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Estimating the Impacts of Land Degradation on Changes in Crop Yields and Soil Carbon Stocks in Sub-Saharan Africa

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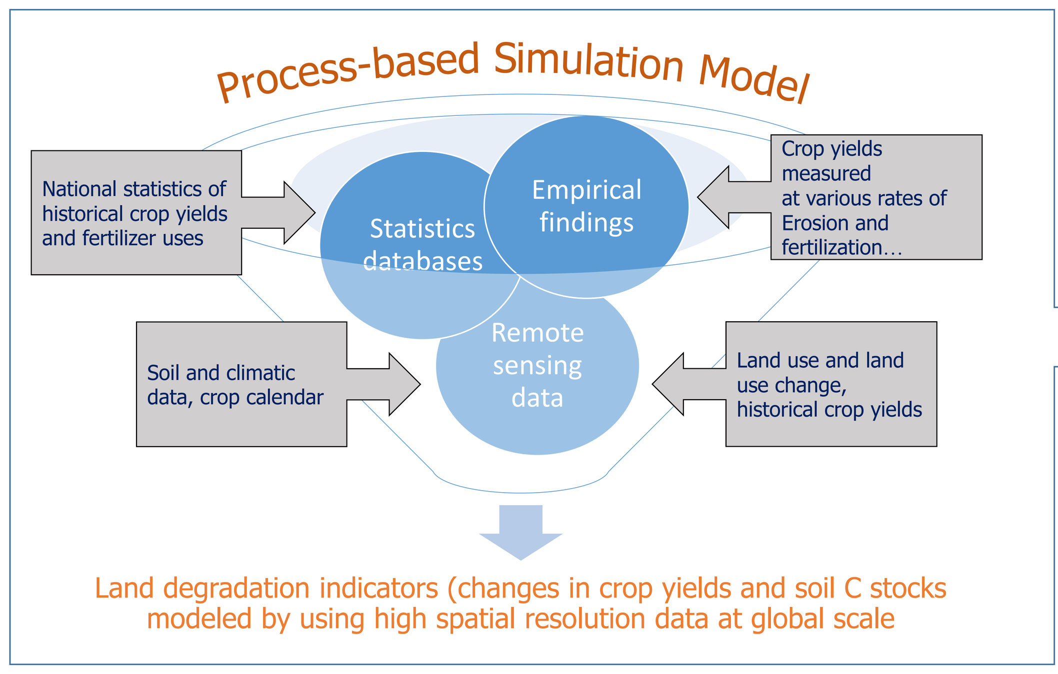
Land Degradation

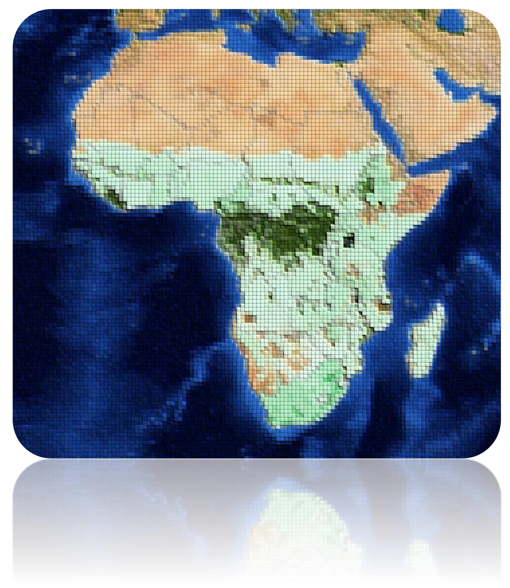
- Over the past few decades, greater attention has turned to the impacts of land degradation on the productivity of land and its ability to provide ecosystem services (Nkonya et al., 2013).
- Definition of land degradation
  - A decline in the current and/or potential capability of soils to produce quantitatively and/or qualitatively goods and services (FAO, 1979).
- More recent definition of the United Nations Convention to Combat Desertification (UNCCD) (1996) extended land degradation to spatial and time dimensions and listed important processes caused land degradation.
  - Soil erosion caused by wind and water.
  - Deterioration of the physical, chemical, and biological or economic properties of soil.
  - Long-term loss of natural vegetation.

Impacts of Land Degradation

- Studies have investigated the impacts of land degradation on productivity (FAO, 2002; den Biggelaar et al., 2004) and soil quality (Lal et al., 2004) of croplands and further linked them with important socio-economic issues like food security and economic cost (Bojo 1996) in regional and global scales.
- Through these studies, land degradation has been identified as one of the most serious threats to food production especially in Sub-Saharan Africa (SSA) where some 200 million population is trapped in a vicious poverty cycle between land degradation and the lack of resources or knowledge to generate adequate income and opportunities to overcome the land degradation (Bationo et al., 2004).



