UNIVERSITY OF SASKATCHEWAN

Quantifying changes in biomass and soil organic carbon after abandonment of croplands in Saskatchewan

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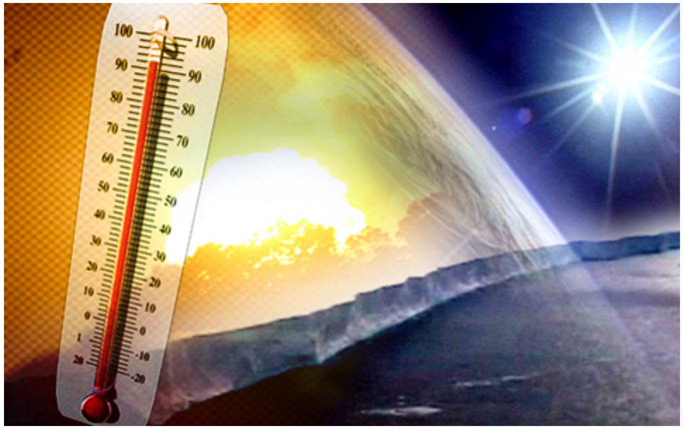
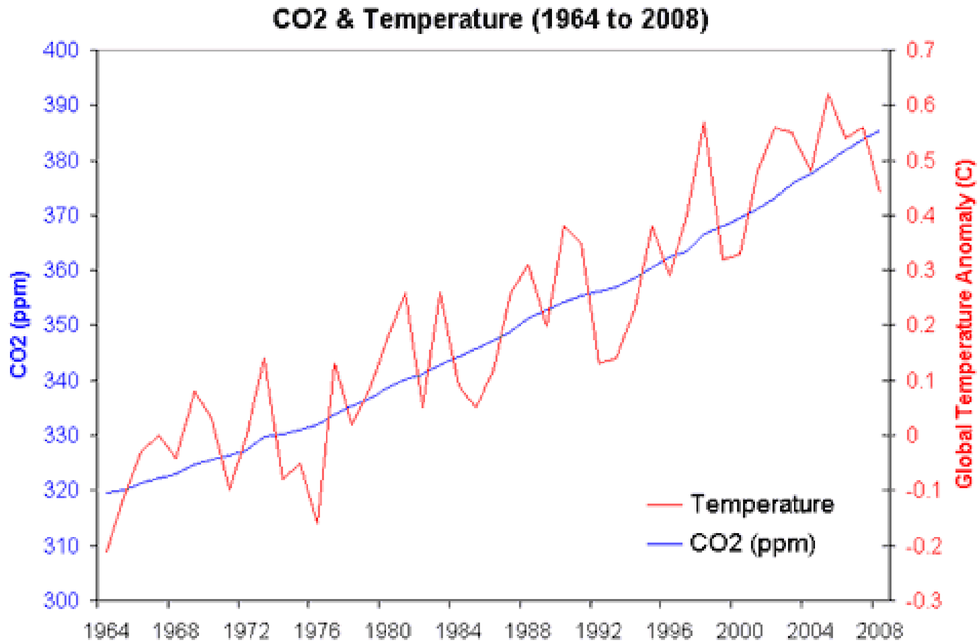
Introduction

- **Global temperature has increased in the last century and is projected to continue to rise in 21st century.**

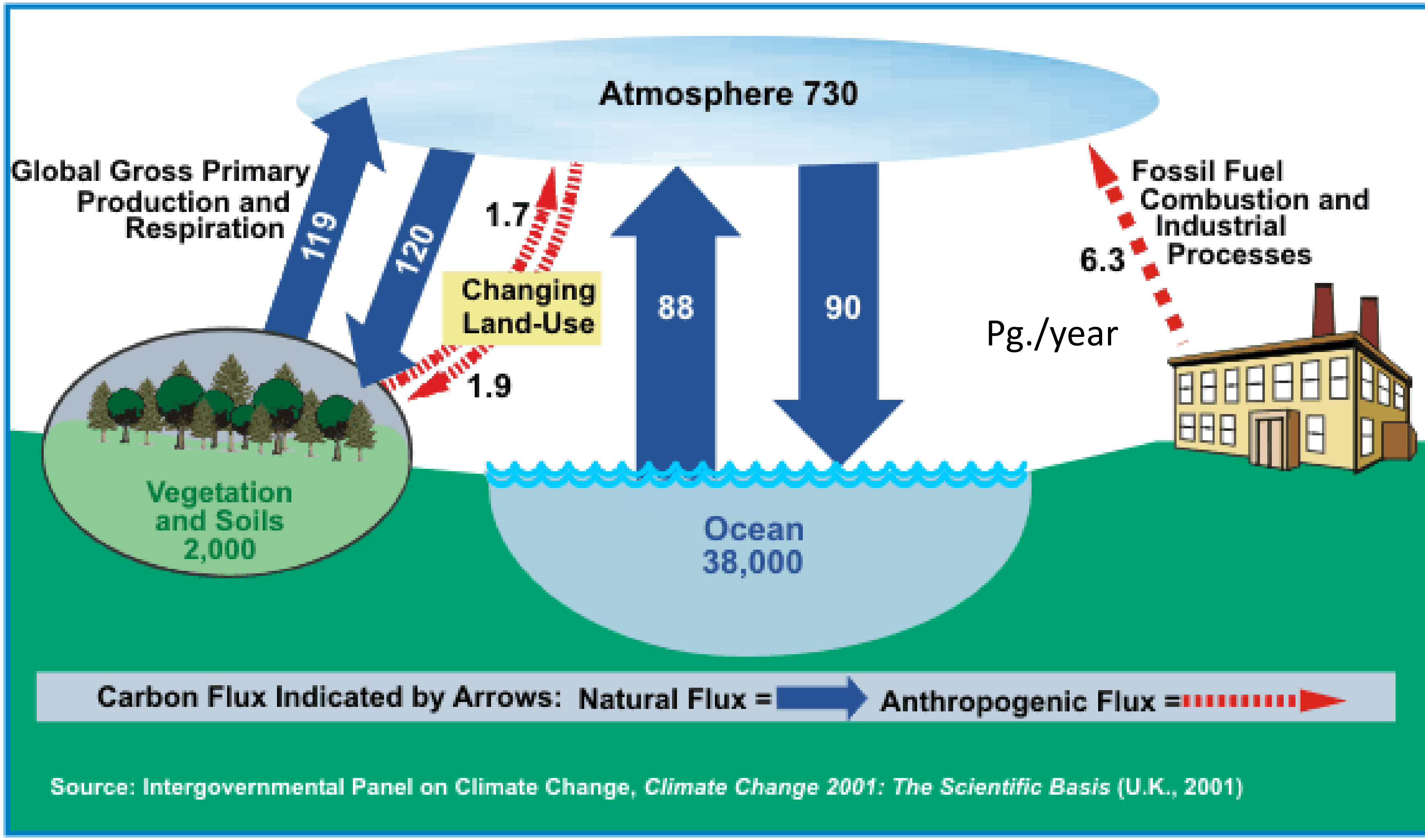




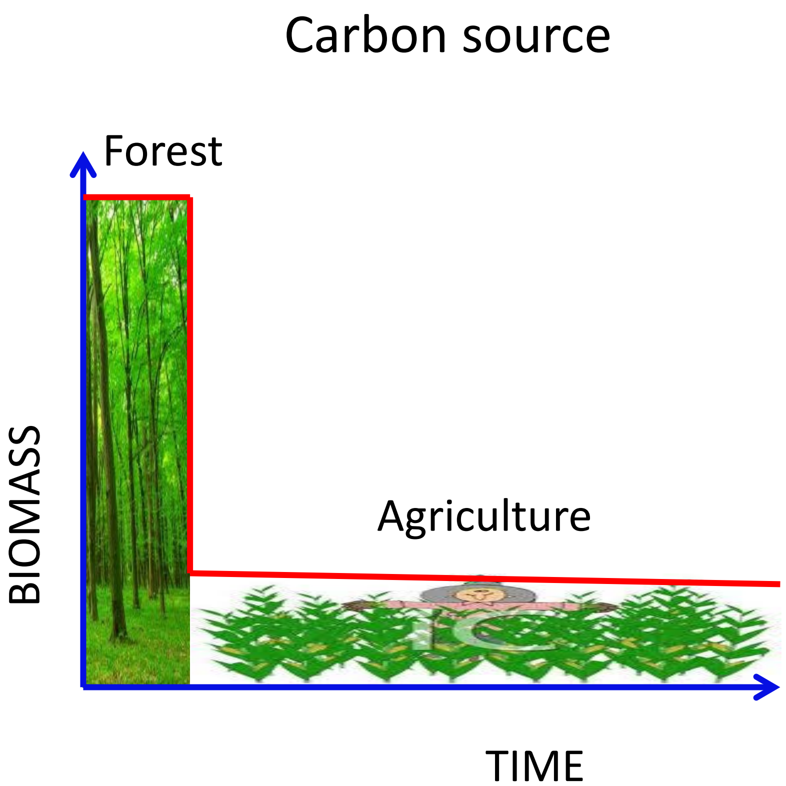
- **The level of carbon dioxide in atmosphere is closely related to global temperature**

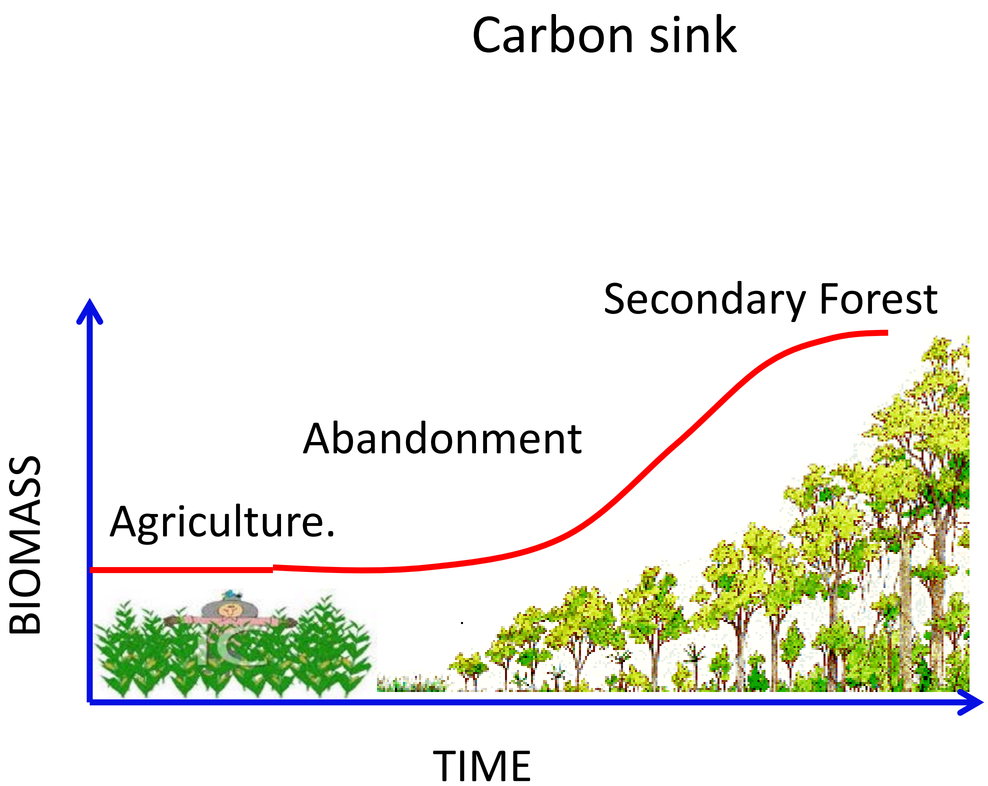
http://www.skepticalscience.com/

Introduction



Introduction





In Saskatchewan: about **191 Km²** croplands were abandoned in period from 1986 to 2006 (Statistics Canada, 2006).

