

Digital soil mapping in British Columbia... a progress report

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Why a digital soil map ?

- 1. It seems everything is done on computer nowadays**
 - Digital products are nice to look at and have greater impact
 - Large scale questions (eg provincial or national) require large datasets that are best handled on computers
 - Complex questions require consideration of multiple inputs
- 2. Its the most efficient way to (1) capture and present existing knowledge, and (2) to develop new knowledge**
- 3. Because we can...**
 - Innovative Technology (GIS, decision support tools)
 - Associated datasets (digital elevation model, climate, etc)
 - Road network (access) – facilitates testing and evaluation
 - Recent advances in soil science.. build on existing knowledge
 - Accessibility of tools to practitioners – enhances competitiveness

Partners and Linkages

BC Ministry of Environment, BC Ministry of Forests

Agriculture Agri-food Canada

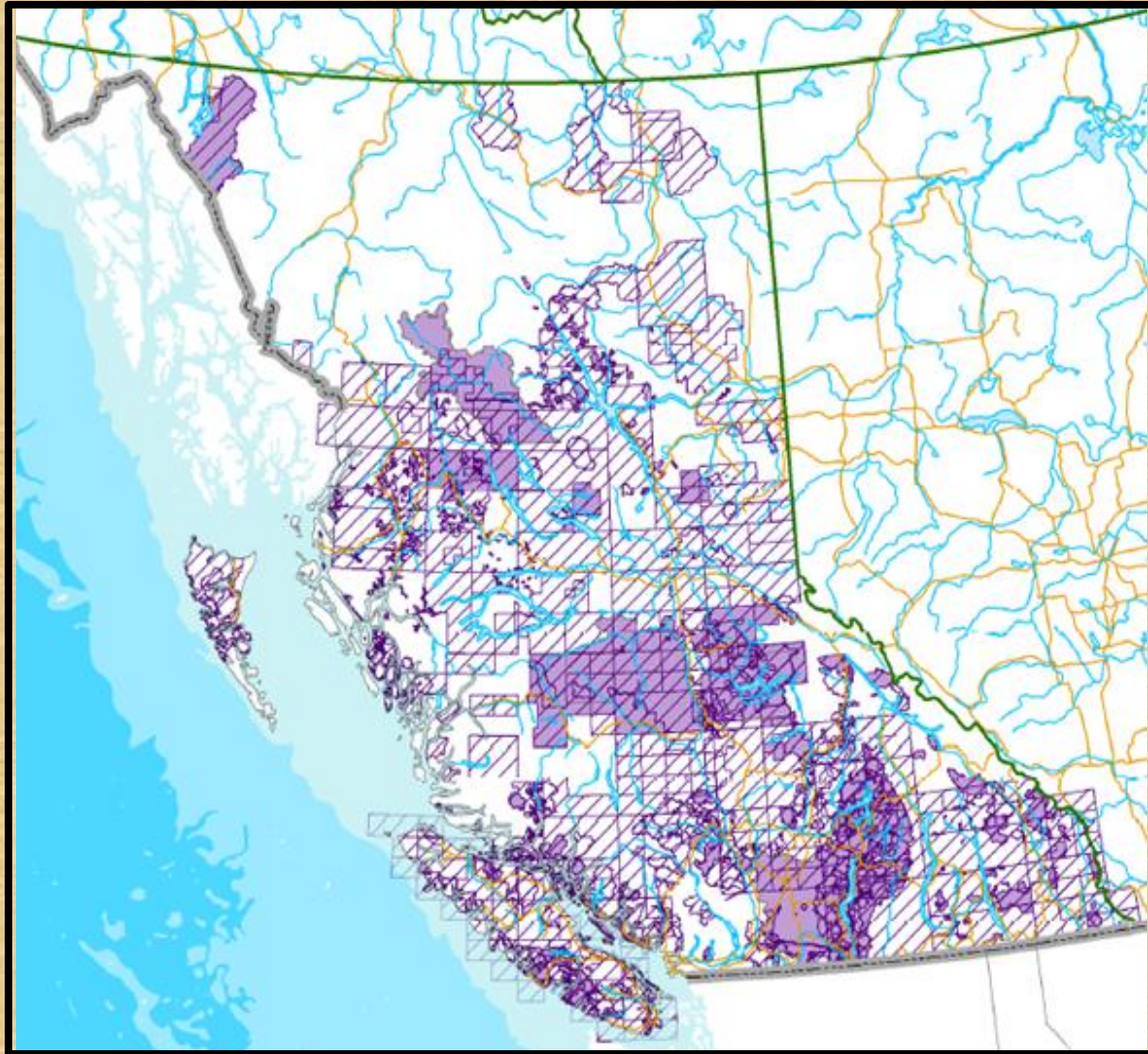
Natural Resources Canada, Environment Canada

Future Forest Ecosystems Scientific Council

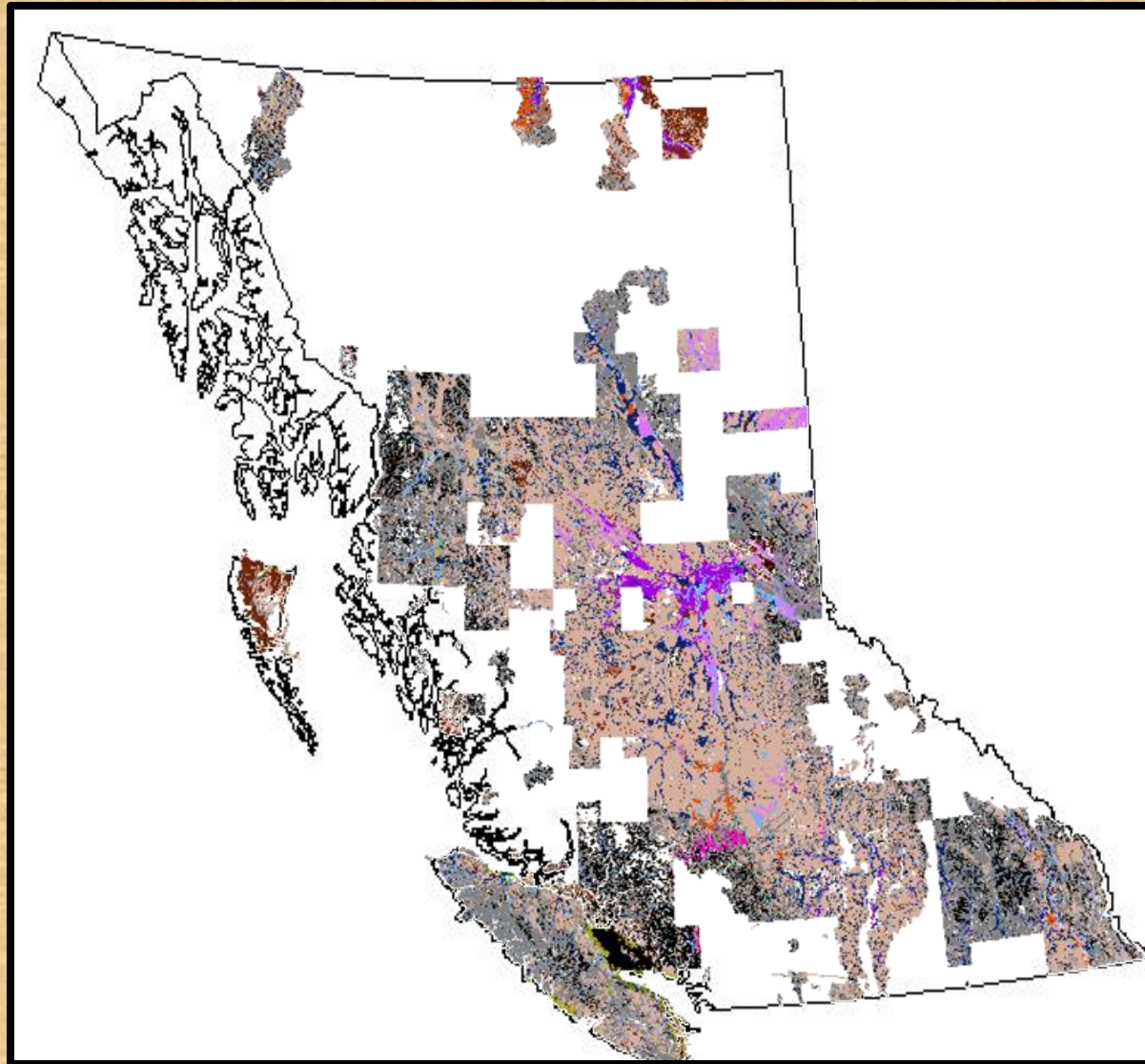
Globalsoilmap.net / Predictive Ecosystem Mapping in BC

Soil scientists in BC

Background (existing soil and terrain 1:50,000 or 1:100,000 coverage):



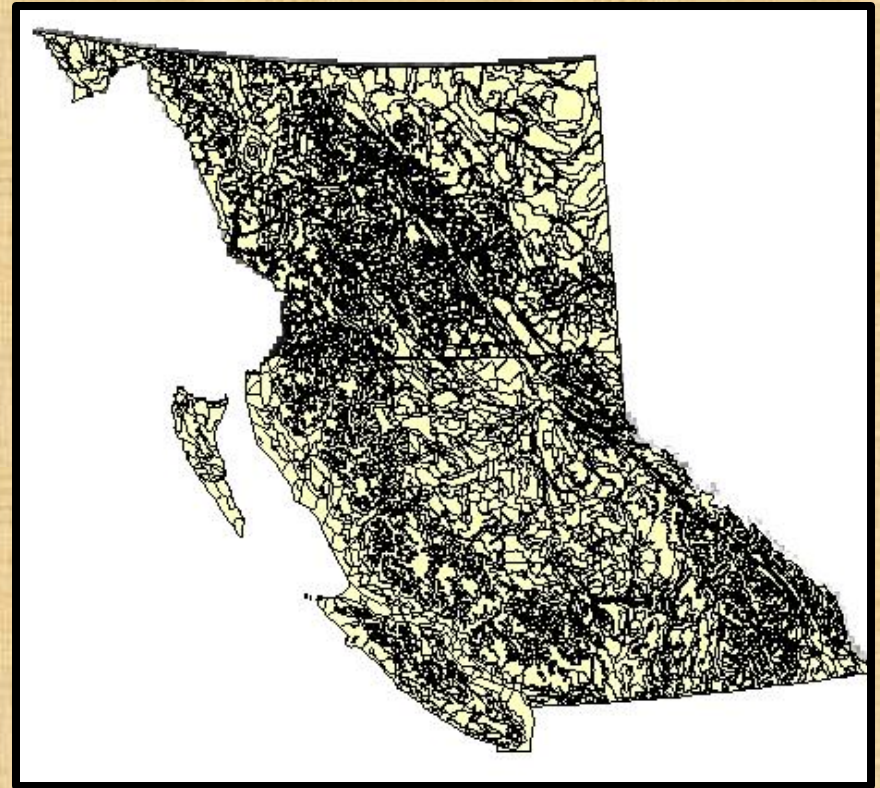
Background *(existing terrain coverage: digital):*



Background *(digital coverage):*

Soil Landscapes of Canada:

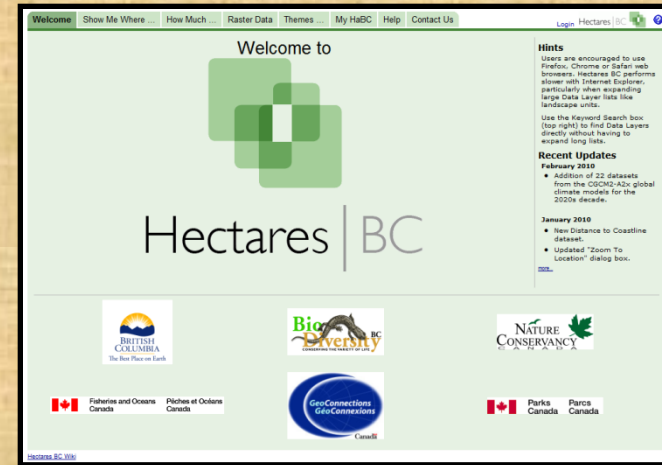
- all of BC (Canada)
- soil landscapes (1:1,000,000 scale)
- a generalized soil map
- intended for broad interpretations
- used for modeling BC & Canada
 - carbon, climate change,
 - productivity, species suitability.
- approx. 2000 polygons and 2000 components (soil types) in BC;
- all polygons are linked to component information tables



Background (digital coverage):

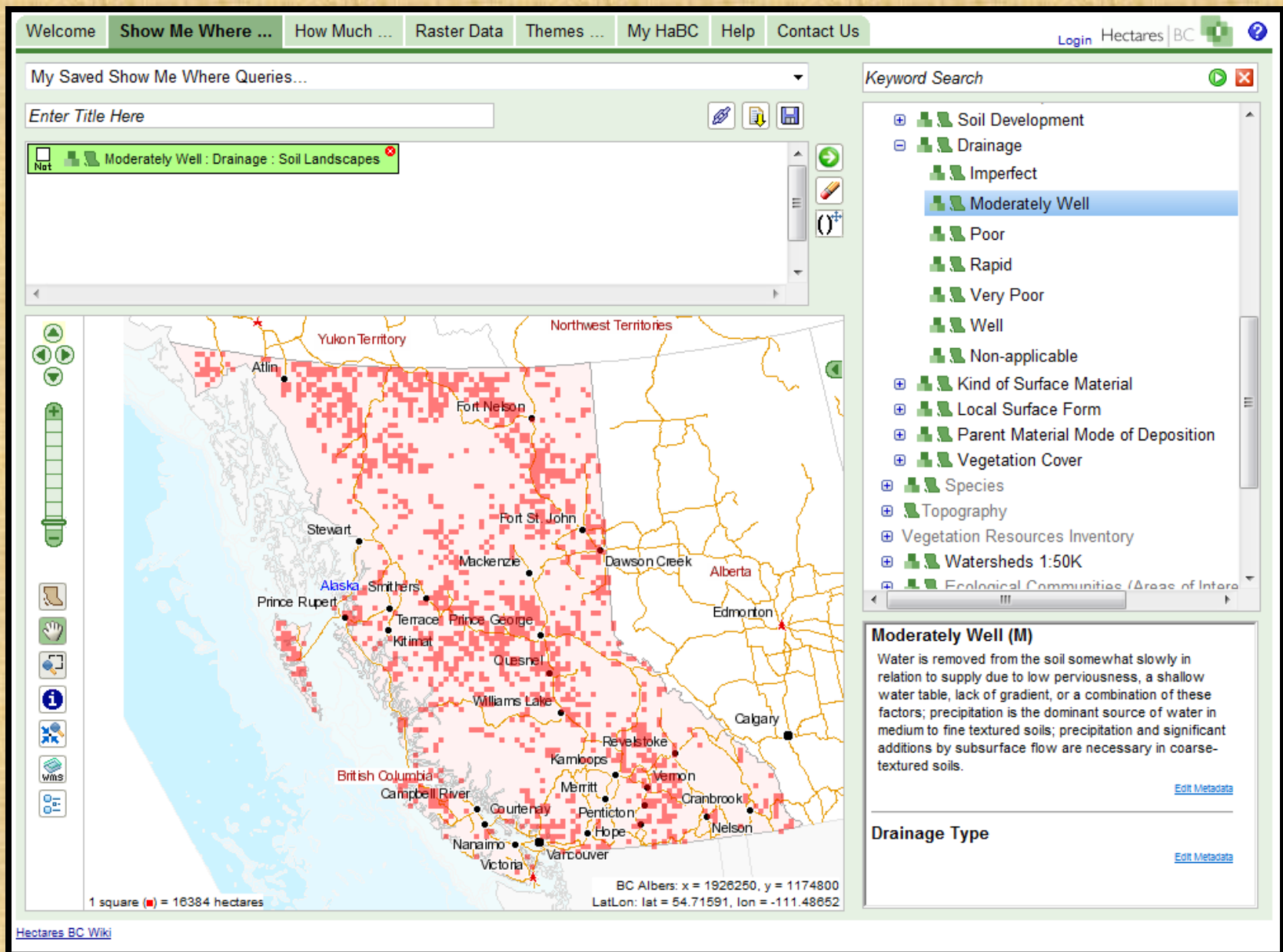
www.hectaresbc.org:

- “GIS for the rest of us”..
- raster data, 1 ha pixel size
- public access to geographic data
 - spatial data “Where”
 - database “How much”
 - download..
- Soil Landscapes of Canada soils coverage
- source of eg DEM, BEC, other data+++

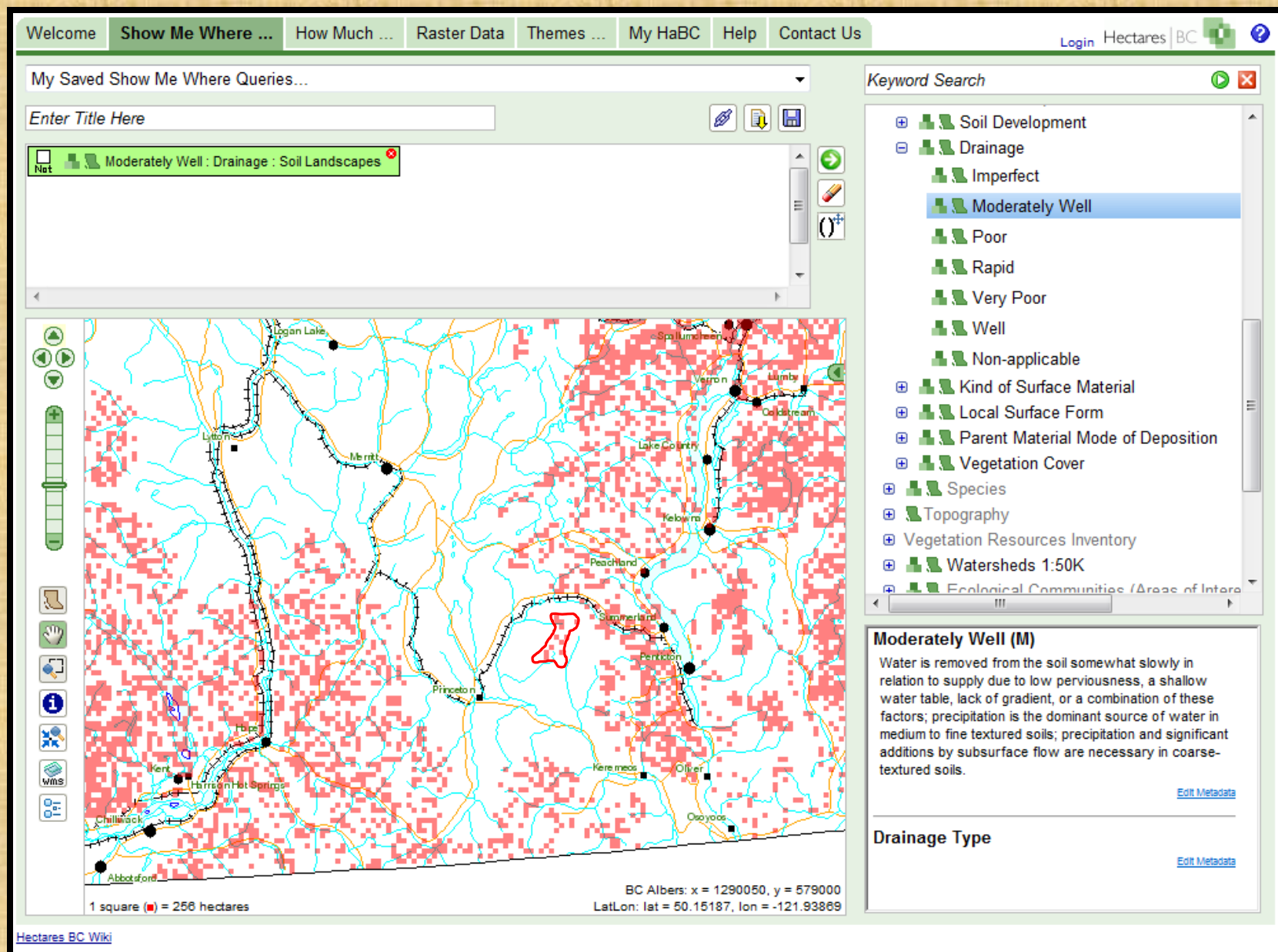


•A natural destination for improved soil and terrain information..

