

Farmer-oriented Management Support Toolbox for Shelterbelt Systems in Saskatchewan

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Research Scope and Goals

Shelterbelts as an Agroforestry Management Practice for the Mitigation of Greenhouse Gases

AGGP-1 (completed)

- Shelterbelts/windbreaks are a century-old agroforestry practice used in the Canadian Prairies to manage soil erosion and fertility loss from farm land.
- During a five-year project (**2011-2016**), shelterbelts were studied for the Agriculture Greenhouse Gases Program (AGGP) of the Government of Canada.
 - We inventoried 60,194 km of shelterbelts in Saskatchewan, planted with varying number of tree rows.
 - The average C sequestration rate ranged from 1.9-6.3 Mg C km⁻¹ yr⁻¹ (per row), and the provincial total ecosystem C stocks for six common shelterbelt species was 10.8 Tg C (1 Tg=1 million Mg), worth \$595 million at \$15 price-per-MgCO₂-eq.
 - About 4.85 Tg C were C stocks additions from shelterbelt planting, 78% of which occurred in the period after 1990.

Management Support Toolbox for Carbon Sequestration Strategies Using Agroforestry Shelterbelt Systems in Saskatchewan

AGGP-2 (current)

- A second, AGGP-2 project (**2017-2021**) is currently underway at the University of Saskatchewan, and is focused on developing a Management Support Toolbox for Carbon Sequestration Strategies Using Agroforestry Shelterbelt Systems in Saskatchewan.
 - The overall aim of the ongoing AGGP-2 project is to create a farmer-oriented, interactive toolbox (for web and smart phone use) for practical knowledge dissemination to farmers when planting new shelterbelts or renewing existing ones.
 - This toolbox will: (1) provide a research-based and evidence-based knowledge to enhance GHG mitigation on farm land by shelterbelt establishment and using beneficial management practices; (2) expand the shelterbelt awareness among farmers in regard to the carbon sequestration potential of shelterbelts, including carbon credit analysis; and (3) provide quick, relevant and practical information to assist farmers in their own crop production and shelterbelt management operations.

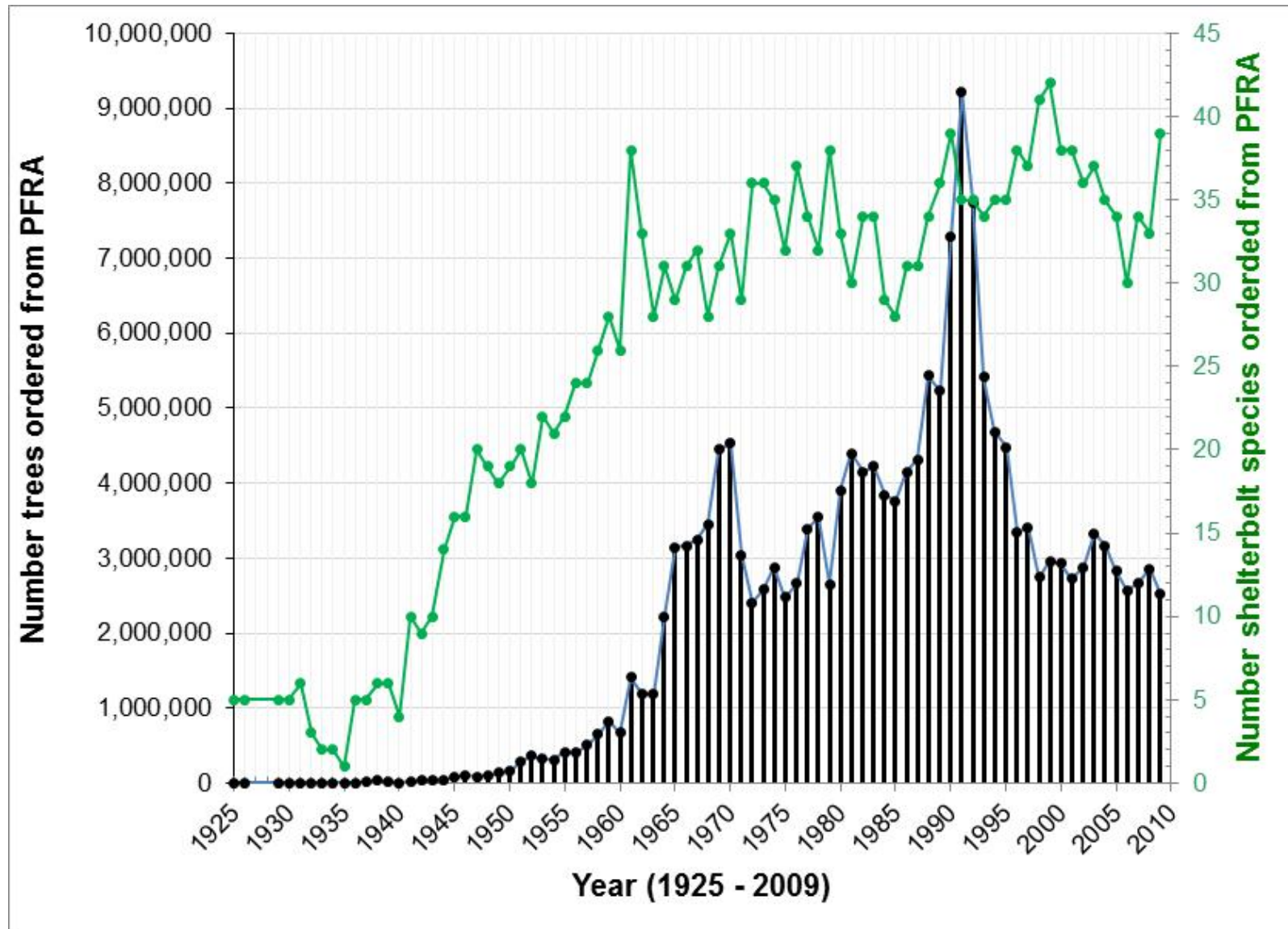
Website: <https://saskagroforestry.weebly.com/>

Planted Shelterbelts: 'when' and 'where'