Agriculture and agri-food Canada requires scientific based estimate for international reporting.

Research questions

1. What percent of agriculture lands were abandoned in the last 50 years (1960 - present)?

2. How much has carbon (Mg ha^{-1}) accumulated and distributed in soil and forest after agriculture abandonment; what is the rate?

3. What is the pattern of carbon stocks and likely changes in abandoned croplands in coming decades?

Main objectives

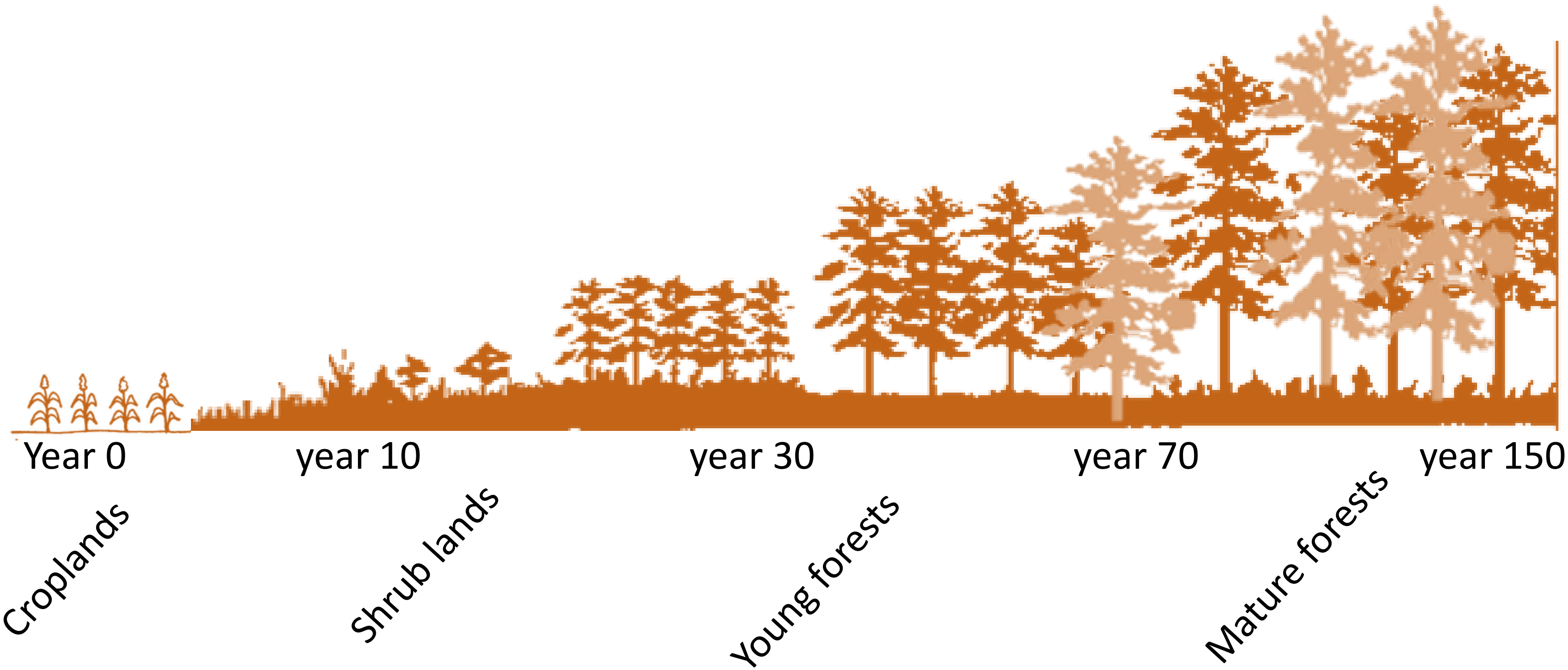
1. Delineate abandoned croplands that have regenerated (10 to 60 years) and converted into shrub lands or forests.

2. Quantify carbon stocks and calculate carbon accumulation rates of abandoned croplands

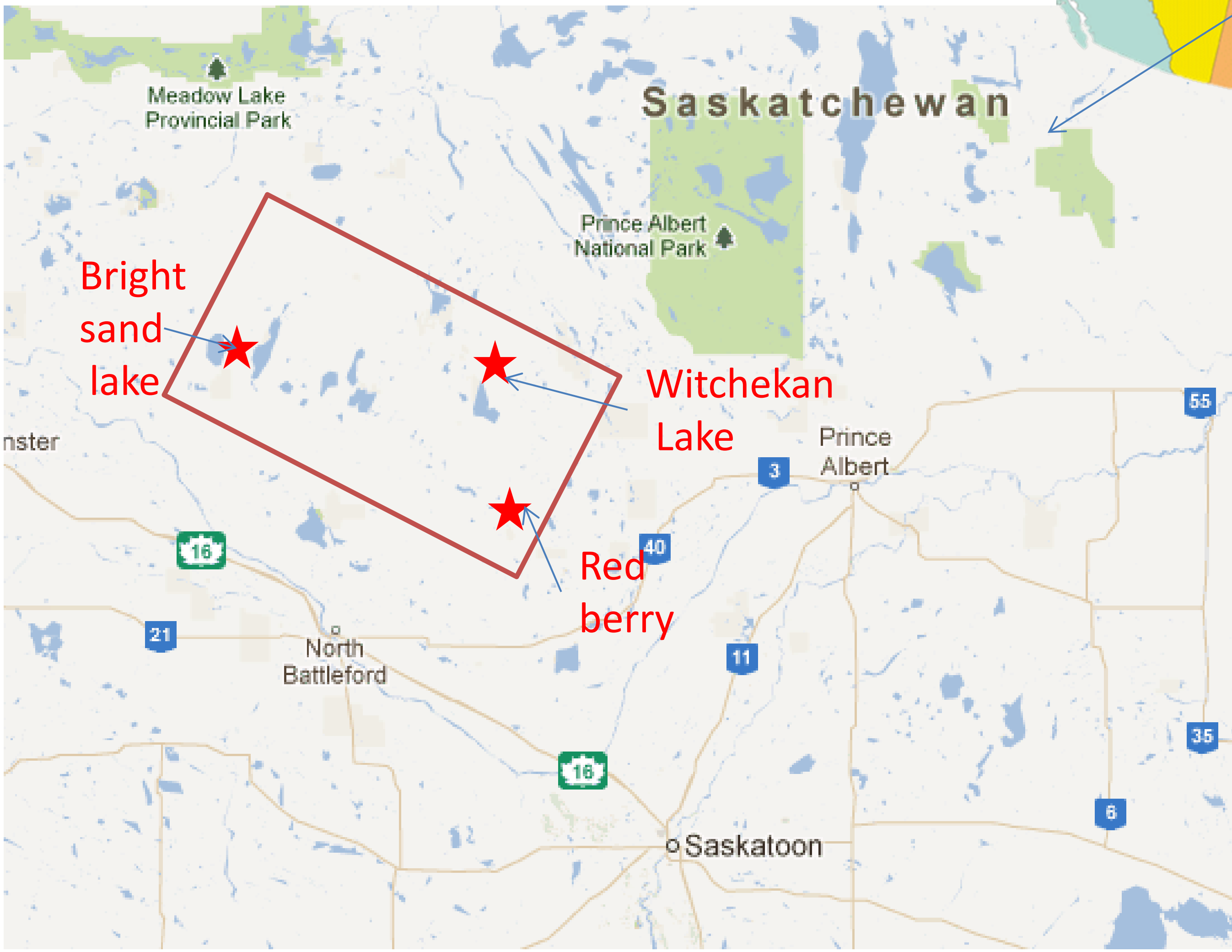
3. Simulate and predict future carbon stocks and changes in forests and soils in abandoned croplands.

Abandoned croplands

Abandoned croplands refer to land that used to be cultivated but cultivation activities have ceased for at least 10 years and regeneration to shrub or forest has begun.



