AGGP-Agroforestry

Mapping Shelterbelt Land Suitability for Maximized Ecosystem Carbon Stocks

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Shelterbelts are a vital component of Canadian farms; however, guidelines are lacking to help land managers locate suitable areas for planting new shelterbelts on their landbases. Therefore, to address this knowledge gap, we created land suitability maps for deciduous, coniferous, and shrub shelterbelt establishment across a wide range of climatic and soil zones of Saskatchewan. Shelterbelt suitability mapping is a means to delineating and ranking the land across large landscapes. This comprehensive land mapping approach can benefit other afforestation and agroforestry adoption studies across Canada and the world.

A Comprehensive Land Suitability Mapping Approach

Maps of shelterbelt carbon data and 50 predictor variables were analyzed using multivariate principal component analysis (PCA), principal component regression (PCR), fuzzy logic analysis, and GIS mapping techniques. The 50 spatial datasets were used as shelterbelt establishment predictor variables (4 groups): 21 climate (1980–2010 normals), 13 land management, 14 soils, and 2 topographic criteria. The shelterbelt carbon inventory spatial layer was used as the shelterbelt establishment indicator dataset. Using PCA and PCR analyses, the overall importance (cumulative loading: positive or negative) of all predictor variables was determined and used to create shelterbelt suitability maps by means of weighted-sum overlays in GIS. Statistically significant positive correlations between mapped shelterbelt suitability levels and observed mean shelterbelt carbon stocks were used to evaluate the resulting deciduous (4.86 million hectares (Mha) study area; $p<0.001$, $R2= 0.79$), coniferous (1.96 Mha study area; $p<0.001$, $R2=0.77$), and shrub suitability maps (2.06 Mha study area; $p<0.001$, $R2=0.83$) (Fig. 1).

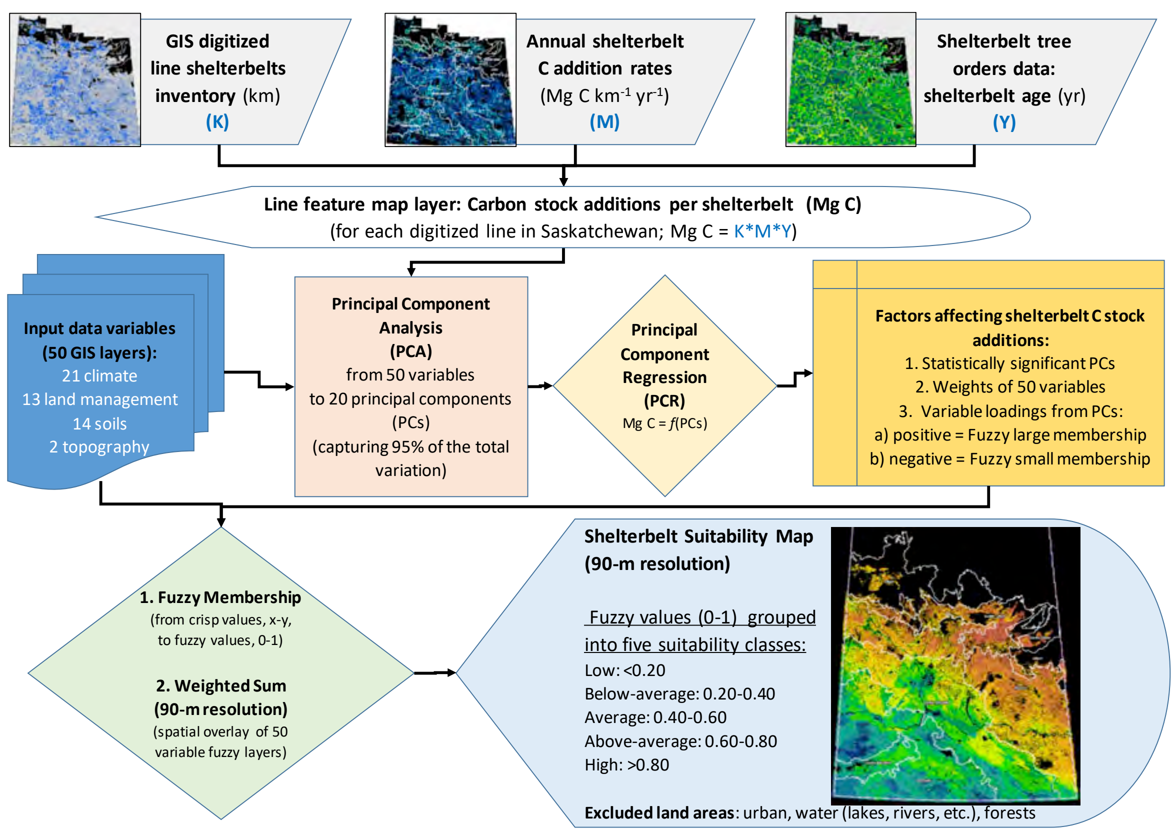

Figure 1. Workflow overview of data extraction, principal component analysis, principal component regression, fuzzy membership, and weighted sum spatial analyses used to assess and map shelterbelt land suitability for maximized ecosystem carbon stocks in the agricultural region of Saskatchewan. These steps were performed separately, once each, for all planted deciduous, coniferous, and shrub shelterbelts.