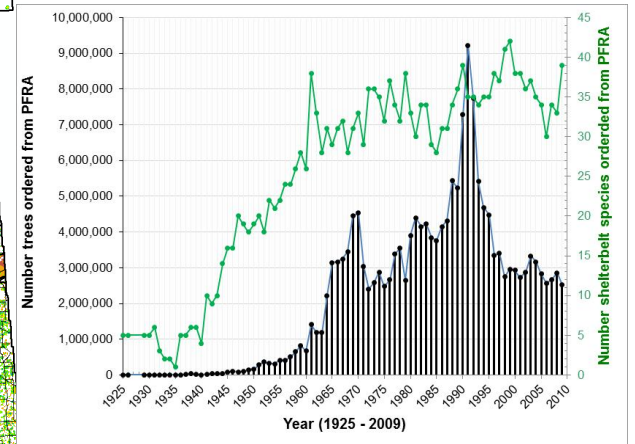
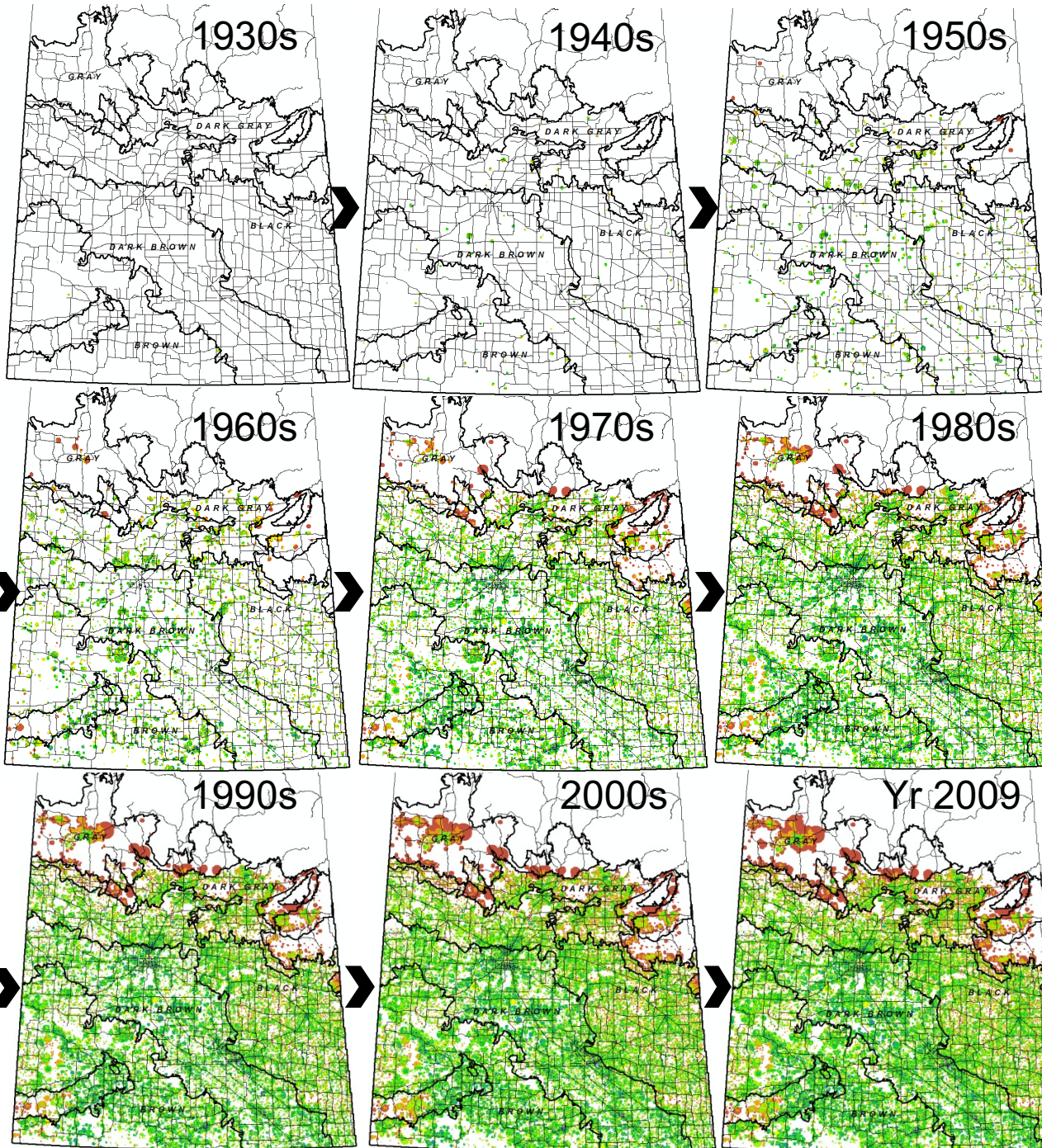


SP; 12342; Age: 23 yrs; Height: 9 m; DBH = 20 cm

Annual (1925 to 2009) record of shelterbelt trees sent to farmers across Saskatchewan through the Prairie Shelterbelt Program



Time-lapse (1925 to 2009) of expected shelterbelt establishment in Saskatchewan

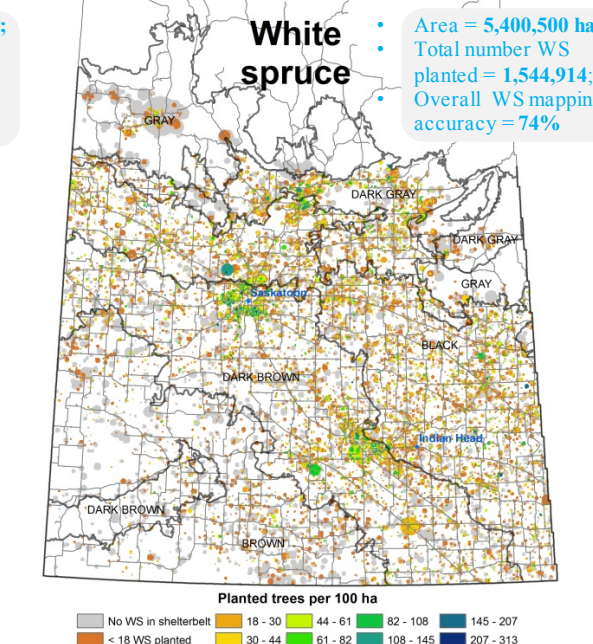
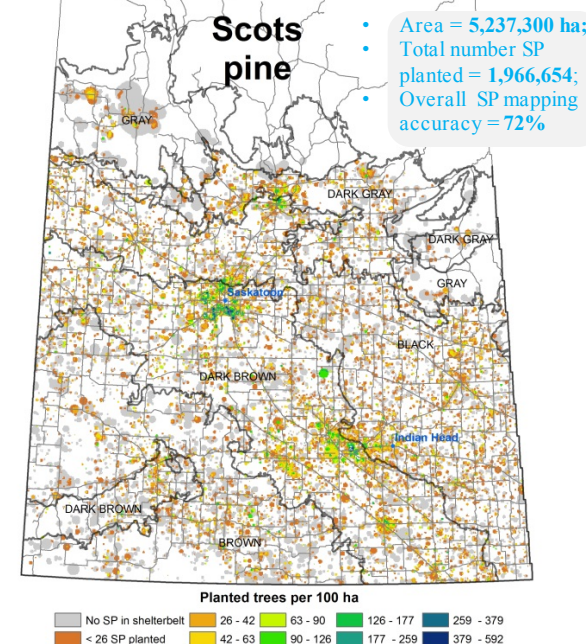
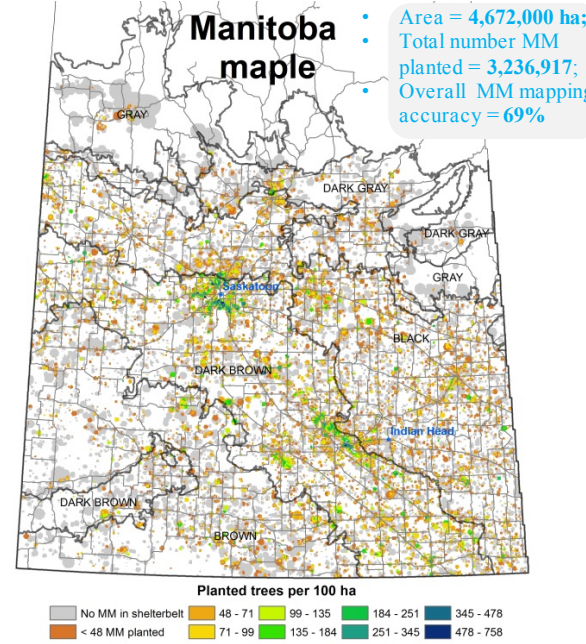
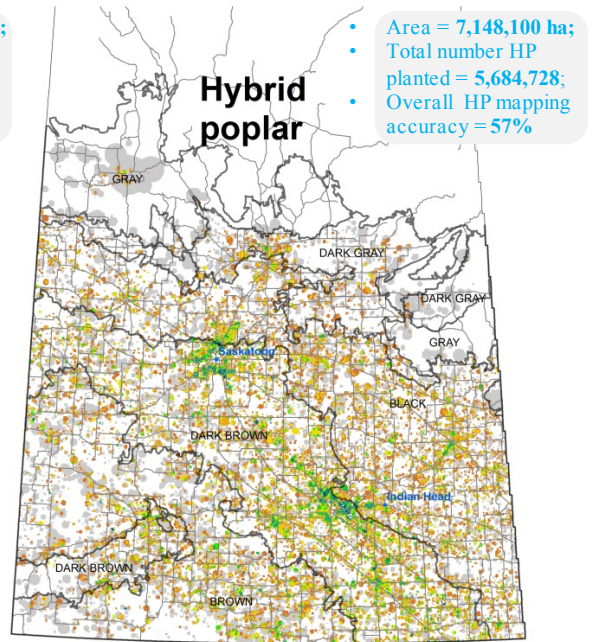
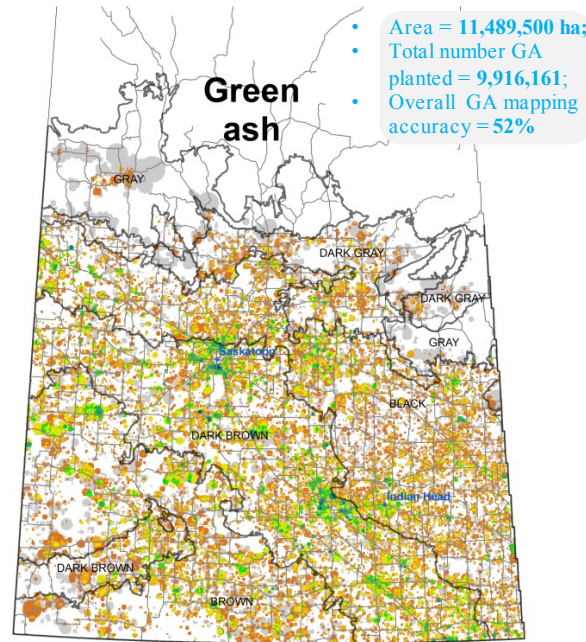
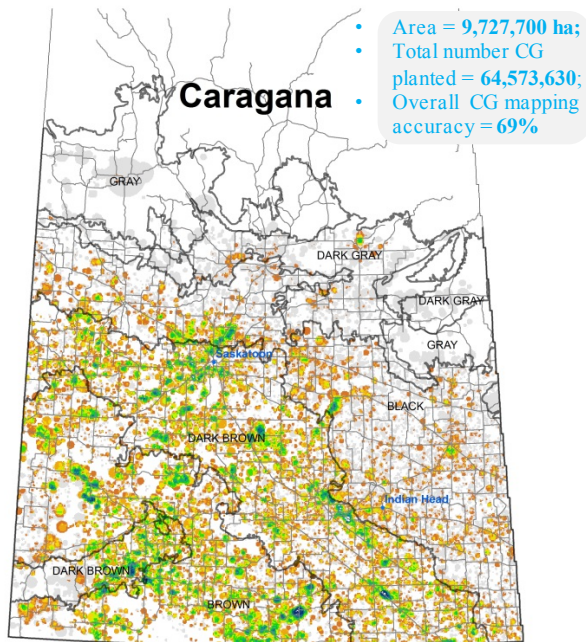