A Case study in Sub-Saharan Africa



Key components

- Baseline and alternative scenarios
  - Business as Usual: conventional tillage, low amounts of crop residues returned to soils.
  - Integrated Soil Fertility Management: no or reduced tillage, high amounts of crop residues returned to soils, and organic amendments.
- Spatial and temporal scales
  - Spatial resolution of a 30 min latitude by 30 min longitude grid cell for the period of 1981 to 2010 when the datasets regarding geographic, demographic, economic, technological, institutional and cultural factors (e.g. climate and agricultural practices, population density, poverty, absence of secure land tenure, lack of market access) are available.

- Empirical findings

Empirical relationship between erosion rates and yield losses (den Biggelaar et al., 2004)

Crop	Erosion-induced yield loss		
	$Mg\ ha^{-1}\ cm^{-1}$ soil erosion	$kg\ ha^{-1}\ Mg^{-1}$ soil erosion	% Mg^{-1} soil erosion
Maize	0.128 (0.003-0.715)	0.86	0.03%
Millet	0.187 (NA)	1.25	0.29%
Beans	0.009 (0.003-0.019)	0.06	0.02%
Cowpeas	0.044 (0.001-0.124)	0.29	0.03%
Cassava	0.594 (0.535-0.653)	3.96	0.03%

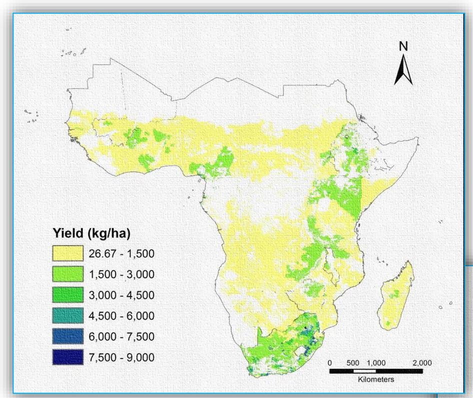
Salt tolerance parameters (FAO, 2002)

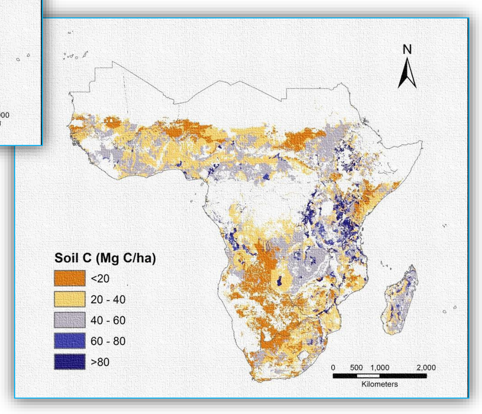
Equation		
Crop	Salt tolerance parameters	
	Threshod (ECe)	Slope
Maize	1.7	12
Wheat	6.0	7.1
Rice	3.0	12

- Datasets

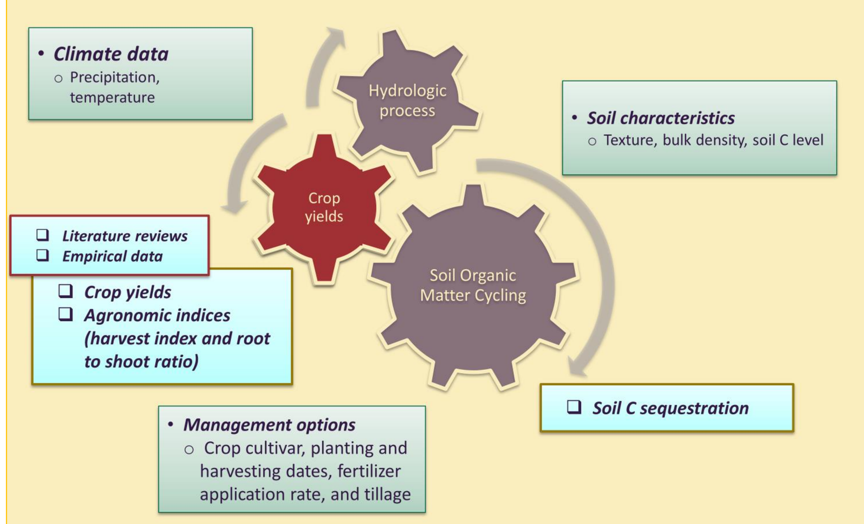
Data	Source	Temporal scale	Spatial resolution
Textures, organic C contents, bulk density, and salinity	FAO/IIASA/ISRIC/ISS-CAS/JRC (2012)	2000	30 sec grid
Planting and harvesting date	Sacks et al. (2010)	2000	5 min grid
Inorganic and manure N application N rate	Potter et al. (2010)	2000	30 min grid
Erosion rate	Symeonakis and Drake (2009)	1996	[a]5 min grid
Crop distribution	You et al. (2006)	2000	5 min grid
Precipitation, temperature, and potential evapotranspiration	Mitchell and Jones (2005)	1901– 2010	10 min grid
Maize, wheat, and rice yield	Iizumi et al. (2013)	1982 – 2006	1.125 degree grid