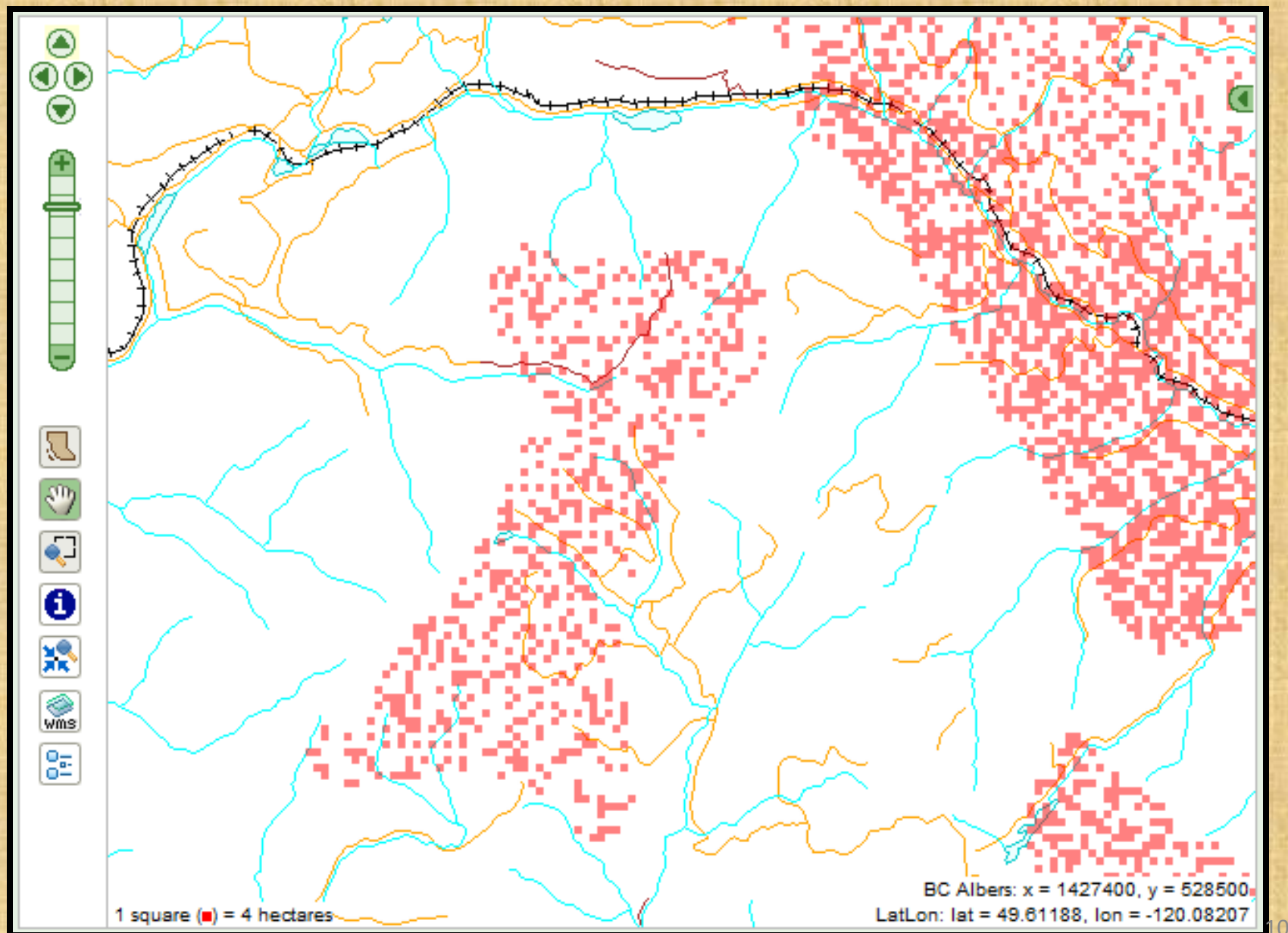
Background (digital coverage: Hectares BC):



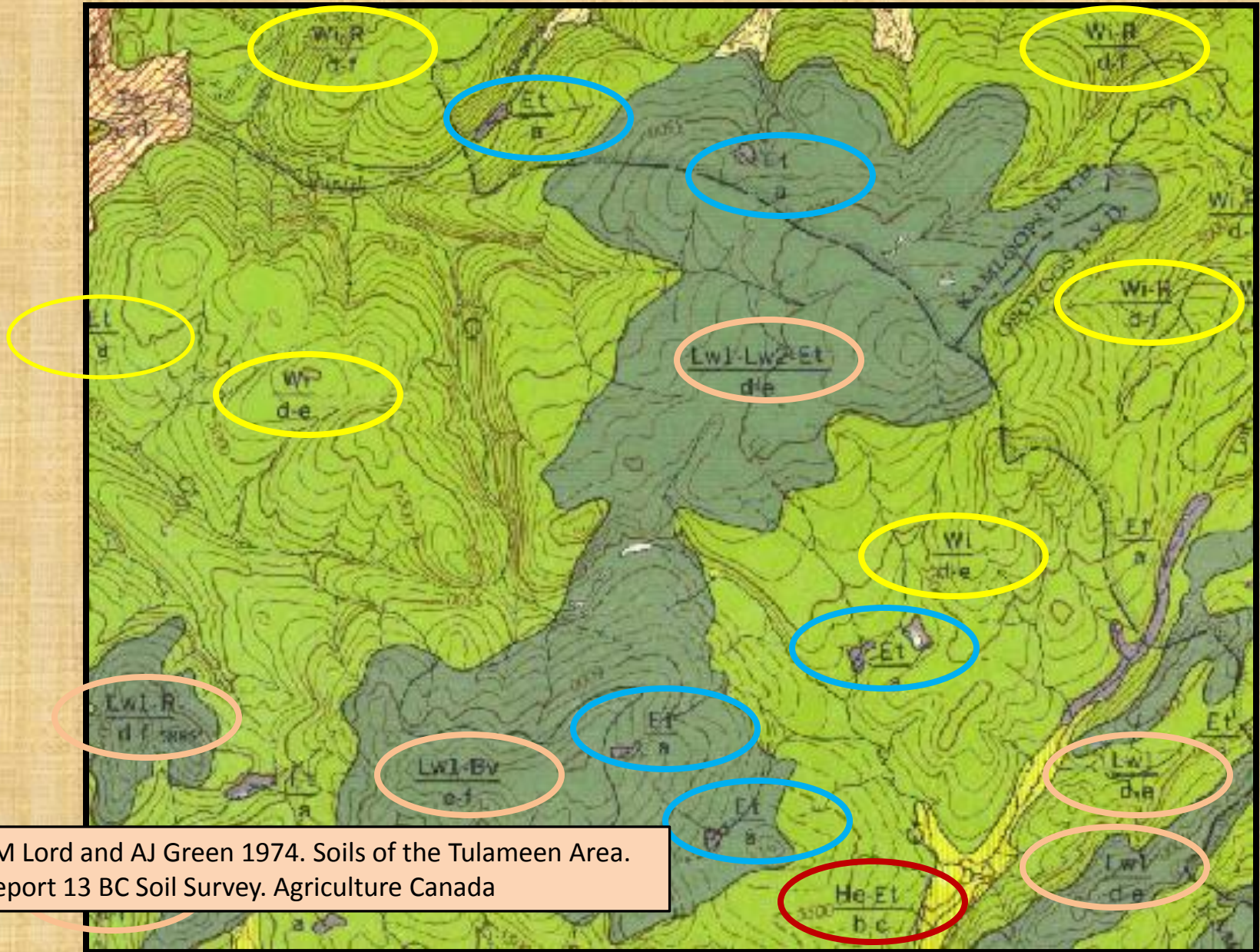
Background (digital coverage: Hectares BC):



Background (digital coverage: Hectares BC):



Disaggregation (Tulameen soil survey 1:125,000):



What's missing? (some examples..)

- 1. Detailed, spatially explicit attribute information**
 - a) Carbon, nutrients**
 - b) Particle size, density, water holding capacity**
 - c) Rooting depth**
- 2. Some areas have very sparse soil information**
- 3. Estimates of reliability, and an approach for improvement**

..and what benefits could be realized if it were available ?

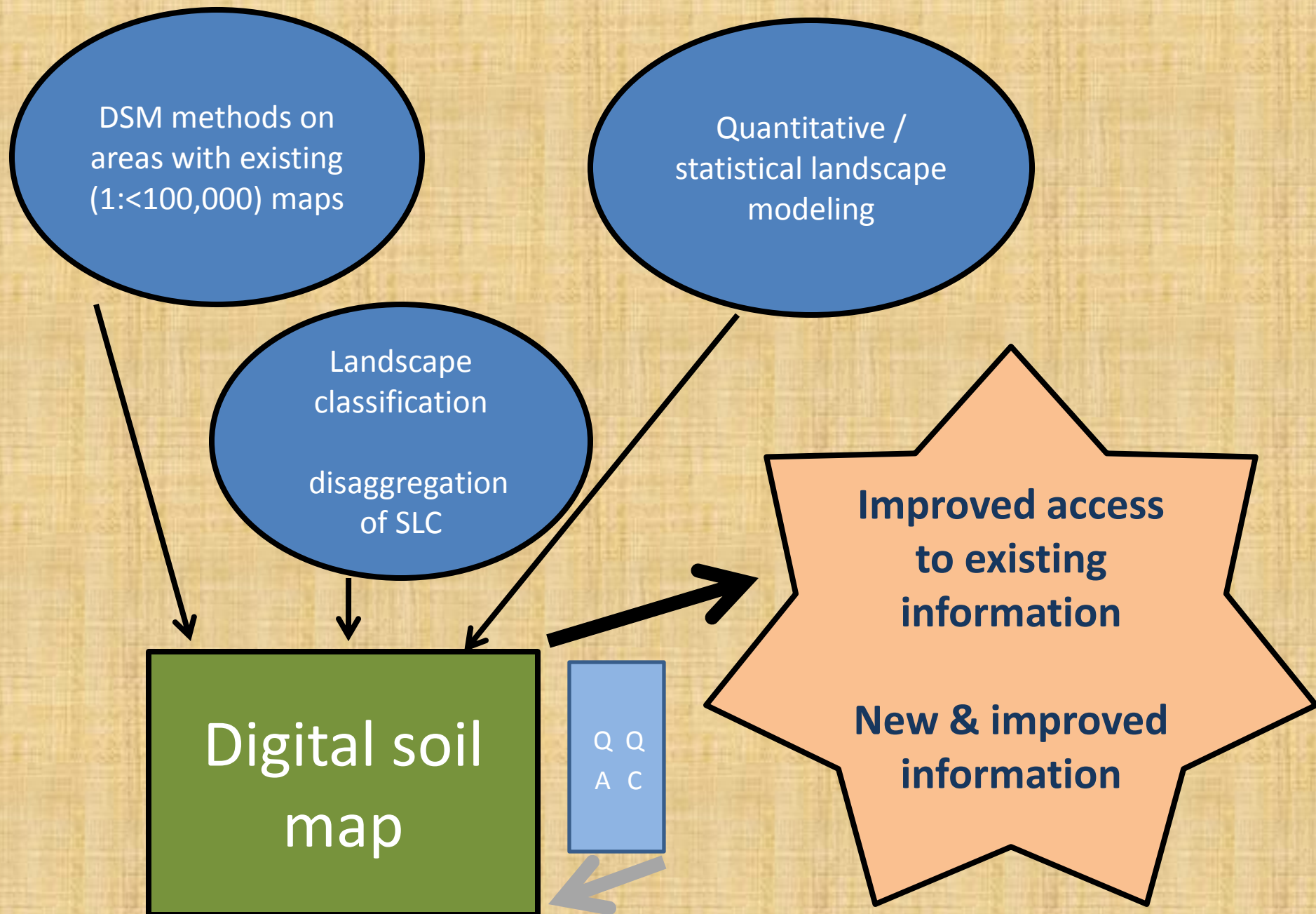
- a) Improved modeling of 'large events'**
 - Climate change, C budgets, bioenergy, C markets**
- b) Better information on what we have (opportunities)**
- c) Better information for management (knowledge)**

Objectives

- 1. Improve access to existing soil & terrain information in BC**
 - Correlate, clean up, improve existing soil & terrain datasets, and link soil databases to digitized maps
 - Speed up the process of making analog soil & terrain maps and information available in a digital format
- 2. Predictive mapping techniques to generate new soil & terrain information for BC**
 - create a digital soil map (DSM) for the entire province

An integrated approach

- **AAFC (Summerland):**
 - pilot study of DSM in the Okanagan Watershed
- **BC MoELP/MoFR (Vernon / Kelowna / Victoria):**
 - Evaluate methods for landscape classification suitable for inclusion in Hectares BC (<http://www.hectaresbc.org>), and its utility for DSM
 - disaggregation of Soil Landscapes of Canada polygons for BC
- **Simon Fraser University:**
 - Quantitative & statistical landscape classification and DSM



Concepts / Methods

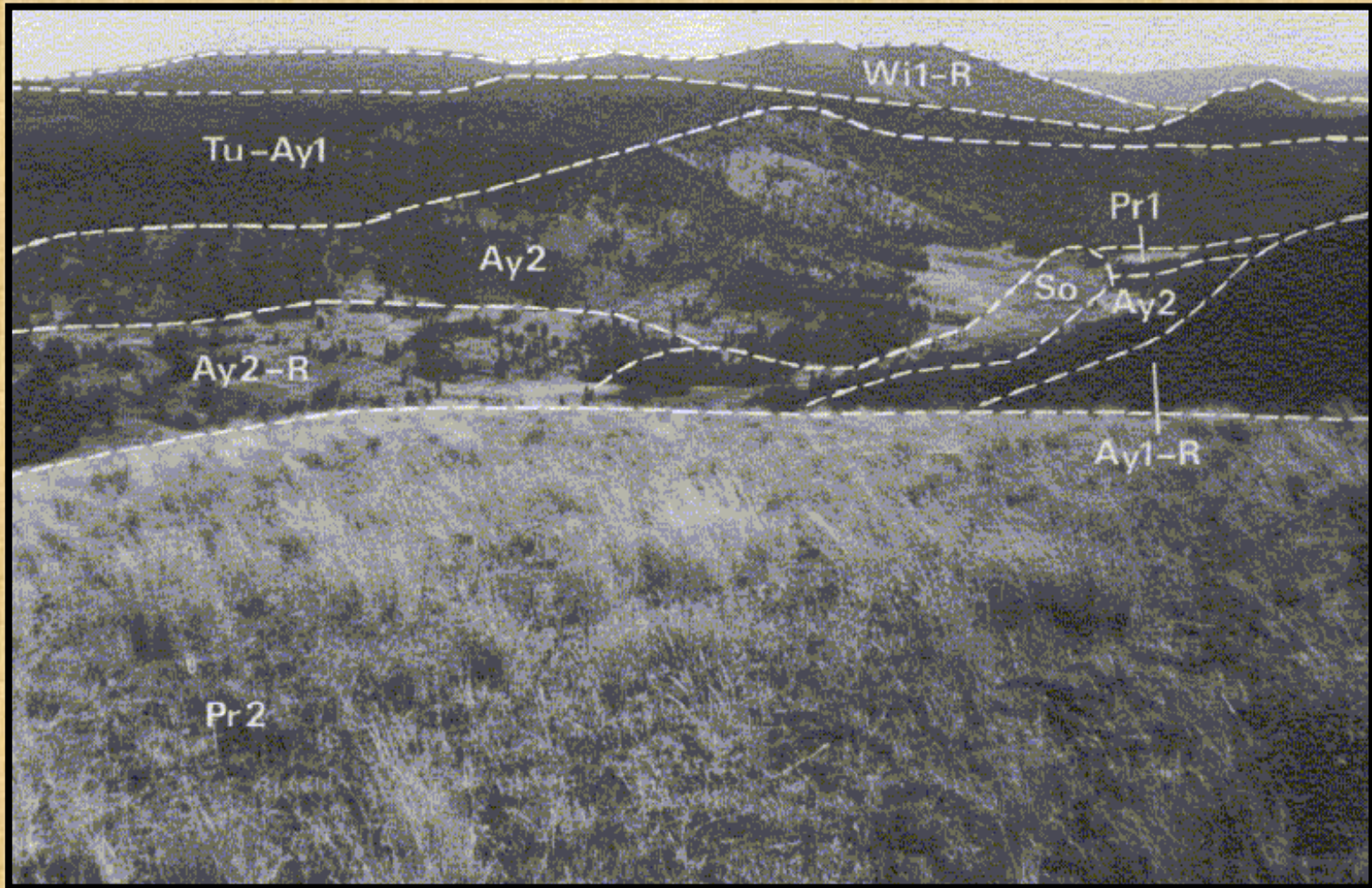


Photo from AJ Green and TM Lord. 1979. Soils of the Princeton area of British Columbia

Concepts:

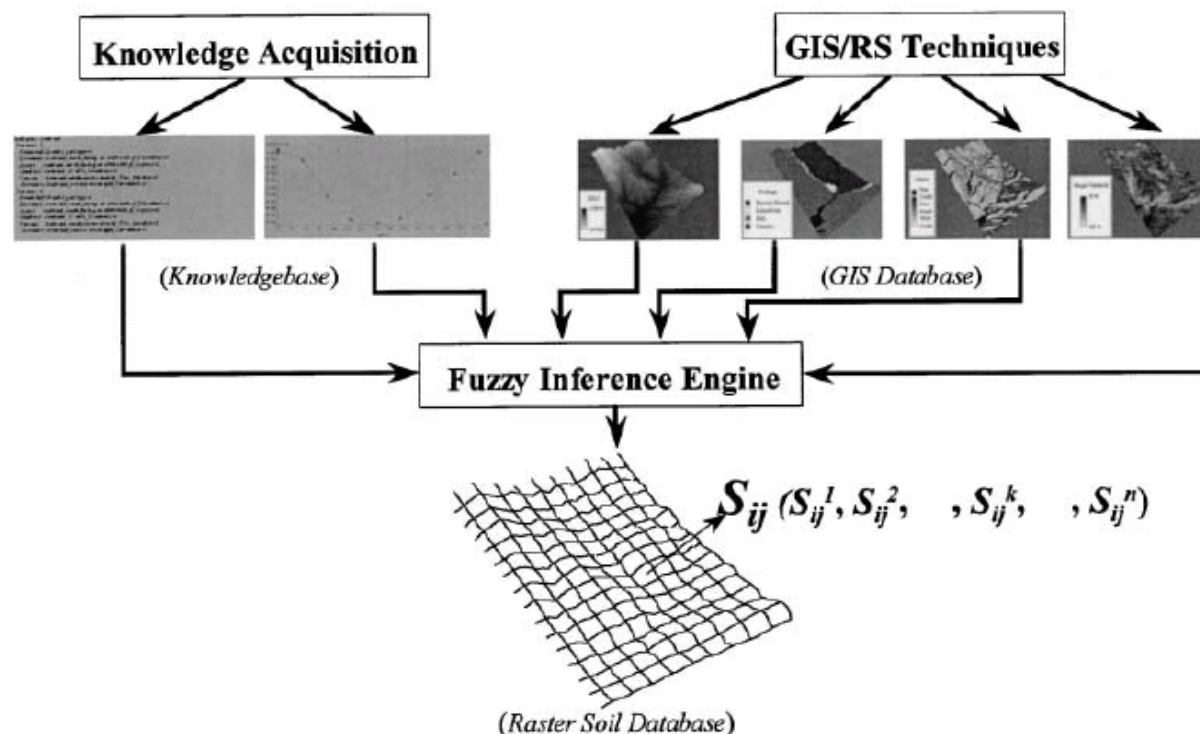
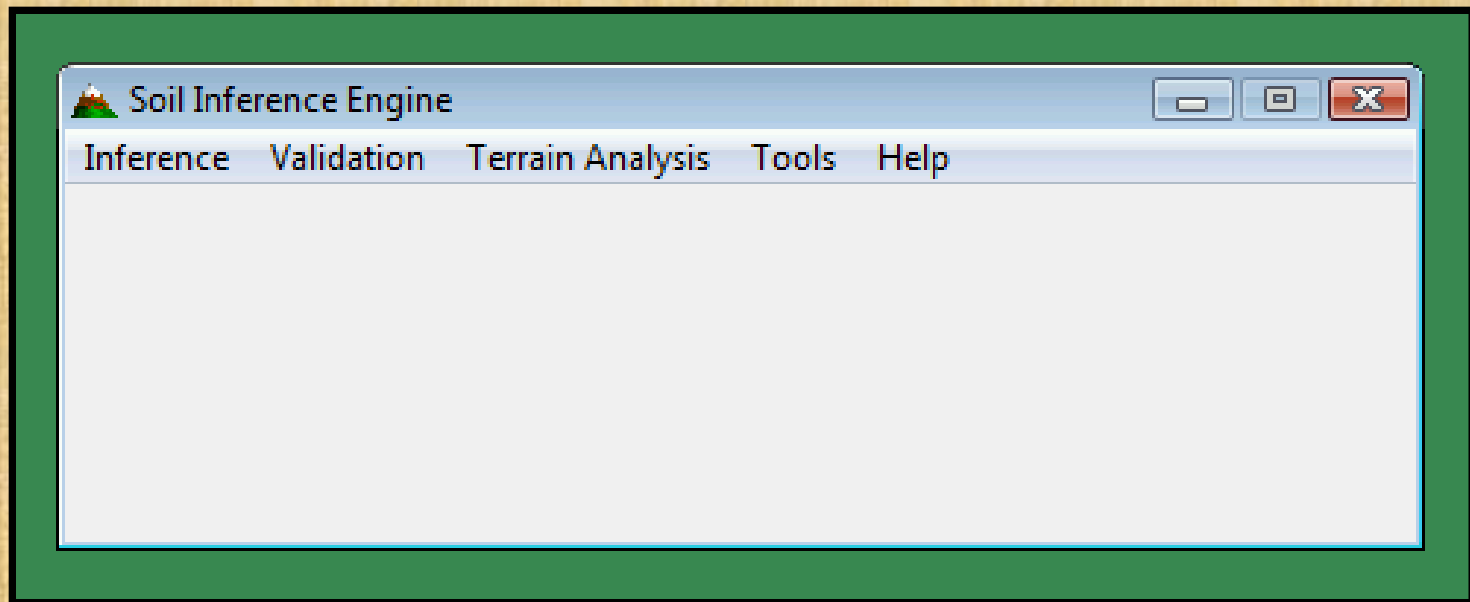


Fig. 4. Soil inference process. The knowledgebase contains knowledge on soil–environmental relationships. The geographical information system (GIS) database contains spatial data on soil formative environmental conditions. The fuzzy inference engine combines the relationships in the knowledge base with the spatial data in the GIS database to produce a raster soil database for the study area.