Probability (%)

 100
 25

Amichev et al. *Agroforestry Systems* 89(1), (2015) 49-65

(Planted 1925-2009)



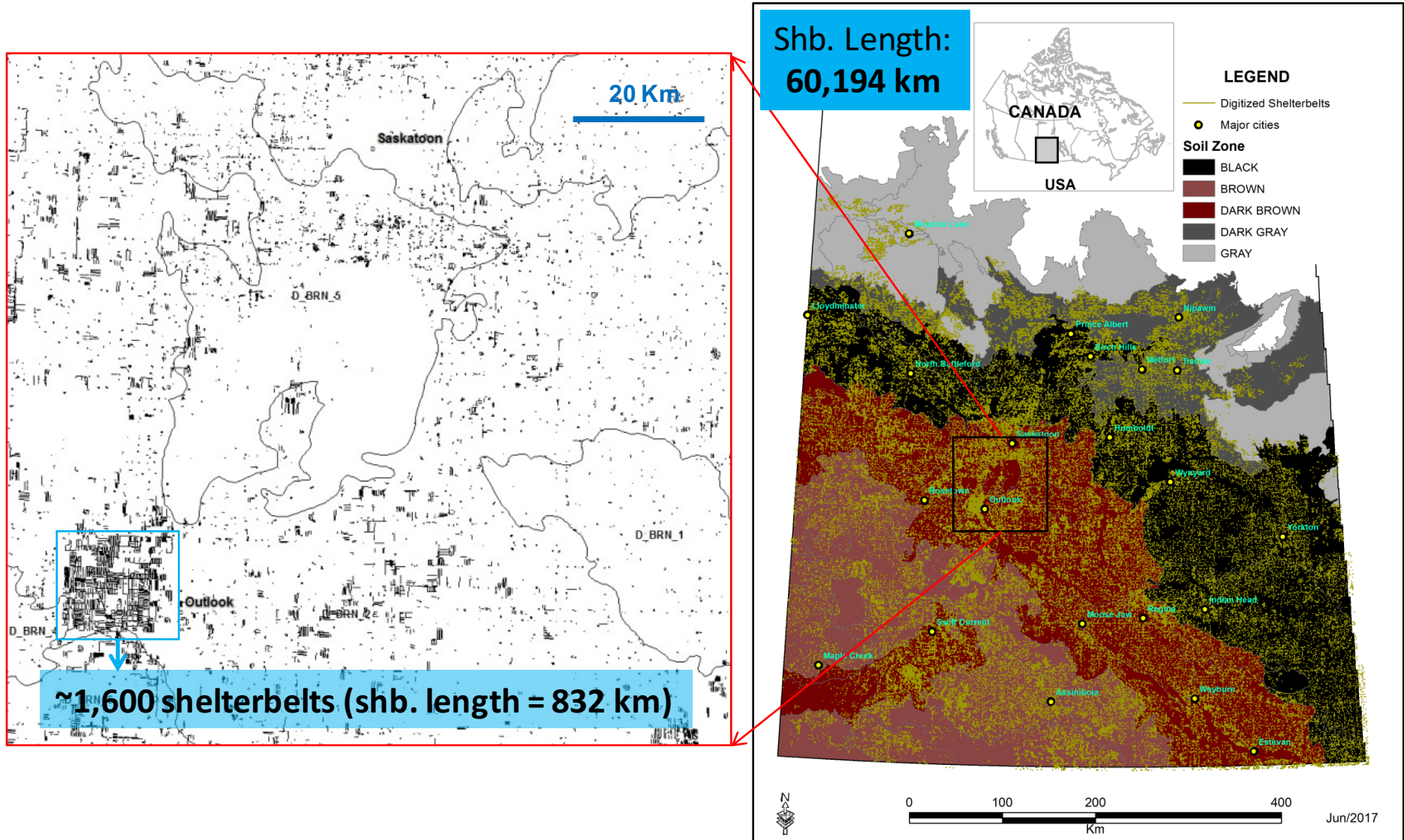
A photograph of a pine forest. In the foreground, a young, thin sapling with green leaves stands prominently. The middle ground is filled with a dense stand of mature pine trees, their trunks forming a vertical line that recedes into the distance. The ground is covered in tall, green grass. In the background, a field of golden-brown crops, likely corn, is visible under a bright, overcast sky.

'... and today'

SP; 12342; Age: 23 yrs; Height: 9 m; DBH = 20 cm

The Saskatchewan Shelterbelt Inventory

(Province-wide digitized dataset completed in 2014-2017)



'Collected data using a unique sampling technique'

Applied across the entire province

Randomized-branch sampling (RBS) with
Importance sampling (IS)