Study areas

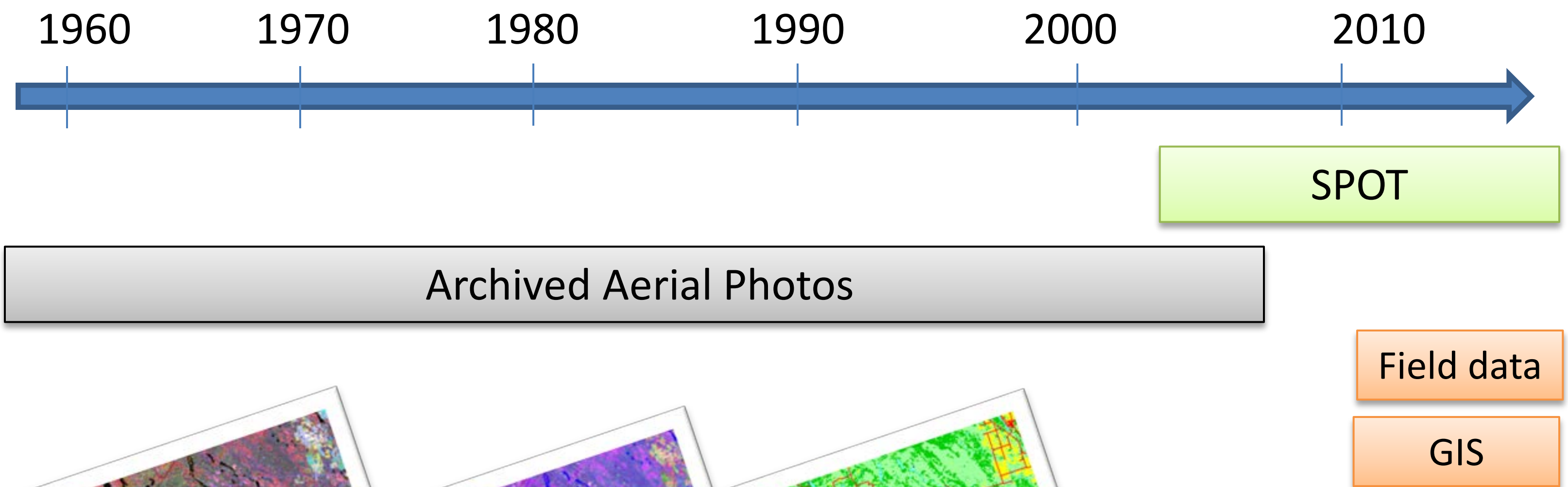


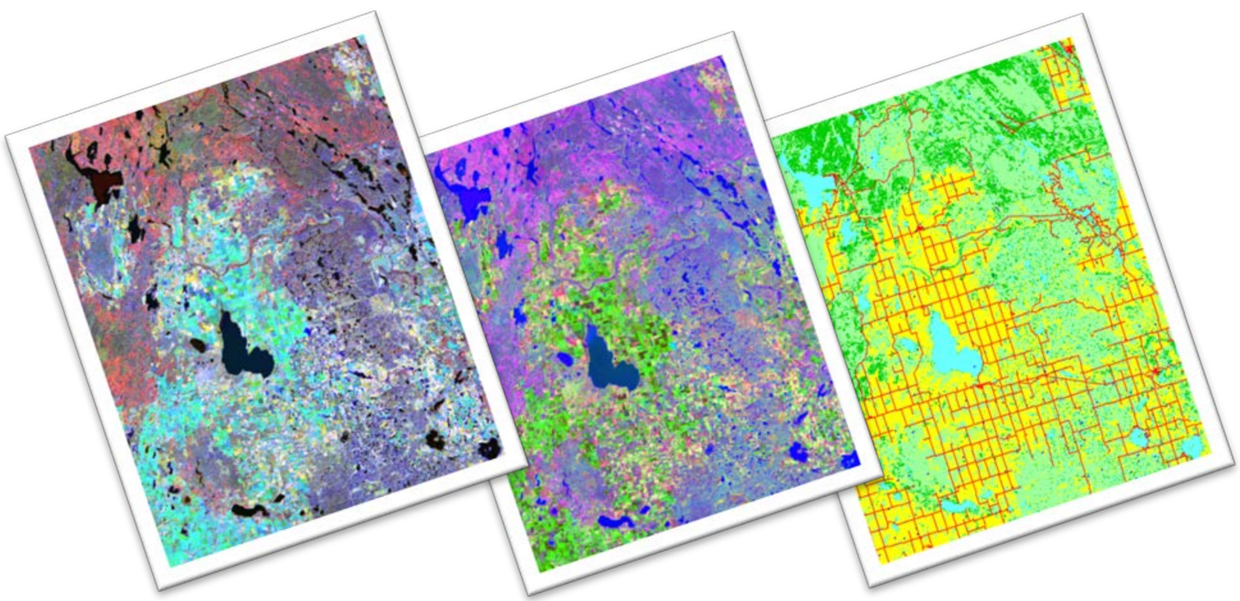
TURTLEFORD - SASKATCHEWAN

53°24'00.000" N
108°57'00.000" W

Data collection

Remotely sensed data & GIS data:





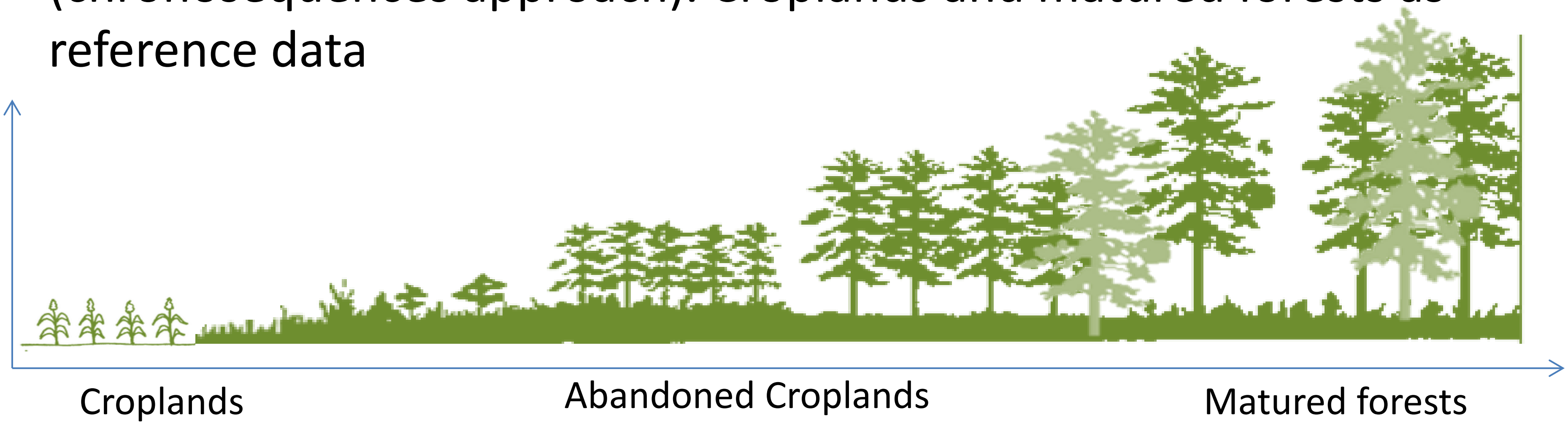
Witchekan
Lake, SK

Data collection

Field data:

Non- Tree biomass + Tree Biomass + Soil organic carbon + Leaf area index

A series of abandoned cropland sites established at different time (chronosequences approach). Croplands and matured forests as reference data



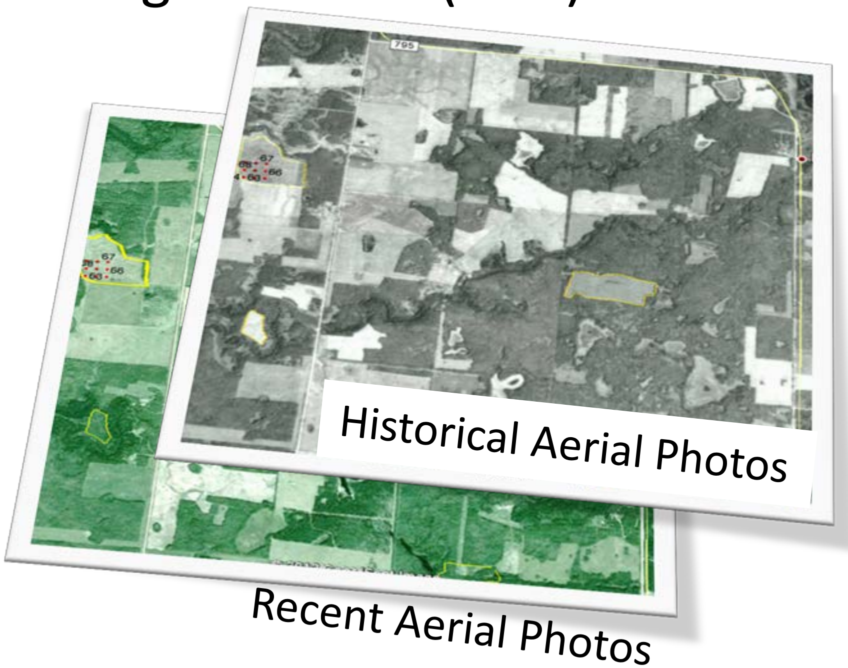
Shugart et al, 2001

Change detection approach

Objective 1:

Delineate abandoned croplands

- Approach 1: Visual on-screen change detection and digitalization (VOS)

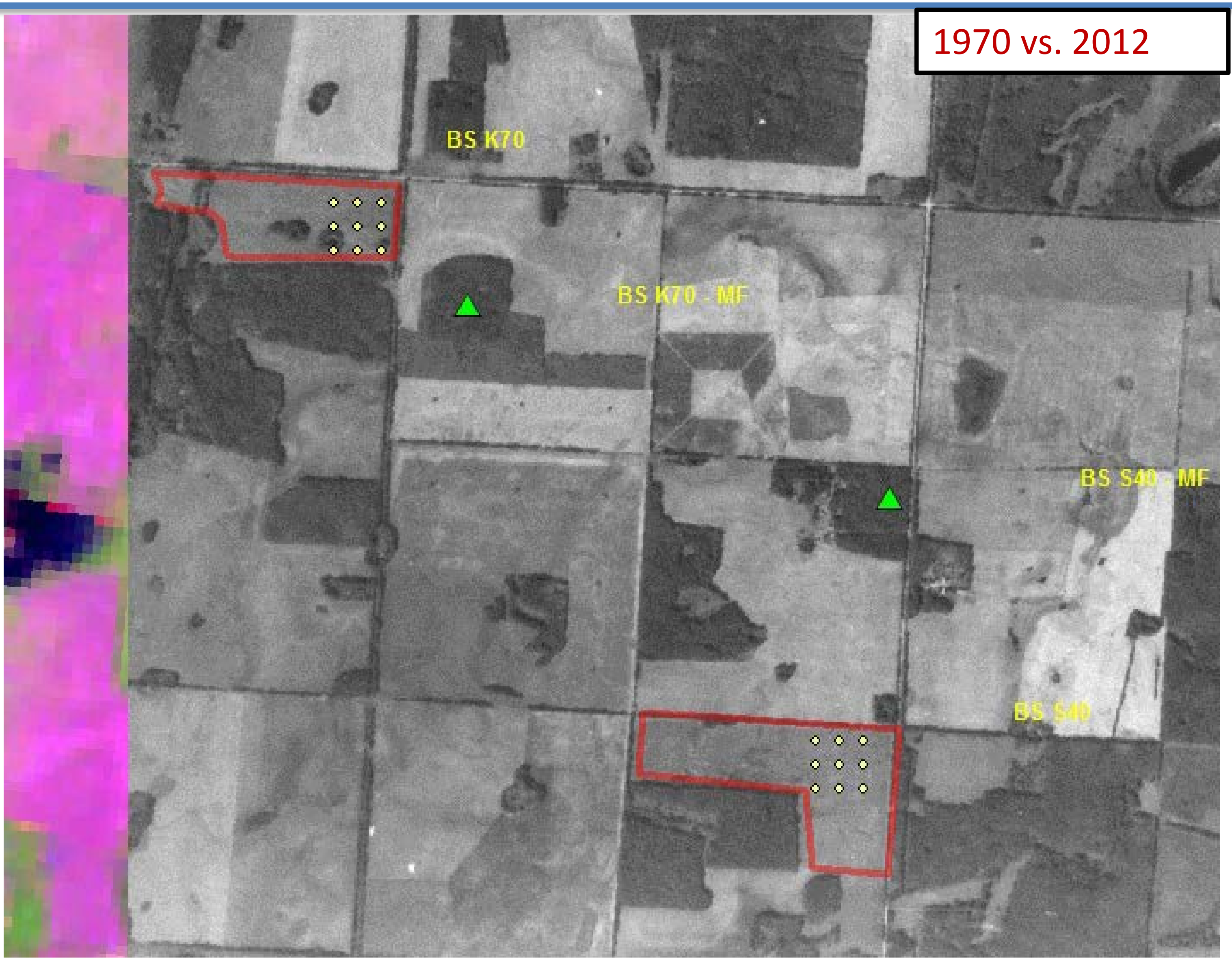


- ✓ Co-georeference in a coordinate system
- ✓ Manual change detection
- ✓ Digitalization
- ✓ Validation

Change detection methods

<u>Objective 1</u>:

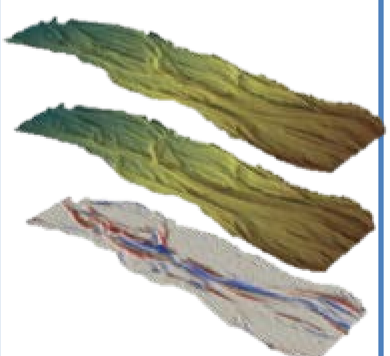
Delineate abandoned croplands



Results from pilot study
(Turtleford, SK)

Objective 1:

Delineate abandoned croplands



Results from pilot study

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Objective 1:

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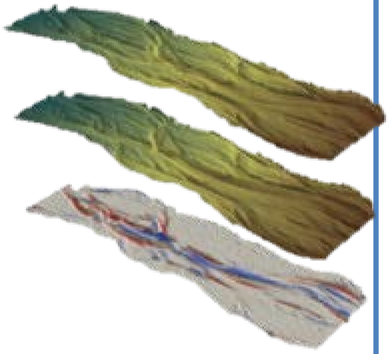


Site name	Area (ha)	Approx. Age
BS N10	17.61	10 - 15
BS E45	15.31	43 - 47
BS L60	39.07	60
BS K70	14.84	70
BS S40	22.27	37 - 40
Red A17	7.08	17
Red B17	32.37	17
WL A47	11.49	47
Sum	**160.04**	

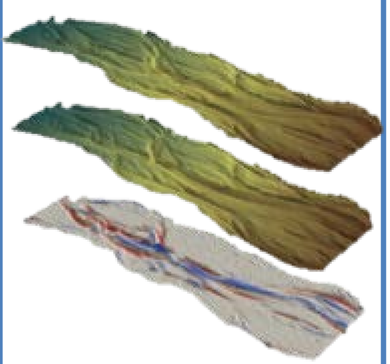
Visual on-screen change detection:

- Simple technique
- Provides high accuracy
- Time consuming
- Labour intensive.

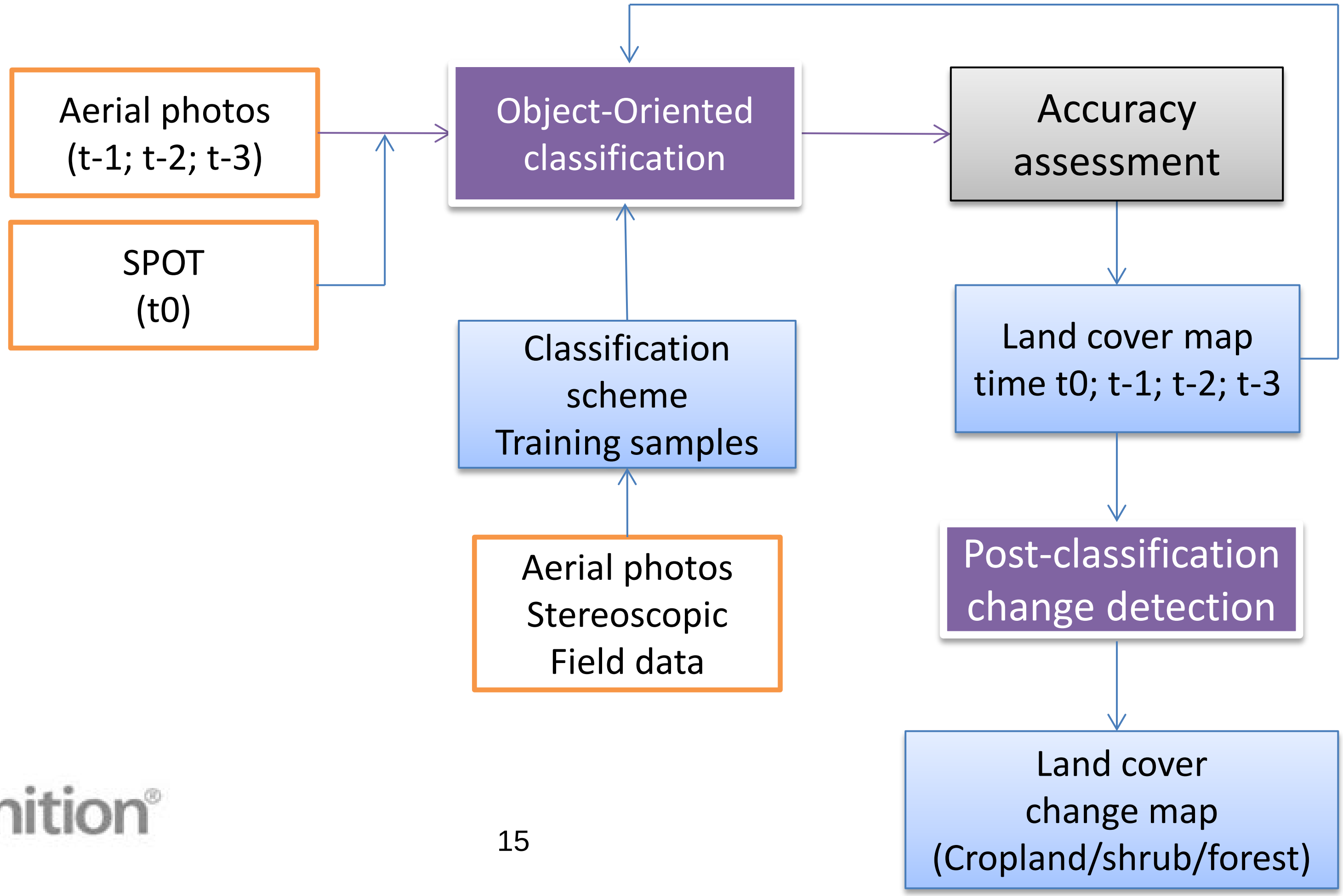
Post-classification method

Objective 1:

Delineate abandoned croplands

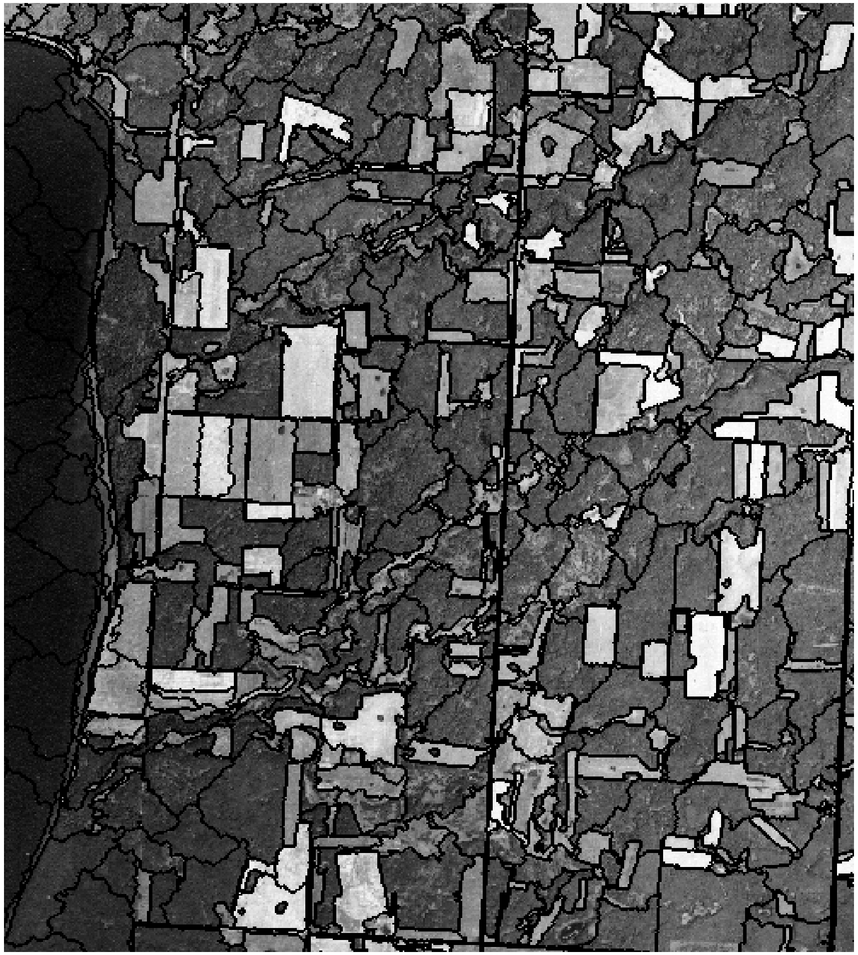


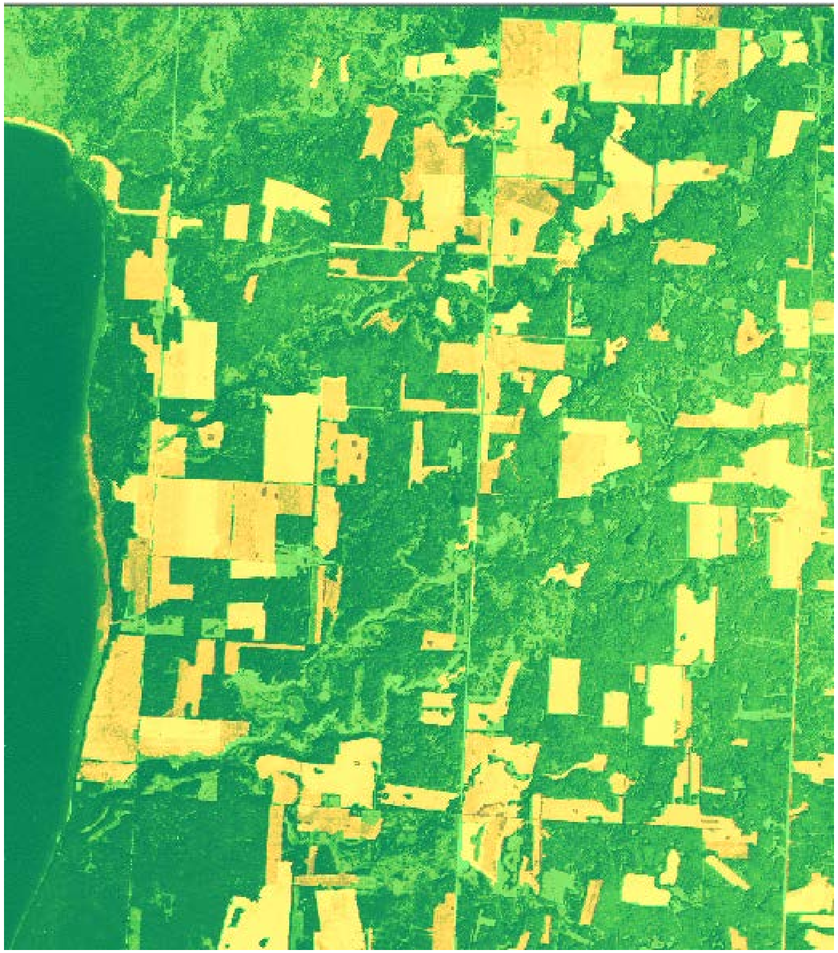
- Approach 2: Post-classification comparison change detection using aerial photographs and SPOT images



eCognition®

Example of object-oriented classification





Segmentation scale: 205; Segmentation colour: 0.5

Expected results

Objective 1:

