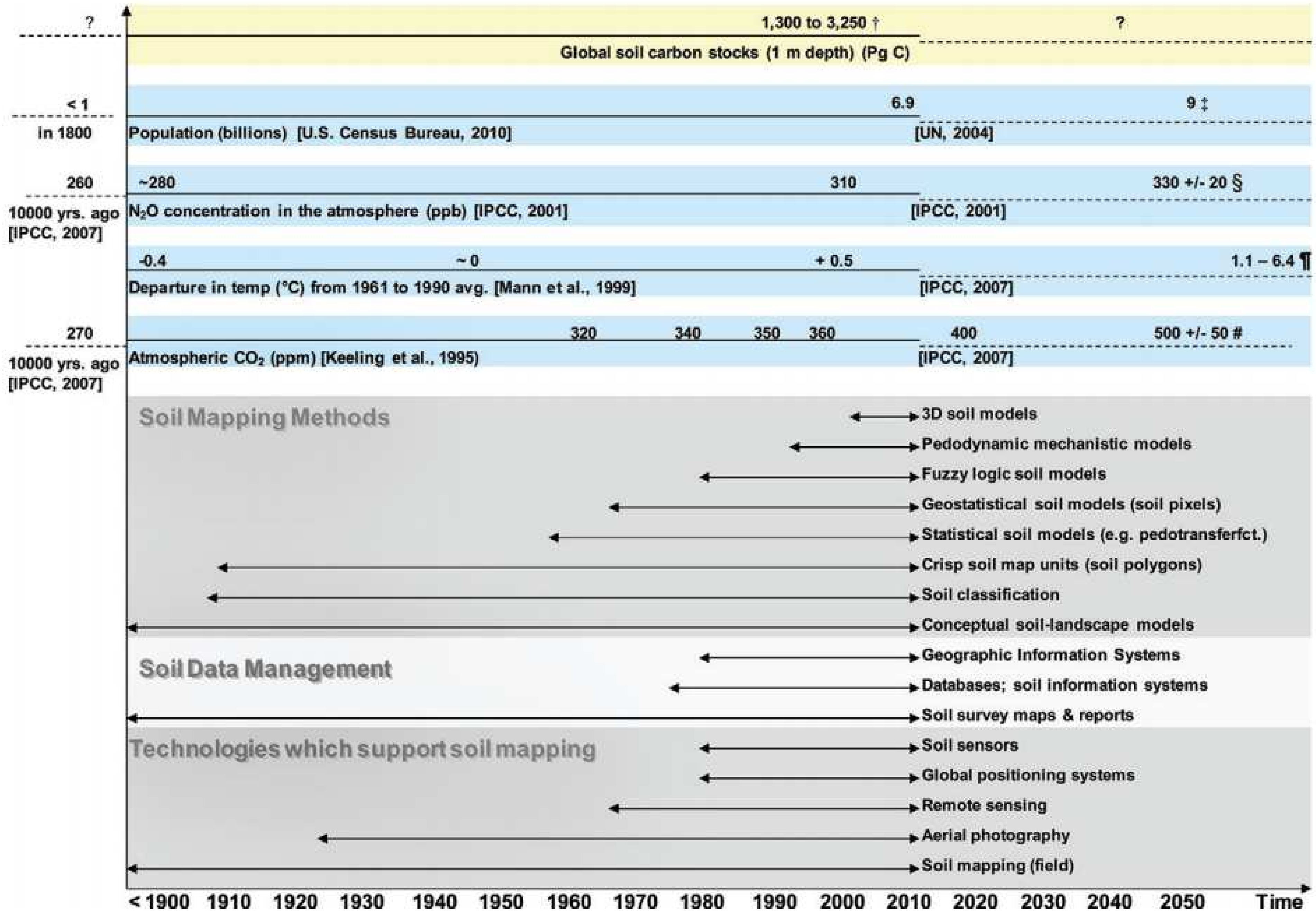
UNEP-WCMC. http://www.carbon-biodiversity.
Scharlemann et al. (2009): Harmonized World
Gibbs (2008): Biomass carbon map using IPC



Grunwald, Myers, Harris, and Comerford. 2012.

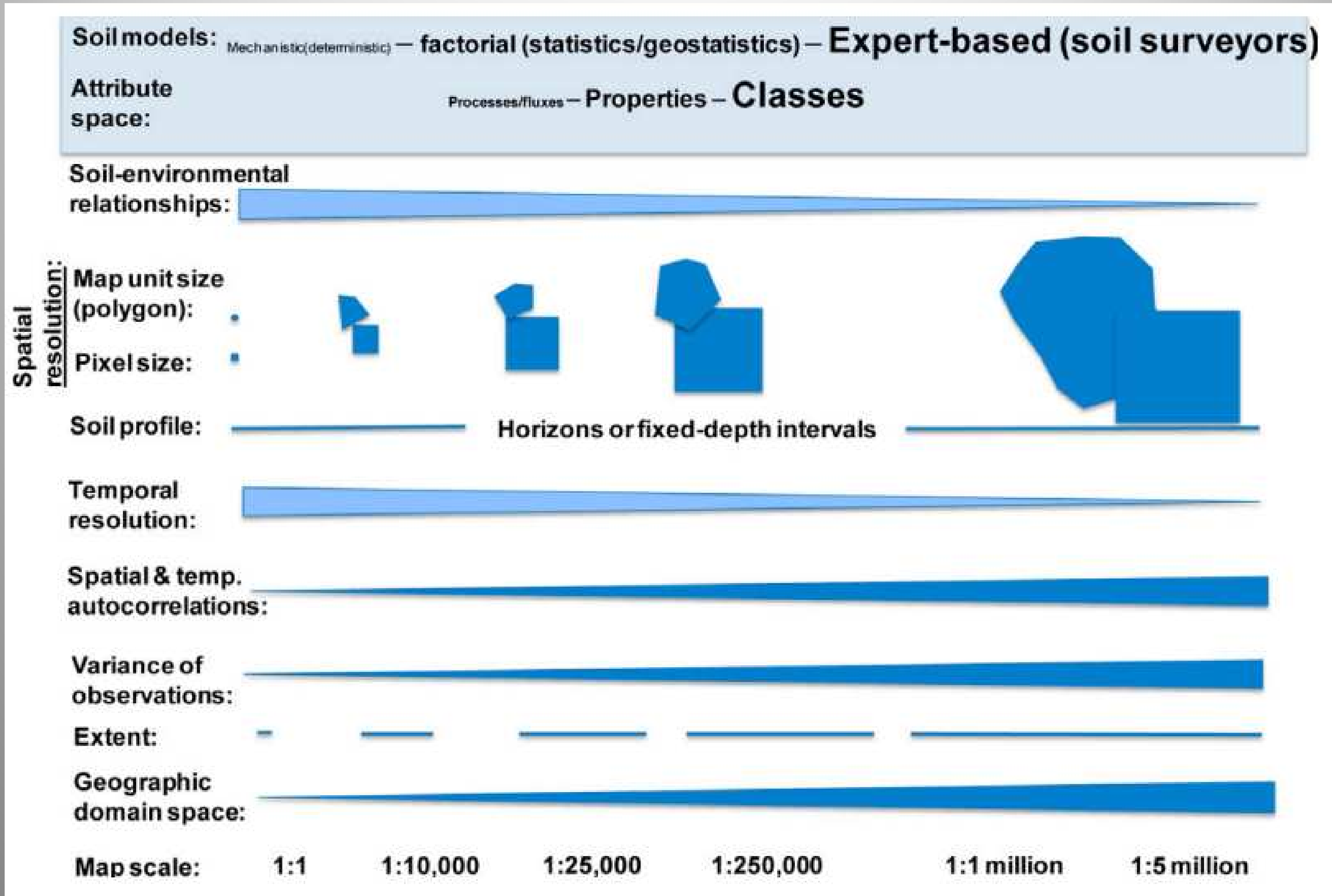


Kim and Grunwald, 2013



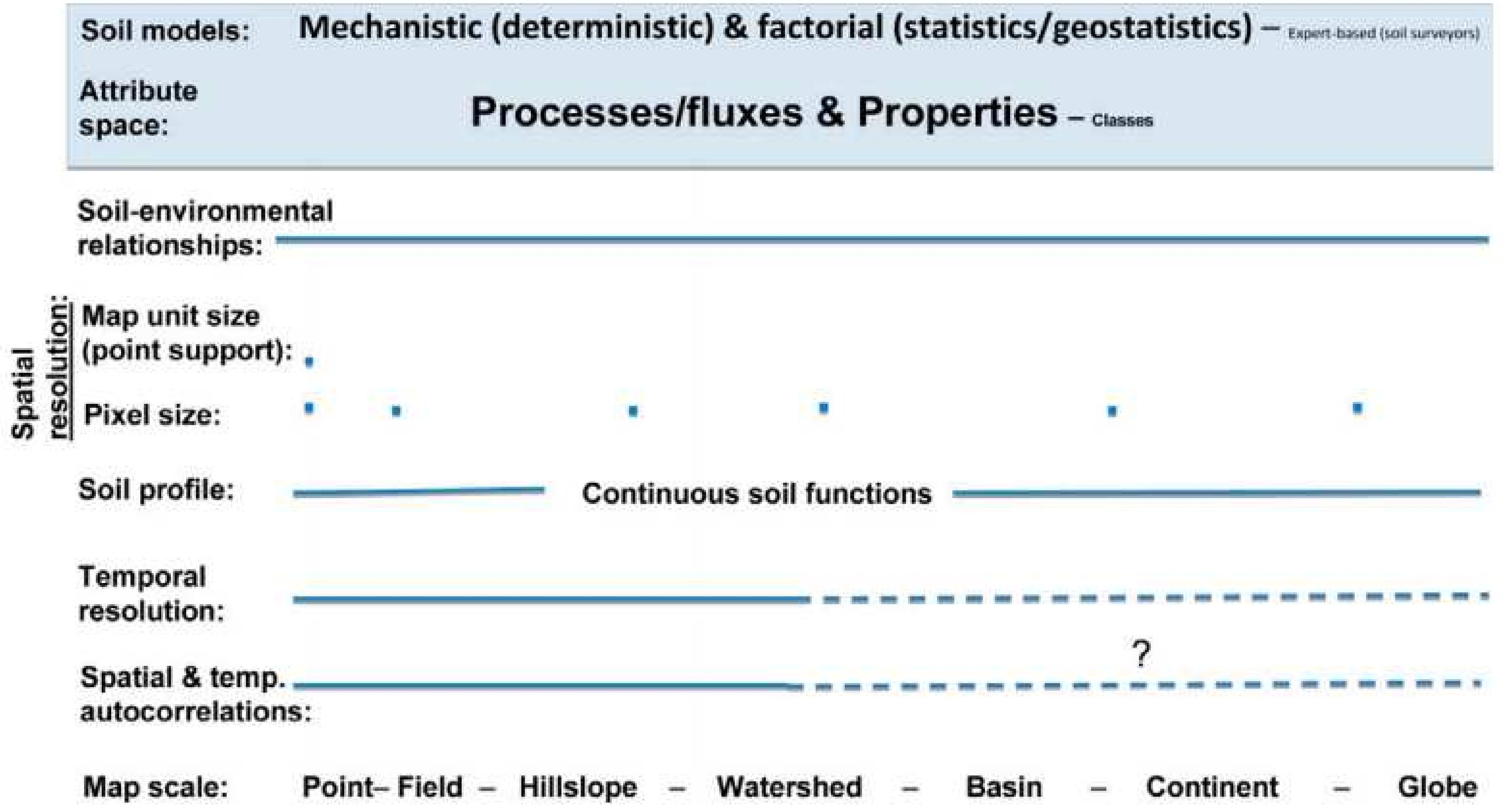
Grunwald et al. (2011). Soil Sci. Soc. Am. J. and Grunwald. 2006. Environmental Soil-Landscape Modeling. CRC Press.