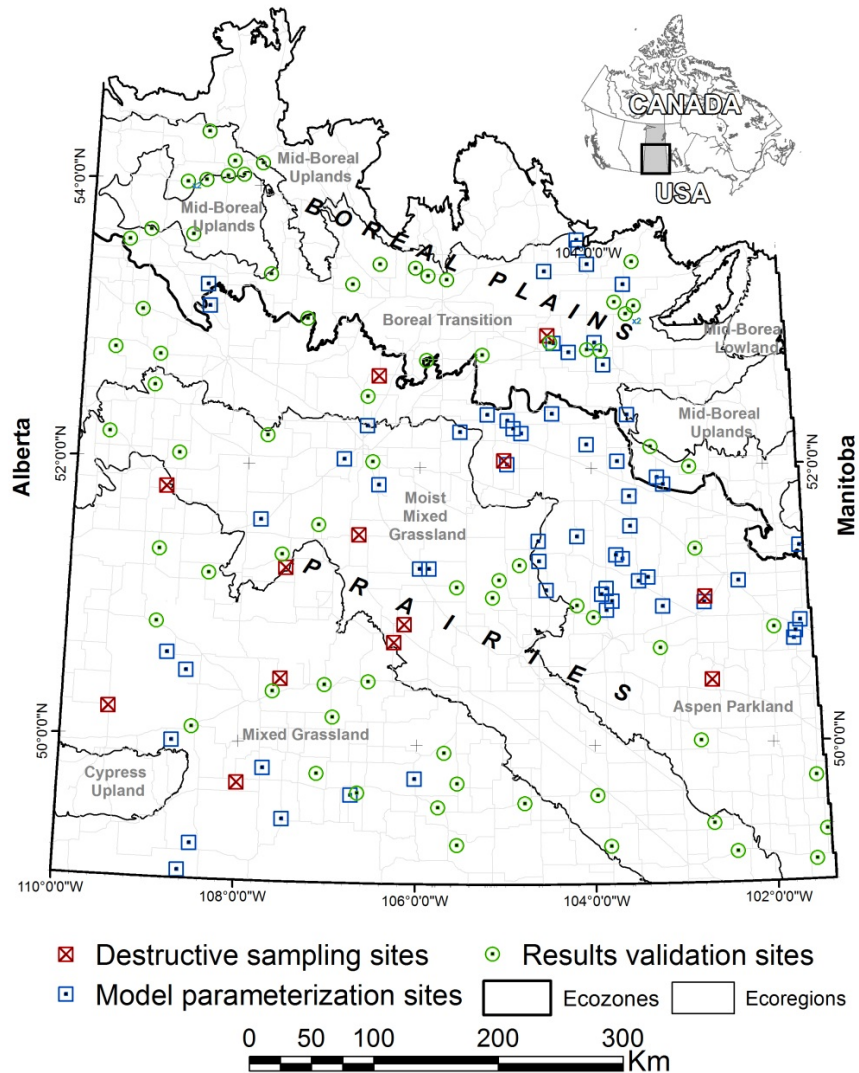
modified

for tree biomass sampling in shelterbelts

SP; Aitken; Age: 26 yrs; Height: 12 m; DBH = 24 cm



Biomass/growth data



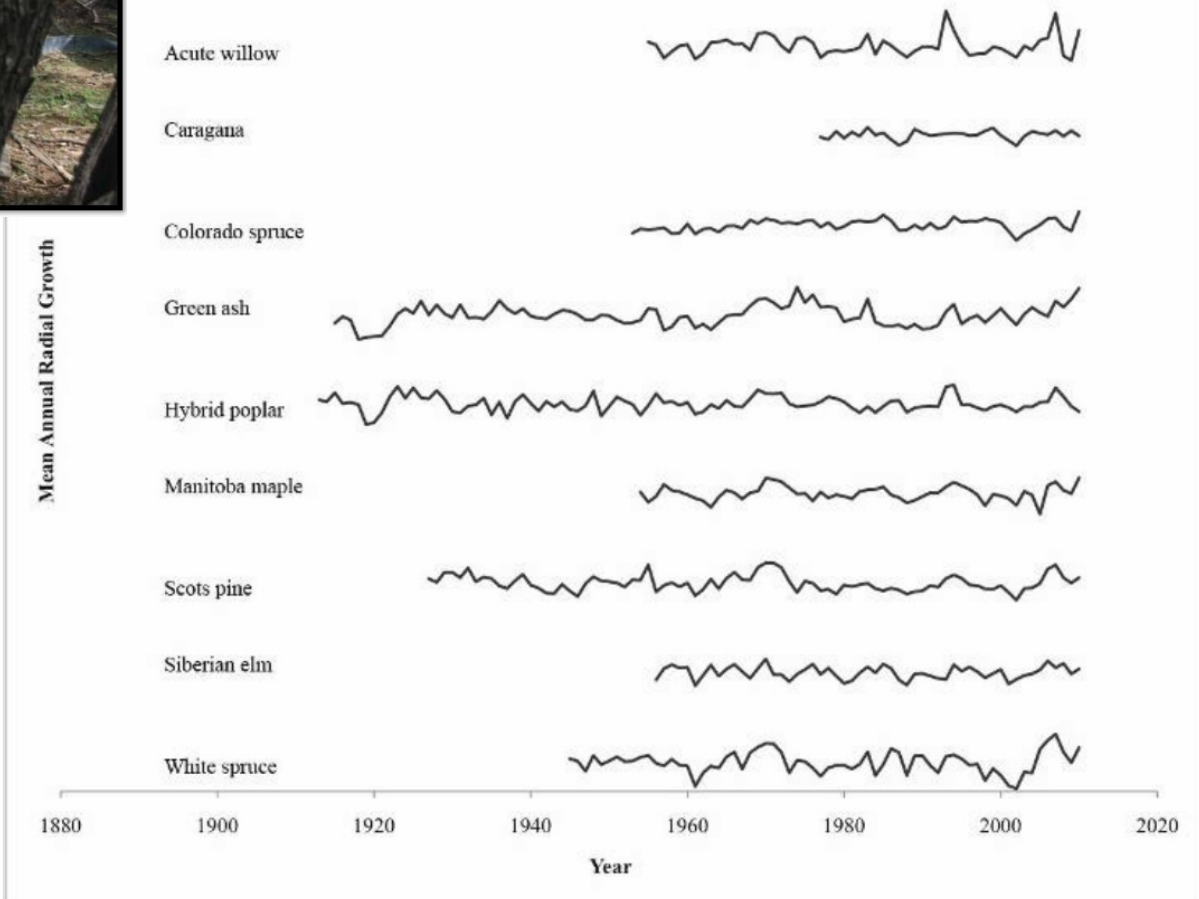
- Exact UTM coordinates
 - DBH (cm)
 - Height (m)
 - Average crown width (m)
 - AGE (yr) via using tree cores
 - MAIN SPECIES
 - TREE SPACING - by length (m)
 - TREE SPACING - by width (m)
 - Shelterbelt DESIGN - N rows
 - Other SPECIES (list)
 - Notes about shelterbelt status, observed problems, history, etc.
 - Tree mortality in shelterbelt (%)
 - Total number trees in shelterbelt
 - Shelterbelt length (m)
 - Soil samples
 - Fine root core samples
-
- TREE Branches and bark (OD, kg)
 - TOTAL tree biomass (OD, kg)
 - TREE Stem and bark (OD, kg)
 - TREE leaves (OD, kg)

Tree Core data: *Nature's climate record*

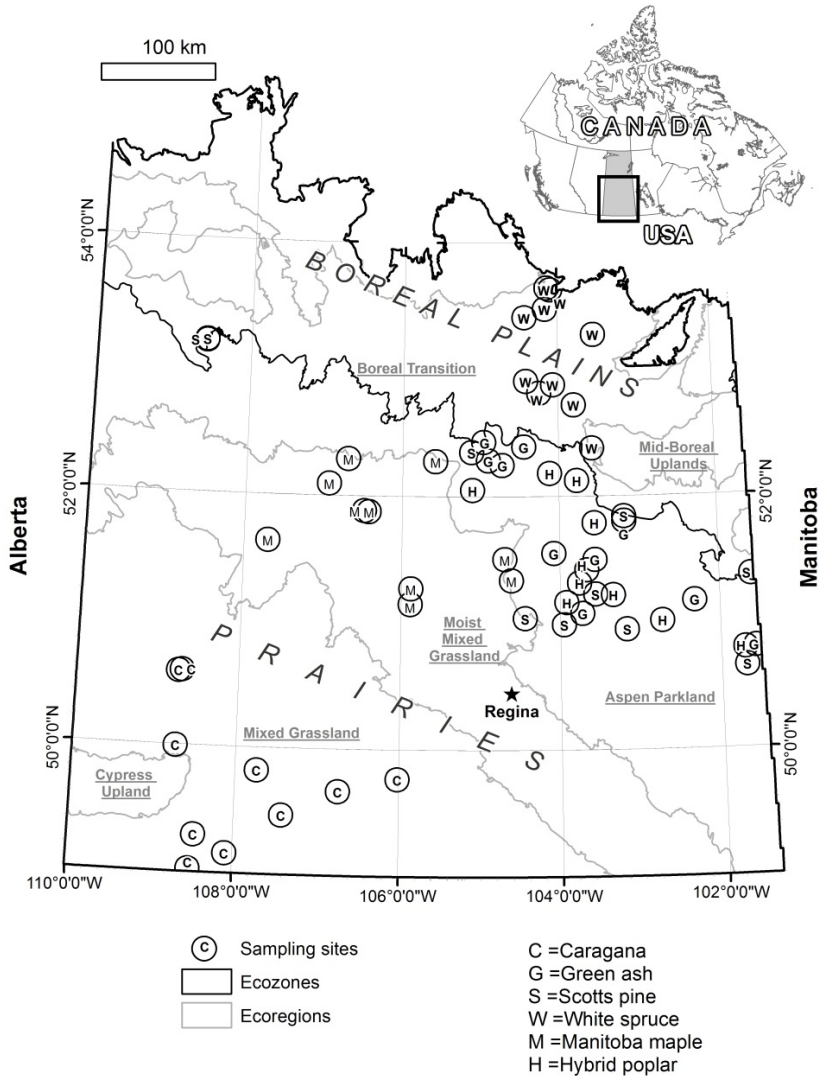


Davis et. Al. *Agroforestry Systems* 87, (2013) 713-727;