Methods:

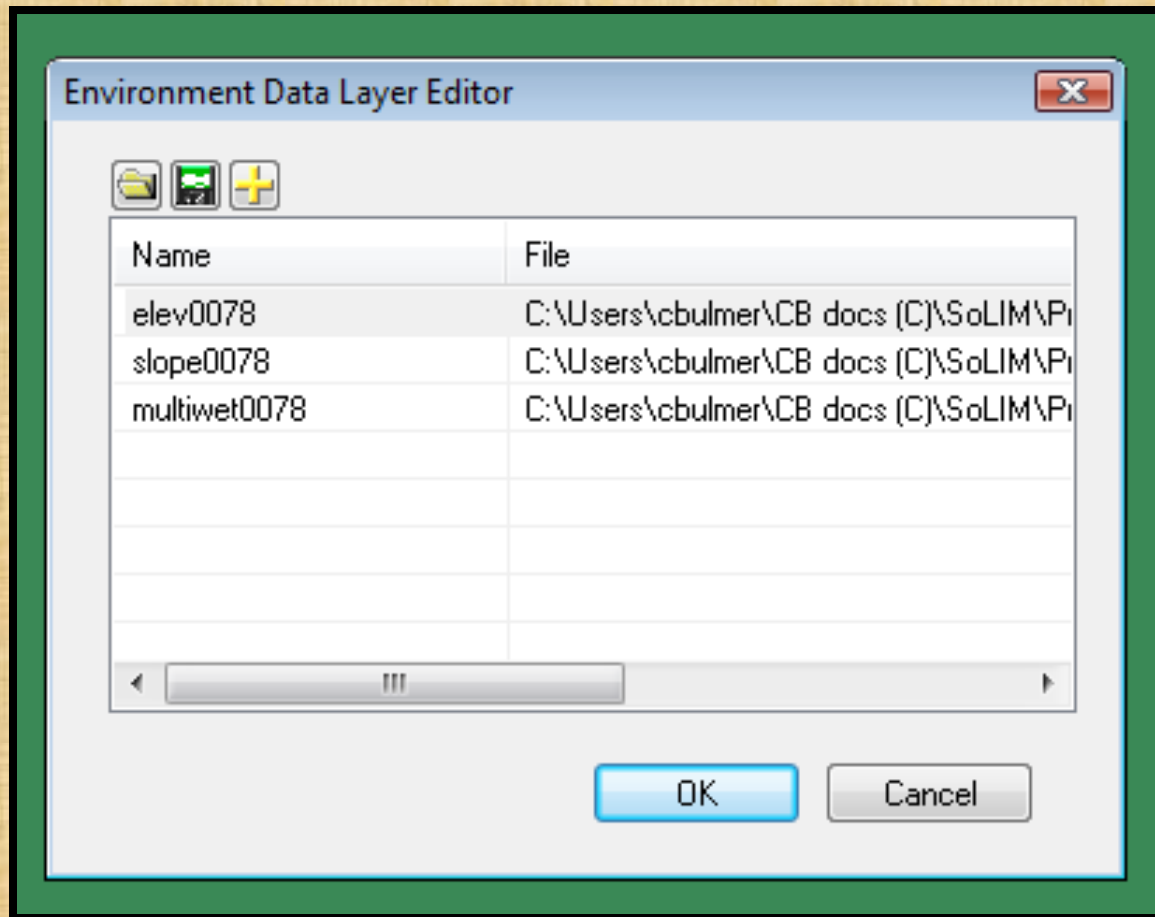
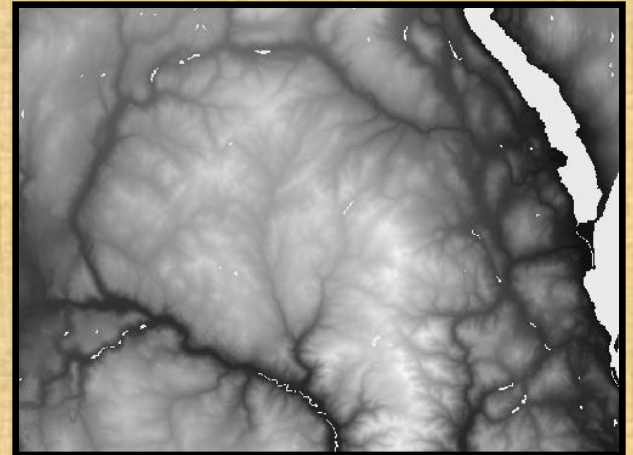
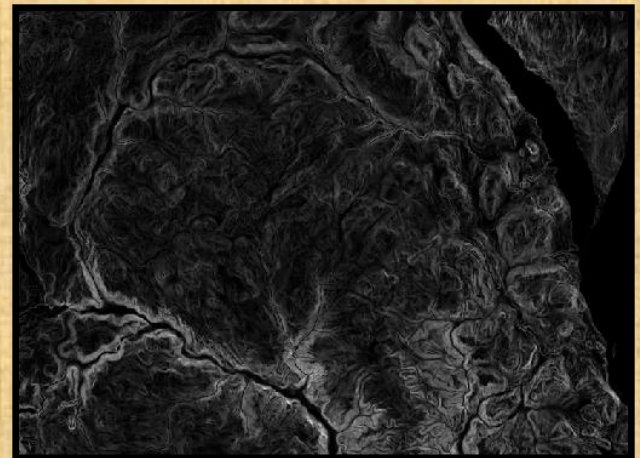


“Fuzzy soil mapping” using ‘rule’ based and ‘case’ based reasoning

RBR (e.g.): If elevation > 650m, then the soil is typical for type “A”
- pedologist specifies the value

CBR (e.g.): If elevation is similar to location ‘a’, soil is typical for type “A”
- pedologist specifies the location

Methods:



Methods:

The screenshot shows the 'Inference' window with the following components:

- Left Panel:** Radio buttons for 'Attribute Rule' (selected), 'Point Case', 'Line Case', 'Polygon Case', and 'Raster Case'.
- Tree View:** A hierarchical list of features including '590078', 'bov', 'bov1', 'glf', 'glf1', 'skt', 'skt1', 'lawnic', and 'lawnic1'. 'glf1' is currently selected.
- Table:** A table with columns 'Limiting' and 'Feature'.

Limiting	Feature
☒	elev0078
☐	slope0078
☒	multiwet0078
- Graph:** A fuzzy membership function graph with a green curve. The y-axis represents membership values from 0 to 1. The x-axis represents data values. Key points on the curve are marked with red squares at (1502, 1), (1820, 0.5), and (1848, 0). The curve drops from 1 to 0 between 1820 and 1848. Input values are shown in boxes: v1=1810, w1=1e+006, r1=2 on the left; v2=1810, w2=10, r2=2 on the right.
- Right Panel:** Radio buttons for 'Positive' (selected) and 'Negative'. A 'Membership Value' input box is set to 1. A 'Make Fuzzy Bnd' checkbox is unchecked. A 'Weight Features' button is present.
- Bottom Right:** Three buttons: 'Spatial Setting >>', 'More Options', 'Do This', and 'Do Batch'.
- View Type:** A dropdown menu at the bottom center is set to 'Data Range'.

Methods:

Inference

☒ Attribute Rule
☐ Point Case
☐ Line Case
☐ Polygon Case
☐ Raster Case

590078
[-] bov
 bov1
[-] glf
 glf1
[-] skt
 skt1
[-] lawnic
 lawnic1

Limiting	Feature
☒	elev0078
☐	slope0078
☒	multiwet0078

☒ Positive
☐ Negative

Membership Value:

☐ Make Fuzzy Bnd
Weight Features

v1
w1
r1

1
0.5
-3.

0.
-2.645

17.

v2
w2
r2

Spatial Setting >>
More Options
Do This
Do Batch

View Type:

Methods:

Inference

☒ Attribute Rule
☐ Point Case
☐ Line Case
☐ Polygon Case
☐ Raster Case

590078
[-] bov
 bov1
[-] glf
 glf1
[-] skt
 skt1
[-] lawnic
 lawnic1

Limiting	Feature
☒	elev0078
☒	slope0078
☐	multiwet0078

☒ Positive
☐ Negative

Membership Value: 1

☐ Make Fuzzy Bnd
Weight Features

v1 18 w1 1 r1 2 v2 18 w2 1e+006 r2 2

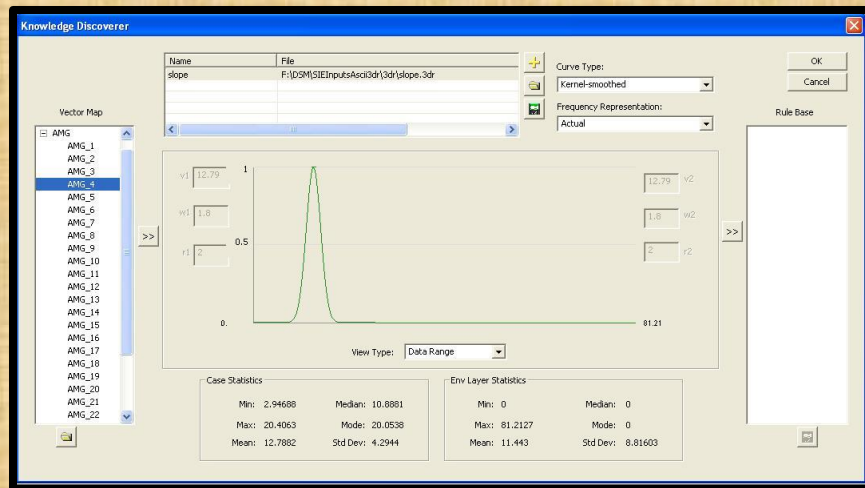
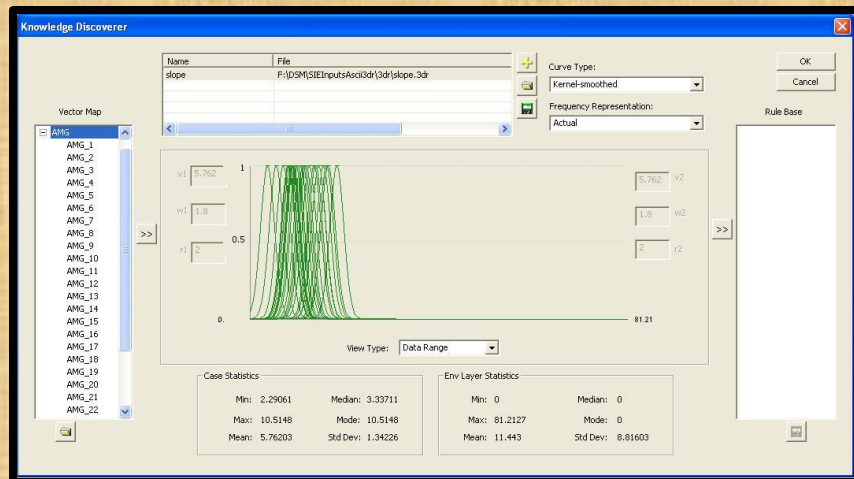
17. 14.35 48.

View Type: Data Range

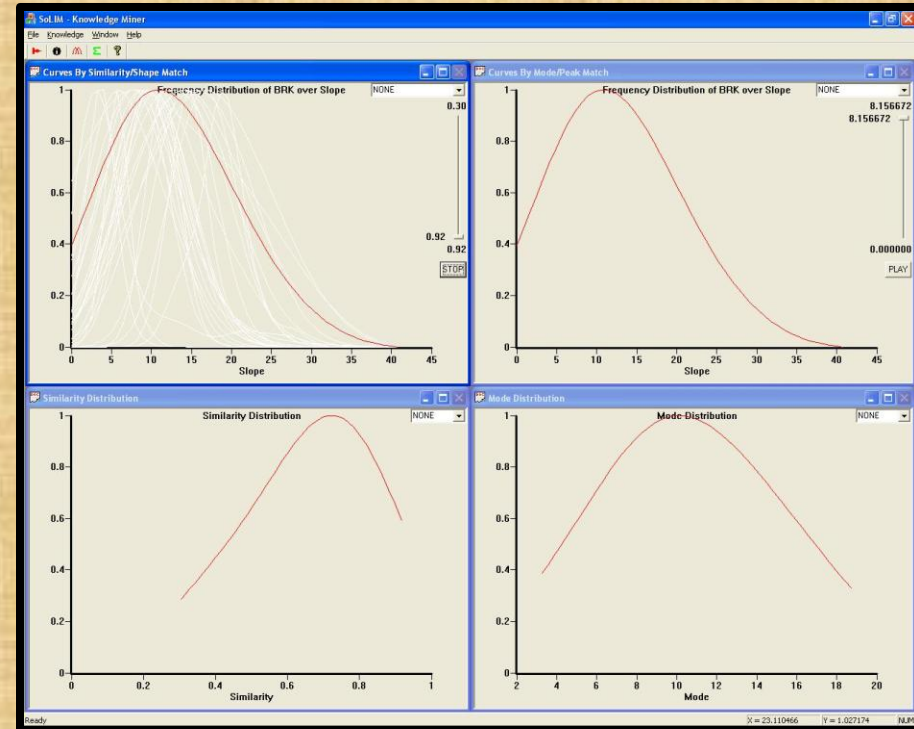
Spatial Setting >>
More Options
Do This
Do Batch

Methods:

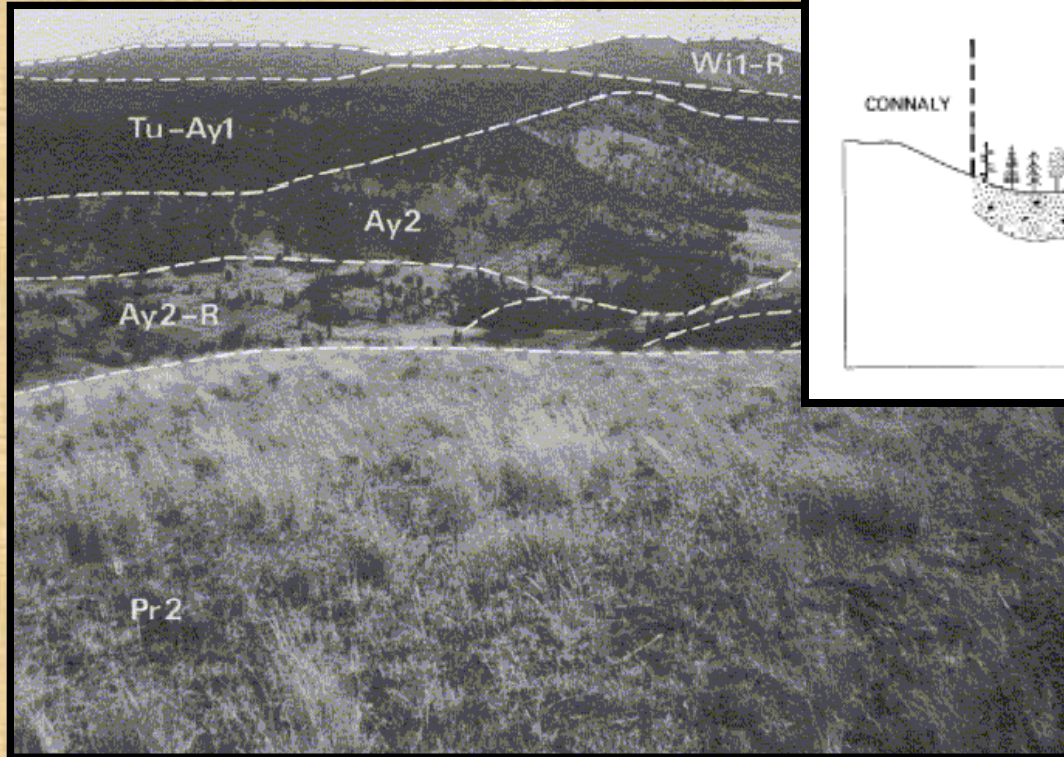
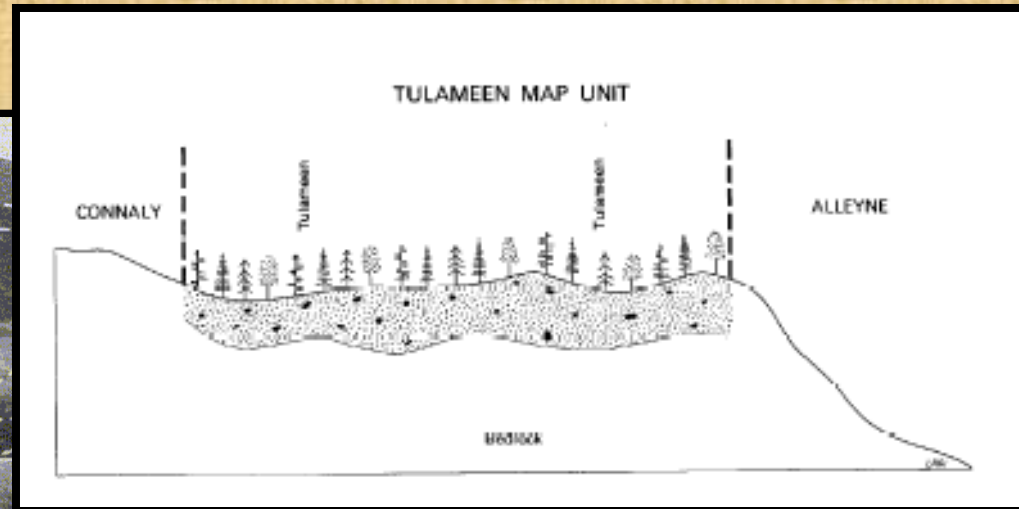
SIE Knowledge Discoverer



SOLIM Knowledge Miner



Methods:

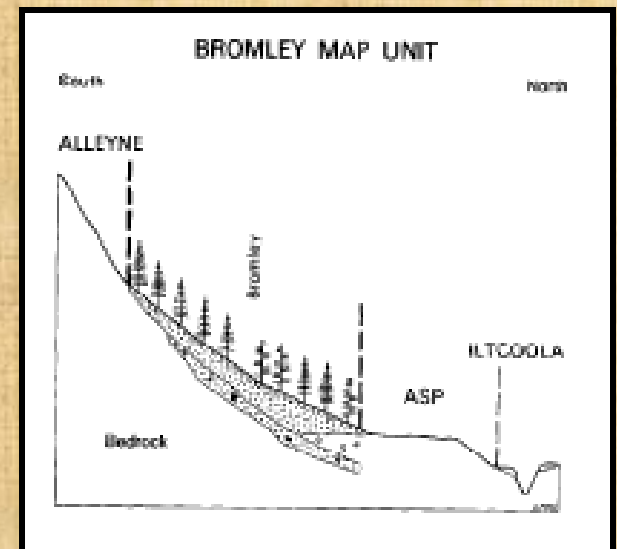


RBR (e.g.): If elevation > 650m, then the soil is typical for type "A"

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CBR (e.g.): If elevation is similar to location 'a', soil is typical for type "A"

- pedologist specifies the location



DSM in the Okanagan

Okanagan Valley

- valley bottom dominated by Okanagan Lake, agriculture, and urban
- surrounding plateau is mostly forested.
- several large forest processing facilities,
- cogeneration plant using wood residues to produce electricity.