Delineate abandoned croplands

- Maps of abandoned croplands
- Stand age map
- Conversion rate

$$r = \frac{1}{(t_2 - t_1)} * \ln \frac{A_2}{A_1}$$

Where: r is the change rate; t is time; and A is area

Puyravaud (2003))

Data collection

Objective 2

Quantify carbon stocks and calculate carbon accumulation rates of abandoned croplands

- Define Carbon pools

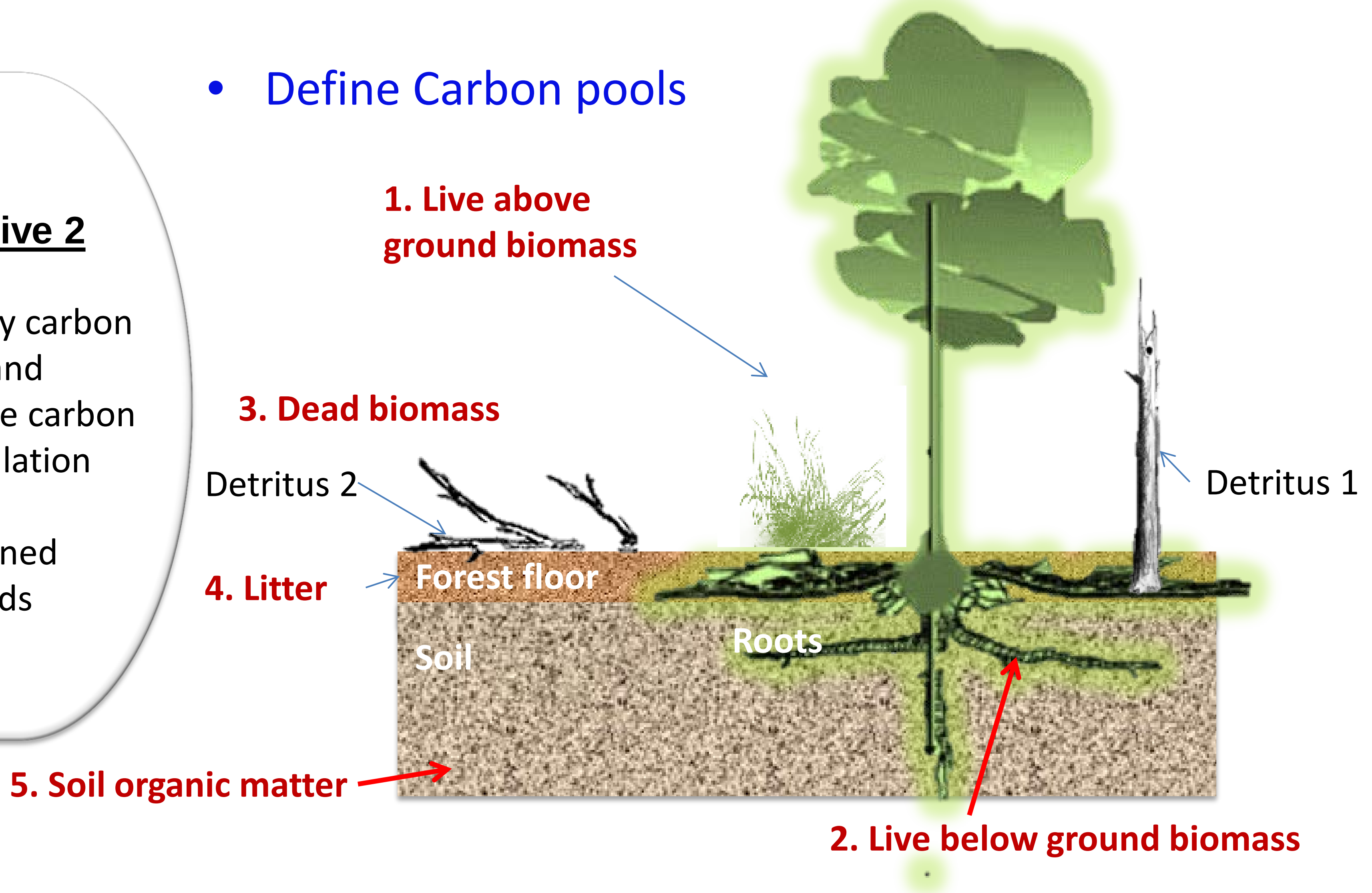
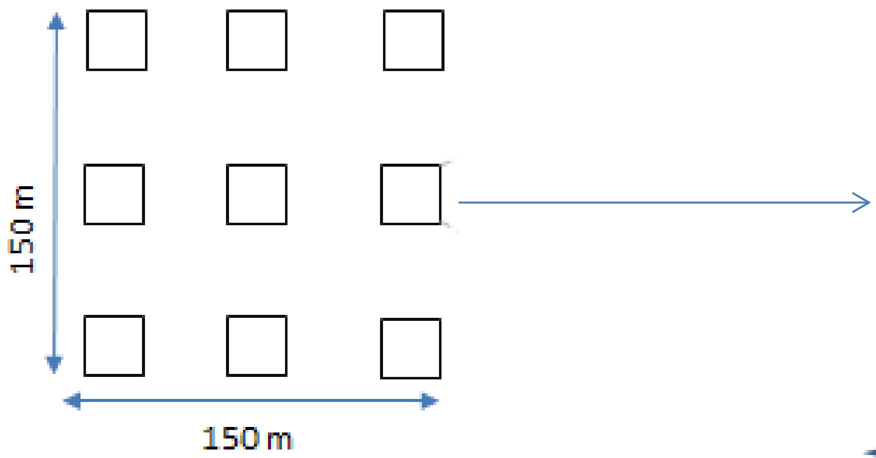


Image source: http://carbon.sref.info/components

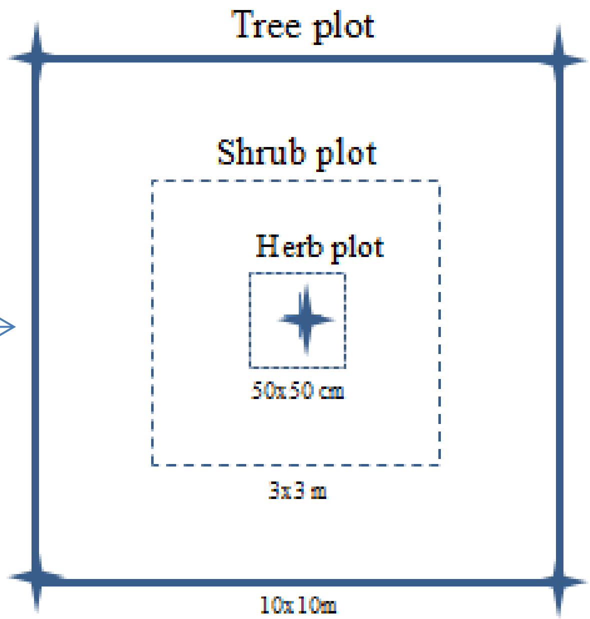
IPCC, 2006

Data collection and sample design

- Sample design



- Data collection

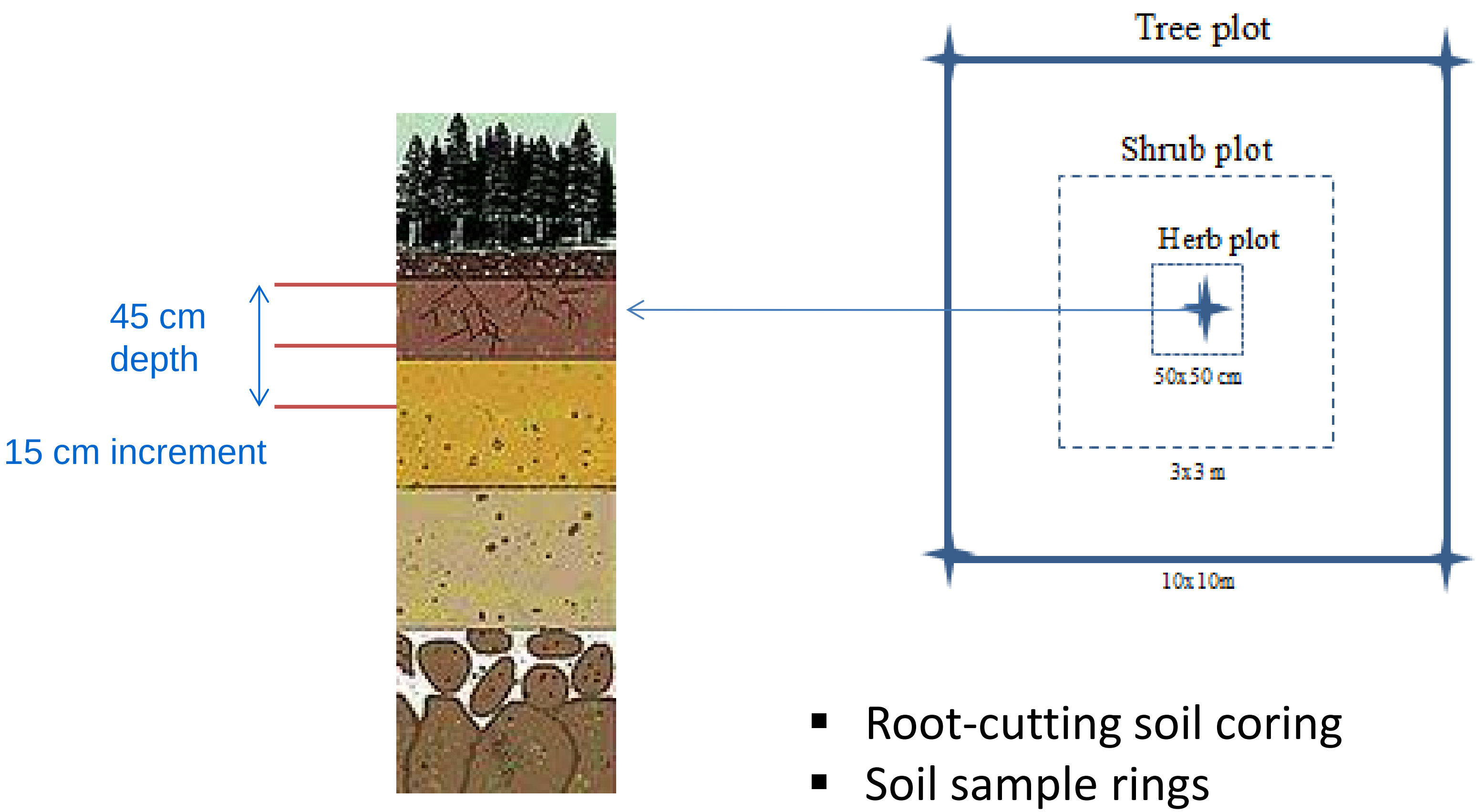


Sample points were designed in a systematic grid of 3x3

Pennock, 2006

Data collection

- Soil sampling



- Root-cutting soil coring
- Soil sample rings
- Truck-mounted soil sampler

Fitzsimmons et al., 2004

Data collection methods

Biomass pools	Indicators	Methods for data collection	Plot type
Living trees	> 3 m in height	Non-destructive measurement of diameter at breast high or DBH (1.3m), tree species and tree height (H); Non-destructive leaf area index (LAI)	Tree
Dead standing (detritus 1)	> 10 cm in diameter	Non-destructive, apply cylinder equation	Tree
Shrub vegetation	0.5-3 m in height	Average height Harvest and separate via tree species, weight wet and subsample (~10%) for oven dry.	Shrub
Lying dead wood, dead branches (detritus 2)	2-10 cm in diameter	Destructive, oven dry, weight	Shrub
Grass	<0.5m in height	Destructive, weight wet and subsample for oven dry weight.	Herb
Litter	0-2 cm in diameter	Destructive, oven dry, weight	Herb
Soil	15 cm increment to 45 cm depth	Soil coring, soil pit	soil