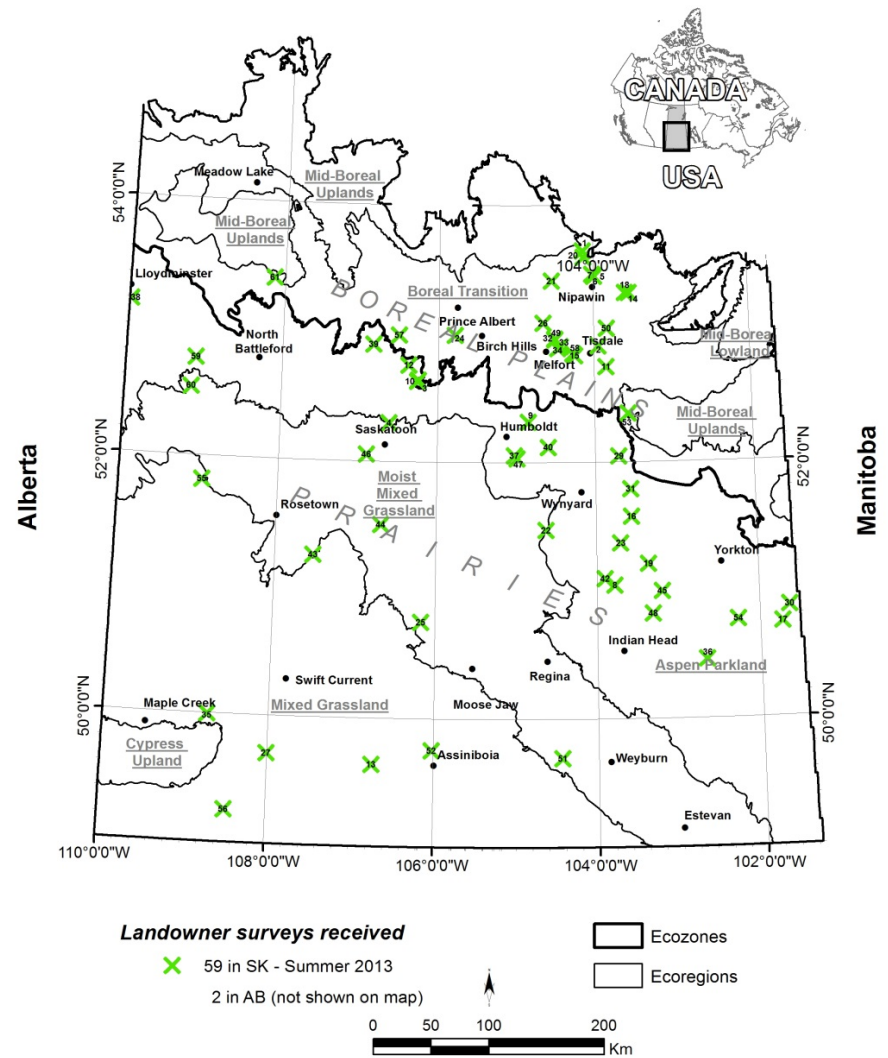
Master chronologies of nine shelterbelt species, demonstrating standardized ring-width growth over time



Shelterbelt and adjacent field soil samples



Landowner surveys received (e.g. removal)



HP; Blakely; Age: 20-30yrs; Height: 16 m; DBH = 35 cm

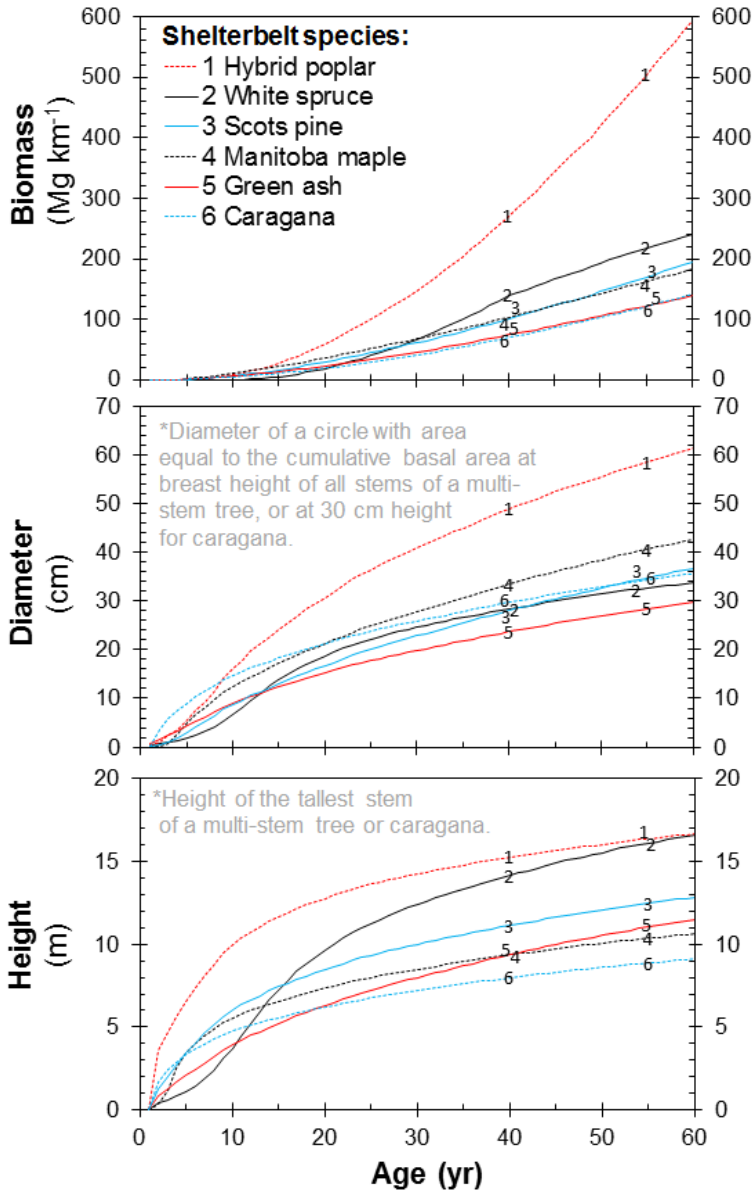


'...and **LEARNED** a **LOT**'