Overview of Phenomena of Space and Time, Distribution of Soil Properties and Processes at Escalating Spatial Scale



Grunwald et al. (2011). Soil Sci. Soc. Am. J.

Envisioned Future of Digital Soil Mapping and Modeling

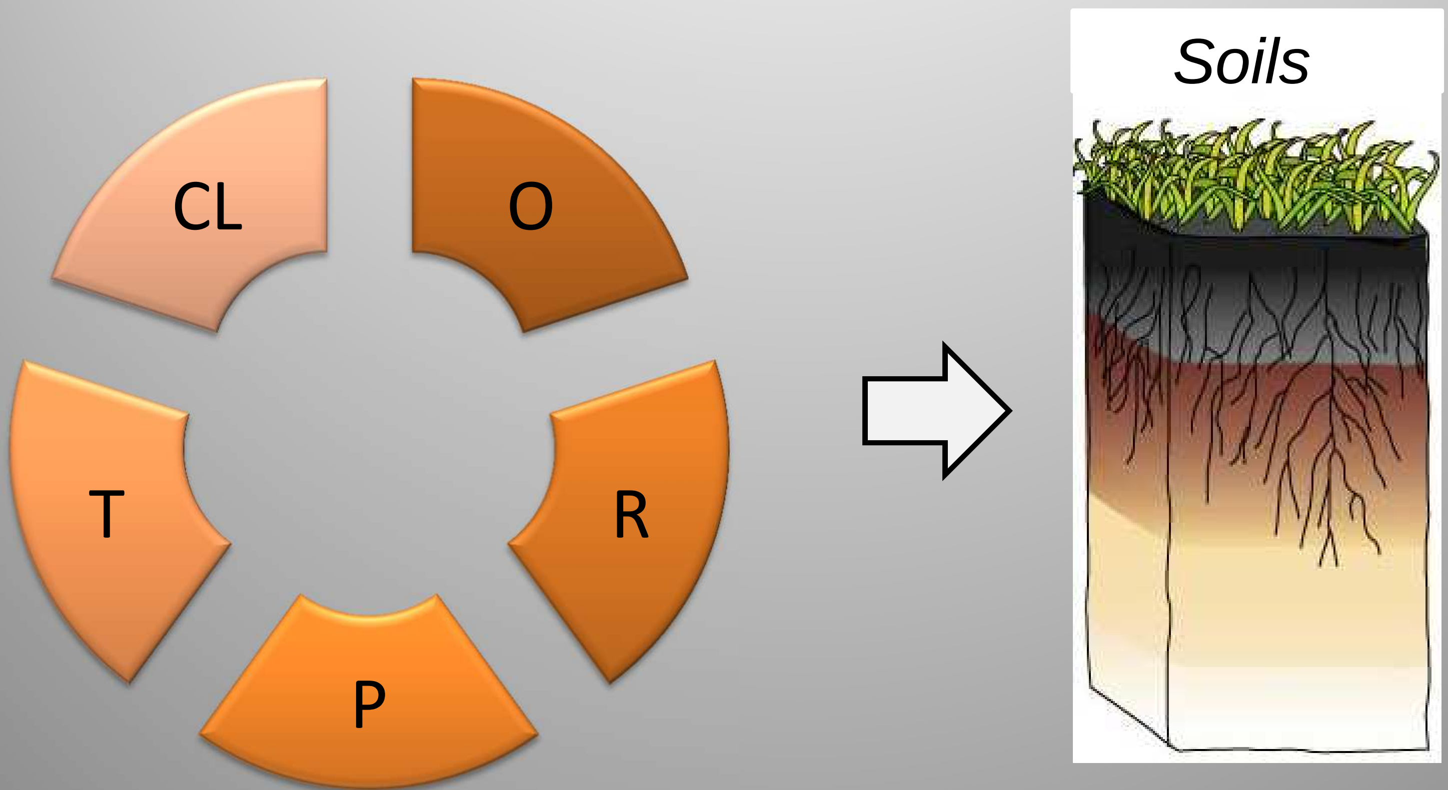


Grunwald et al. (2011). Soil Sci. Soc. Am. J.

Conceptual Soil Formation Models

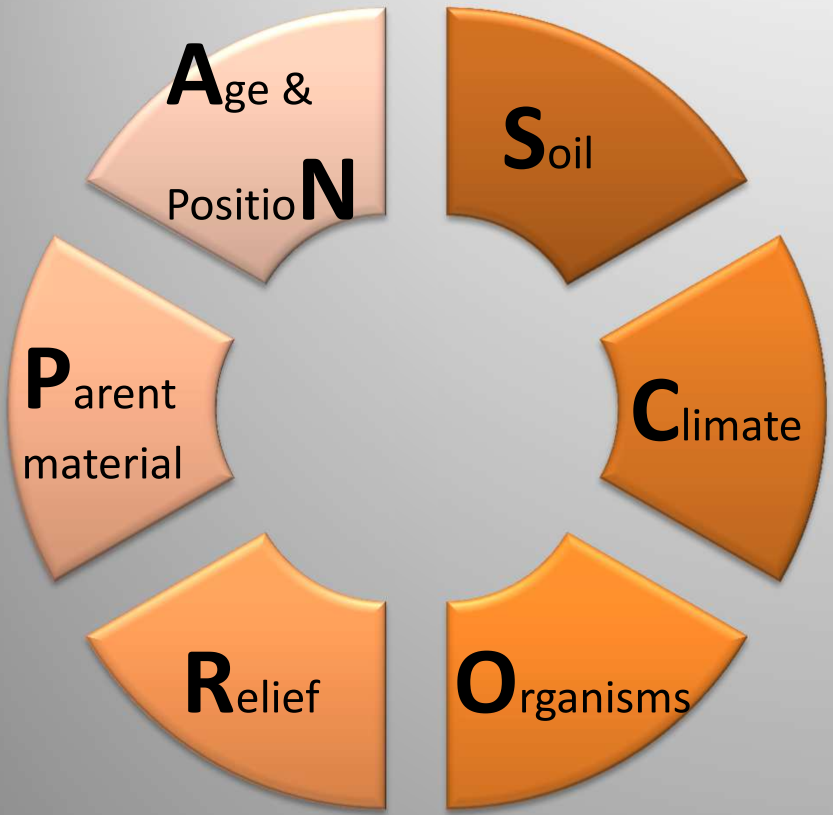
Factorial soil models:

The soil forming factors - climate (CL), organisms (O), relief (R), parent material (P), and time (T) - form soils



Jenny (1941)

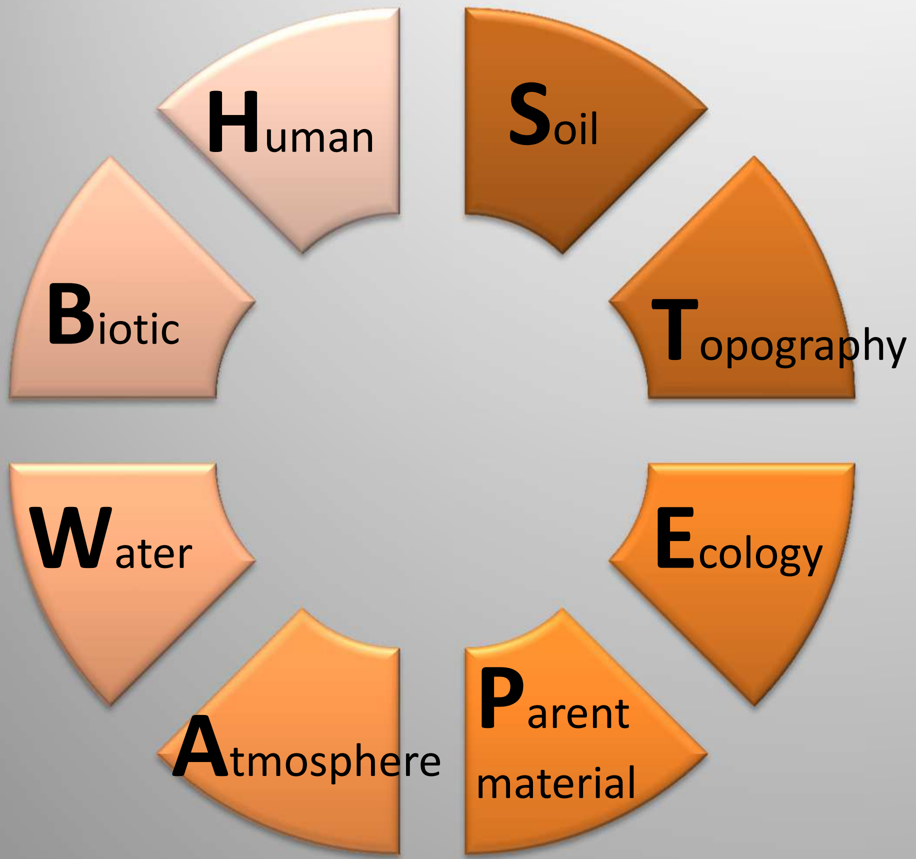
SCORPAN Model ⇨ Soil Properties/Classes



McBratney et al. (2003)
Geoderma

- Quantitative framework suited for digital soil mapping (DSM)
- Empirical model
- Factors and soil predictions are spatially-explicit (x, y) and temporally-explicit (t)

STEP-AWBH Model ⇨ Soil Properties/Classes



Grunwald et al. (2011) SSSAJ
Thompson et al. (2012). DSM: Interactions w/ and applications for hydropedology.