Tree biomass estimation methods

Above-ground biomass estimation methods

Parameters	Methods for biomass estimation
Living trees	• Trembling aspen and balsam poplar, white spruce : Lambert et al. (2005). • Choke cherry, and willow: Ter-Mikaelian et al. (1997). • Others: Bond-Lamberty et al. (2002); Bella and Defranceschi (1980); Stanek and State (1978).
Detritus 1	$V = \pi r^2 h$ (cylinder equation for dead standing)
Shrub vegetation	Wet mass → dry mass → carbon
Grass/mosses and lichens	Wet mass → dry mass → carbon
Detritus 2	Wet mass → dry mass → carbon
Litter	Wet mass → dry mass → carbon

Root biomass and Soil C estimation methods

Objective 2

Quantify carbon stocks and calculate carbon accumulation rates of abandoned croplands

Below-ground biomass and soil carbon

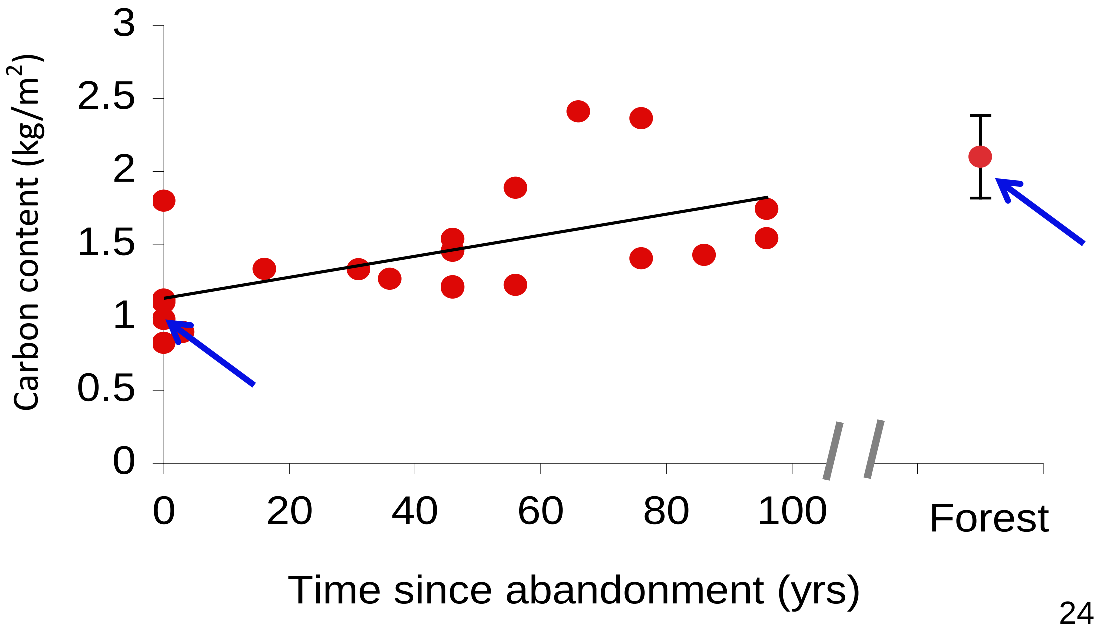
Parameter	Unit	Method
Coarse roots	Mg C ha^{-1}	Allometric equations (Li et al. 2003)
Bulk density	gcm^{-3}	Oven dry (M/V)
Soil organic carbon	Mg C ha^{-1}	Dry combustion (Leco CR-12 Carbon Analyser) SOC density using Meersmans's equation (Meersmans et al. 2008)

Tree biomass and soil C estimation

$$C\ stock = \sum(C_{Living\ biomass} + C_{Dead\ biomass} + C_{Litter} + C_{Soil})$$

Change rate $\triangle C = \dfrac{C\,t_2 - C\,t_1}{t_2 - t_1}$

Total C sequestration = rate * area



Foote and Grogan, 2007

Initial work

Number sites and samples collected in SK 2012:

- 8 abandoned sites
- 4 croplands
- 4 mature forests

Total of 16 sites

- 231 soil samples
- 12 soil pits
- 1656 tree measurements
- 66 tree boring samples
- 360 LAI sample points
- 68 litter samples
- 65 herb samples
- 50 dead detritus samples
- A number of shrub samples in different species.

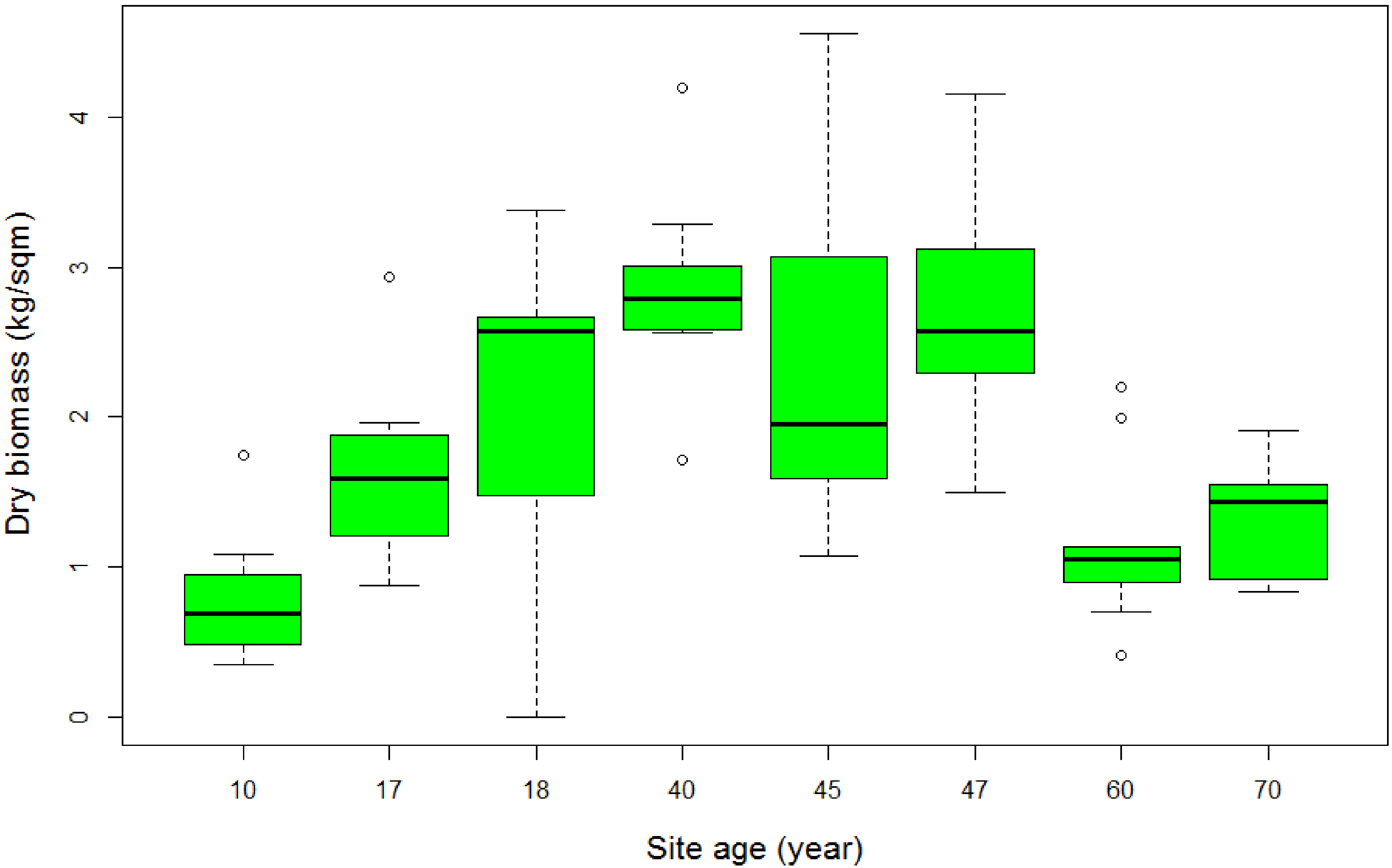
Results

	B	C	D	E	F	G	I	J	K	L	M
	Site Name		Av. LAI	Av. Litter	Av. Herb	Av. Dead	Site age	Av. H	Av. DBH	Tree No.	Soil subgroup
				g/0.25 sqm	g/0.25 sqm	g/0.25 sqm		m	cm	900	
1	BS N70	TA, BW	0.8	0.25	0.19	1.17	10	4.19	3.90	35	Eluviated Brown Chernozem
2	RED A17	TA, BP	1.83	0.60	0.45	5.36	17	4.19	2.99	519	Orthic Black Chernozem
3	RED B17	TA, BW, CC, BP	1.85	0.24	0.04	16.30	17	4.01	4.41	35	Dark Brown Orthic chernozem
4	BS S40	TA	2.48	1.36	0.13	59.07	40	7.81	6.11	782	Eluviated Black Chernozem
5	BS E45	TA, BP, WS, SP	2.98	1.70	0.07	30.36	45	6.86	6.67	420	Eluviated Brown Chernozem
6	WL A47	TA, BP, BW	2.14	0.77	0.28	34.97	47	4.32	5.09	572	
7	BS L60		1.47	0.39	0.15	11.18	60	6.28	6.04	208	Orthic Black Chernozem
8	BSK70	TA	1.63	0.37	0.28	12.63	70	8.33	9.01	25	Dark Grey Luvisol