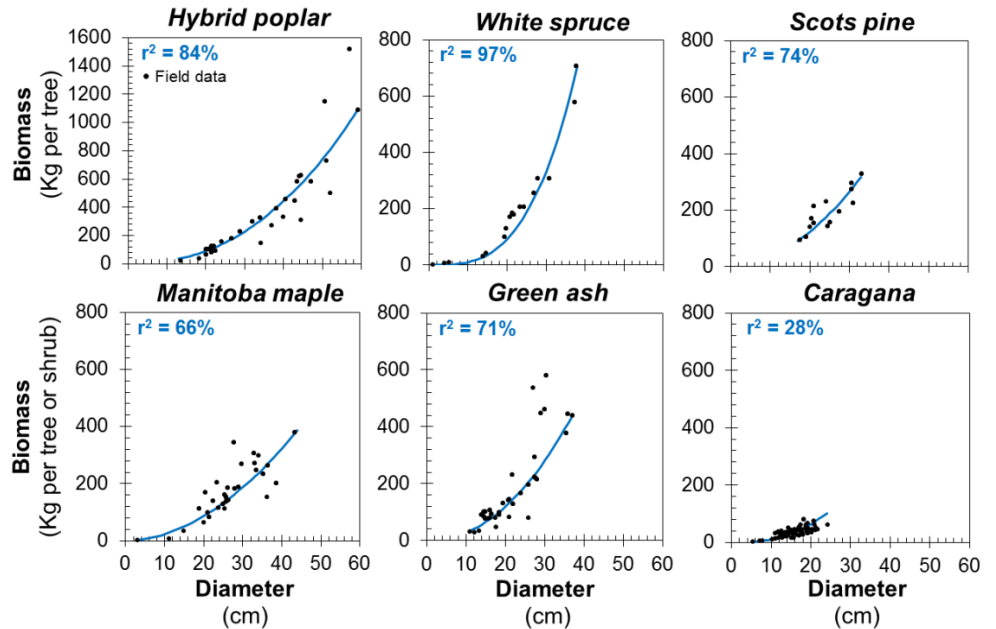


Shelterbelt Vs. no-shelterbelt

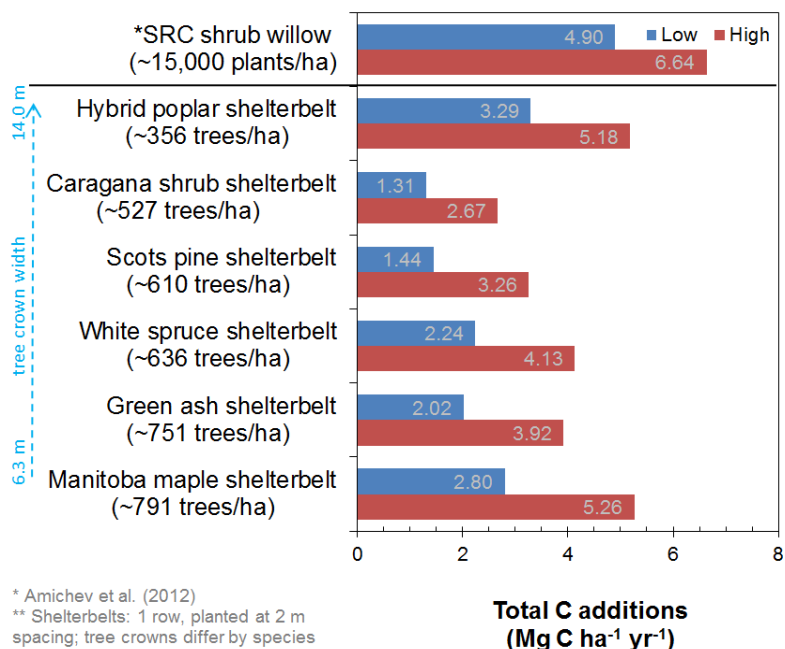
HP; Blakely; Age: 20-30yrs; Height: 16 m; DBH = 35 cm



Species	$Biomass (Kg) = a * (Diameter, cm)^b$				
	a	b	r ² (%)	RMSE(%)	Bias(%)
Hybrid poplar	0.091417	2.3011	84	39	-16
White spruce	0.006603	3.1832	97	22	27
Scots pine	0.432635	1.8870	74	19	1
Manitoba maple	0.294275	1.8980	66	32	-9
Green ash	0.206365	2.1217	71	48	-0.3
Caragana	0.028397	2.5760	28	40	-7



C additions comparison in Saskatchewan



2015 C stocks and shelterbelt length		Shelterbelts planted 1925-2009				Length Km
		Total Ecosystem C		C Additions		
No	Species	Since 1925 Mg C	Since 1990 Mg C	Since 1925 Mg C	Since 1990 Mg C	
1	Caragana	7,864,038	3,712,920	3,403,911	2,617,188	35,245
2	Green ash	964,207	576,098	432,497	346,605	5,841
3	Hybrid poplar	1,303,391	734,540	684,186	568,097	4,144
4	Manitoba maple	364,000	170,453	212,503	141,542	2,646
5	Scots pine	184,214	96,290	64,392	55,936	1,573
6	White spruce	131,750	78,359	50,440	45,348	991
Totals (Mg C):		10,811,599	5,368,660	4,847,929	3,774,715	50,439
(Tg C =)		10.81	5.37	4.85	3.77	

Ha-to-Km conversion:

(HP example) 356 trees/ha * 2 m/tree * (1/1000) = 0.712 Km/ha
5.18 Mg C/ha/yr * (1/0.712 Km/ha) = 7.82 Mg C/Km/yr

(MM example) 791 trees/ha * 2 m/tree * (1/1000) = 1.58 Km/ha
5.26 Mg C/ha/yr * (1/1.58 Km/ha) = 3.32 Mg C/Km/yr

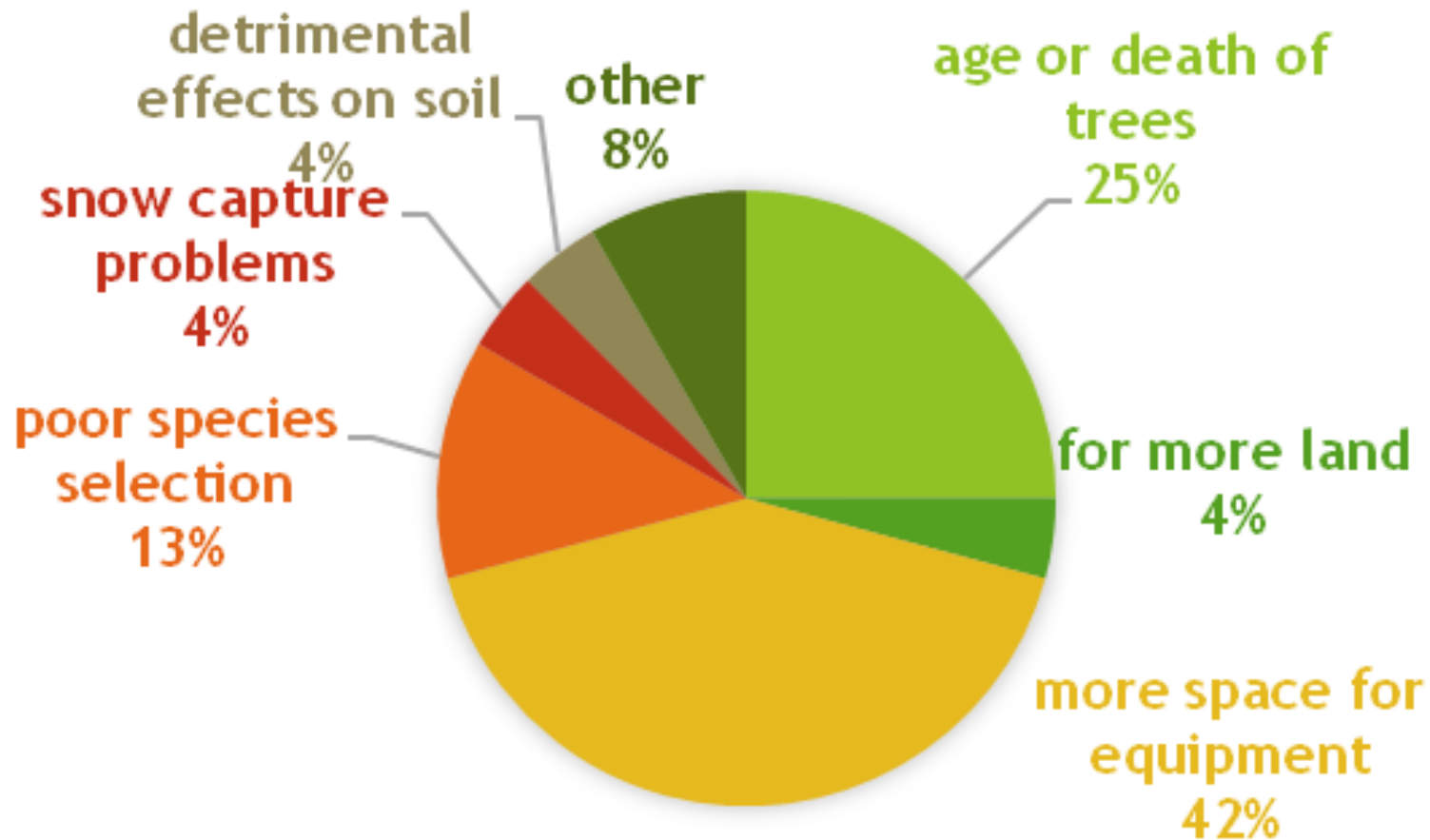
The (\$) value of carbon in planted shelterbelts