- Spatially and temporally explicit
- Additional factors (W, H)
- Accounts for time-dependent variation of STEP-AWBH variables
- Facilitates modeling of soil evolution and change
- Space-time model

STEP-AWBH Model

Target soil property, rate, change, process, risk, etc.

Soil **Topography** **Ecology** **Parent material**

$$SA(z, p_x, t_c) = f\{\sum_j^n S_j(z, p_x, t_c), T_j(p_x, t_c), E_j(p_x, t_c), P_j(p_x, t_c)\};$$

Spatially-explicit, ~stable across time

$$\int_{i=0}^{m} \{\sum_j^n A_j(p_x, t_i), W_j(p_x, t_i), B_j(p_x, t_i), H_j(p_x, t_i)\}$$

Spatially-explicit + account for time-dependent variation of variables

Soil Depth

Pixel w/ size x

Current (c) time

Atmosphere **Water** **Biota** **Human**

S Factor

e.g. soil org. C

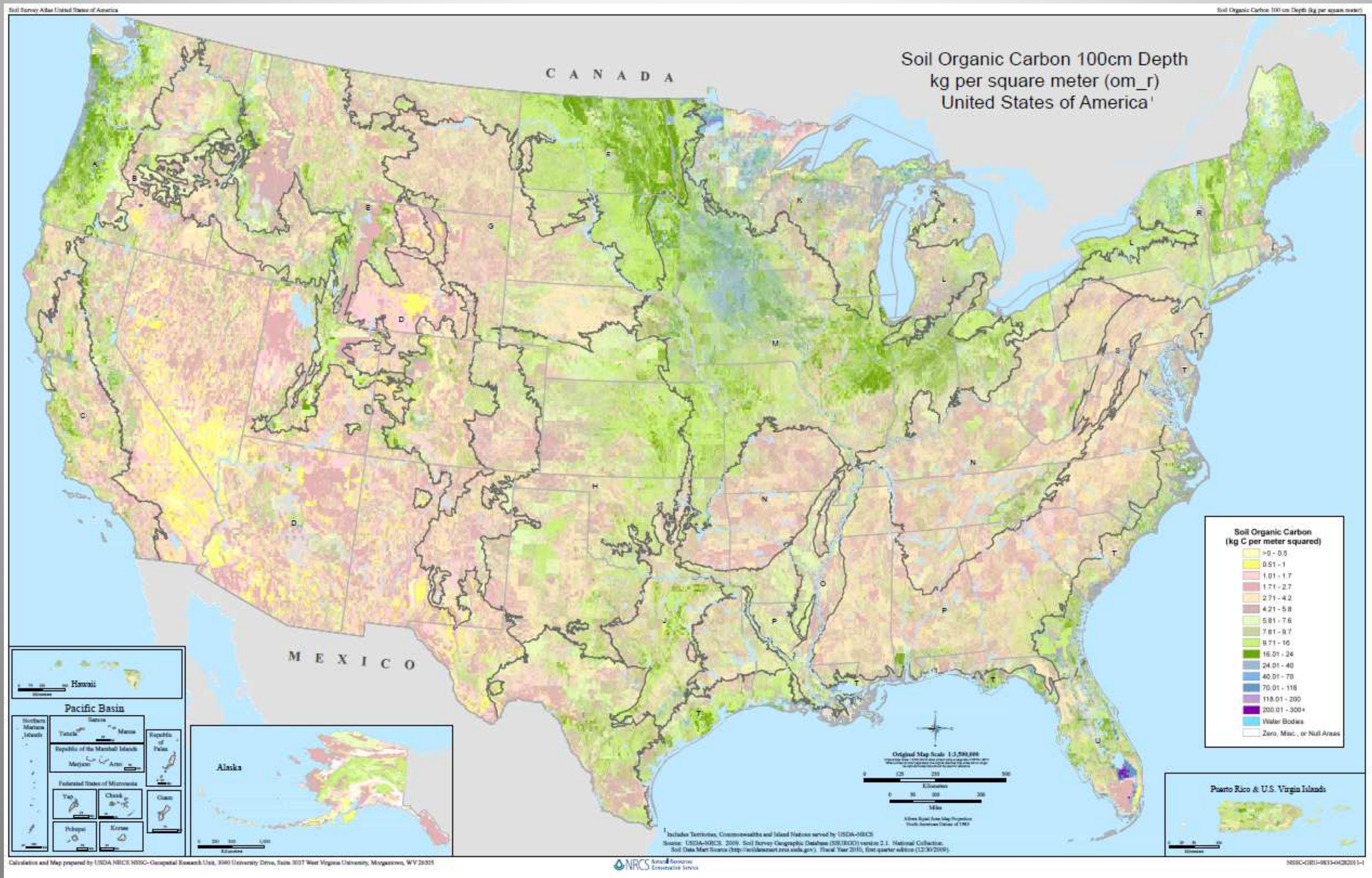
$$SA(z, p_x, t_c) =$$

$$f\{\sum_{j}^{n} S_j(z, p_x, t_c)\}$$

Examples - How to populate the S factor:

- Soil taxonomic data (e.g., soil order, great groups)
- Soil drainage class map
- Available water storage top 25 cm
- Soil texture map (clay, silt, sand content)
- Soil organic matter map

S Factor: Historic Soil Organic C (U.S.)



Data source: Soil Survey Geographic Database (SSURGO) Soil Data Mart, NRCS

A Factor

e.g. soil org. C

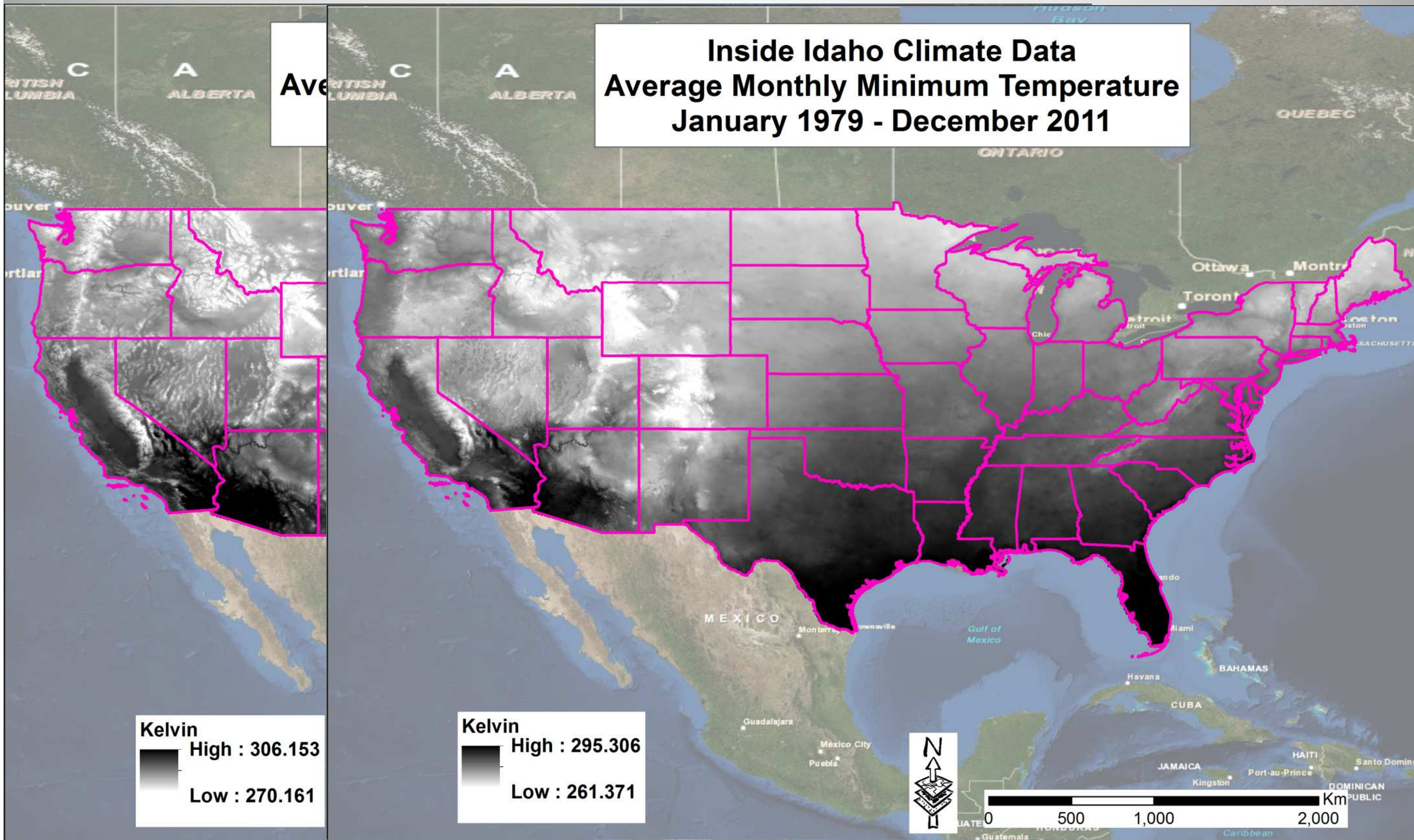
$$SA(z, p_x, t_c) =$$

$$\int_{i=0}^{m} \{\sum_{j}^{n} A_j(p_x, t_i)\}$$

<u>Examples - How to populate the A factor</u>:

- Long-term mean precipitation
- Aggregated precipitation during summer months
- Max. temperature last year
- Max. temperature over the past 30 years
- Daily, weekly or monthly soil moisture
- Soil moisture yearly average

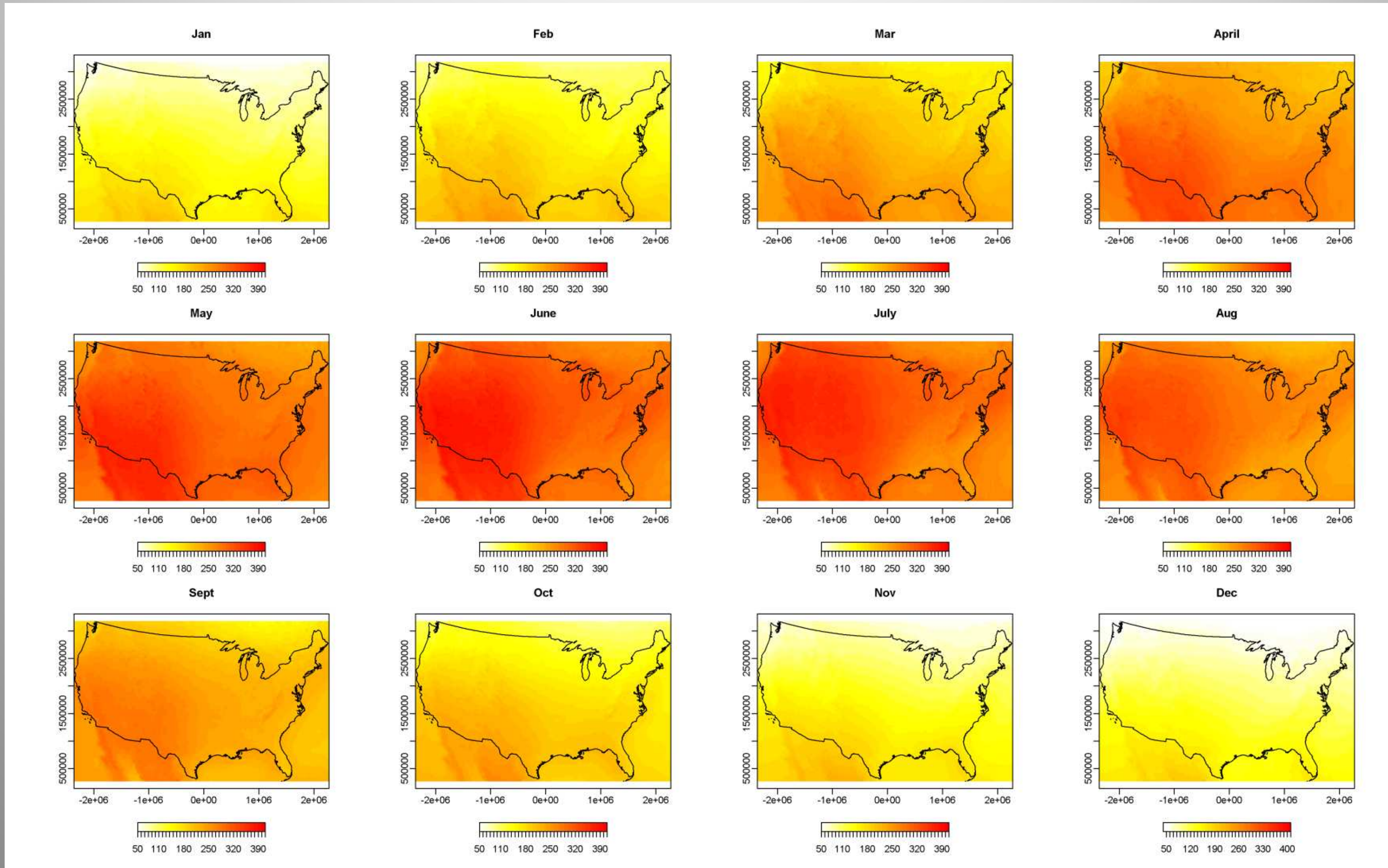
A Factor: Temperature



Data source: Idaho Geospatial Spatial data extraction: R. Patarasuk (GIS-Pedometrics Team)

A Factor: Solar Radiation

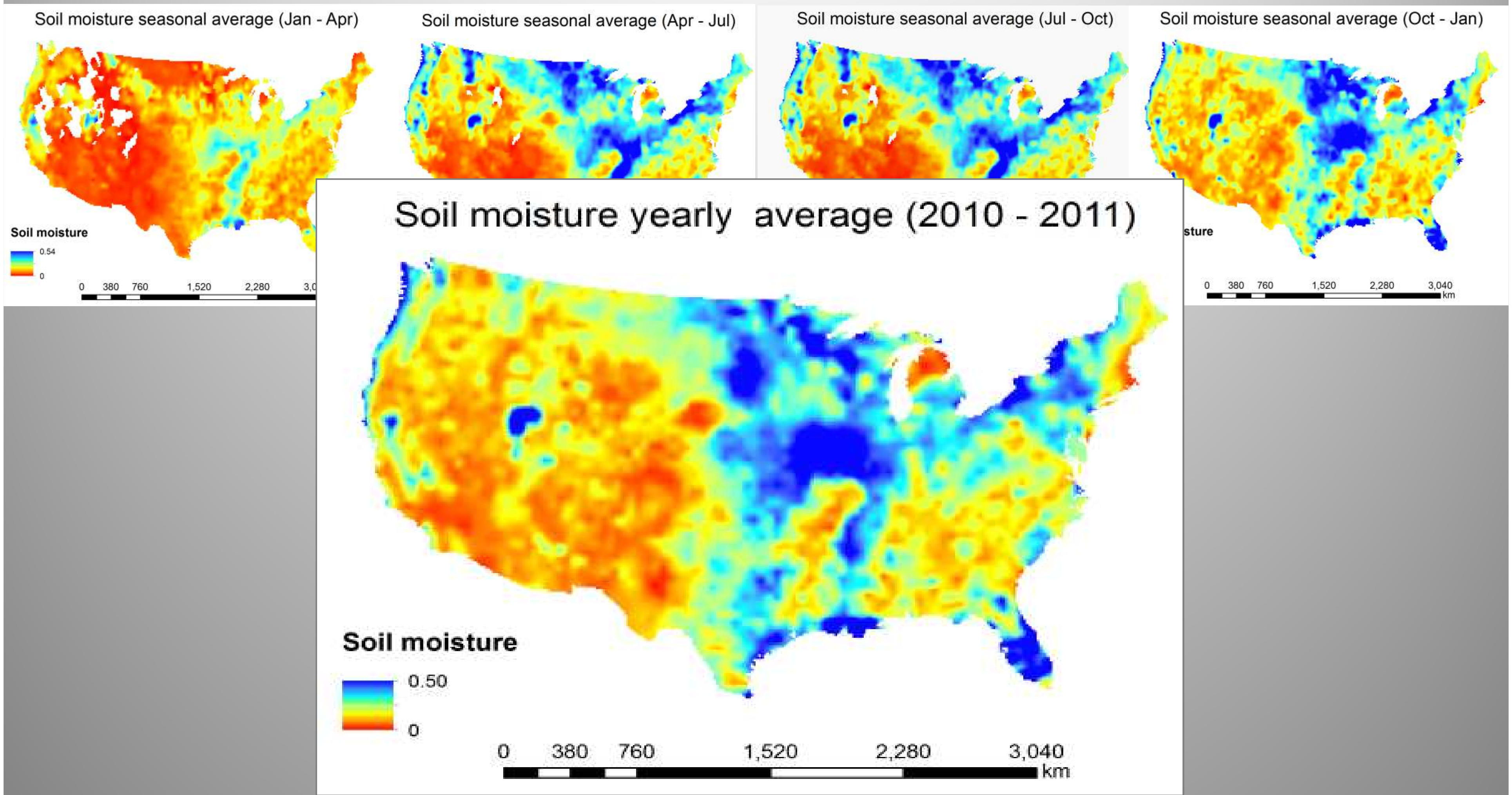
Solar radiation – *30 yr averages for each month*



Data source: North American Regional Reanalysis (NARR) – National Oceanic and Atmospheric Administration (NOAA)

Spatial data extraction: X. Xiong (GIS-Pedometrics Team)

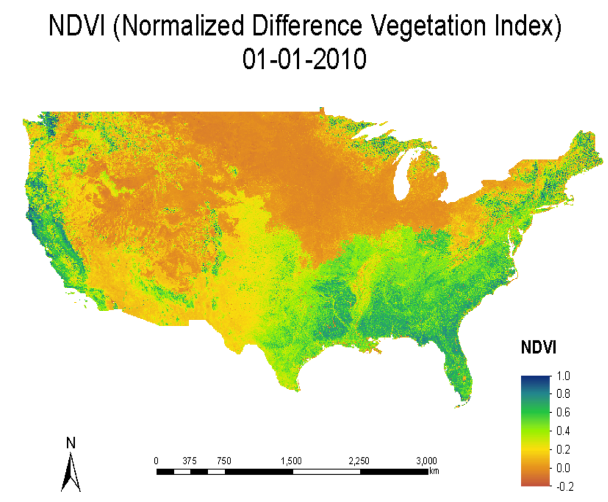
W Factor: Soil Moisture

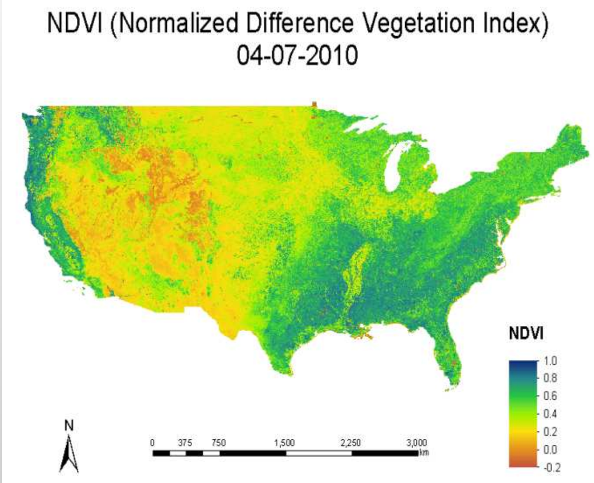


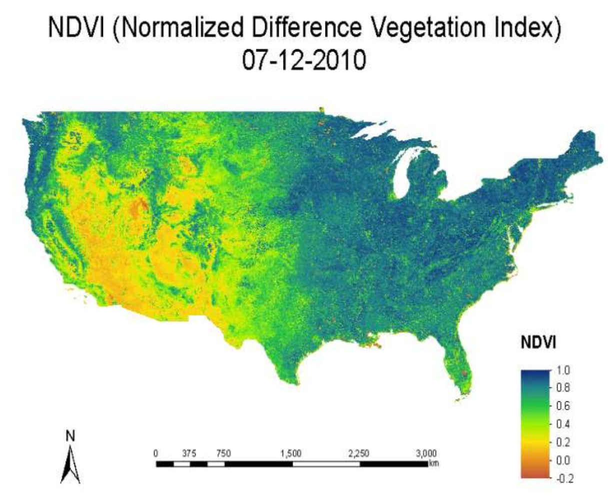
Spatial data extraction: X. Xiong (GIS-Pedometrics Team)