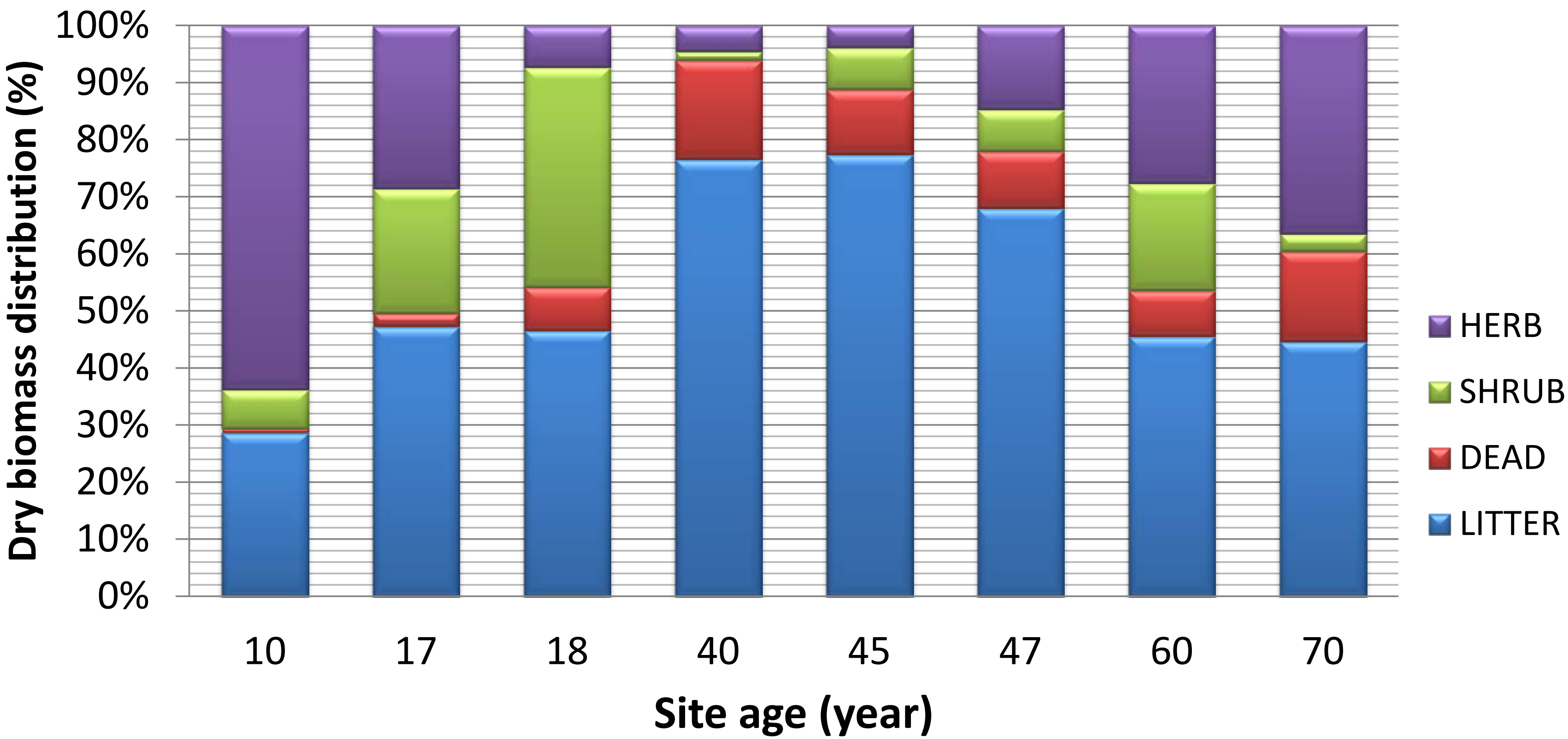
General info:

- Range age: 10 -70 years
- Range dbh: 1-30 cm
- Soil order: Chernozem
- Range of LAI: 0.1-5.0
- Dominant species: Trembling aspen, Birch willow, Balsam poplar, ,,,,

Contribution of the non-tree above ground biomass pool



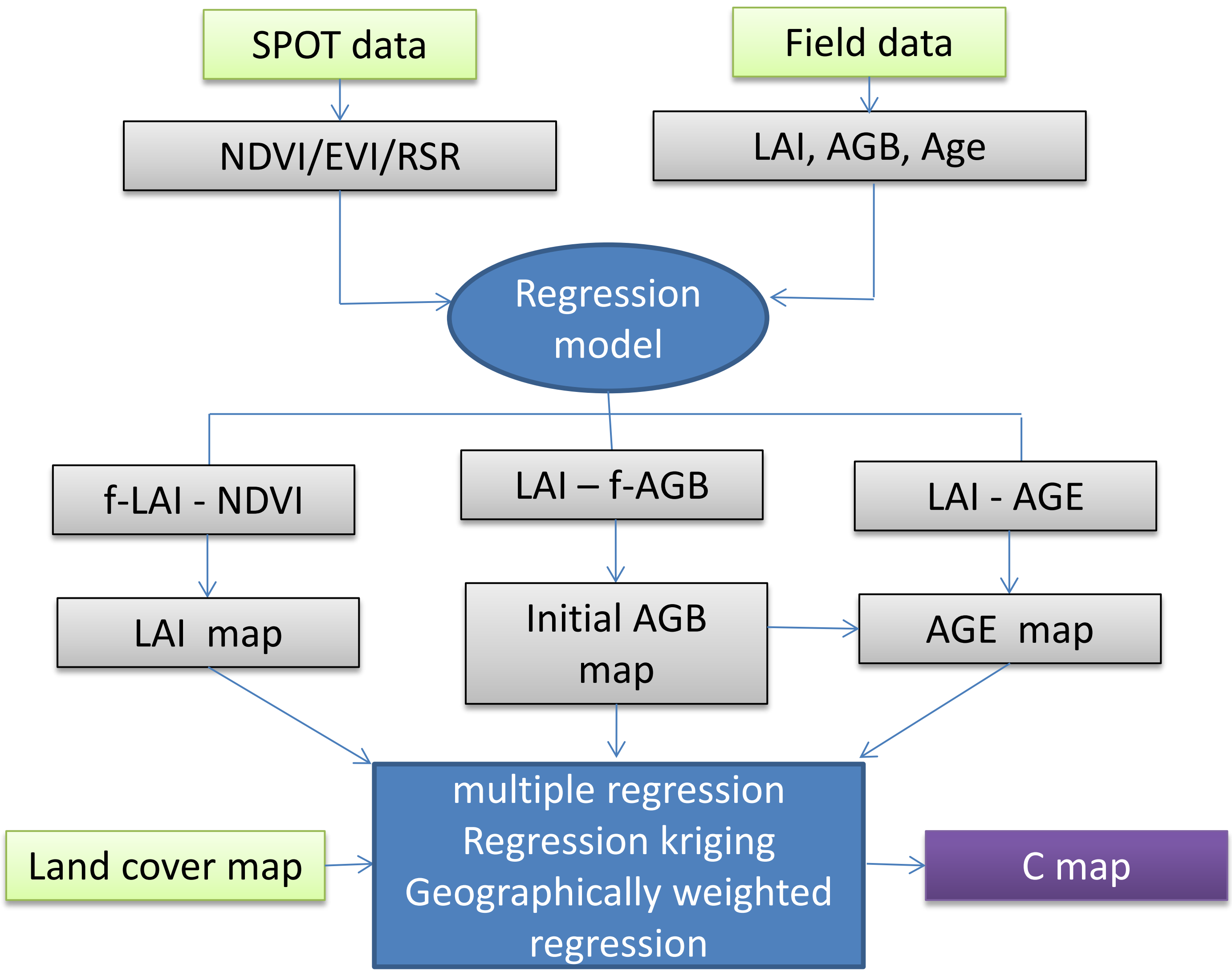
Biomass proportion of the non-tree above ground biomass pools



Spatial distribution of C

Objective 3

Estimate spatial distributions of forest and soil carbon at landscape scale.



Potithep et al. (2010)

CBM-CFS3 model

Objective 4

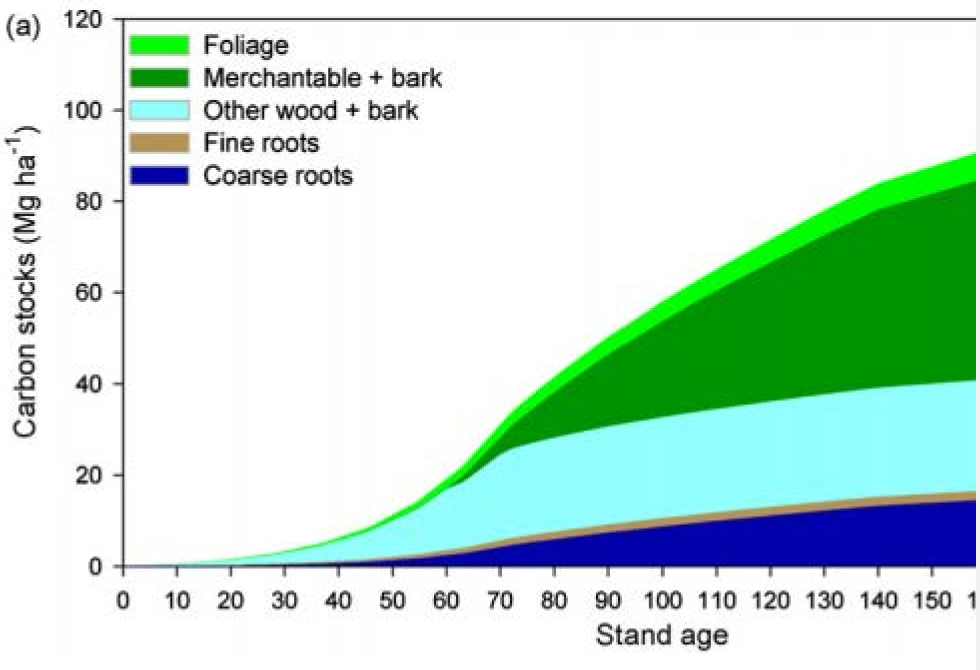
Simulate and predict carbon stocks and changes in forests and soils in abandoned croplands.