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FACTORS AFFECTING SHELTERBELT C STOCK ADDITIONS

- **High ranks**: The top ranking variables affecting shelterbelt distribution were mean annual temperature, maximum annual temperature, and annual growing degree-days (GDD), all describing the temperature regime of an area. Other top-ranking variables were aridity index and mean annual precipitation, both describing the moisture regime of an area (Table 1)
- **Middle ranks**: Herbicides, fertilizer, irrigation, and tillage applications (management criteria) ranked in middle ranking positions of the overall list, emphasizing the secondary role on shelterbelt distribution, following the climate criteria. Variables from the soils and topography criteria were mostly middle and low ranking.
- **Species comparisons**: The main difference between the coniferous and the other two shelterbelt species was that the correlations for the top three variables were negative. That is, coniferous shelterbelts were predominant in areas with lower mean and max temperatures, and lower GDD (Table 1). While deciduous and shrub shelterbelts were positively correlated, meaning that they were mainly distributed in areas with higher temperatures and GDD.

➔ Table 1. Ranking of 50 variables from four criteria groups (Clim = climate; Mgmt = land management; Soils = soil characteristics; Topo = topography) affecting agricultural land suitability for maximized shelterbelt ecosystem C stocks in Saskatchewan for three shelterbelt species groups (D=deciduous, C=coniferous, S=shrub). Ranks (1=highest; 50=lowest), top-third shown in bold and bottom-third as underlined values, are based on principal component analysis (i.e., variable loadings) and principal component regression (see Fig. 1). ➔

Criteria Group	50 Variables	Units	Rank by species D	Rank by species C	Rank by species S	Median Rank
Clim	Mean annual Temp	°C	**2**	**1**	**1**	**1**
Clim	Max annual Temp	°C	**4**	**2**	**2**	**2**
Clim	Growing Degree-Days annual	°C·day	**1**	**3**	**3**	**3**
Clim	Min annual Temp	°C	**5**	**4**	**4**	**4**
Clim	GDD JanJul	°C·day	**3**	**5**	**5**	**5**
Clim	Max July Temp	°C	**6**	**6**	**6**	**6**
Clim	Lowest Min Temp	°C	**7**	**7**	**8**	**7**
Clim	Vapour pressure deficit	kPa	**8**	**9**	**9**	**9**
Mgmt	Hybrid poplar suitab. index	-	**9**	**13**	**7**	**9**
Clim	Frost days	day	**11**	**10**	**10**	**10**
Clim	Solar radiation in July	MJ/m²	**15**	**8**	**11**	**11**
Clim	Aridity Index	-	**10**	30	**12**	**12**
Clim	Mean July Temp	°C	**12**	**11**	**13**	**12**
Clim	Mean annual precipitation	mm	**13**	45	**14**	**14**
Mgmt	Hardiness zone	-	**14**	**12**	**15**	**14**
Mgmt	Env. Indic. GHG farm emiss.	kg CO2-eq./ha	**16**	21	17	**17**
Clim	Rain days	day	18	20	**16**	18
Clim	Wind speed	km/h	17	19	19	19
Clim	Solar radiation	MJ/m²	20	**16**	20	20
Soils	Agric. land erosion class	-	21	22	18	21
Soils	Buk density (0-5 cm depth)	Mg/m3	22	18	25	22
Topo	Elevation	m	24	23	21	23
Clim	Rain for July	mm	26	48	24	26
Soils	Soil organic C (0-25 cm)	Mg/ha	25	26	27	26
Mgmt	Tillage farms-in-CCS	%	19	43	28	28
Soils	Soil depth (plant-exploit.)	cm	40	28	29	29
Soils	Coarse fragments (0-5 cm)	vol. %	28	42	30	30
Mgmt	Fertilizer farms-in-CCS	%	36	31	31	31
Mgmt	Herbicides farms-in-CCS	%	37	32	32	32
Clim	Wind speed in Feb	km/h	33	46	22	33
Mgmt	Tillage in-farm	%	23	44	33	33
Clim	Growing season days	day	34	27	35	34
Mgmt	Irrigation farms-in-CCS	%	27	40	34	34
Mgmt	Env. Indic. wind erosion	Mg/ha/yr	47	33	36	36
Topo	Distance to water	m	45	36	23	36
Clim	Min July Temp	°C	31	38	37	37
Soils	Agric. land drainage class	-	30	37	39	37
Mgmt	Crop type class	-	44	35	38	38
Soils	Agric. land capability class	-	38	17	40	38
Clim	Wind speed in July	km/h	39	49	26	39
Soils	pH (0-5 cm)	-	35	39	41	39
Mgmt	Herbicides in-farm	%	41	**15**	42	41
Soils	Agricultural land texture cl.	-	42	29	45	42
Mgmt	Fertilizer in-farm	%	43	**14**	43	43
Soils	Elec. conductivity (0-5 cm)	mS/m	32	50	44	44
Mgmt	Irrigation in-farm	%	29	47	46	46
Soils	Clay (0-5 cm depth)	mass %	46	34	47	46
Soils	Silt (0-5 cm depth)	mass %	50	41	48	48
Soils	AWHC (0-30 cm)	mm	48	25	49	48
Soils	Sand (0-5 cm depth)	mass %	49	24	50	49

The suitability maps clearly delineated land of higher suitability for coniferous shelterbelts in the northern agricultural regions, while the southern regions were delineated as more suitable for deciduous and shrub shelterbelts. Additional 8.76, 7.90, and 9.77 Mha were identified across five soils zones in Saskatchewan as suitable for planting future deciduous, coniferous, and shrub shelterbelt systems, respectively, mapped as above-average or high suitability land.

FURTHER READING: Amichev et al. 2020. New Forests. doi: 10.1007/s11056-019-09766-1

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