C market \$ value		Shelterbelts planted 1925-2009				Only those planted since 1990			
		TEC ^a		Additions ^b		Length ^c Km	TEC - (\$15 per tonne of CO ₂) -	Additions Km	Length
No	Species	Since 1925 ^d	Since 1990 ^e	Since 1925	Since 1990				
1	Caragana	\$ 433 mill.	\$ 204 mill.	\$ 187 mill.	\$ 144 mill.	35,245	\$ 83 mill.	\$ 23 mill.	7,053
2	Green ash	\$ 53 mill.	\$ 32 mill.	\$ 24 mill.	\$ 19 mill.	5,841	\$ 18 mill.	\$ 5 mill.	2,482
3	Hybrid poplar	\$ 72 mill.	\$ 40 mill.	\$ 38 mill.	\$ 31 mill.	4,144	\$ 12 mill.	\$ 3 mill.	942
4	Manitoba maple	\$ 20 mill.	\$ 9 mill.	\$ 12 mill.	\$ 8 mill.	2,646	\$ 2 mill.	\$ 0.7 mill.	375
5	Scots pine	\$ 10 mill.	\$ 5 mill.	\$ 4 mill.	\$ 3 mill.	1,573	\$ 3 mill.	\$ 0.6 mill.	479
6	White spruce	\$ 7 mill.	\$ 4 mill.	\$ 3 mill.	\$ 2 mill.	991	\$ 2 mill.	\$ 0.4 mill.	347
Total \$ value:		\$ 595 mill.	\$ 295 mill.	\$ 267 mill.	\$ 208 mill.	50,439	\$ 121 mill.	\$ 33 mill.	11,678
(Tg CO ₂ -eq. =)		39.64	19.69	17.78	13.84		8.05	2.21	

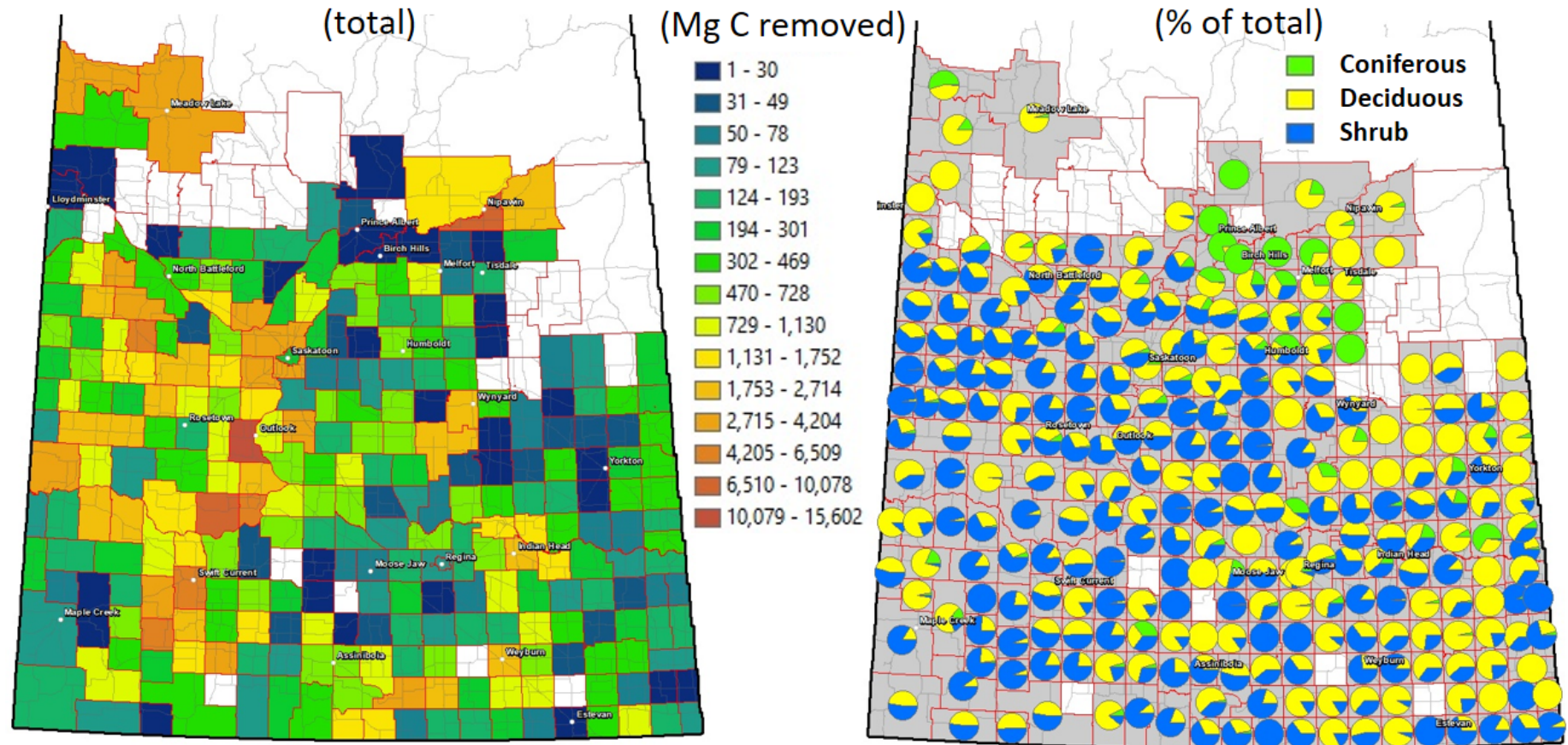
\$ 595 million ...Worth it!

Removal of Shelterbelts

Identified the costs, benefits and the barriers to adoption and retention of shelterbelts that influence agricultural producers and landowners' management decisions related to shelterbelts.

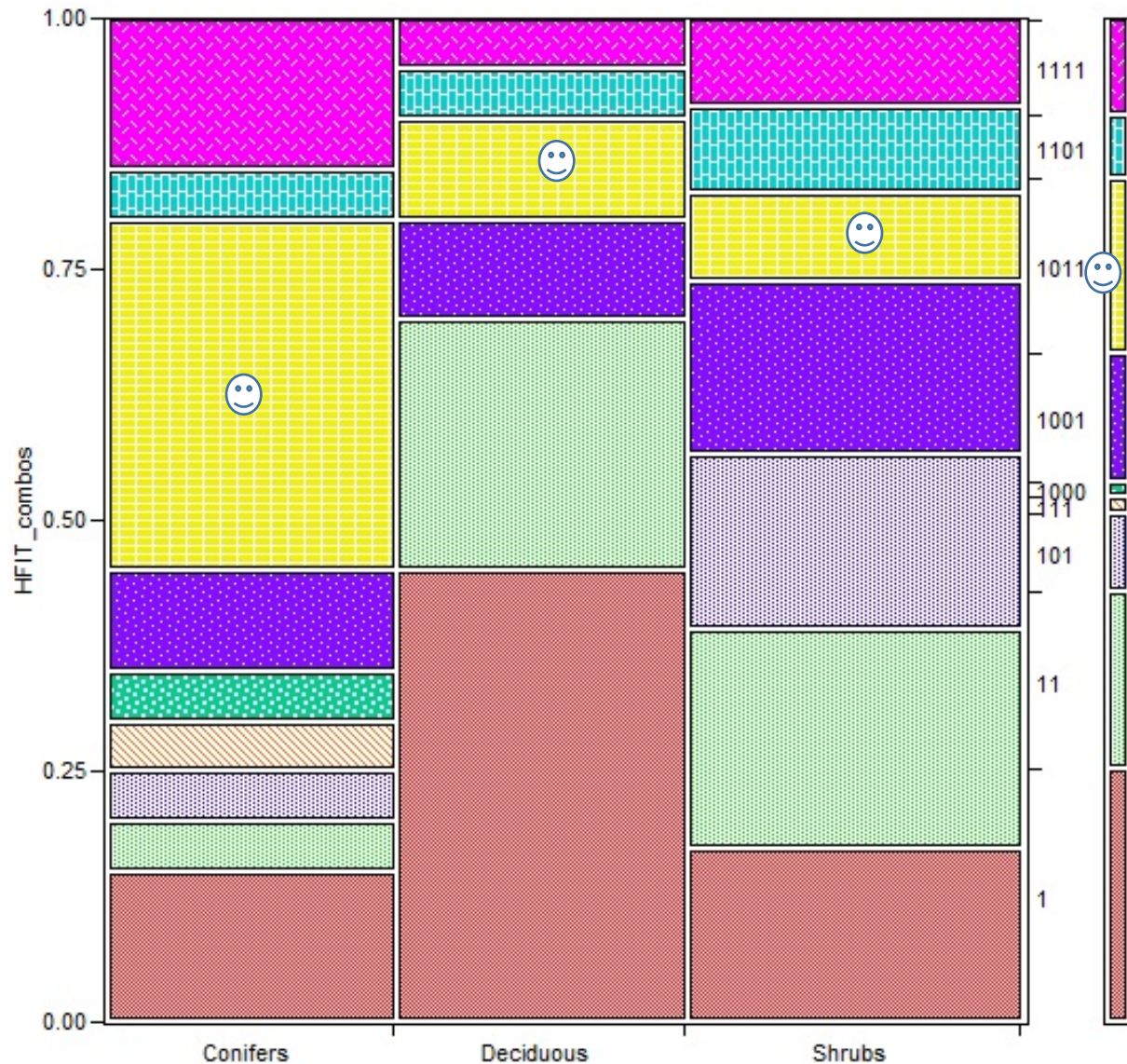


Reasons for removal of shelterbelts



- **Maps** show the extent and C stocks of removed shelterbelts in Saskatchewan during 2008-2016 period. Total removed C stocks and % of total values are for individual Canada Census Subdivision units (N=299, delineated by red polygons).
- A total of **2,604 km** of planted shelterbelts were removed, sequestering **202 Gg C** (1 Gg = 1,000 Mg = 1,000 tons) in five soil zones in the province, dominated by shrub shelterbelt removal in south-west, deciduous in south-east, and coniferous shelterbelts in central Saskatchewan.
- The majority of removals were **shrub** shelterbelts (1,770 km, sequestering 113 Gg C), followed by **deciduous** (737 km, =80 Gg C) and **coniferous** shelterbelts (97 km; =5.5 Gg C), ranging in age from 10 to 80-years-old.