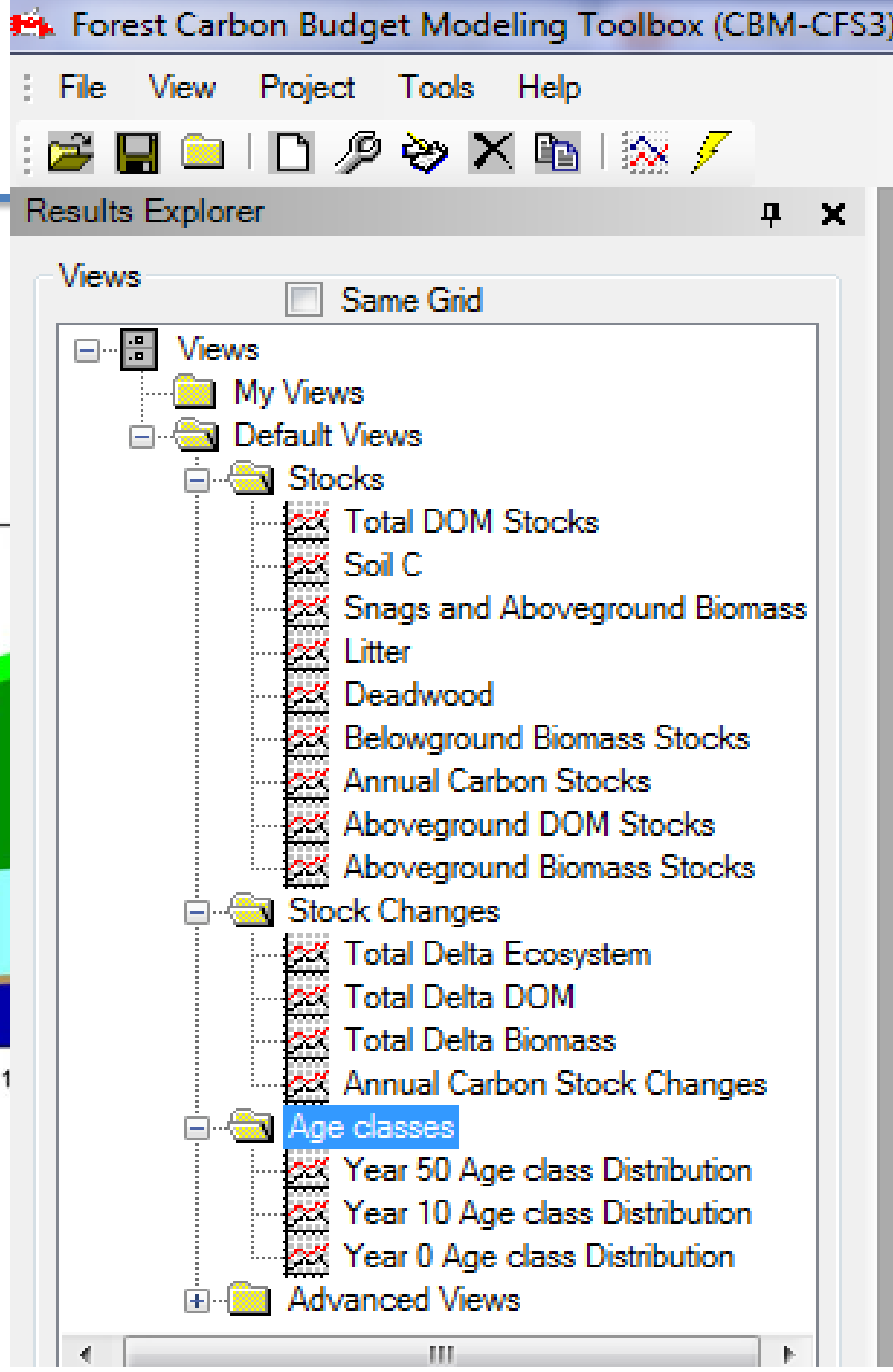
- Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) is an aspatial, stand- and landscape-level modeling framework that simulates the dynamics of all forest carbon stocks required under the Kyoto Protocol.
- This is a well established model but this model was built from data that measured from mature forest; So, it is not applicable directly to my research.
- Here, new dataset from shrub and younger forest will be used to enable the model for research objective 4

Kurz et al. 2009

CBM-CFS3 model

- Output variables
- Expectation results





Kull et al. 2007

CENTURY model

CENTURY was originally developed to simulate soil C, N, P, S dynamics in the prairie grasslands of North America (Parton et al., 1987).

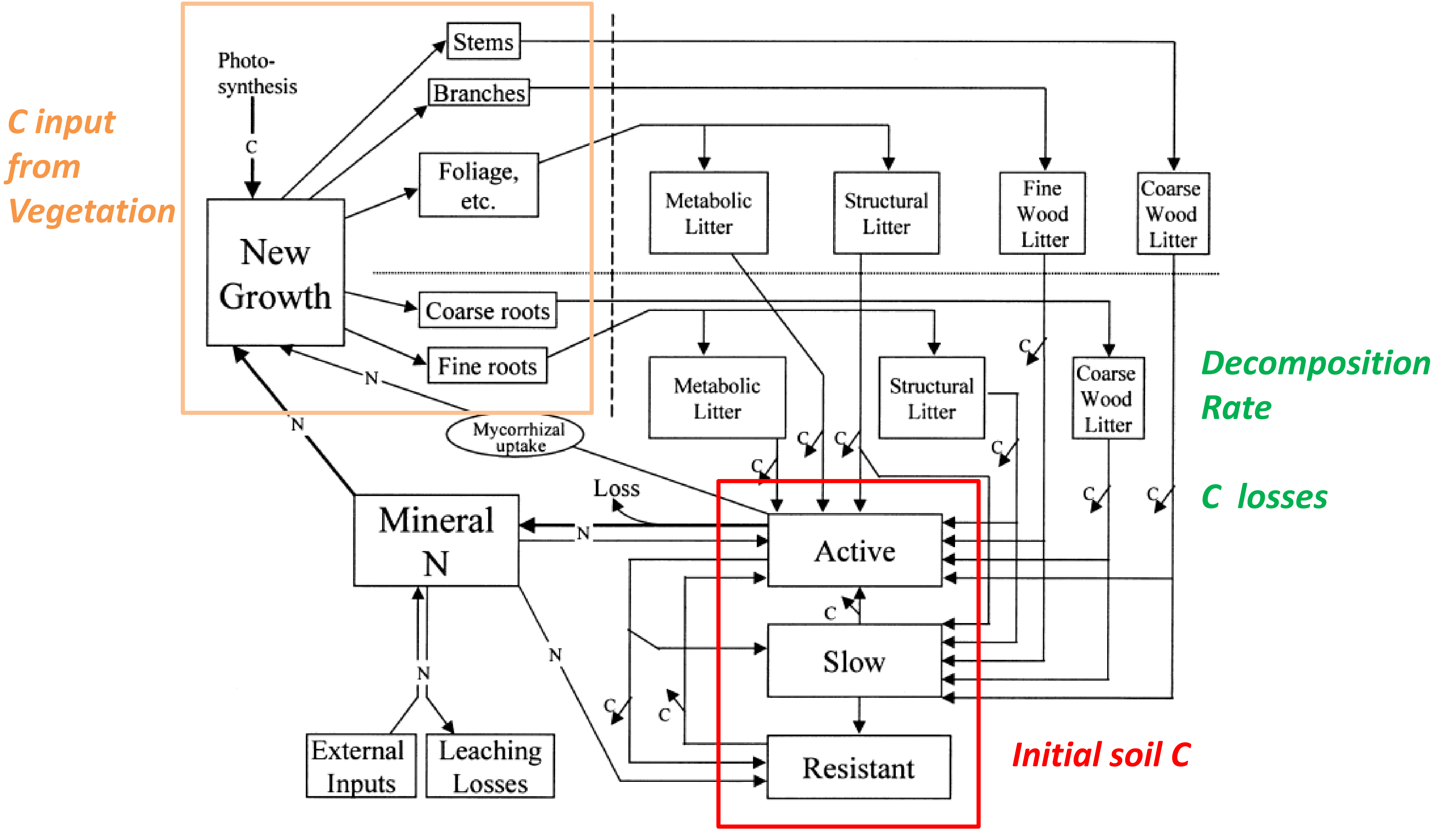
Submodels:

- Soil Organic Matter
- Nitrogen
- Phosphorus
- Sulfur
- Crop and Grassland
- Forest
- Savanna

Other Simulated Effects

- Depth Distribution of Organic C
- Weather Data
- Parameterization

CENTURY MODEL



Simulate carbon stocks and changes in soil

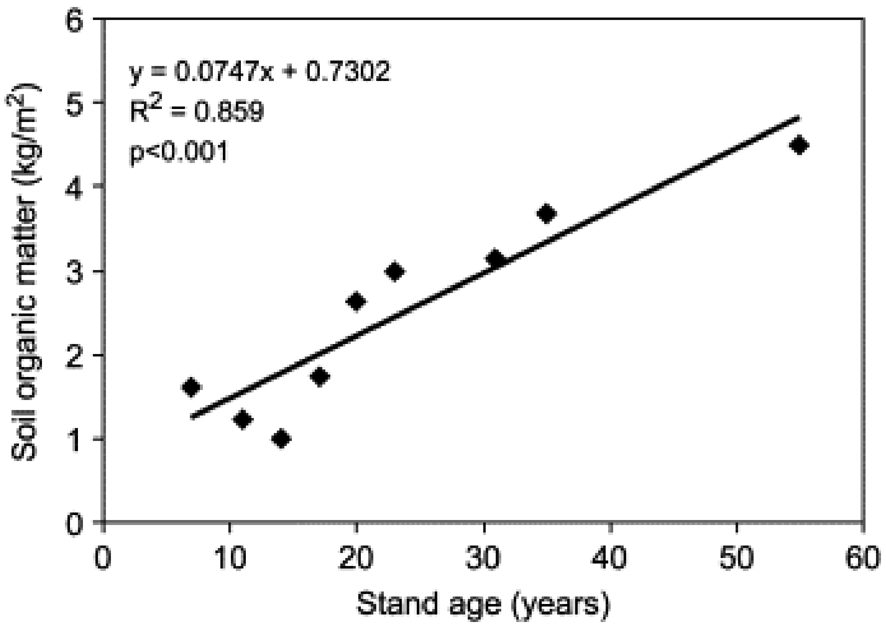
Kirschbaum and Paul, 2002

CENTURY MODEL - Expected results

Objective 4

Simulate and predict future carbon stocks and changes in forests and soils in abandoned croplands.

- **Carbon stock (Mg C ha^{-1} yr^{-1}) in different stand ages (year).**
- **The absolute rate of carbon change (Mg C ha^{-1} yr^{-1}) over a 60 year period under cropland to forest conversion.**



Berg and Laskowski, 2005

Model evaluation

Objective 4

Simulate and predict future carbon stocks and changes in forests and soils in abandoned croplands.

1. **Relative root mean square of error (RMSE)**
2. **Model efficiency**
3. **Relative error**
4. **Coefficient of determination**
5. **Mean different**

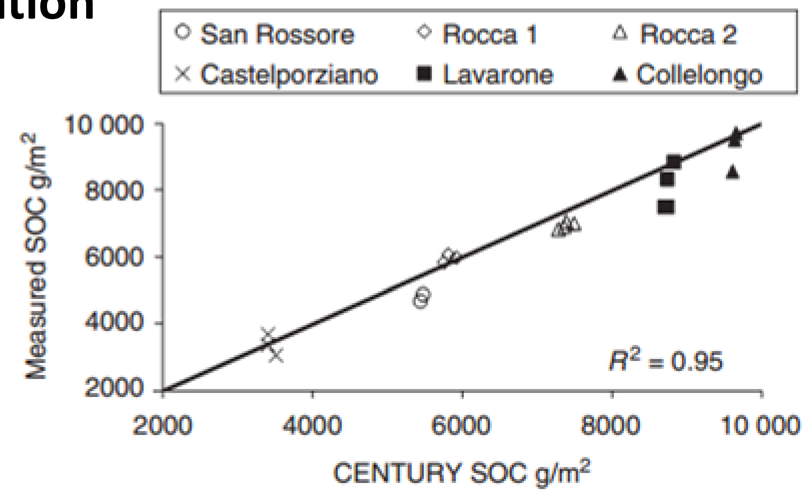


Figure 2 Measured against modelled soil organic carbon stocks. The line indicates the 1:1 relation.

Chiti et al. 2010

SUMMARY

1. **Main objectives:**
   1. Delineating abandoned croplands (since 1960) and identifying the change rate.
   2. Quantifying carbon stocks and changes. Estimate C spatial distribution.
   3. Simulating temporal distribution of carbon in different pools.

2. **Input data:**
   1. Field data (using chronosequence approach)
   2. Remotely sensed data (Aerial photos, Landsat, SPOT).

3. **Method:**
   1. Visual on-screen change detection and digitalization and post-classification comparison change detection.
   2. Multiple regression model for simulating aboveground biomass.
   3. CMB-CFS3 and CENTURY model for simulating carbon stocks and changes in abandoned croplands.

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• College of Graduate and Research	U of S

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