Goal:

develop methods for predicting soil properties over this entire landscape based on topography, climate, parent material and vegetation.

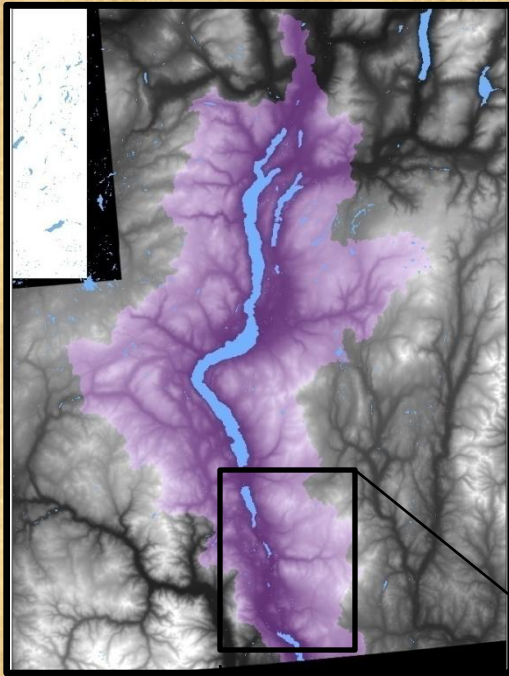
Based on high quality soil survey dataset (Okanagan “seamless’ coverage)

1:20,000 mapping in valley bottom

1:50,000 in forested uplands

Existing soil mapping:

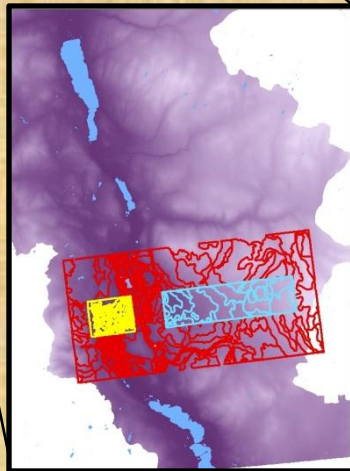
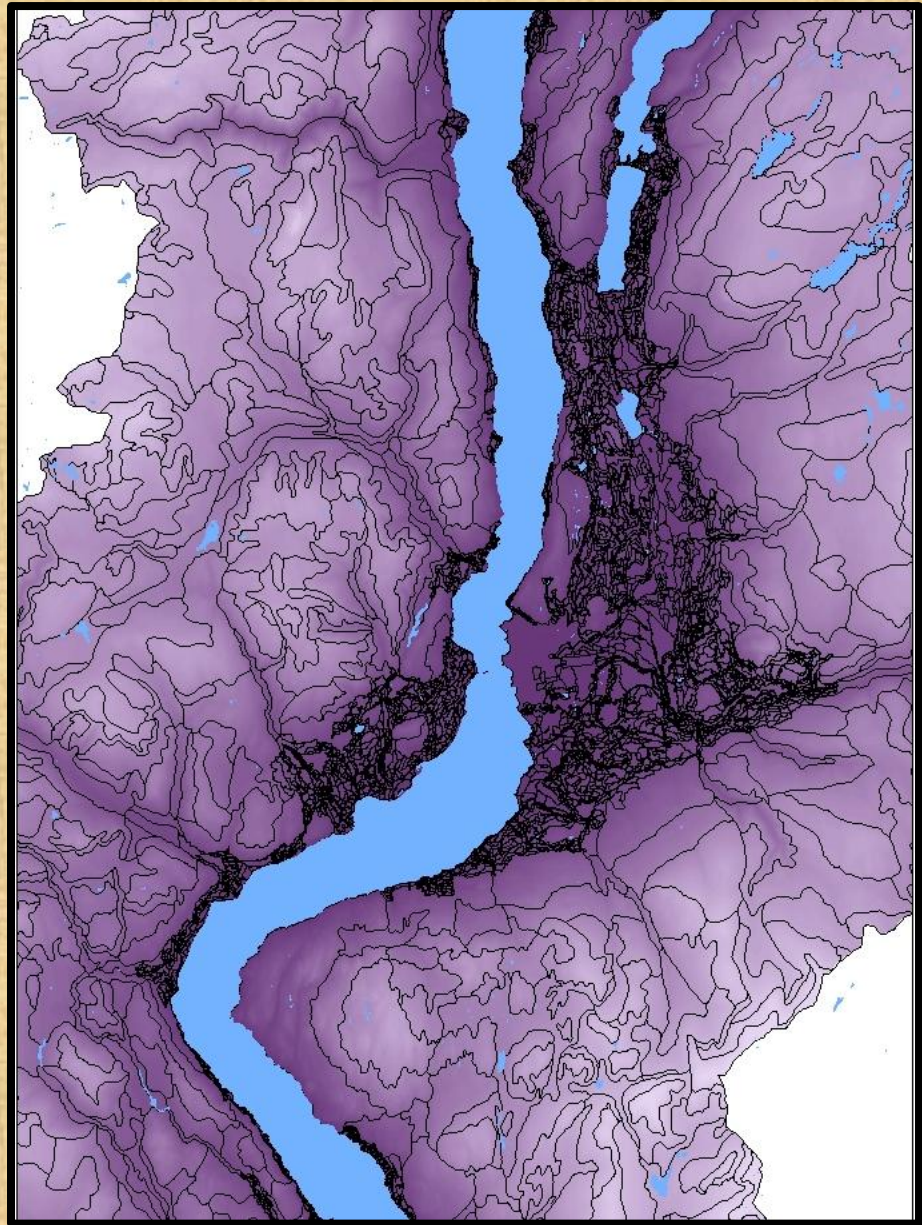
Okanagan Valley:



Polygons:
9245

Soil types:
171

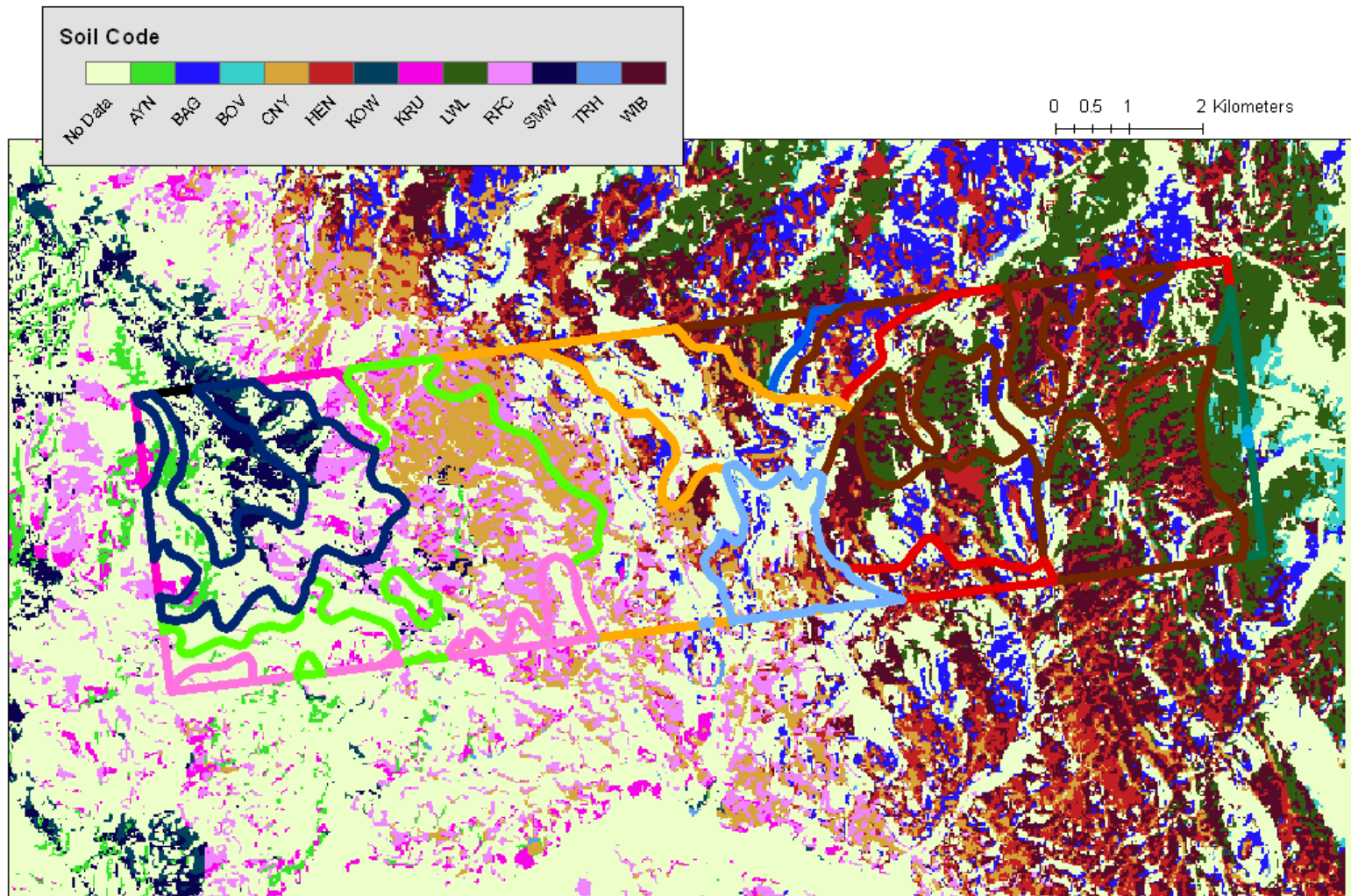
Test areas:



Images: G. Frank and E. Flager

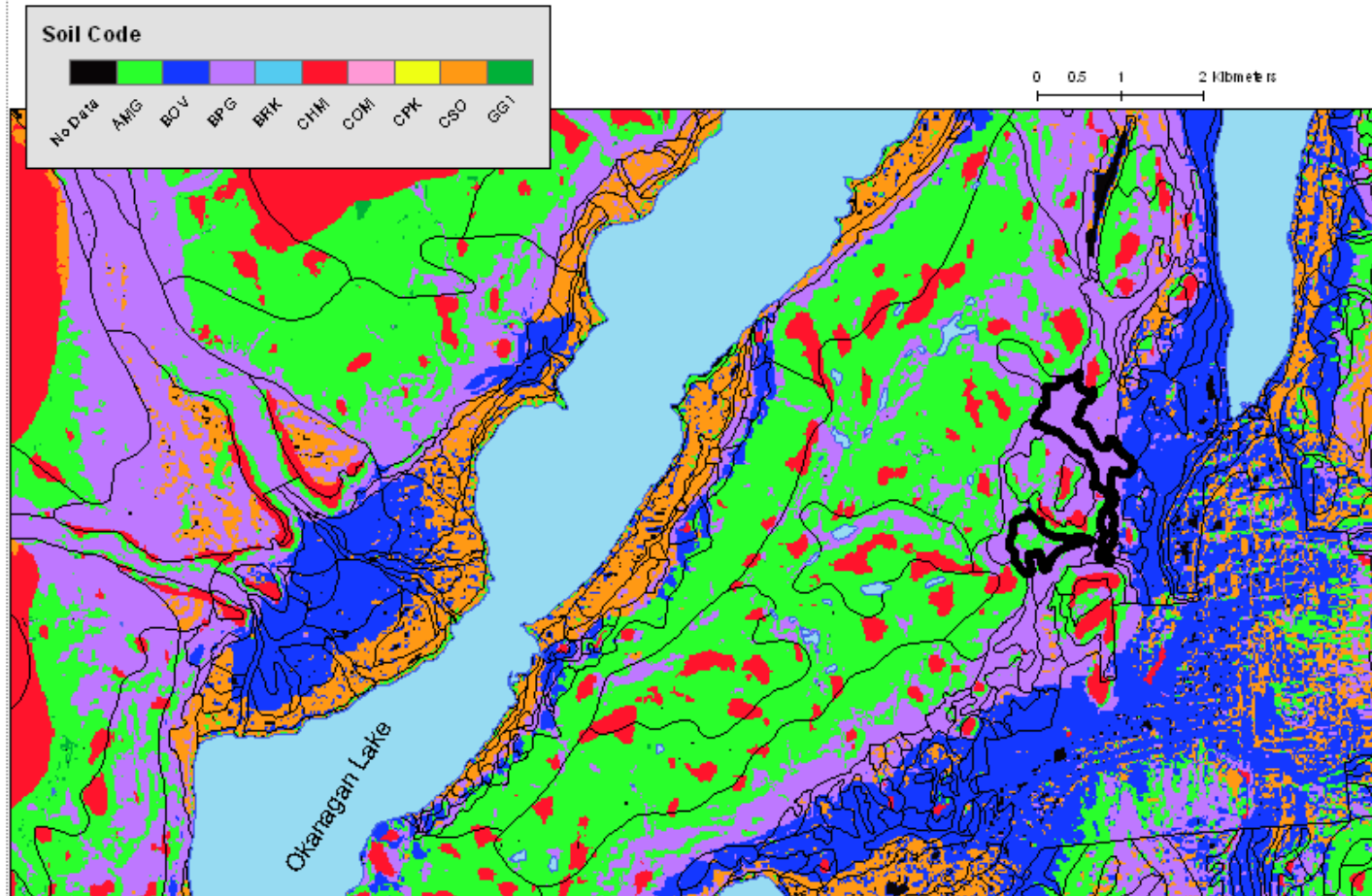
Okanagan Valley:

ArcSIE Prediction Of Uplands Southern Okanagan Test Area
Inputs: Aspect, Elevation; Curvature; Slope; TPI Landforms



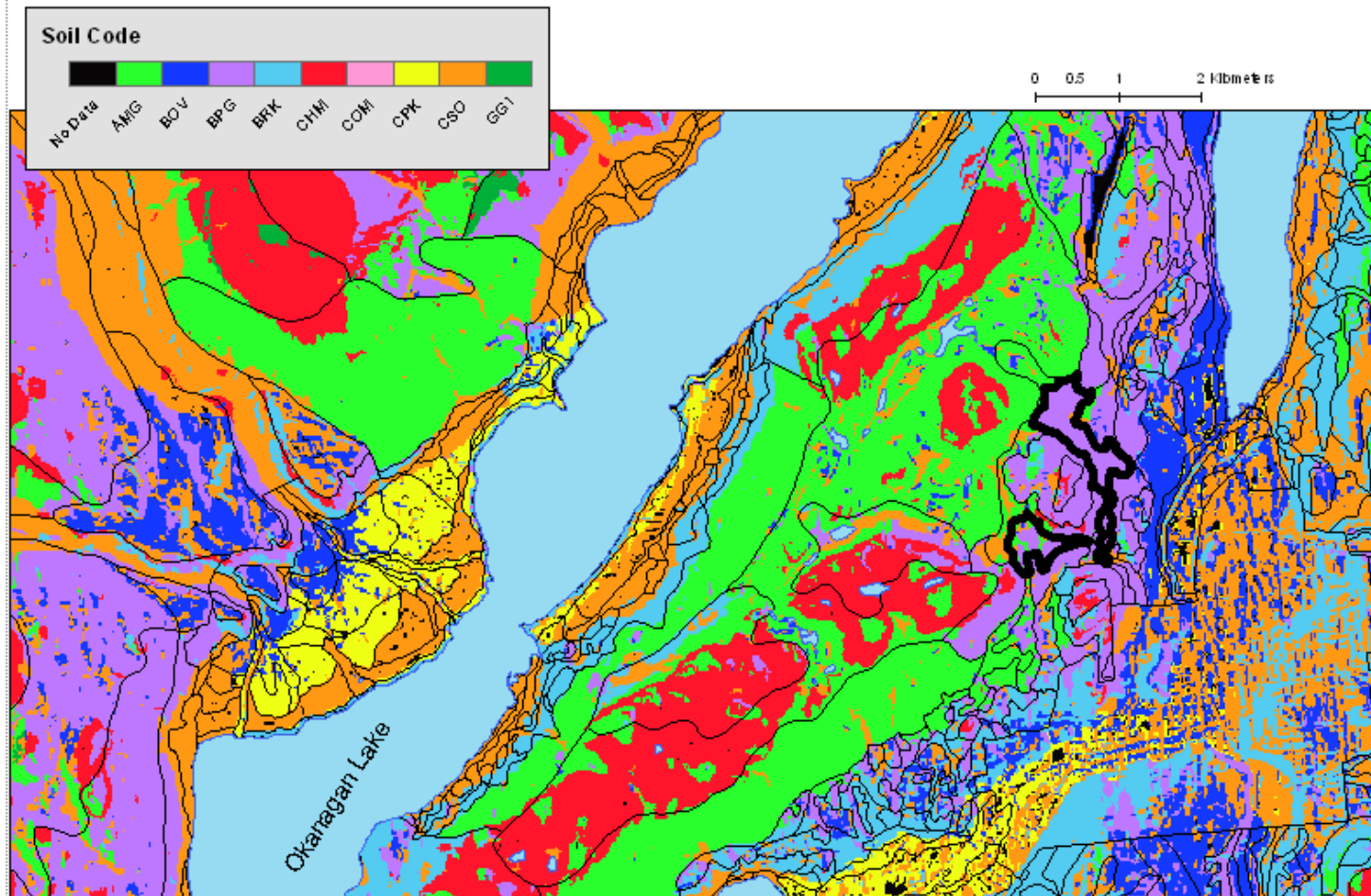
Okanagan Valley:

ArcSIE Soil Prediction of 9 Soil Types in Northern Okanagan
Inputs: Aspect; Elevation; Curvature; Slope; TPI Landforms; BEC zone/subzone



Okanagan Valley:

ArcSIE Soil Prediction of 9 Soil Types in Northern Okanagan
Inputs: Aspect; Elevation; Curvature; Slope; TPI Landforms; BEC zone/subzone



Landscape classification

“landscape classification is a fundamental aspect of DSM”

- establishes a base layer for modeling of environmental processes

our Goal:

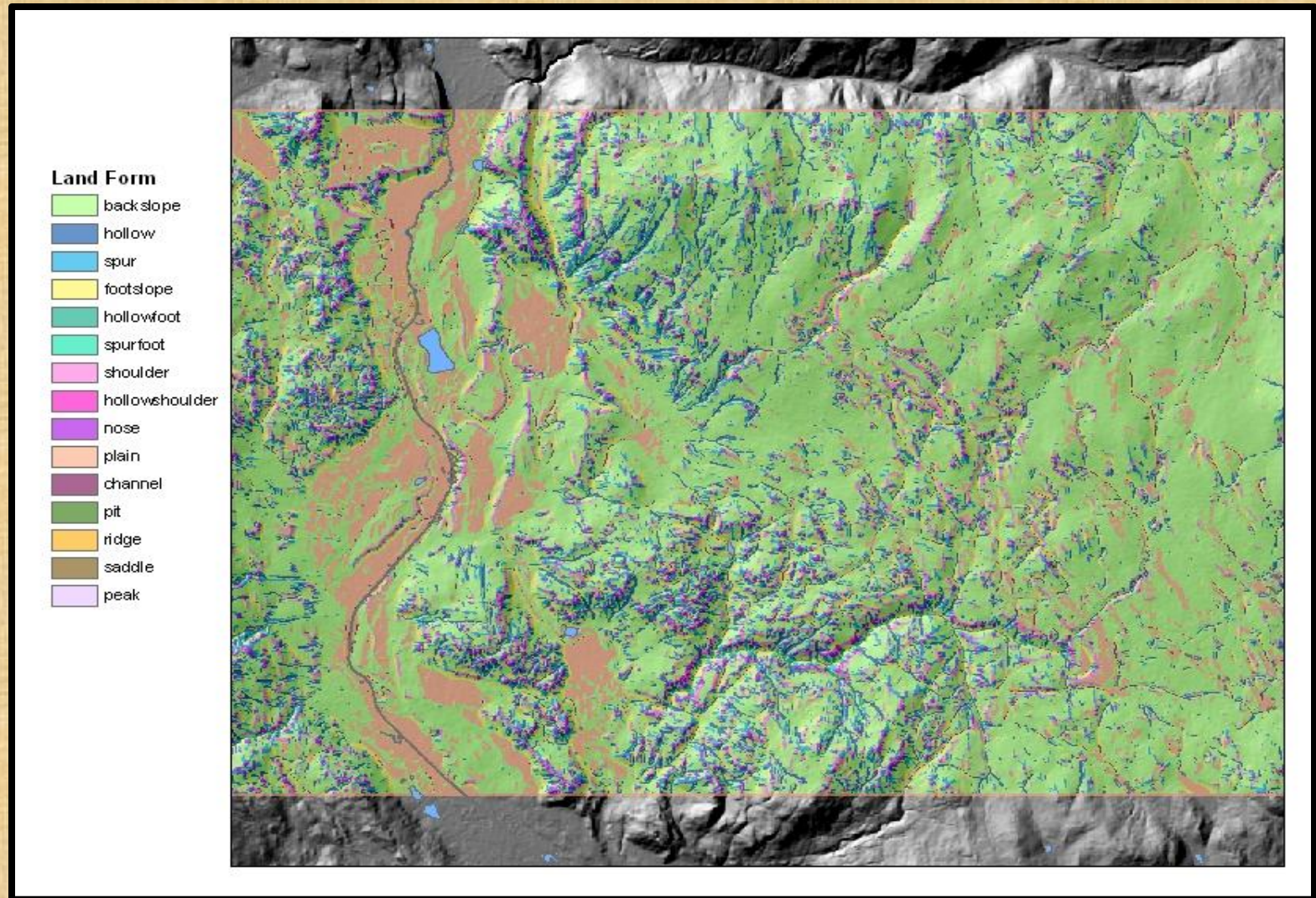
- to find or develop a procedure to classify BC's landscapes
- apply it to DSM
- evaluate the benefits in comparison to *“Direct to soil series”*

Questions: scale, ‘neighborhood’ size (analysis window), interpretation

Landscape classification:

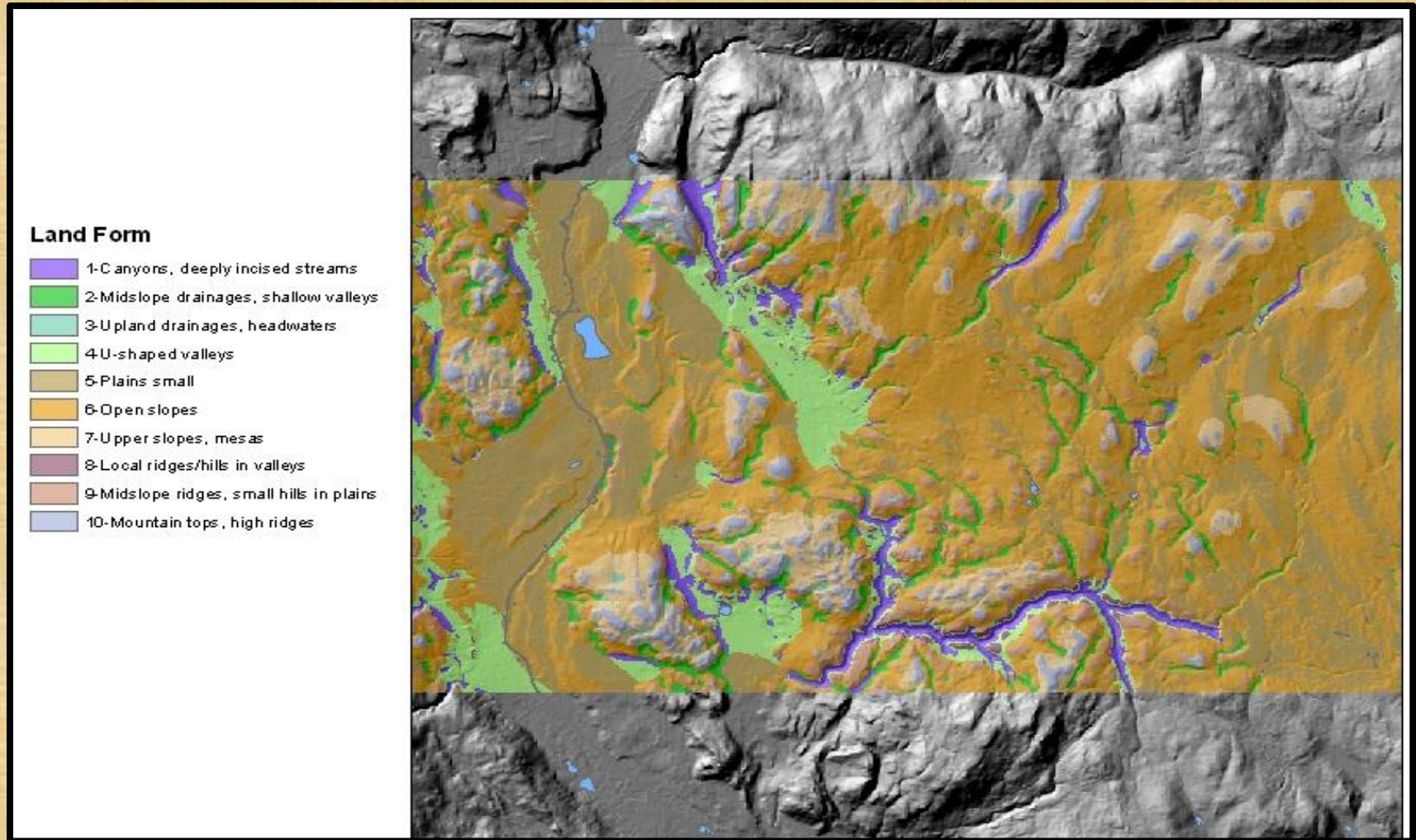
25m DEM

Schmidt & Hewitt



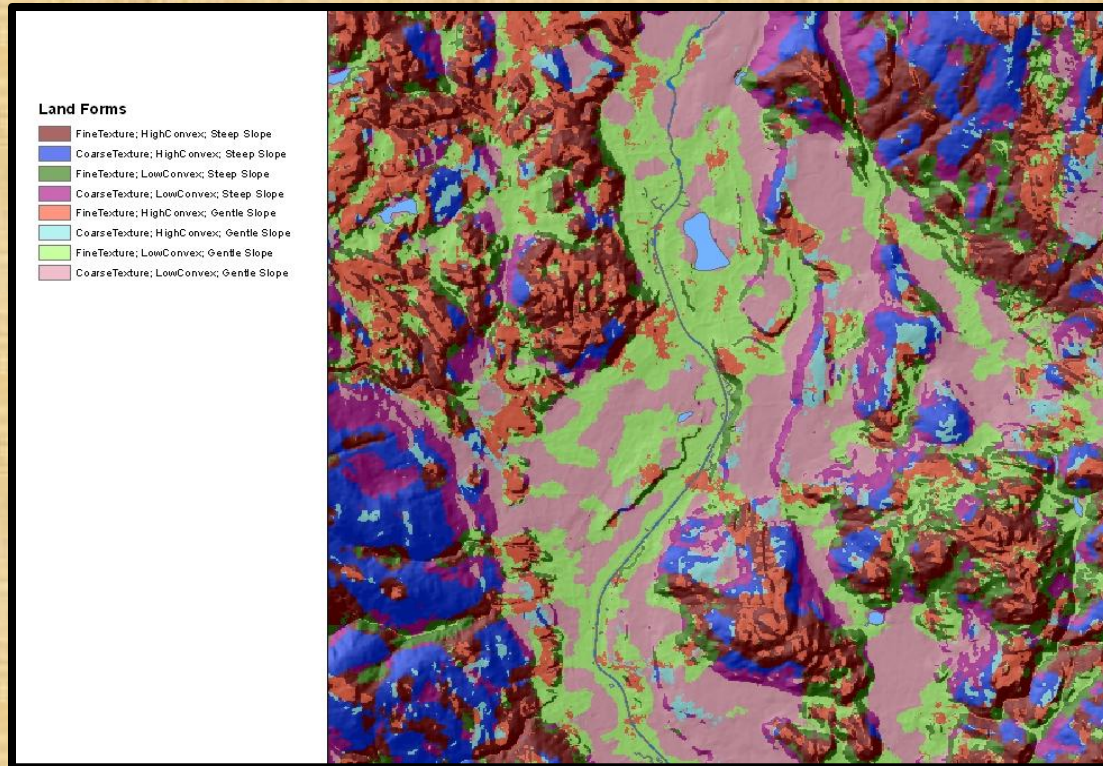
Landscape classification:

TPI (topographic position index)



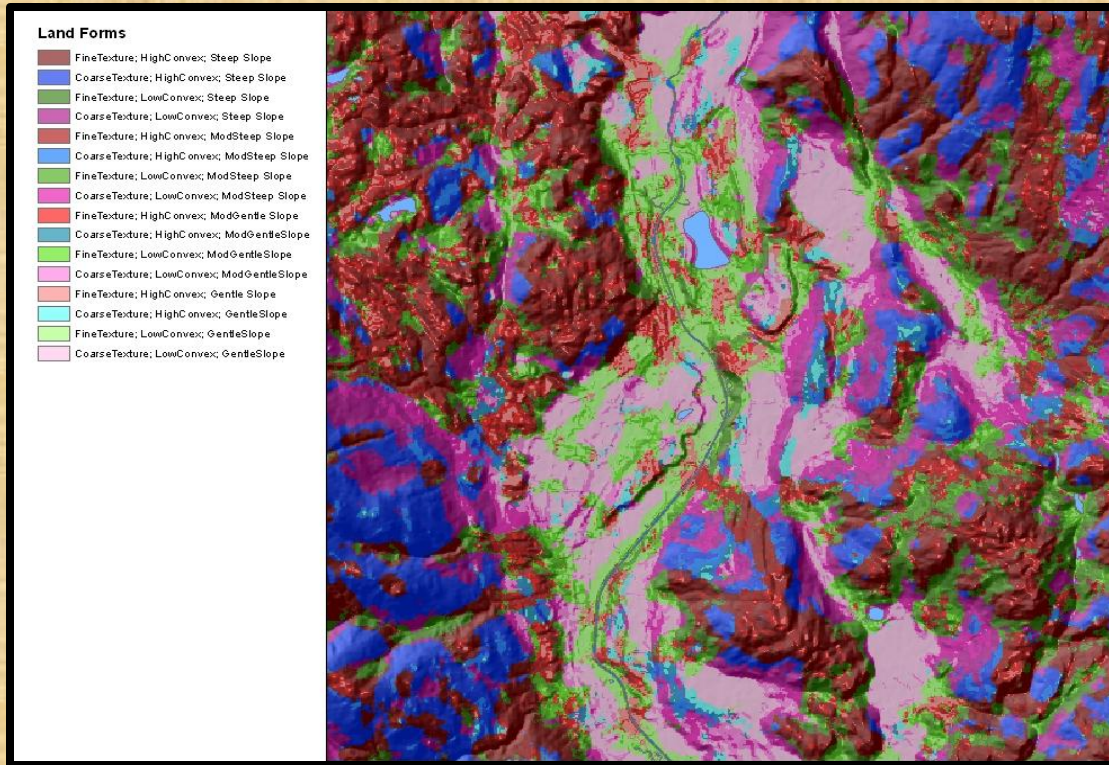
Landscape classification:

Iwahashi 8



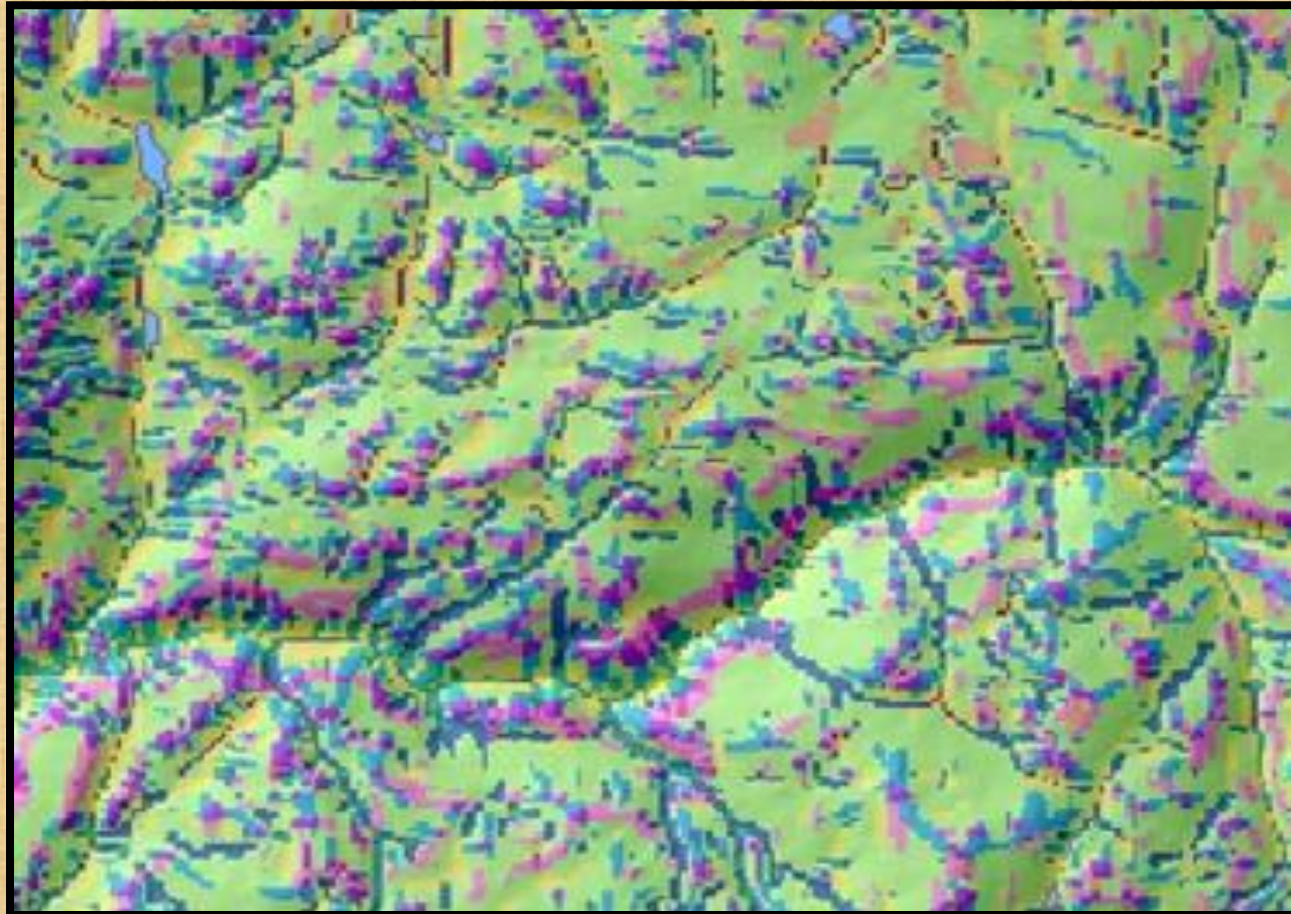
Landscape classification:

Iwahashi 16



Landscape classification:

25m DEM Schmidt Hewitt



Land Form

	back slope
	hollow
	spur
	fotslope
	hollowfoot
	spurfoot
	shoulder
	hollowshoulder
	nose
	plain
	channel
	pit
	ridge
	saddle
	peak

Landscape classification:

TPI

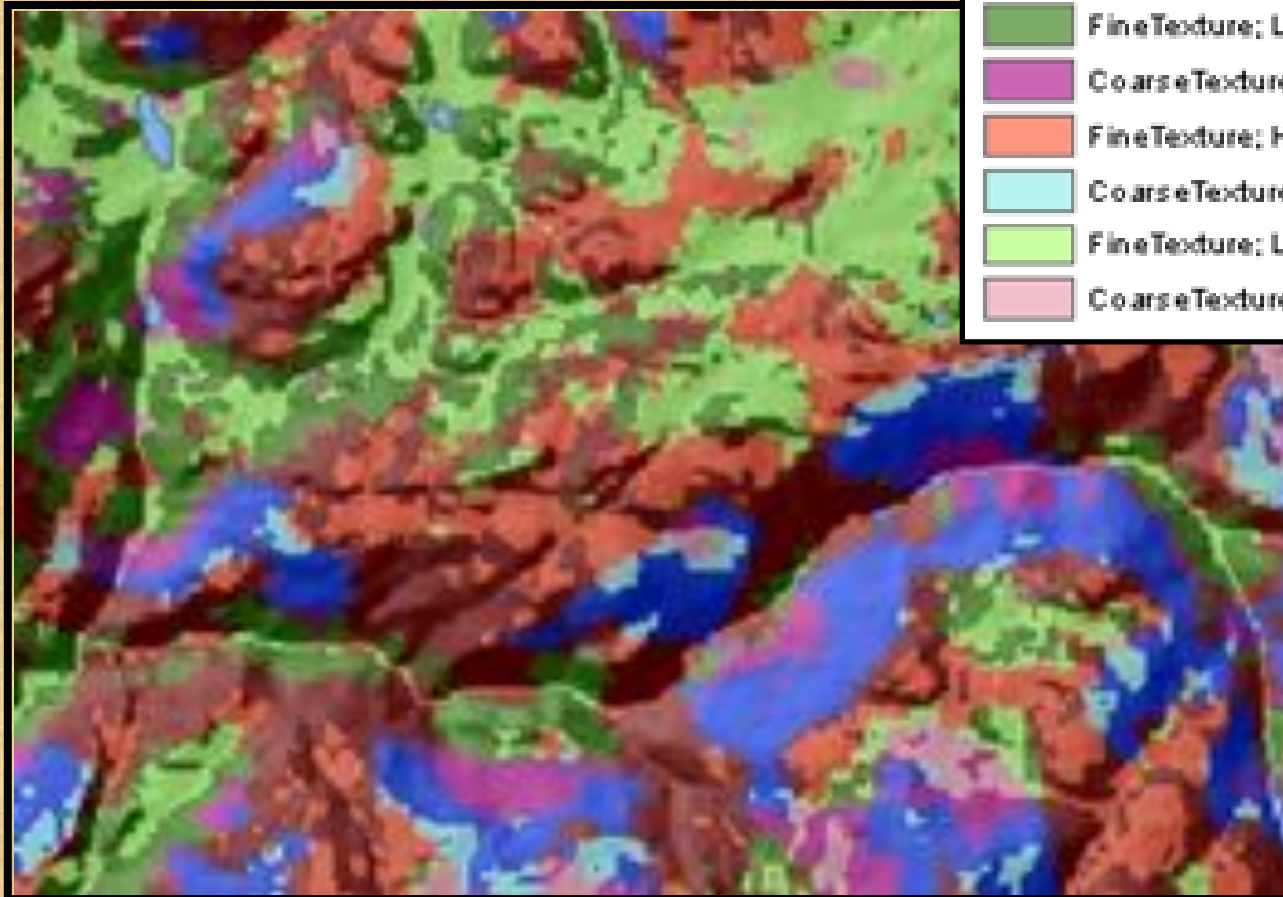
Land Form

- 1-C anyons, deeply incised streams
- 2-Midslope drainages, shallow valleys
- 3-U pland drainages, headwaters
- 4-U-shaped valleys
- 5-Plains small
- 6-Open slopes
- 7-Upper slopes, mesas
- 8-Local ridges/hills in valleys
- 9-Midslope ridges, small hills in plains
- 10-Mountain tops, high ridges