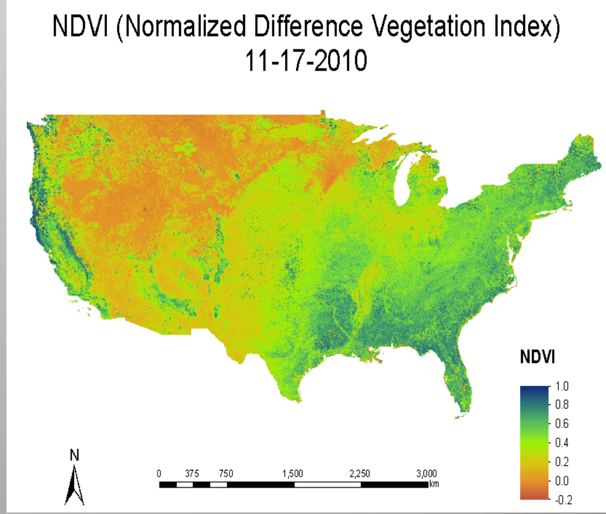
Soil Moisture Data (SMOS) (European Space Agency, ESA)

B Factor: NDVI





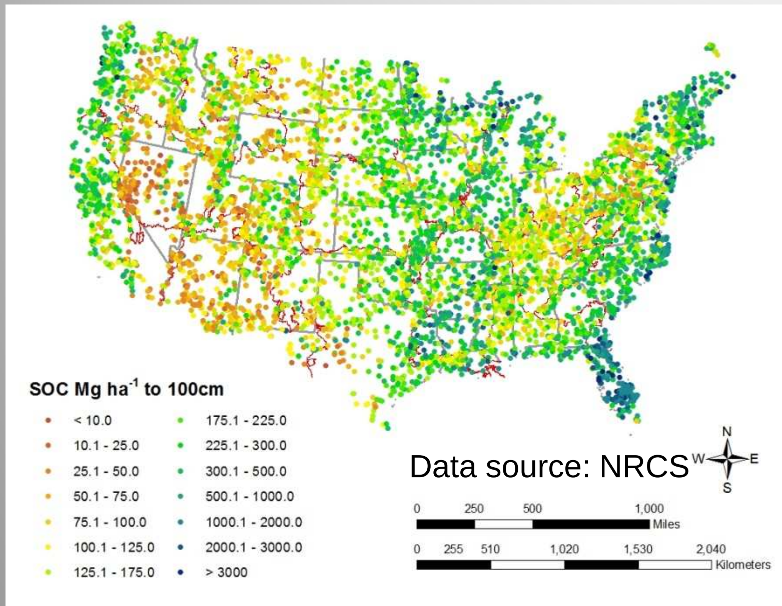




Spatial data extraction: X. Xiong (GIS-Pedometrics Team) and Y. Qiu (Geography, UF)

Data source: MODIS (NASA) Moderate-resolution Imaging Spectroradiometer

Soil Carbon Assessment across the U.S.



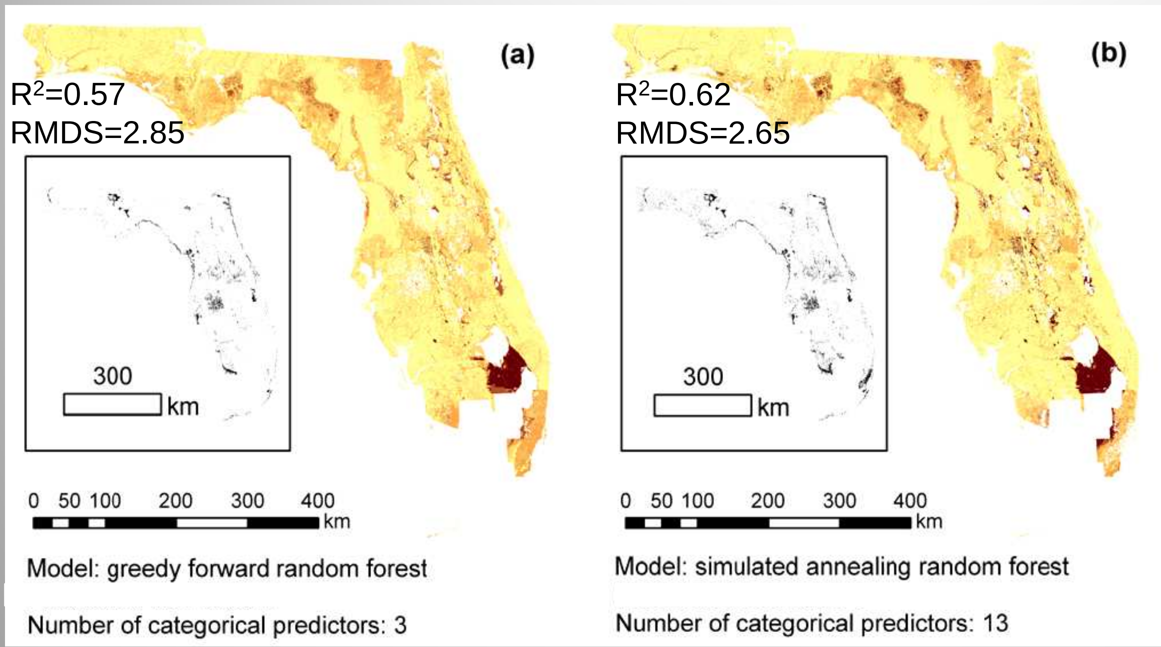
+ STEP-AWBH
(environmental covariates)

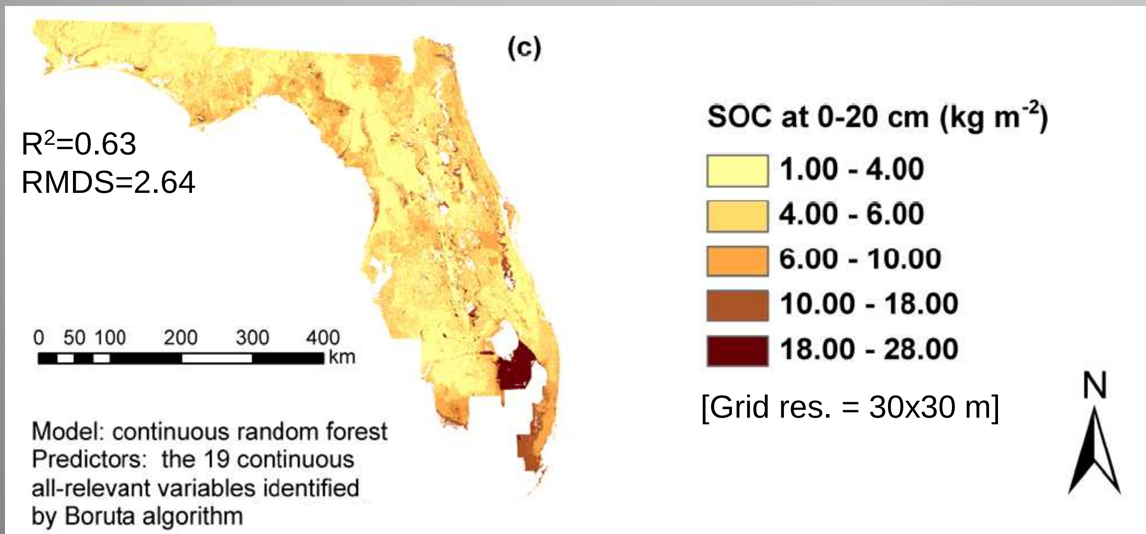
Soil carbon map

Soil Carbon Assessment across Florida, U.S.