[a] Regional dataset (Sub-Saharan Africa)





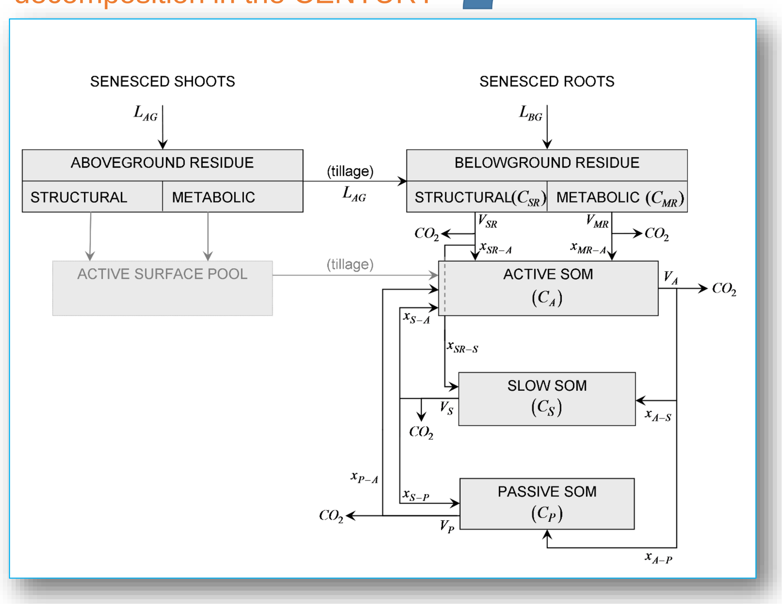
- Process-Based Model



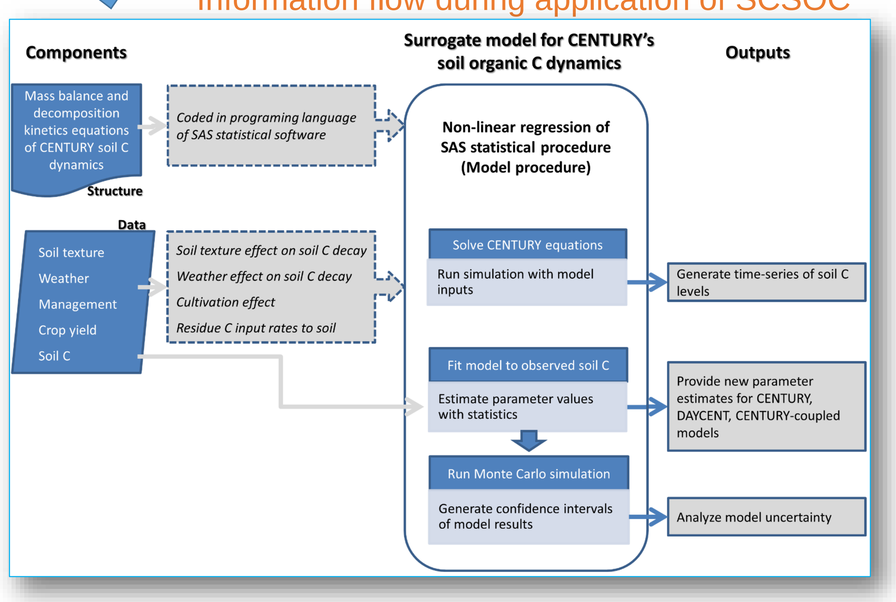
- CENTURY soil organic matter (SOM) model (Parton et al., 1987)
  - Adapt multiple "pool" structure to model soil C changes
  - Applied across a wide geographical range and at spatial scales ranging from individual plots to continents to the global biomes
  - Has been coupled with several sophisticated models, including EPIC, SWAT, and DSSAT
  - Serves as the basis of a national, online Carbon Management Evaluation Tool (COMET-VR) in the US