Landscape classification:

Iwahashi 8



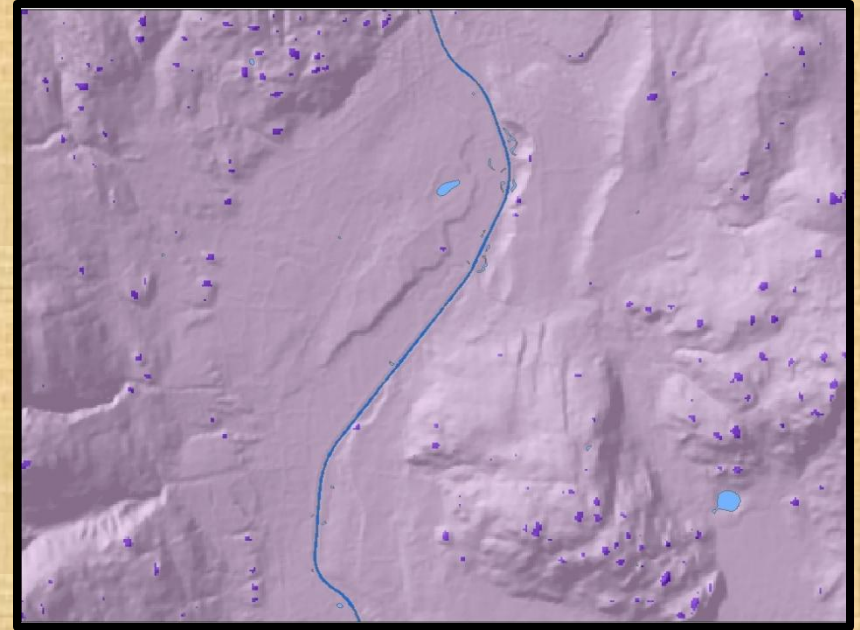
Land Forms

	FineTexture; HighConvex; Steep Slope
	CoarseTexture; HighConvex; Steep Slope
	FineTexture; LowConvex; Steep Slope
	CoarseTexture; LowConvex; Steep Slope
	FineTexture; HighConvex; Gentle Slope
	CoarseTexture; HighConvex; Gentle Slope
	FineTexture; LowConvex; Gentle Slope
	CoarseTexture; LowConvex; Gentle Slope

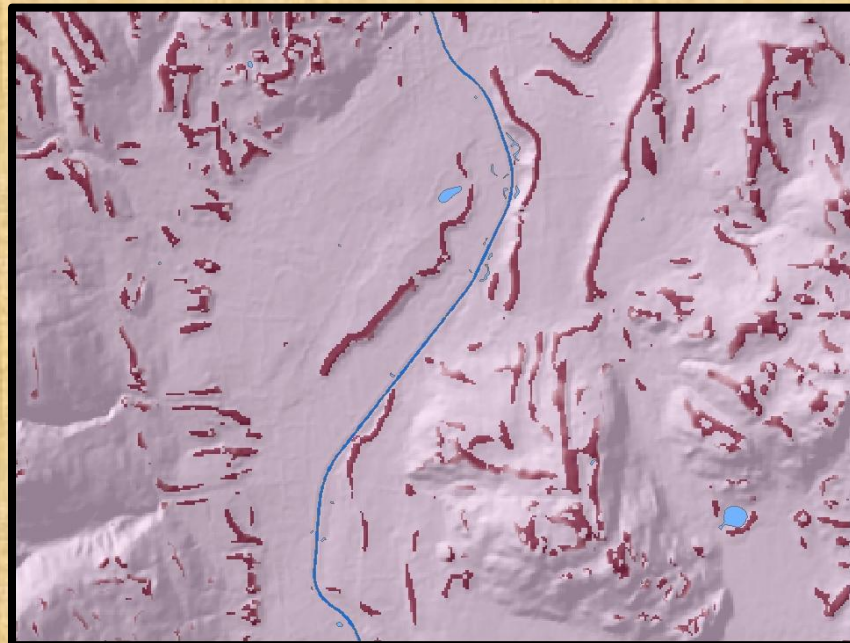
Schmidt Hewitt Plain



Schmidt Hewitt Peak

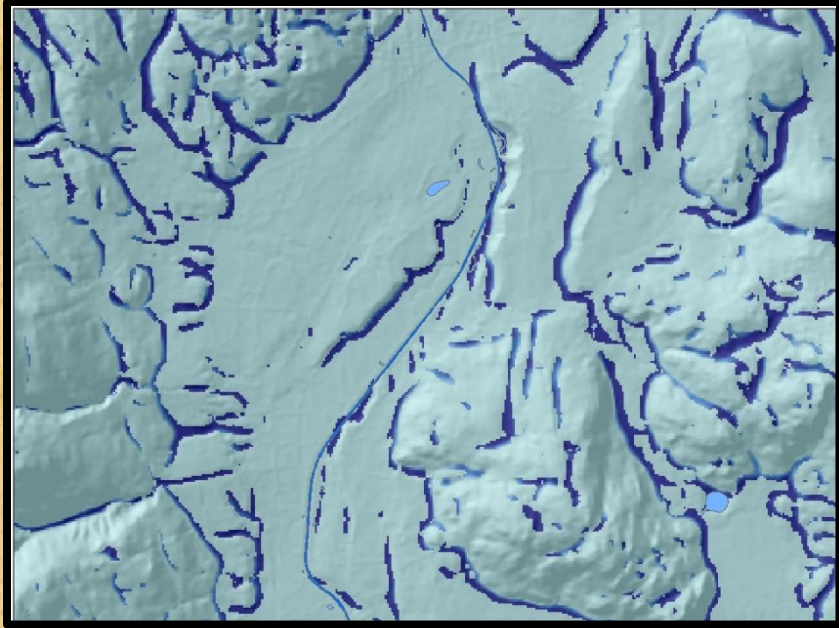


Schmidt Hewitt Ridge

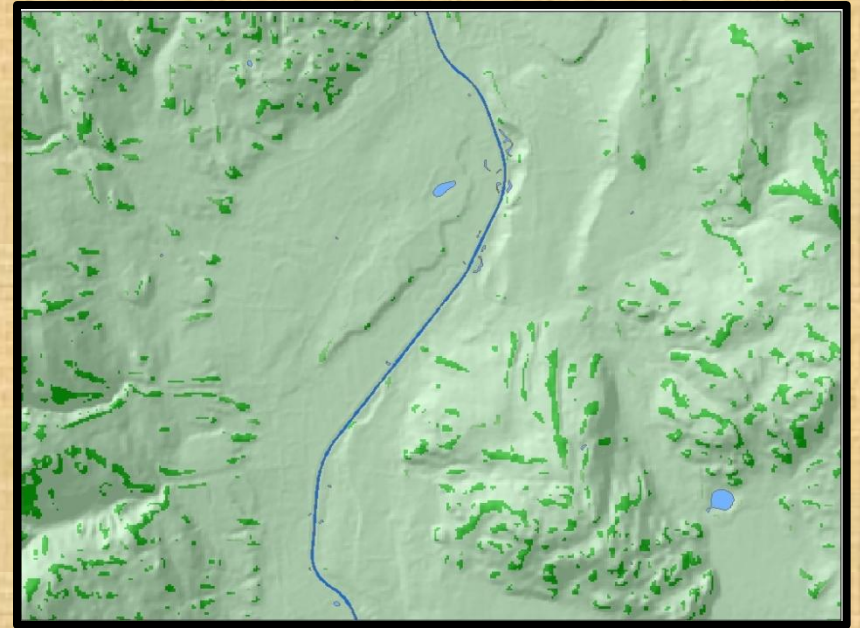


25m DEM

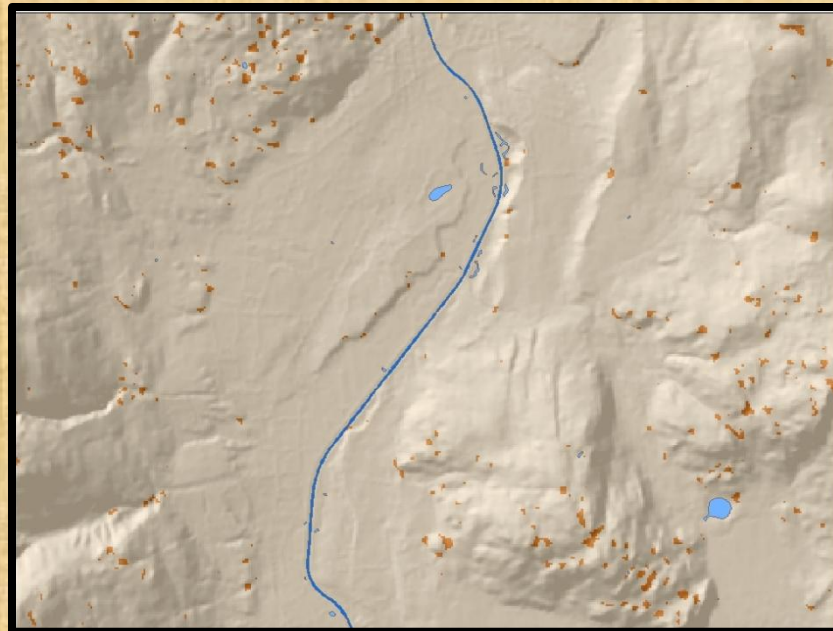
Schmidt Hewitt Channel



Schmidt Hewitt Spur

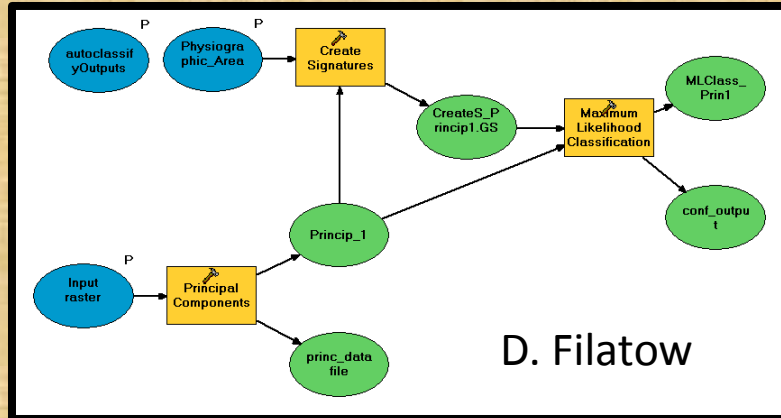


Schmidt Hewitt Saddle

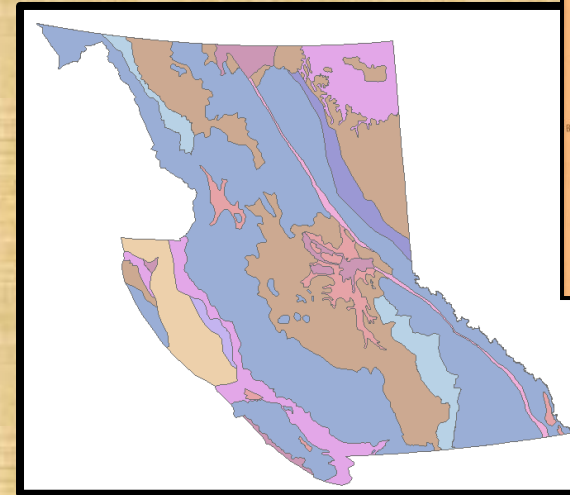
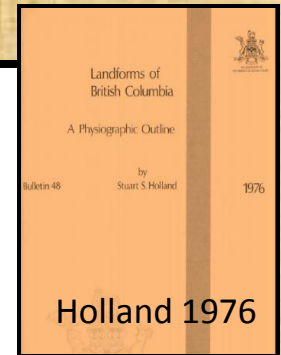


Landscape classification:

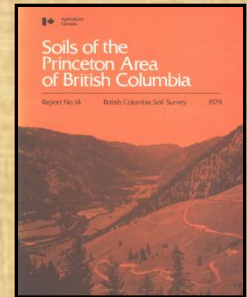
Auto Classify Model...



Physiographic Regions of BC

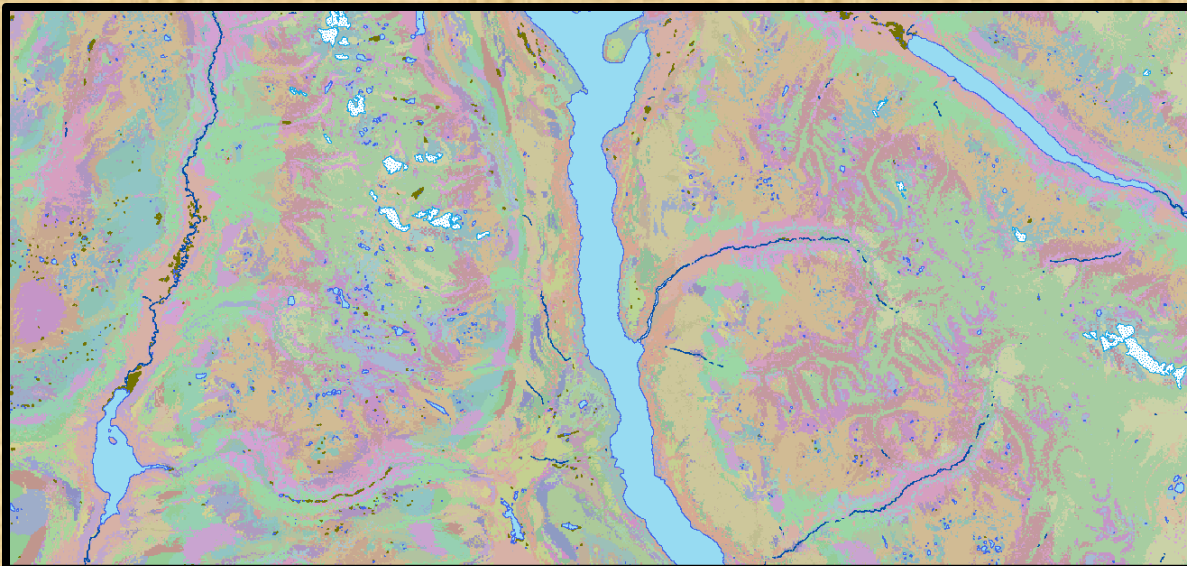


landforms



soils

Auto Classify ML output...



Quantitative analysis

- DEM scale ?
- neighbourhood size ?
- relation to soil props ?

Disaggregation of SLC polygons

Soil landscapes polygons generally contain more than one component

Spatial disaggregation based on topography and other attributes

Provides more detailed, and spatially explicit information on soil conditions

Goal: experiment with techniques for a small area in south interior

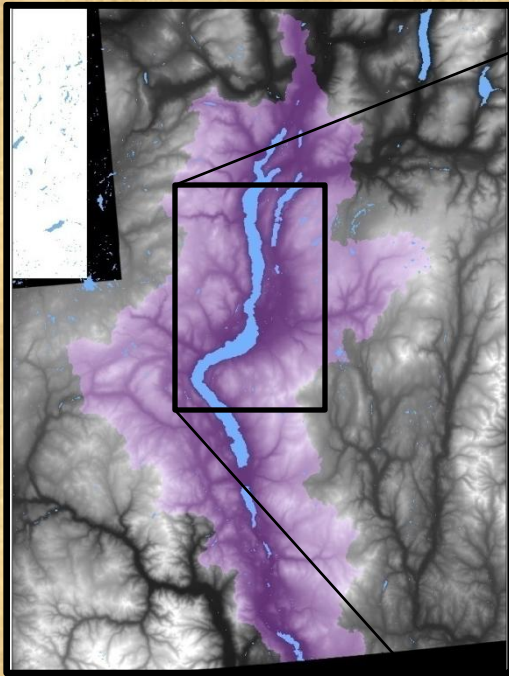
Results will also relevant for more detailed soil and terrain maps

Current focus:

- 1 ha DEM from HectaresBC
- test methods on a small area in southern BC
- develop methods suitable for efficient application over large areas

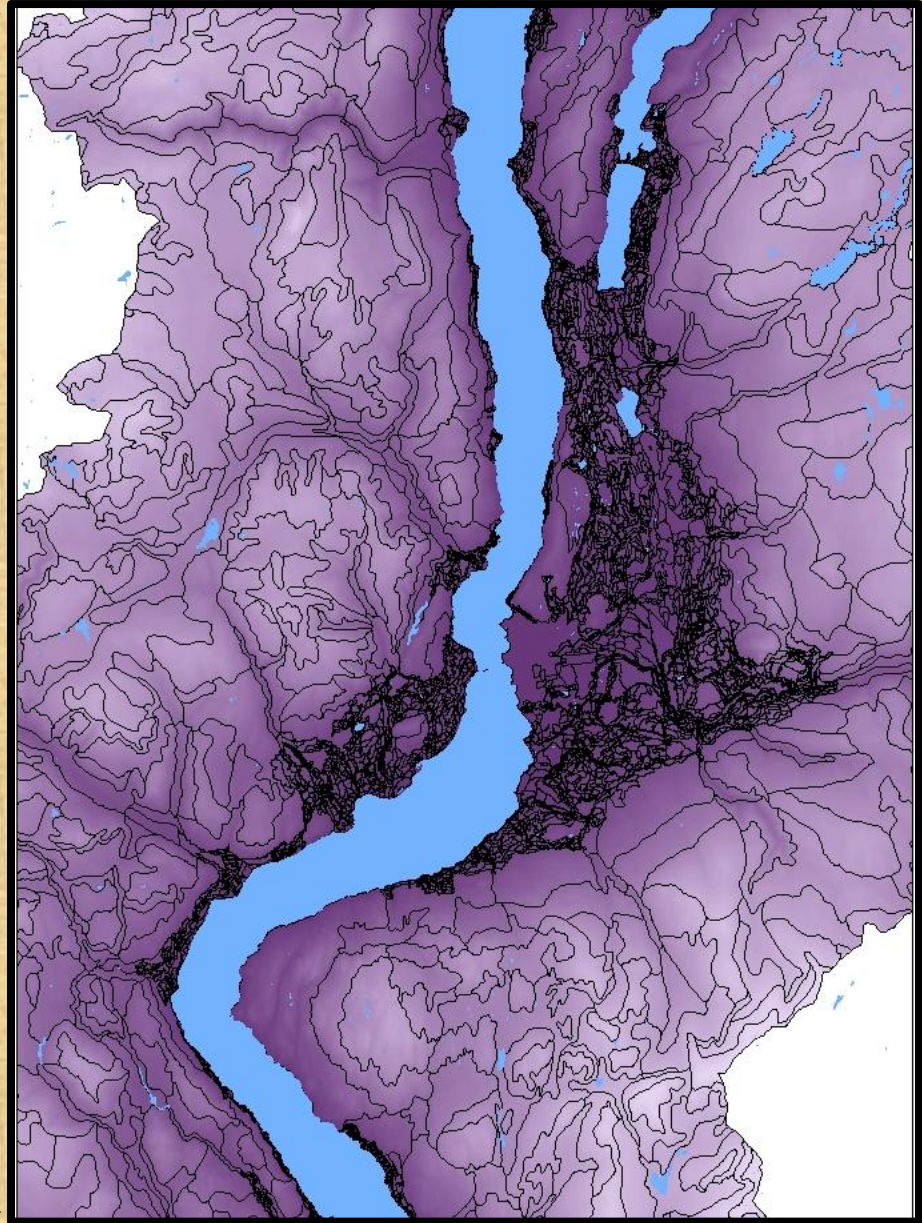
Existing soil mapping:

Okanagan Valley:



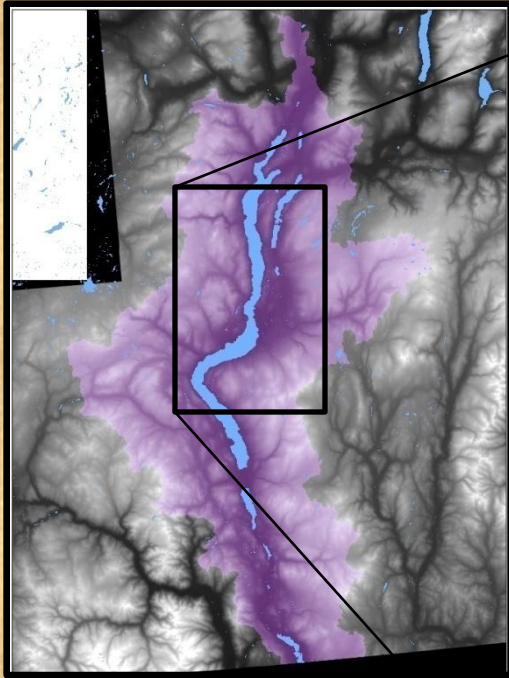
Polygons:
9245

Soil types:
171



Soil mapping(SLC):