(Xiong, Grunwald et al. 2013. Geoderma)

Validation results





STEP-AWBH
variables = 210

<u>Significant continuous predictor variables</u>
AWC (25 and 50 cm)
SOM
Soil albedo
Sand %
Slope
Dist Stream
Landsat (Bd5, Bd7, PC1, TC1)
Dry Biomass Vegetation
EVI (April)
MODIS (small NDVI peak integral)
MODIS (GPP)
MODIS (NPP)
(PrecipFeb and PrecipSept)
(PrecipAvg)

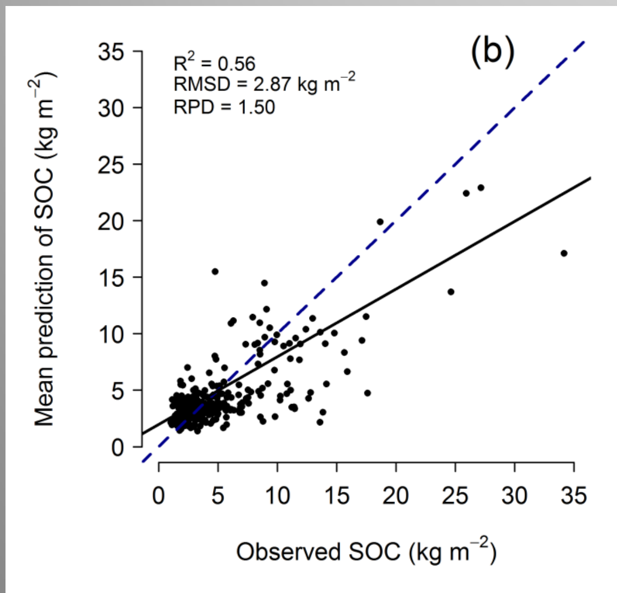
<u>Significant categorical predictors</u>:
LULC
VegType
Soil Hydration

Bayesian Geostatistical Modeling of SOC with Uncertainty Assessment

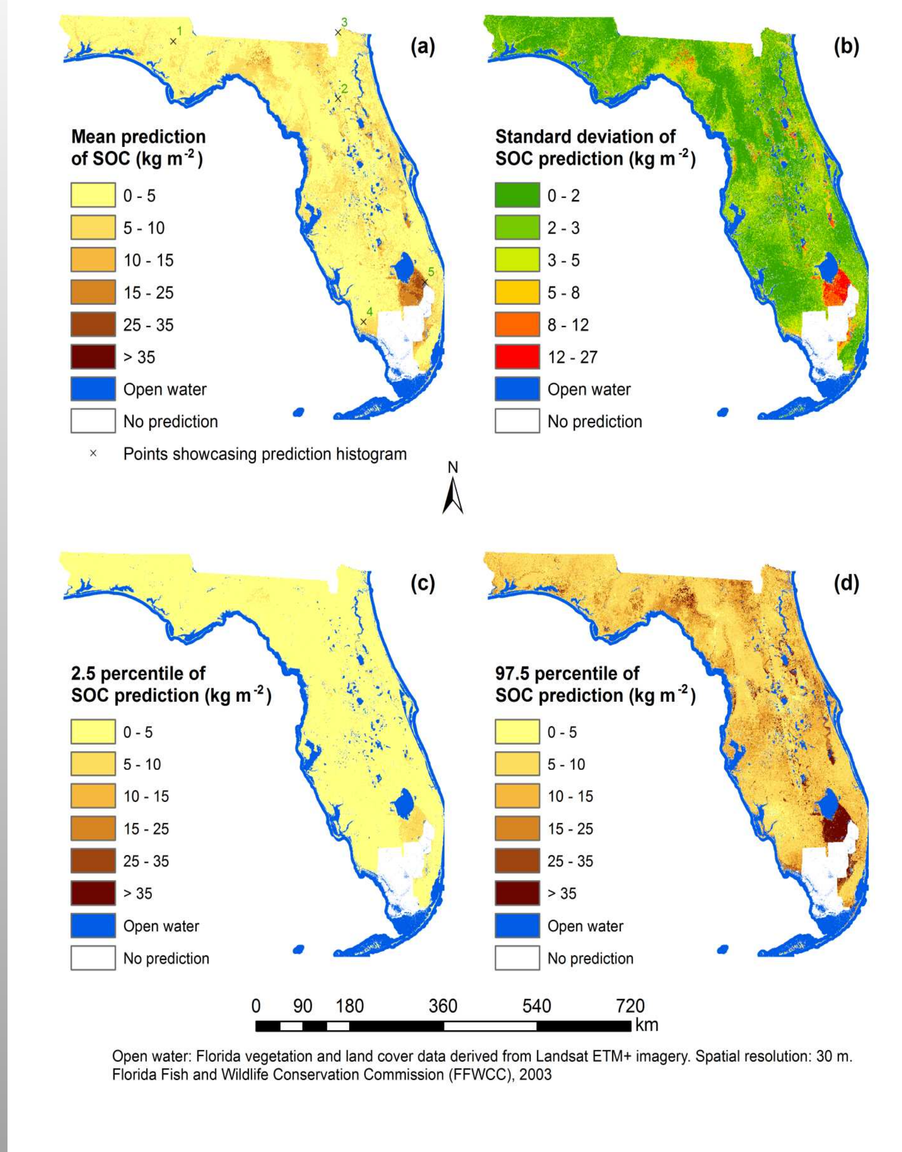
Xiong X., S. Grunwald, D.B. Myers, J. Kim, W.G. Harris, N. Bliznyuk and N.B. Comerford. 2013. Geophys. Res. Biogeosciences

Posterior mean (a), standard deviation (b), 2.5 percentile (c) and 97.5 percentile (d) of soil organic carbon (SOC) prediction at 0-20 cm depth in Florida from Bayesian geostatistical model with both fixed and spatial random effects.

(Markov Chain Monte Carlo (MCMC) simulation, after Diggle et al. 1998)

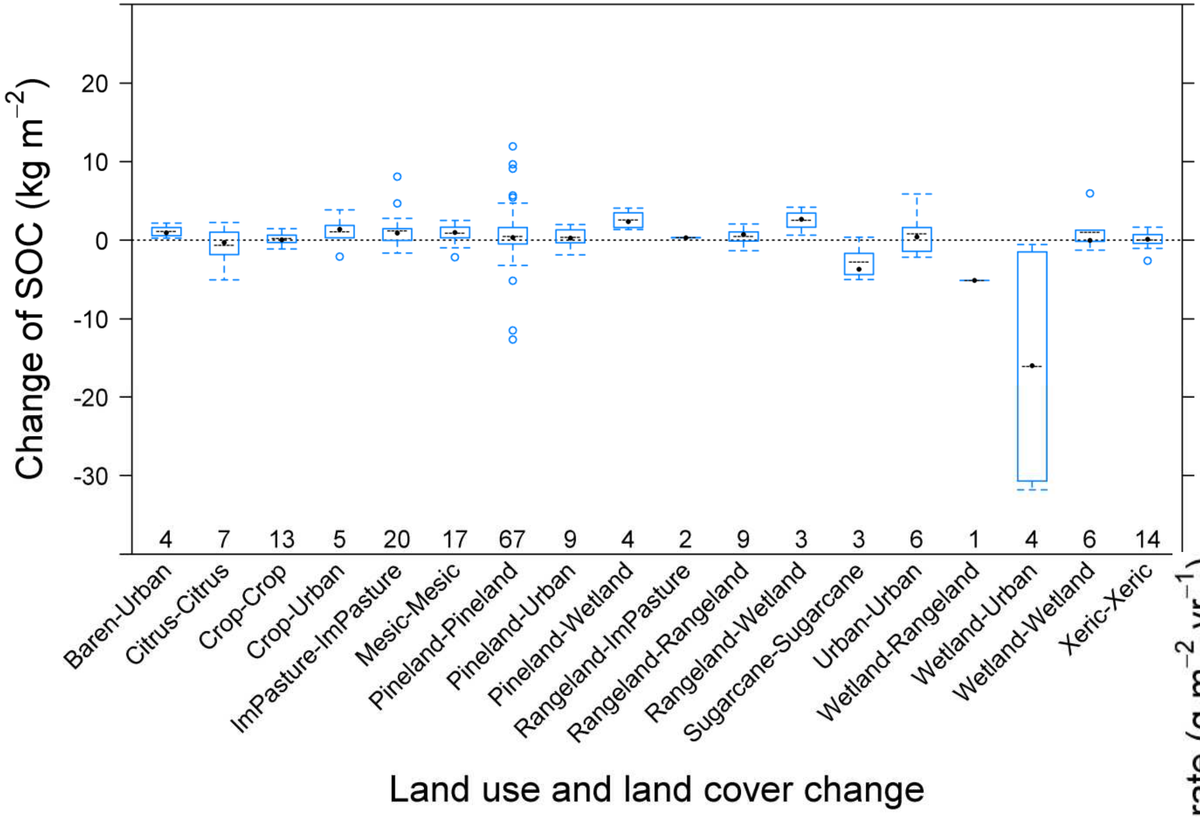


Environmental covariates: AWC, SOC (SSURGO), dry surface albedo, Landsat PC1, CTI, LAI

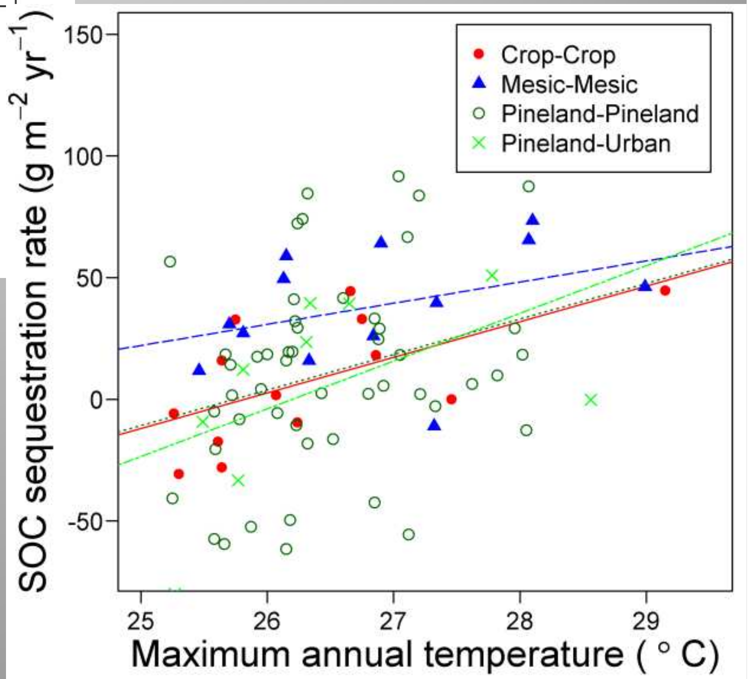


Soil Carbon Change 1965 to 2010 (Florida)

(Xiong, Grunwald et al. 2013.)