- A surrogate model for CENTURY soil organic C dynamics (SCSOC) (Kwon and Hudson, 2010)
  - Develop to rapidly and objectively estimate site-specific parameters of CENTURY SOM model from time-series data
  - CENTURY's mass balance and decomposition kinetics equations for three primary SOM pools is coded and written within SAS statistical software
  - Decoupled from models of plant growth, nutrient cycling, and hydrologic processes
  - Allow users to easily modify time-dependent CENTURY inputs

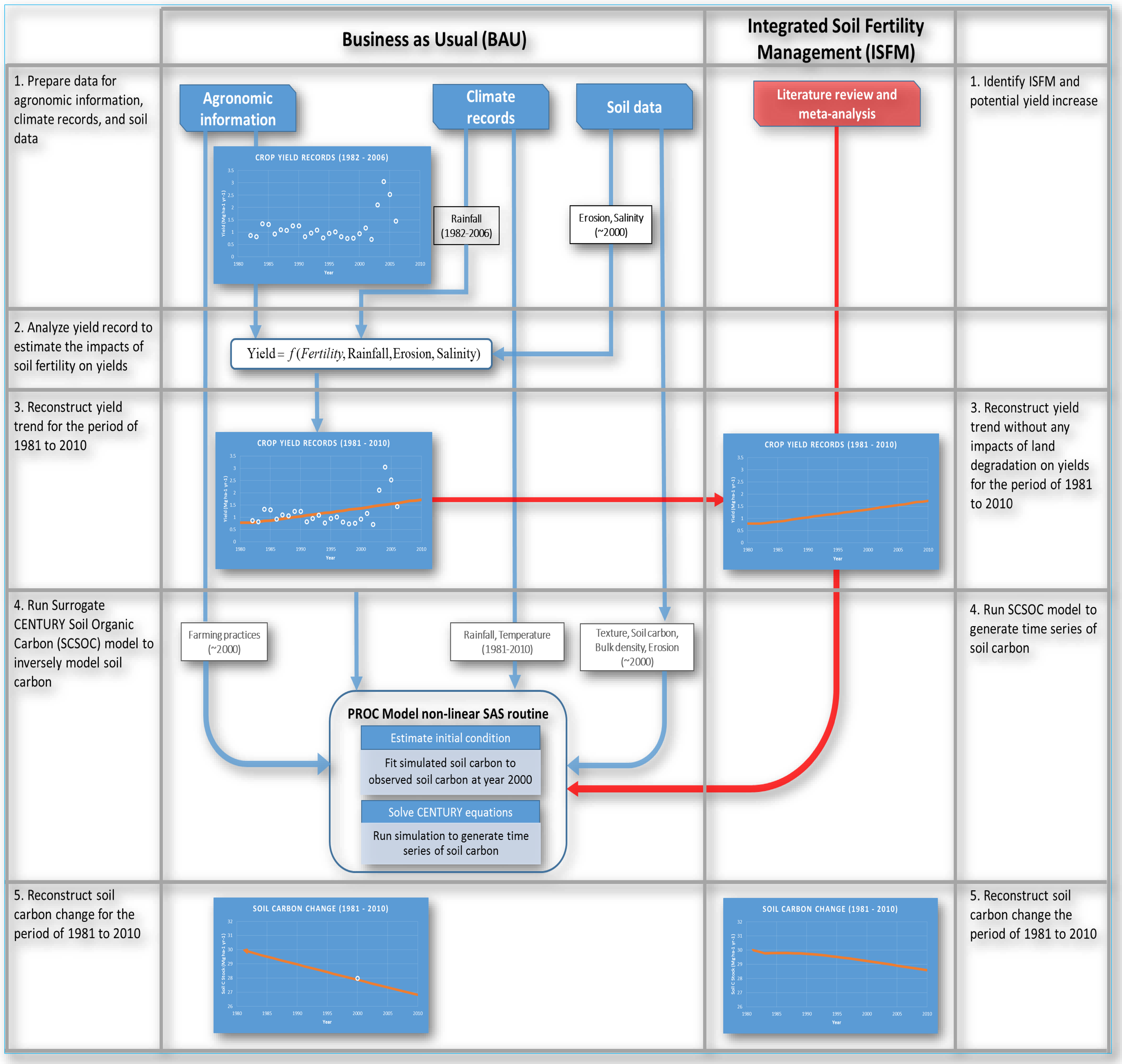
SOM pools and C flows during decomposition in the CENTURY



Information flow during application of SCSOC



Modeling Framework



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