Okanagan Valley:



Polygons:
9245

Soil types:
171

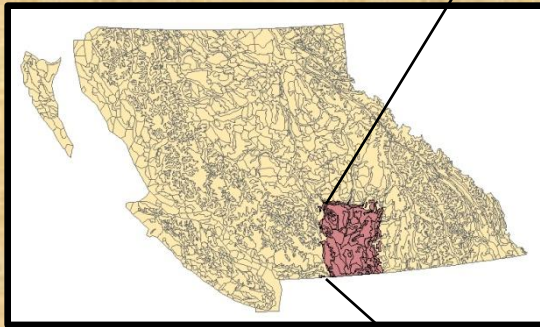
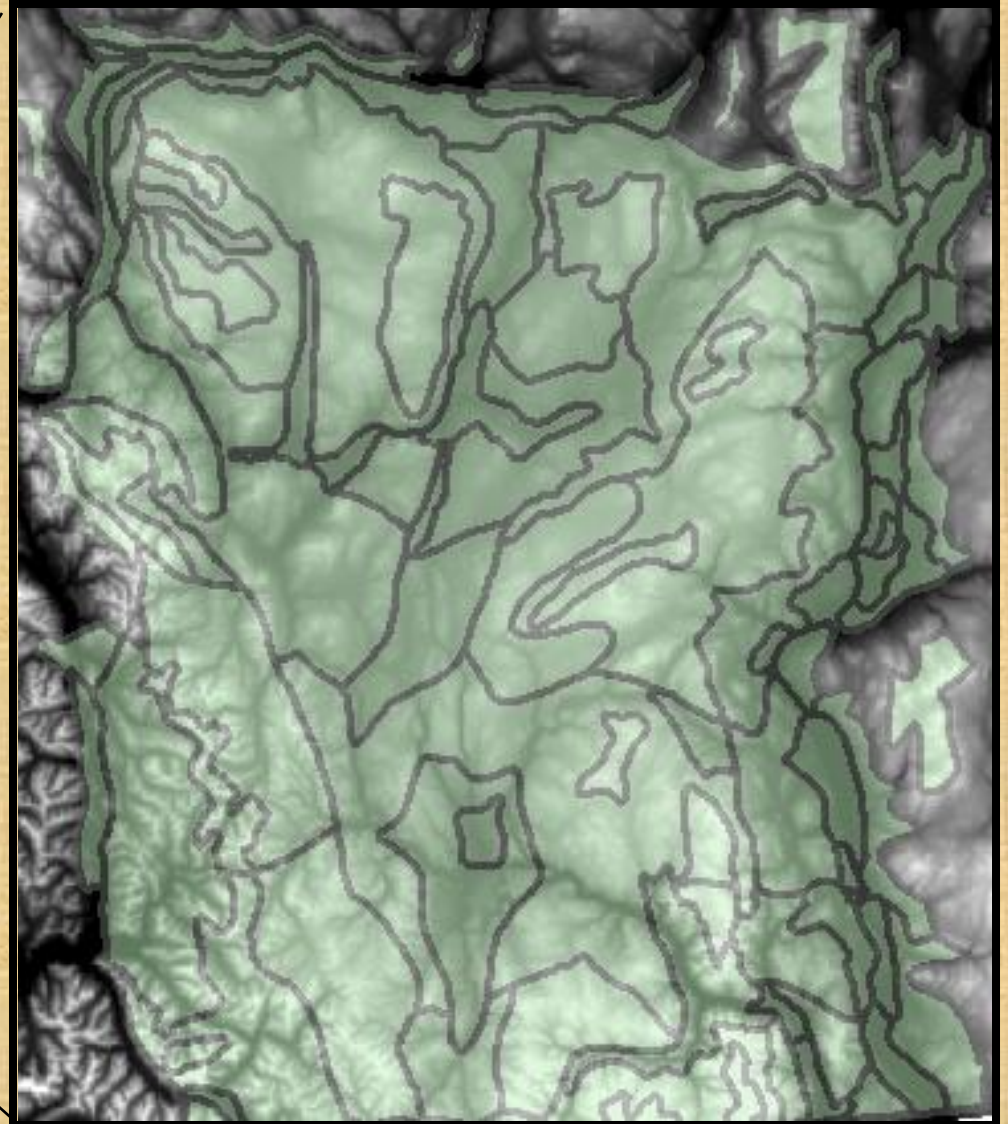
**SLC poly's:
104**



Disaggregation:

Test area:

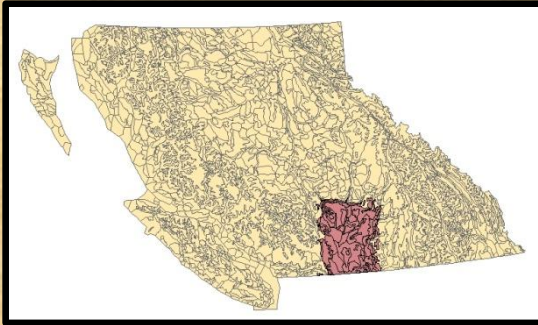
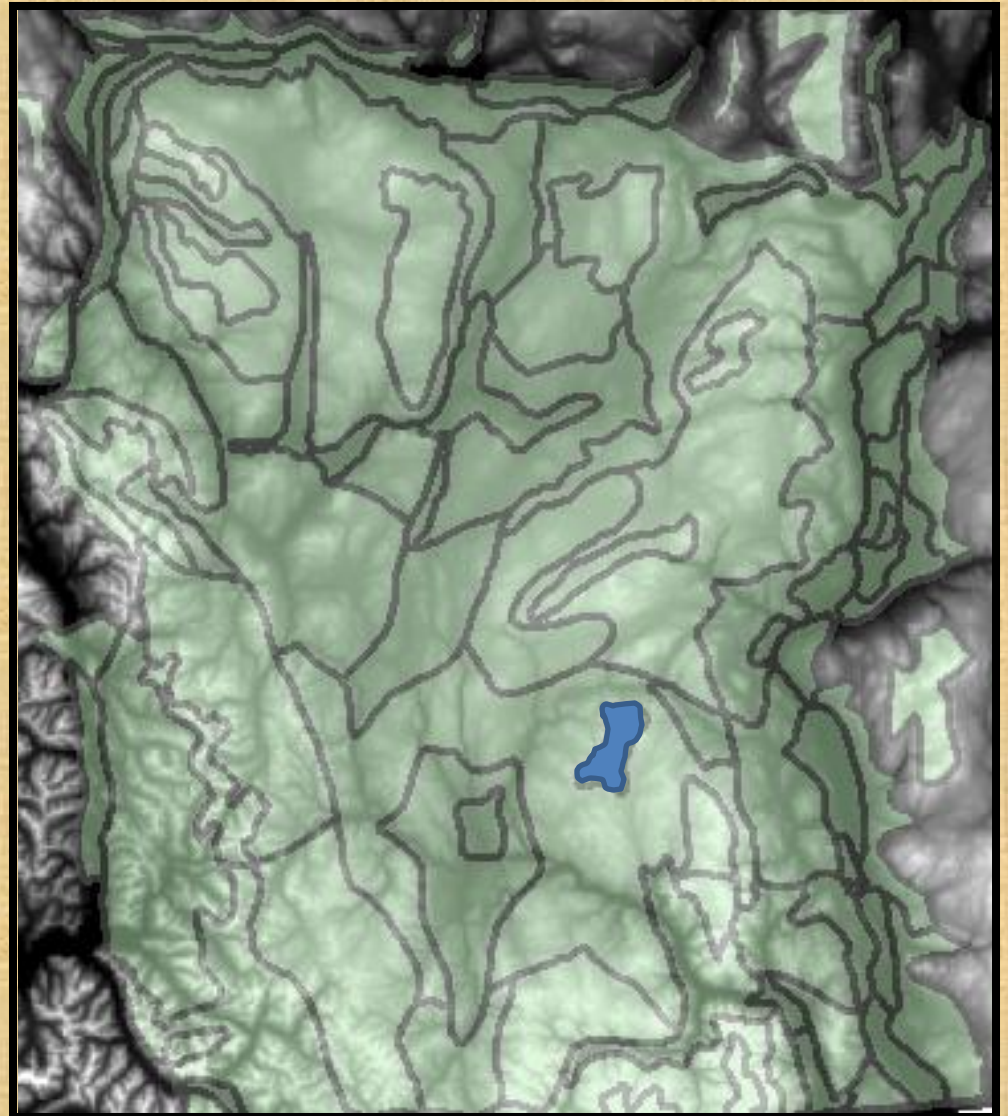
- Okanagan / Thompson
- ca. 100 polygons
- ca. 100 soil types



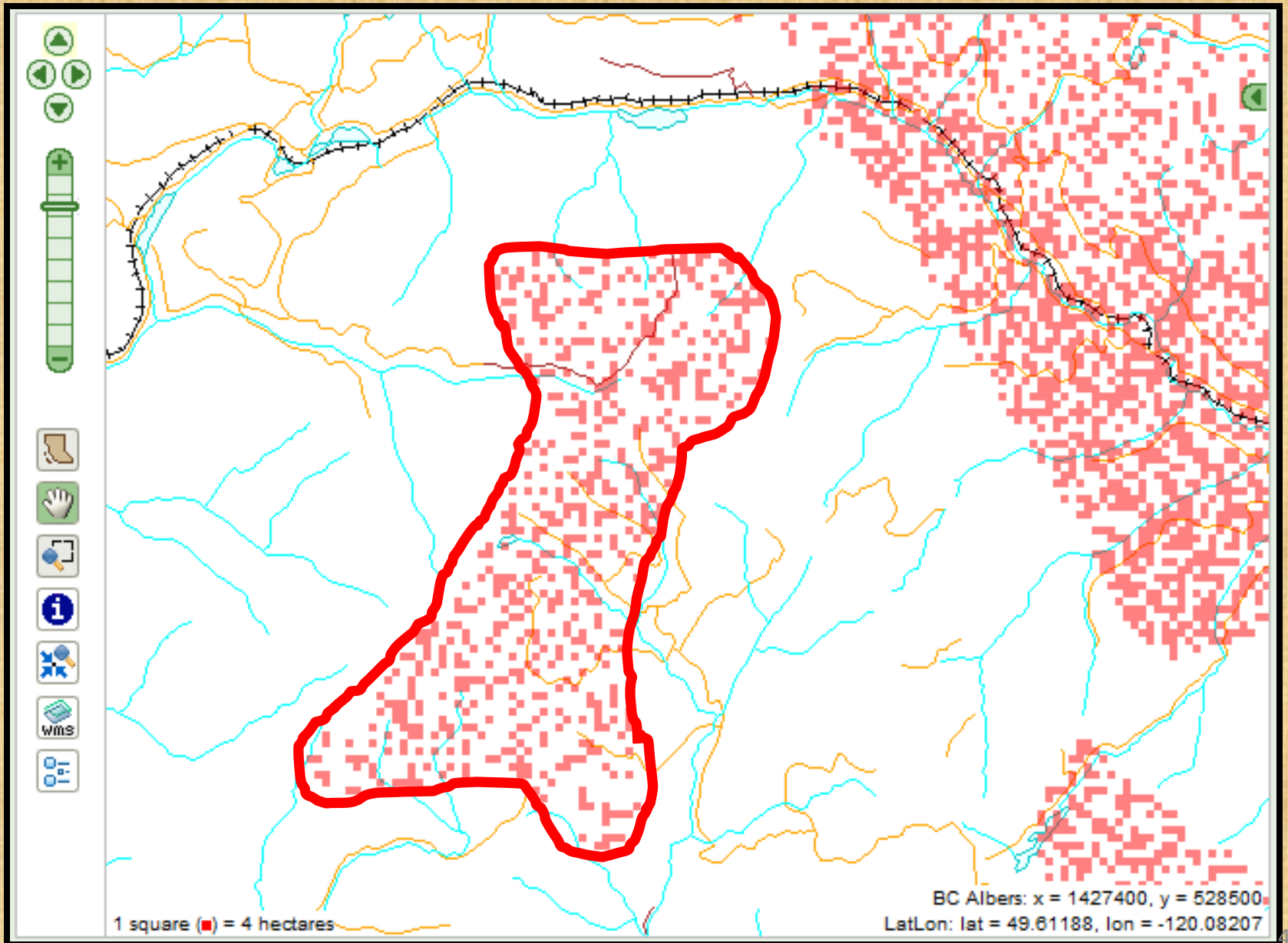
Disaggregation:

Test area:

- Okanagan / Thompson
- ca. 100 polygons
- ca. 100 soil types

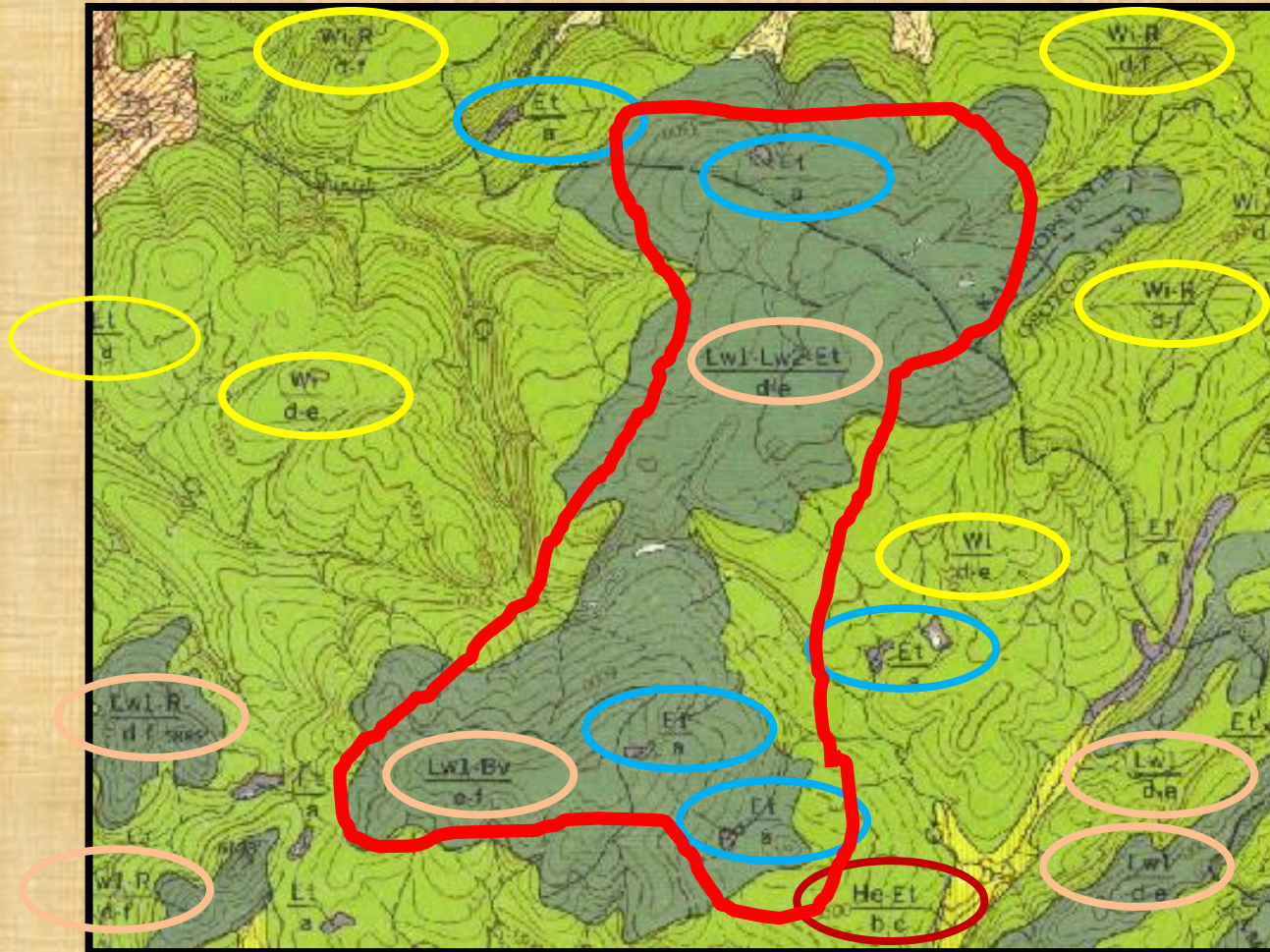


Background (digital coverage: Hectares BC):



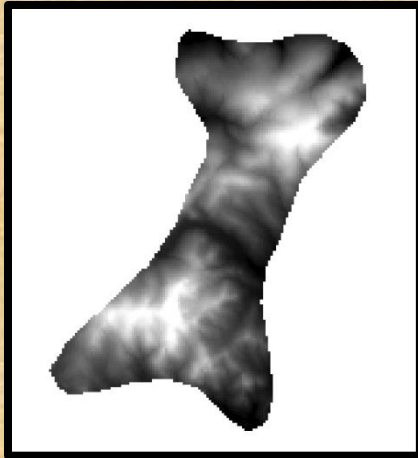
Background (Tulameen soil survey 1:125,000):

TM Lord and AJ Green 1974. Soils of the Tulameen Area.
Report 13 BC Soil Survey. Agriculture Canada



Disaggregation (1ha pixels):

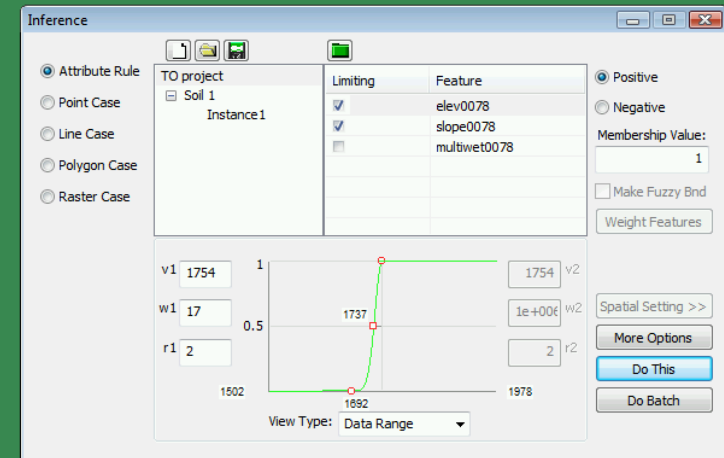
Elevation



Slope



Soil inference:



Database (11 rasters per polygon):

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	SL	CMP	%	KIND	VEGET	PINDEX	FRAG	ROOTFOR	DRAN	DEVEL	CALC	LOCSE	SLOPE	SNF	SOIL_CC	MODIFIED	SLCMP	
2	590078	1	30	SO	C	M	C	B	M	W	0	M	C	BC	LWL		59007801	
3	590078	2	30	SO	C	M	C	B	W	W	0	M	C	BC	NCM		59007802	
4	590078	3	15	SO	C	C	C	B	W	W	0	M	D	BC	SKT		59007803	
5	590078	4	15	SO	TA	C	C	B	R	N	0	M	D	BC	BOV		59007804	
6	590078	5	10	SO	T	M	B	B	P	U	0	U	B	BC	GLF		59007805	
7																		
8																		
9																		
10		590078		590078		590078		590078		590078			590078		590078		590078	
11		elev		slope		curv25		multiwet		10kWh			dec	590078	iwahashi		590078	
12		low		low		-5		-4		103		IMA	0	0.00	1		0.02	
13	0.0	1510		6		-2		-3		103		IDF	1	0.00	2		0.03	
14	0.1	1620		6		-2		-3		114		ESSF	2	0.72	3		0.00	
15	0.2	1660		8		-1		-2		116		ICH	3	0.00	4		0.00	
16	0.3	1680		10		-1		-2		119		CMA	4	0.00	5		0.56	
17	0.4	1710		11		-1		-2		121			6	0.00	6		0.34	
18	0.5	1730		13		-1		-1		122		MS	7	0.28	7		0.04	
19	0.6	1750		15		-1		-1		124		CVWH	8	0.00	8		0.01	
20	0.7	1780		17		-1		-1		125		PP	12	0.00	NODATA		0	
21	0.8	1800		19		-1		-1		127		BG	15	0.00				
22	0.9	1840		23		0		0		129					NODATA		0	
23	1.0	1940		43		4		15		133								
24		high		high		convex		wet		more								
25	NODATA	#N/A		1		1		1		1								
26																		
27																		
28	Comments:	Assign soils in the following order: Bonnevier (high elevation - tundra) Gulliford (wet), Look for wetland layer Skait (steep) Lawless/Nicomen. Complex of whatever is left LAWNIC										590078	590078	590078	590078	590078		
29												wetlands						
30												lakes						
31											yes	0.00	0.00	0.00	0.00	0.00		
32											no	1.00	1.00	1.00	1.00	1.00		
33																		
34																		
35	Limiting values of attributes (* = used in inference)																	
36																		
37	SL	CMP	PERCENT		Elev*	Slope*	Curv	Wet	10_kWh						Name	SLCMP		
38	590078	1	30		<1840	6<sl<19	<3								Lawless	59007801		
39	590078	2	30		<1840	6<sl<19	<3								Nicomen	59007802		
40	590078	3	15		<1840	>19	<3								Skait	59007803		
41	590078	4	15		>1840		<3								Bonnevier	59007804		
42	590078	5	10		<1840	<6	>3								Gulliford	59007805		
43																		