N = 194

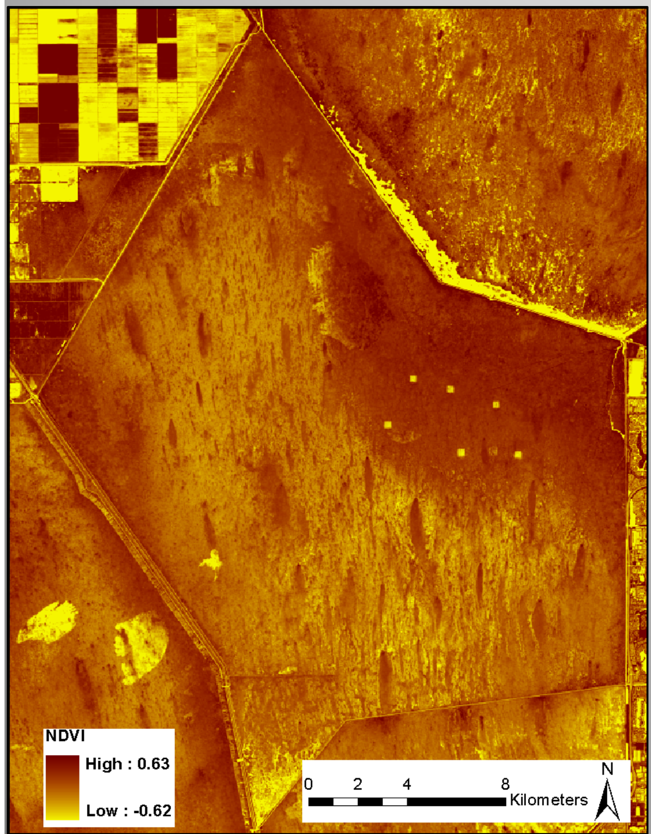


Remote Sensing Supported DSM

(Kim, Grunwald et al. 2012)

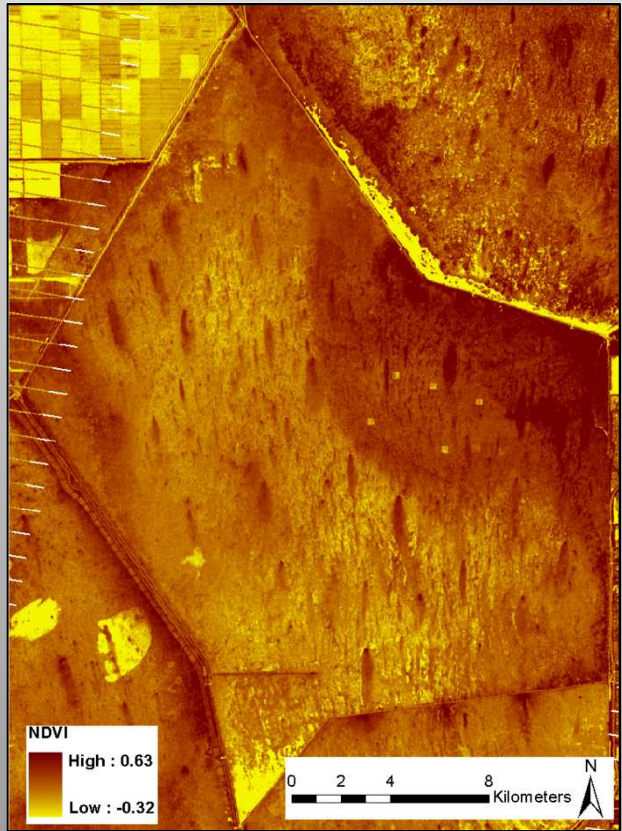
- Water Conservation Area 2A, Florida, Everglades
- Spectral indices: EVI, MSI, NDVI, NDVI green, NDWI, RSR, SR, TVI

SPOT (10 m)



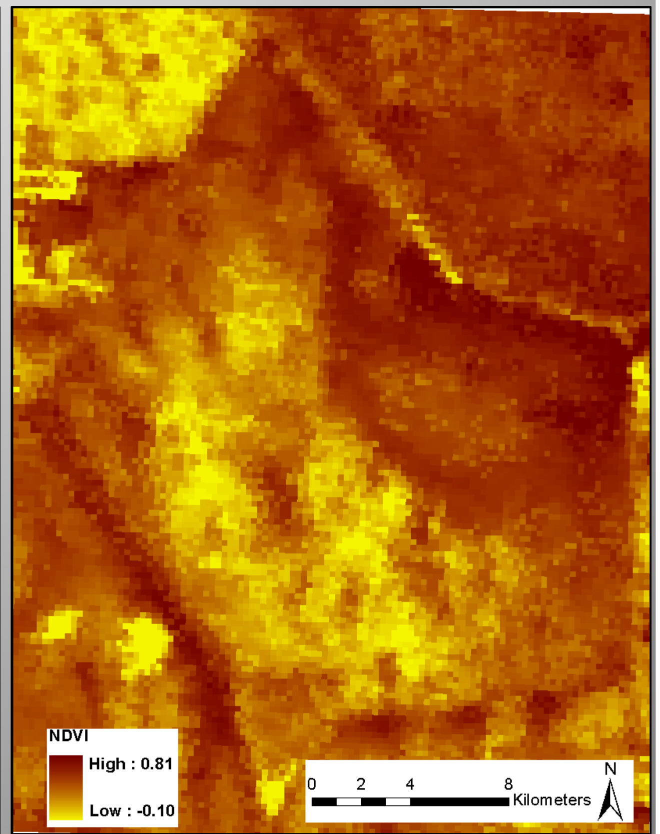
Jan. 09, 2009

Landsat ETM+ (30 m)



Feb. 16, 2010

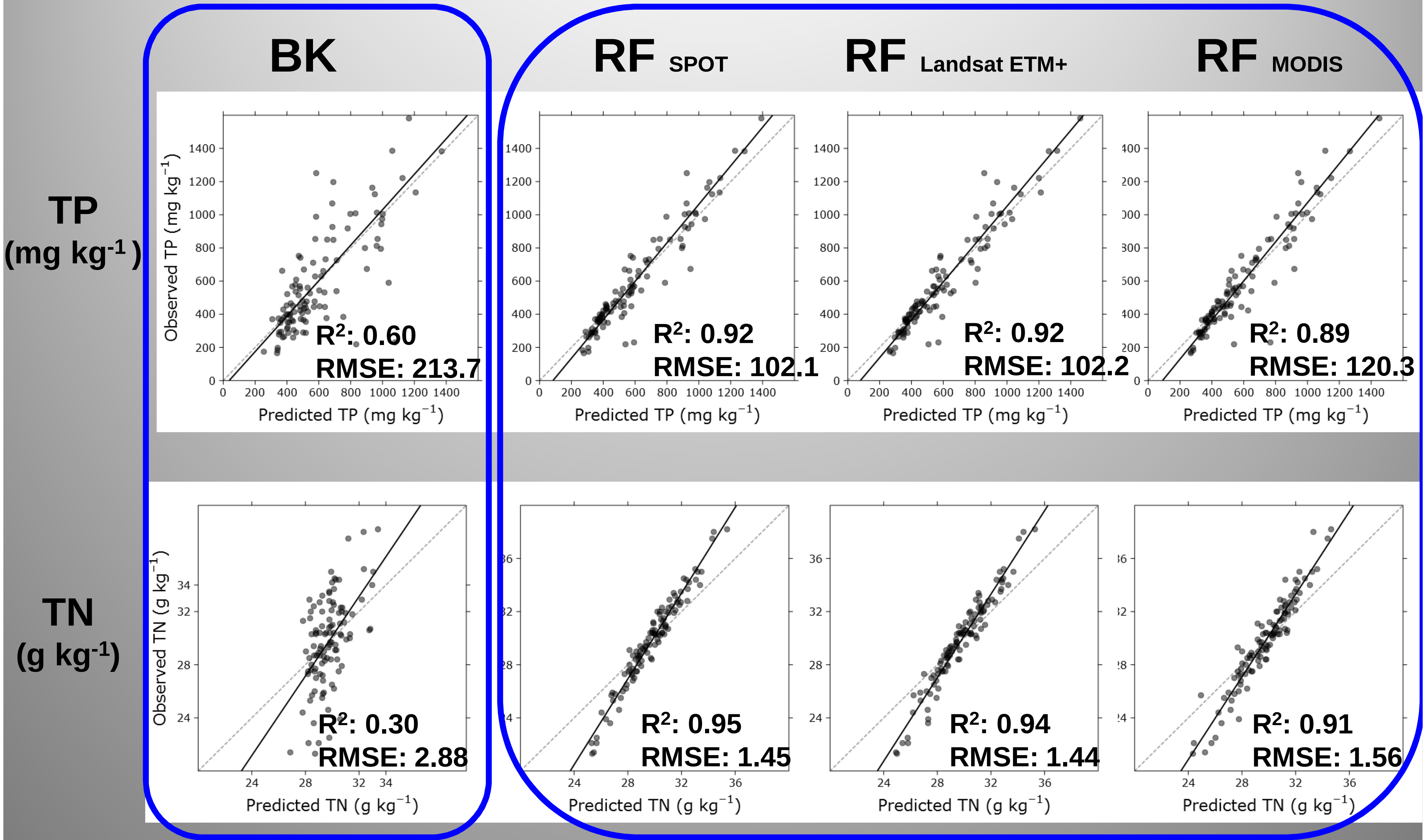
MODIS (250 m)