Prevalence of Management Practices Used in Shelterbelt (N=63 surveys)



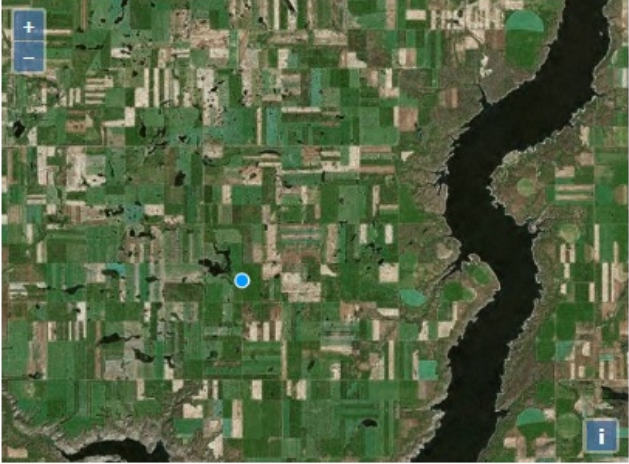
Total %	1	11	101	111	1000	1001	1011(☺)	1101	1111
Conifers	4.76	1.59	1.59	1.59	3.17	3.17	11.11	1.59	4.76
Deciduous	14.29	7.94	0.00	0.00	0.00	3.17	3.17	1.59	31.75
Shrubs	6.35	7.94	6.35	0.00	0.00	6.35	3.17	3.17	36.51
	25.40	17.46	7.94	1.59	12.70	17.46	6.35	9.52	

- Legend:**
- 1111 = HFIT
 - 1101 = HF[^]T
 - ☺ 1011 = H[^]IT
 - 1001 = H^{^^}T
 - 1000 = H^{^^^}
 - 111 = [^]FIT
 - 101 = [^]F[^]T
 - 11 = ^{^^}IT
 - 1 = ^{^^^}T

(H-F-I-T)
 Herbicide
 Fertilizer
 Irrigation
 Tillage

☺=example

Shelterbelt DSS Home About Contact



Plant a shelterbelt
 Remove a shelterbelt

Length: 510m

Rows:

Species Mix:

Shelterbelt Type:

Optimize for:

Fast growing
Fruit bearing
Wind control
Aesthetics

Inputs

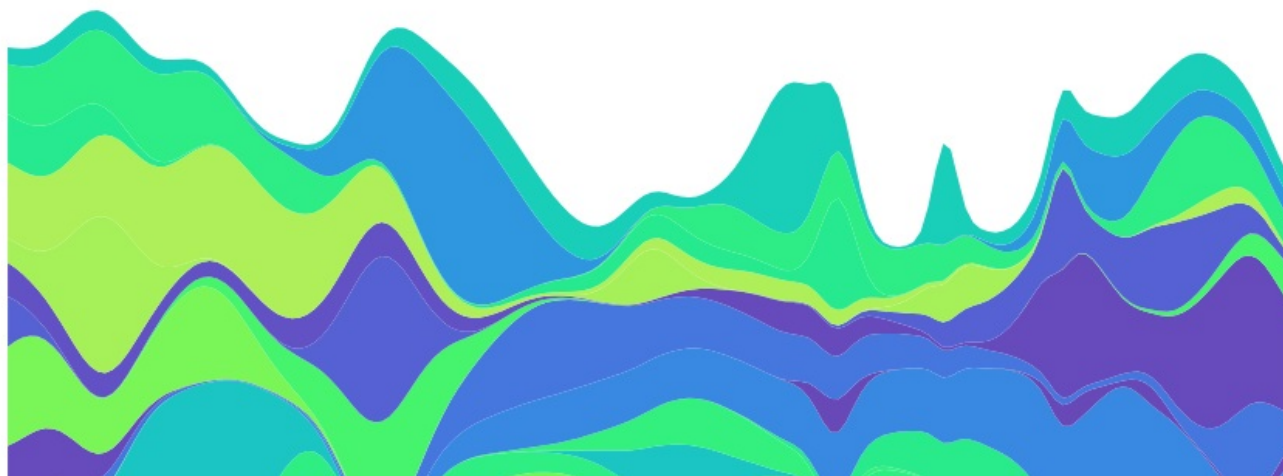
- ✓ Geographic position.
- ✓ Soil information.
- ✓ Shelterbelt length.
- ✓ Tree spacing.
- ✓ Number of tree rows.
- ✓ Shelterbelt species composition.
- ✓ Shelterbelt type (field, yard, roadside, riparian, etc.).
- ✓ Optimization preference (fast growth, max GHG sequestration, etc.).

Outputs

- Recommended species, design, and management for new shelterbelts.
- Growth and sequestered carbon rate and stocks for current and future years.
- Cost of implementing and maintaining shelterbelt.
- Summary of environmental benefits.
- Summary of socio-economic benefits.

C02 Sequestration: XXX Mg

Cost: \$1303



Publications (AGGP-1 & AGGP-2)

2018

16. Shelterbelt Agroforestry Systems Inventory and Removal Analyzed by Object-based Classification of Satellite Data in Saskatchewan, Canada. Canadian Journal of Remote Sensing (Submitted on 29-Mar-2018)

2017

15. Greenhouse gas emissions along a shelterbelt-cropped field transect. Agriculture, Ecosystems and Environment
14. Carbon sequestration and growth of six common tree and shrub shelterbelts in Saskatchewan, Canada. Canadian Journal of Soil Science
13. Spectroscopic investigation of soil organic matter composition for shelterbelt agroforestry systems. Geoderma
12. Distribution of soil organic carbon in the light and heavy fractions for six shelterbelt species and their adjacent agricultural fields in Saskatchewan. Canadian Journal of Soil Science
11. Soil organic carbon sequestration by shelterbelt agroforestry systems in Saskatchewan. Canadian Journal of Soil Science
10. A dendroclimatological assessment of shelterbelt trees in a moisture limited environment. Agricultural and Forest Meteorology
9. The Saskatchewan Shelterbelt Inventory. Canadian Journal of Soil Science
8. Costs and benefits of shelterbelts: A review of producers' perception and mind map analysis for Saskatchewan, Canada. Canadian Journal of Soil Science

2016

7. Soil-atmosphere exchange of carbon dioxide, methane and nitrous oxide in shelterbelts compared with adjacent cropped fields. Agriculture, Ecosystems and Environment
6. Greenhouse gas mitigation potential of shelterbelts: Estimating farm-scale emission reductions using the Holos model. Canadian Journal of Soil Science
5. Carbon sequestration by white spruce shelterbelts in Saskatchewan: 3PG and CBM-CFS3 model simulations. Ecological Modelling

2015

4. Mapping and quantification of planted tree and shrub shelterbelts in Saskatchewan, Canada. Agroforestry Systems
3. Accurate and Precise Measurement of Organic Carbon Content in Carbonate-Rich Soils. Communications in Soil Science and Plant Analysis

2014

2. (Book Chapter) Shelterbelts on Saskatchewan farms: An asset or a nuisance. In: Climate change and forest ecosystems

2013

1. Evaluating the suitability of nine shelterbelt species for dendrochronological purposes in the Canadian Prairies. Agroforestry Systems

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