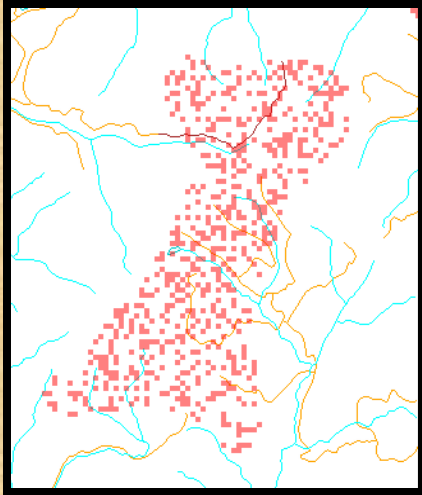
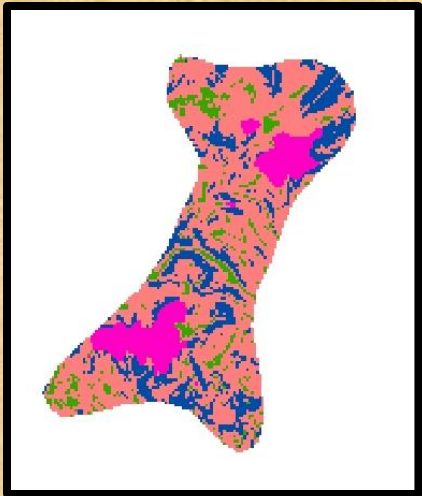
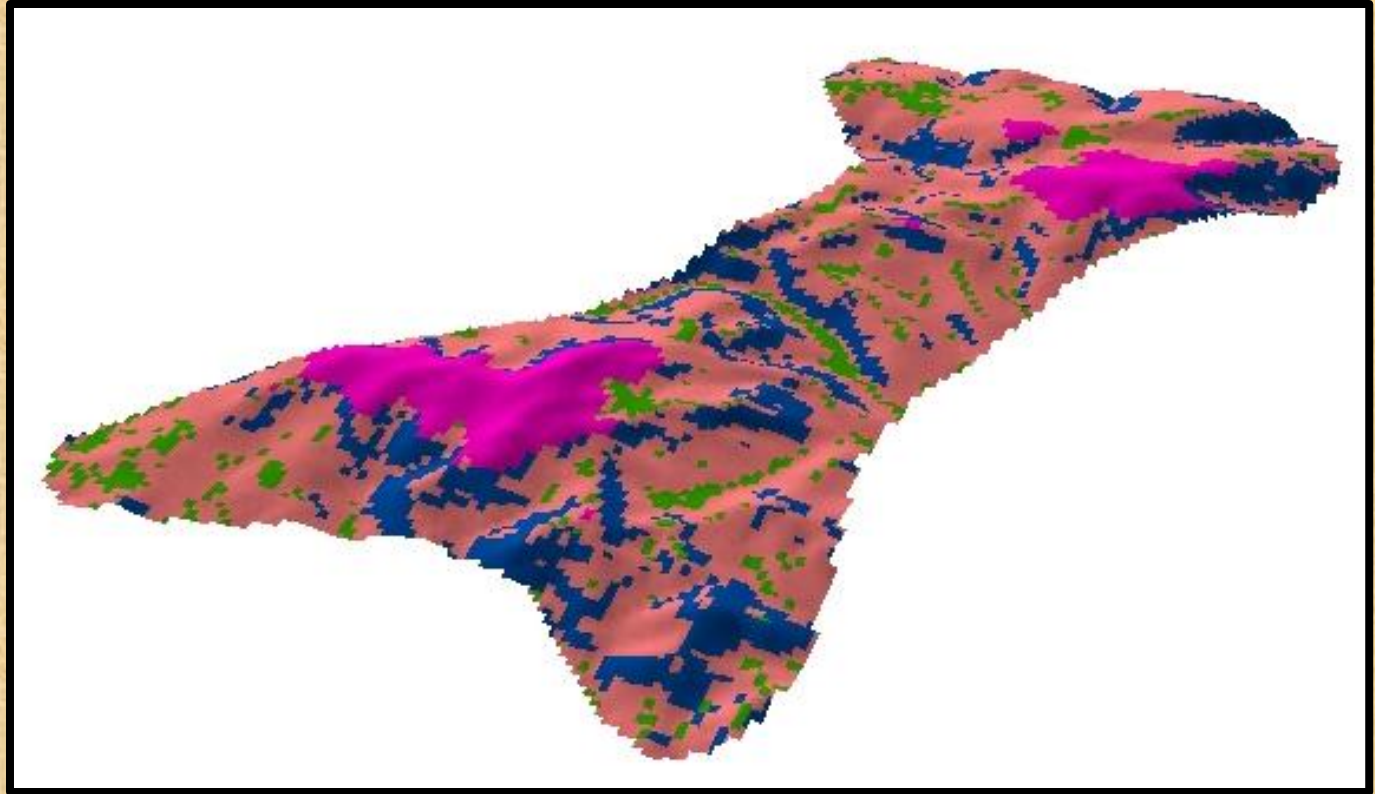
Disaggregation:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	SL	CMP	%	KINDMAT	VEGET	PMDEP	CFRAG	ROOTDF	DRAIN	DEVEL	CALC	LOCSF	SLOPE	SNF	SOIL_CC	MODIFIE	SLCMP
2	590078	1	30	SO	C	M	C	B	M	W	0	M	C	BC	LWL		59007801
3	590078	2	30	SO	C	M	C	B	W	W	0	M	C	BC	NCM		59007802
4	590078	3	15	SO	C	C	C	B	W	W	0	M	D	BC	SKT		59007803
5	590078	4	15	SO	TA	C	C	B	R	N	0	M	D	BC	BOV		59007804
6	590078	5	10	SO	F	M	B	B	P	U	0	U	B	BC	GLF		59007805
7																	
8																	
9																	
10		590078		590078		590078		590078		590078			590078			590078	
11		elev		slope		curv25		multiwet		10kWh			bec	590078		iwahashi	590078
12		low		low		concave		dry		less		IMA	0	0.00		1	0.02
13	0.0	1510		0		-6		-4		103		IDF	1	0.00		2	0.03
14	0.1	1620		6		-2		-3		114		ESSF	2	0.72		3	0.00
15	0.2	1660		8		-1		-2		116		ICH	3	0.00		4	0.00
16	0.3	1680		10		-1		-2		119		CMA	4	0.00		5	0.56
17	0.4	1710		11		-1		-2		121			6	0.00		6	0.34
18	0.5	1730		13		-1		-1		122		MS	7	0.28		7	0.04
19	0.6	1750		15		-1		-1		124		CWH	8	0.00		8	0.01
20	0.7	1780		17		-1		-1		125		PP	12	0.00		NODATA	0
21	0.8	1800		19		-1		-1		127		BG	15	0.00			
22	0.9	1840		23		0		0		129			NODATA	0			
23	1.0	1940		43		4		15		133							
24		high		high		convex		wet		more							
25	NODATA	#N/A		1		1		1		1							
26																	
27																	
28	Comments:				Assign soils in the following order:												
29					Bonnevier (high elevation - tundra)							590078	590078	590078	590078	590078	
30					Gulliford (wet).. Look for wetland layer							wetlands	lakes	rivers	quatern		
31					Skaist (steep)						yes	0.00	0.00	0.00	0.00	0.00	
32					Lawless/Nicomen.. Complex of whatever is left LAWNIC						no	1.00	1.00	1.00	1.00	1.00	
33																	
34																	
35	Limiting values of attributes (* = used in inference)																
36																	
37	SL	CMP	PERCENT		Elev*	Slope*	Curv	Wet		10_kWh					Name		SLCMP
38	590078	1	30		<1840	6<s <19		<3							Lawless		59007801
39	590078	2	30		<1840	6<s <19		<3							Nicomen		59007802
40	590078	3	15		<1840	>19		<3							Skaist		59007803
41	590078	4	15		>1840			<3							Bonnevier		59007804
42	590078	5	10		<1840	<6		>3							Gulliford		59007805
43																	

Disaggregation:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	SL	CMP	%	KINDMAT	VEGET	PMDEP	CFRAG	ROOTDF	DRAIN	DEVEL	CALC	LOCSF	SLOPE	SNF	SOIL_CD	MODIFIE	SLCMP
2	590078	1	30	SO	C	M	C	B	M	W	0	M	C	BC	LWL		59007801
3	590078	2	30	SO	C	M	C	B	W	W	0	M	C	BC	NCM		59007802
4	590078	3	15	SO	C	C	C	B	W	W	0	M	D	BC	SKT		59007803
5	590078	4	15	SO	TA	C	C	B	R	N	0	M	D	BC	BOV		59007804
6	590078	5	10	SO	F	M	B	B	P	U	0	U	B	BC	GLF		59007805
7																	
8																	
9																	
10		590078		590078		590078		590078		590078			590078			590078	
11		elev		slope		curv25		multiwet		10kWh			bec	590078		iwahashi	590078
12		low		low		concave		dry		less		IMA	0	0.00		1	0.02
13	0.0	1510		0		-6		-4		103		IDF	1	0.00		2	0.03
14	0.1	1620		6		-2		-3		114		ESSF	2	0.72		3	0.00
15	0.2	1660		8		-1		-2		116		ICH	3	0.00		4	0.00
16	0.3	1680		10		-1		-2		119		CMA	4	0.00		5	0.56
17	0.4	1710		11		-1		-2		121			6	0.00		6	0.34
18	0.5	1730		13		-1		-1		122		MS	7	0.28		7	0.04
19	0.6	1750		15		-1		-1		124		CWH	8	0.00		8	0.01
20	0.7	1780		17		-1		-1		125		PP	12	0.00		NODATA	0
21	0.8	1800		19		-1		-1		127		BG	15	0.00			
22	0.9	1840		23		0		0		129			NODATA	0			
23	1.0	1940		43		4		15		133							
24		high		high		convex		wet		more							
25	NODATA	#N/A		1		1		1		1							
26																	
27																	
28	Comments: Assign soils in the following order:																
29	Bonnevier (high elevation - tundra)																
30	Gulliford (wet).. Look for wetland layer																
31	Skaist (steep)																
32	Lawless/Nicommen.. Complex of whatever is left LAWNIC																
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34																	
35	Limiting values of attributes (* = used in inference)																
36																	
37	SL	CMP	PERCENT		Elev*	Slope*	Curv	Wet		10_kWh					Name		SLCMP
38	590078	1	30		<1840	6<sl<19		<3							Lawless		59007801
39	590078	2	30		<1840	6<sl<19		<3							Nicommen		59007802
40	590078	3	15		<1840	>19		<3							Skaist		59007803
41	590078	4	15		>1840			<3							Bonnevier		59007804
42	590078	5	10		<1840	<6		>3							Gulliford		59007805
43																	

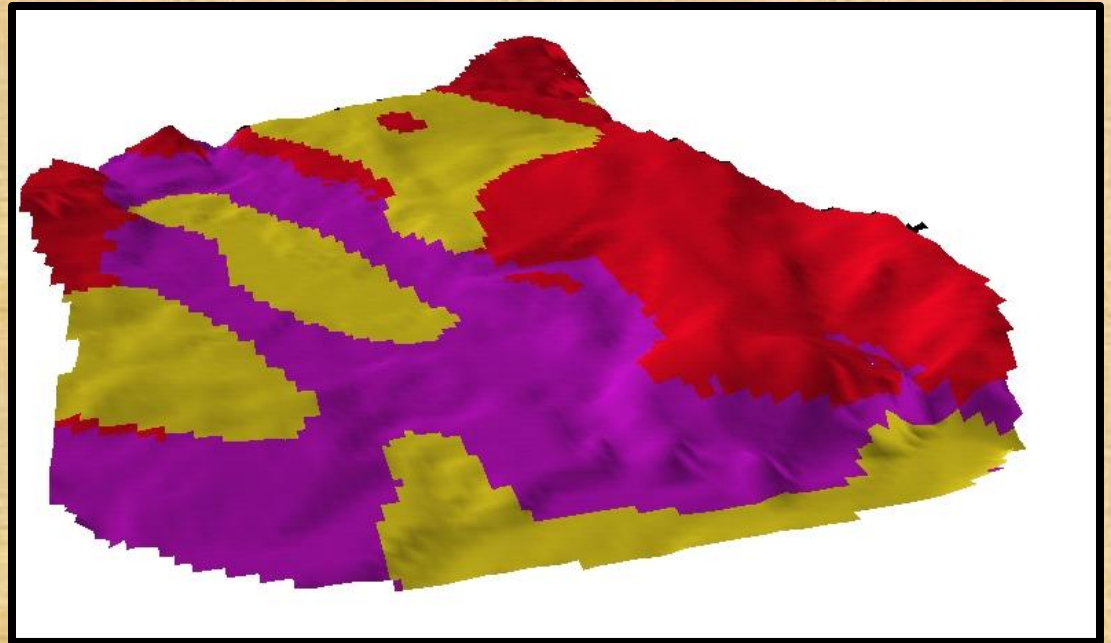
Disaggregation (1ha pixels):



Disaggregation:

Datasets:

- elevation
 - terrain (slope, curv, etc)
 - wetness
 - aspect / radiation
 - wetlands
 - BEC
 - VRI
 - climate
 - rivers, lakes
 - landform**
-
- Similar approach for detailed terrain and soil maps at 1:100,000 or less



Disaggregated soil polygons provide spatial context for the information in SLC

Benefits:

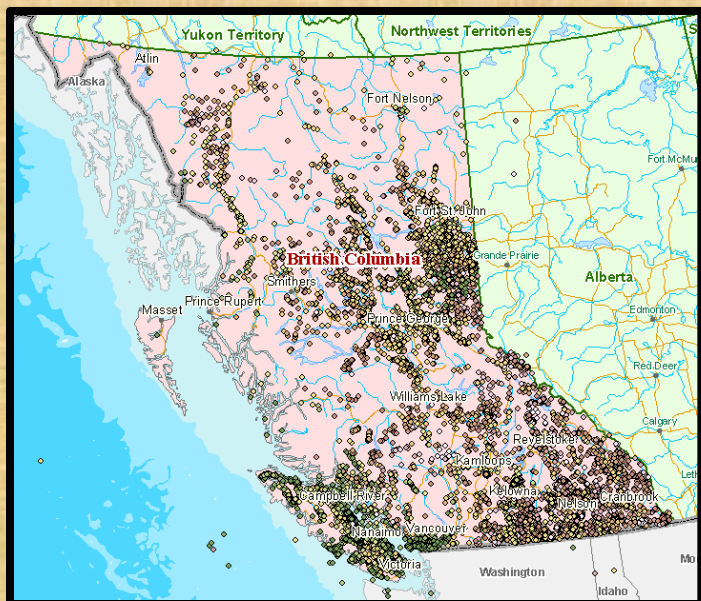
- improved estimates for landscape C
- evaluating suitability for biomass harvest
- climate change impacts

Checking and quality control

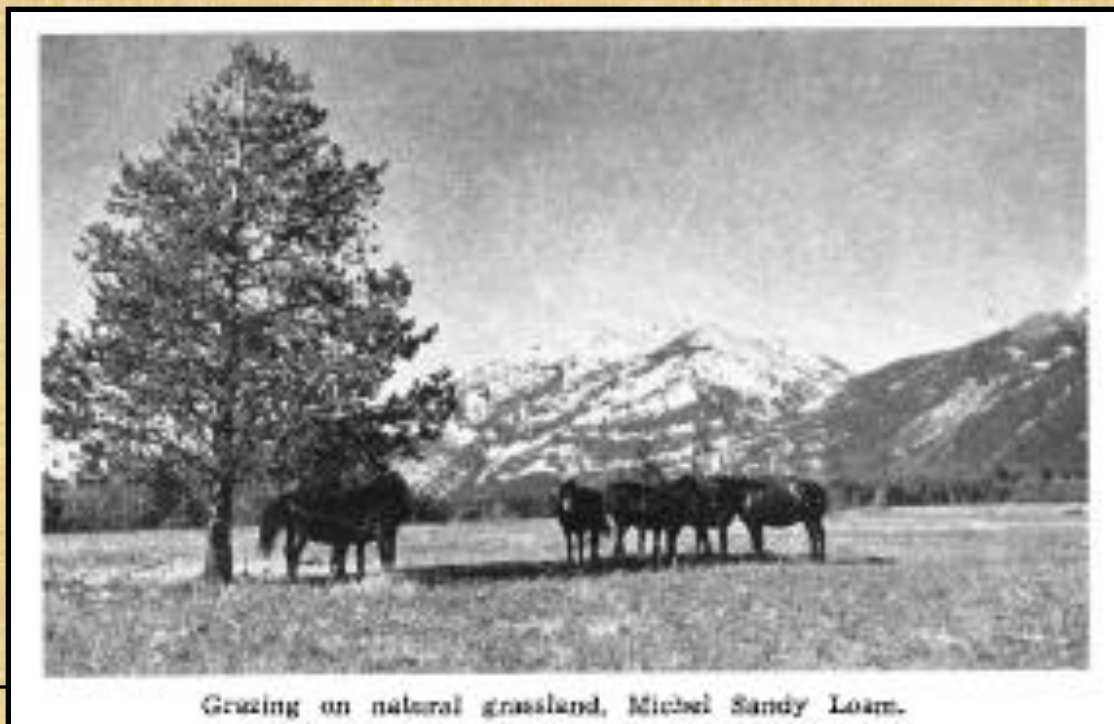
- Its essential
 - ... to provide estimates of reliability and variation
- Several possible approaches to checking / quality control
 - Provincial guidelines for predictive ecosystem mapping
 - Consistency with existing maps and other available information
 - Directed field checking for a limited number of attributes
- Some optimistic thoughts...
 - Extensive road network in many parts of BC facilitates access
 - Internet communication with regional and local soil scientists
 - Web based collaboration, accessible technology
 - GPS, photography

Quality control:

Soil Points



Field work:



Photos from: CC Kelley and PN Sprout.

Soil survey of the upper Kootenay and Elk River Valleys. Report No. 5 BC Soil Survey

Expected outcomes:

- First approximations:
 - landscape classification for BC (initially 1km .. final 100m or 25m)
 - DSM for the Okanagan Valley (with ca. 100 soil types)
- Improved estimates of the time and cost for a complete DSM project to create a high quality and reliable product for BC (100m or 25m resolution).

Next steps:

- Further work on spatial disaggregation of complex polygons..
 - application of method to a wider area for SLC
 - testing of disaggregation at 1:100,000 and 1:50,000 scale; 25m DEM
- More detailed analysis of the landscape classification
- Field checking.. summer of 2010

Conclusion

- DSM can be a useful tool for improving information needed for forest management, climate change and other modern issues
- Tools are not too difficult to master, and software etc is not expensive
- Datasets are often freely available
- DSM will have a large place in future efforts to map ecosystems and soils
- Ultimately, the information will help managers, planners and modellers who are interested in spatial distribution of natural resources and how it influences management.

The end