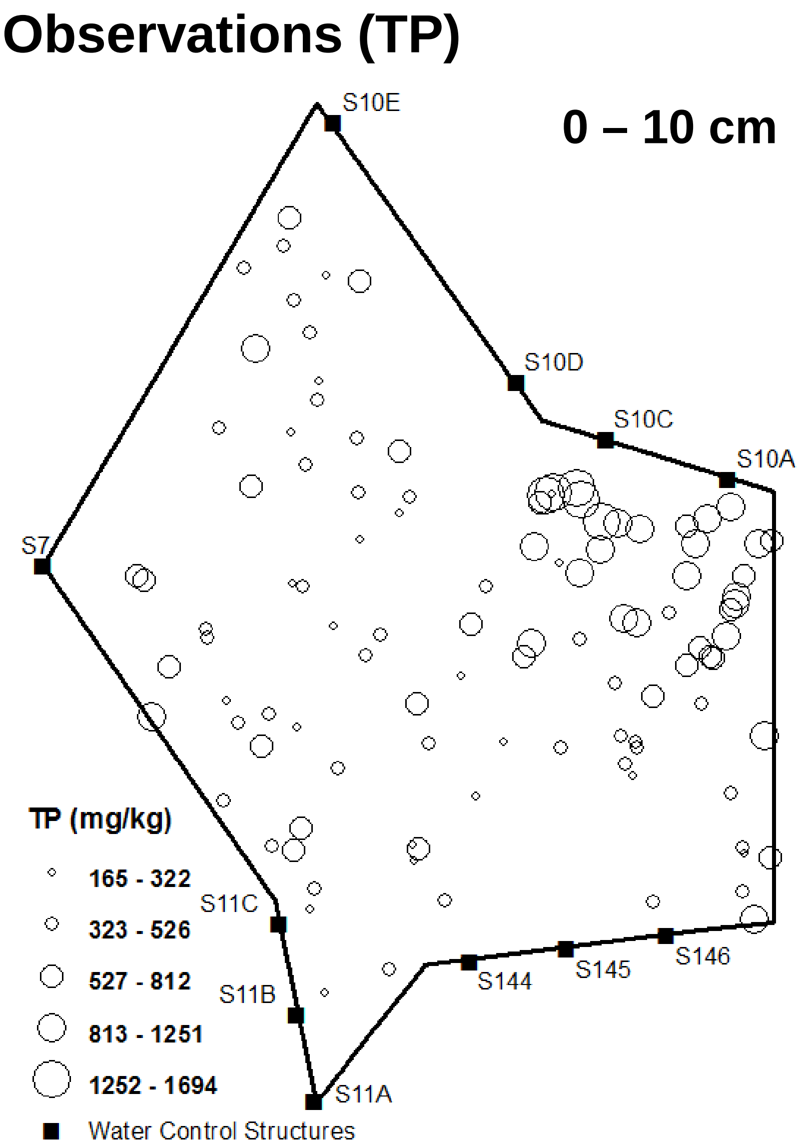


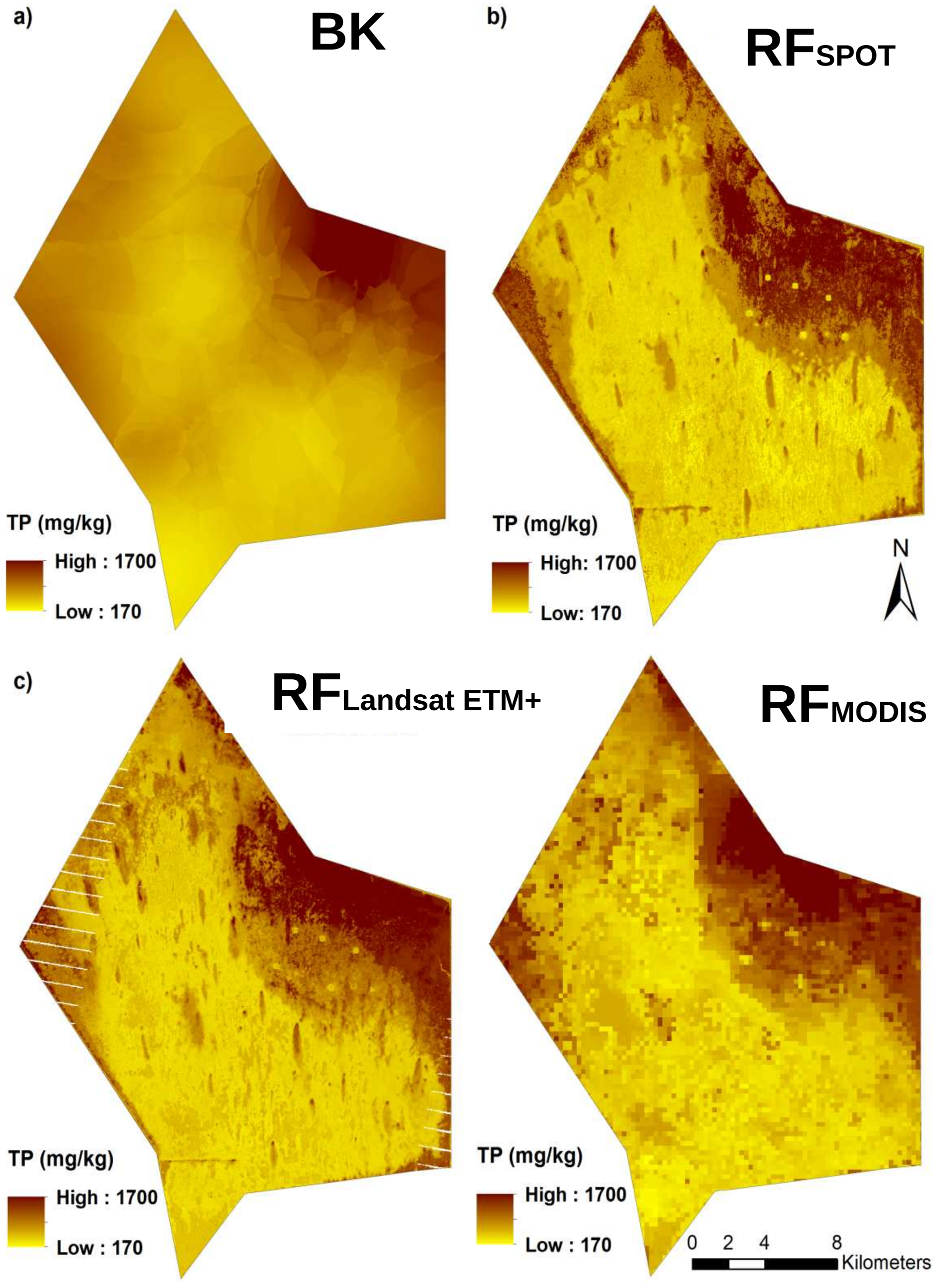
Feb. 18, 2010

Remote Sensing Supported DSM

(Kim, Grunwald and Rivero. 2013. IEEE Trans. Geosci & Remote Sensing J.)

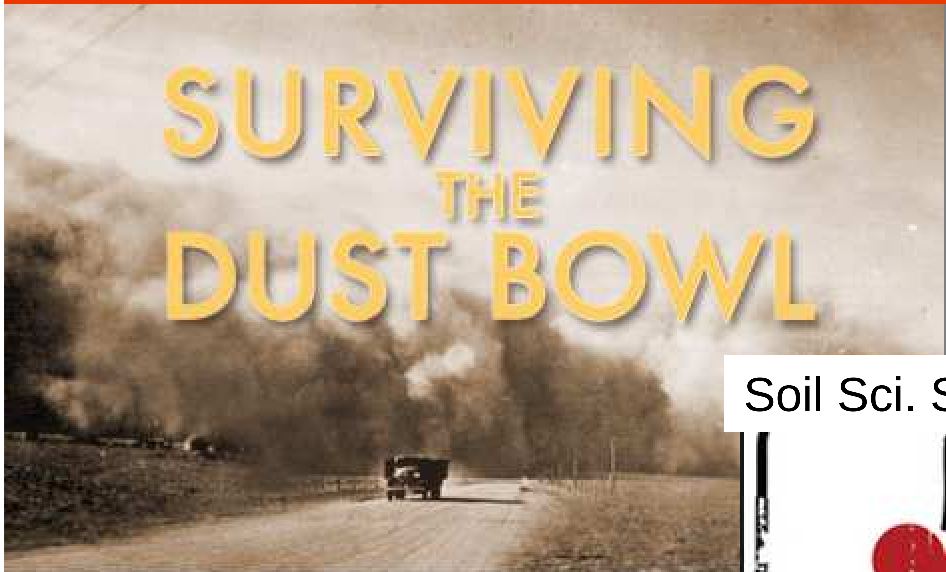






TVI, SR, and NDVI green (biotic factor) ranked high.

Soil Gaps

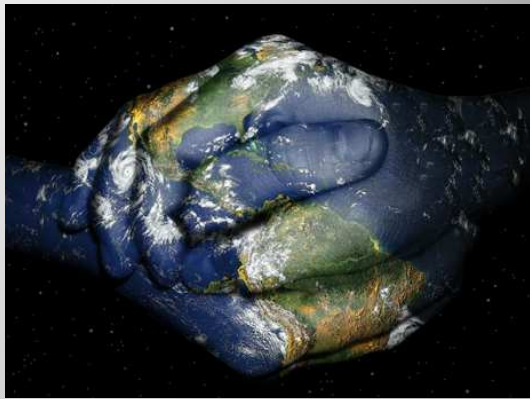


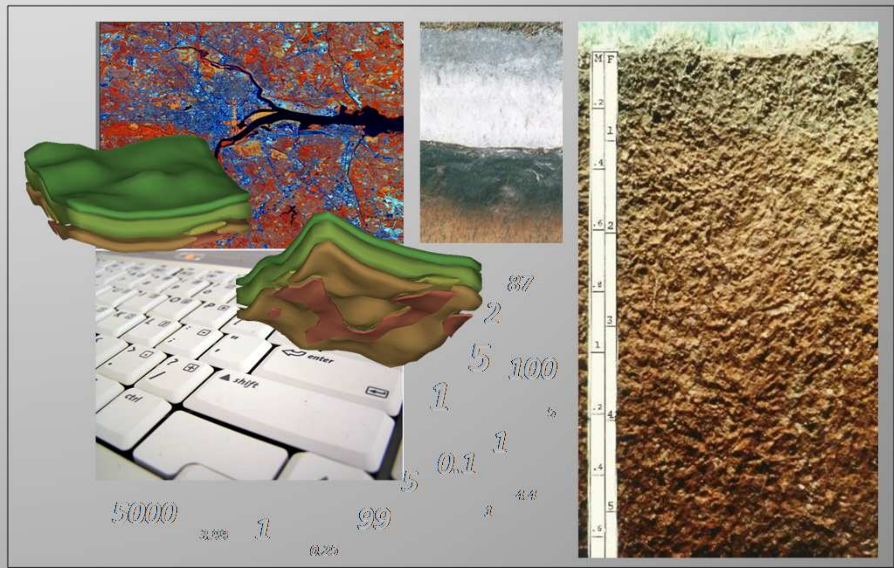
Soil Sci. Soc. Am.

Deep Soil Science

Human activities triggering “Global Soil Change”
(National Geographic, 2010)

Contact: sabgru@ufl.edu
http://soils.ifas.ufl.edu/faculty/grunwald





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