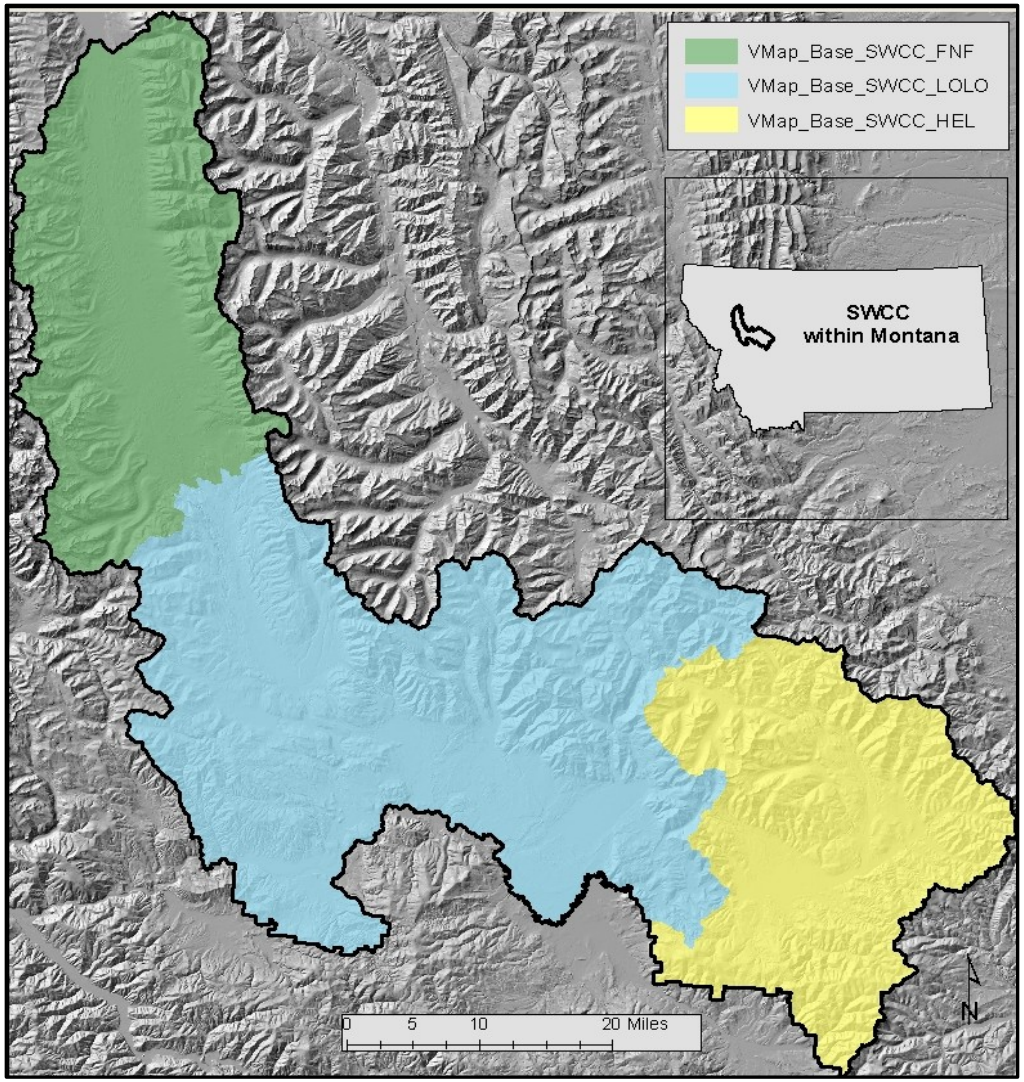
A Data Driven System for Estimating Minimum Stump-to-Mill Costs for Forest Restoration

Robert Ahl, PhD and Keith Stockmann, PhD, Krista Gebert, Steve Brown, Renate Bush

Composite SWCC Vmap

- *The SWCC is located in western Montana, USA.*
- *Composed of 3 Ranger Districts*
- *The region shown in green represents the Flathead NF data, the blue represents Lolo NF data, and the yellow represents Helena NF data.*



Inspiration

BIOMASS UTILIZATION MODELING WITH MAGIS ON THE FLEECER INTEGRATED RESOURCE PROJECT, BEAVERHEAD-DEERLODGE NATIONAL FOREST

By

ANTON JOHN BRENNICK

2010

Dr. John Goodburn, Chair
College of Forestry and Conservation

Dr. Woodam Chung
College of Forestry and Conservation

Dr. Helen Naughton
Department of Economics

Dr. Robert Ahl
Remote Sensing Analyst

Collaborative Forest Landscape Restoration Program (CFLRP)

- The Omnibus Public Land Management Act of 2009 includes Title IV: **Forest Landscape Restoration Act**.

- The purpose is to reduce fire danger and enhance ecosystem and community function

  - Reduce wildfire management costs
  - Encourages economic, social, and ecologic sustainability
  - Addresses the utilization of forest restoration byproducts to offset treatment costs and benefit local economies (http://www.fs.fed.us/restoration/CFLR/index.shtml).

Collaborative Forest Landscape Restoration Program (CFLRP)

- While the intentions and outcomes of restoration may be good and beneficial, **treatments must be paid for somehow**.

- Money for treatments may be available but must be **spent efficiently**

- Illustrates how net treatment costs are **distributed** across the landscape

- Ensures treatment strategy is feasible, and provides **basis for adjustments** to goals.

Pilot Project in Southwestern Crown of the Continent

- The Southwest Crown of the Continent Collaboration area is **1 of 23 sites** selected in USA
- Located in northwestern Montana, USA
- Working together with regional and local stakeholders, referred to as the Southwestern Crown Of the Continent Collaborative (**SWCC**)
- Goal is **quantifying restoration costs in SWCC**

Goals for SWCC Pilot

- **Goal 1**: Generate map, in per/acre units, of generalized break-even delivered log prices for all defined treatment conditions. This is the **Stump-to-Mill** cost, based on harvest and haul costs

- **Goal 2**: Generate map, in per/acre units, of **non-commercial restoration costs**, that include thinning and prescribed fire, non-haul road costs, and invasive weed treatment.

- **Goal 3**: Generate map, in per/acre units of **net estimated revenue or appropriated funds** required to conduct defined restoration treatments. This is based on **harvest revenue** *minus* **treatment cost**, and is the final **Net**.

To design a financially feasible forest restoration plan across a large landscape we need:

- A map that defines Regionally Established Existing Forest Conditions
  - Map is based on spatial and inventory databases (**Vmap and Inventory Integration**)
  - Integrated Map defines vegetation classes with quantitative descriptions
- A defined set of treatments for each considered forest condition
- Regionally Established Calculations applied to selected forest conditions to reveal costs of:
  - Harvest treatment
  - Haul of materials
  - *Non-commercial activities*

Goal: **map of** generalized
break-even delivered log prices per acre when desired treatments are applied

To create a set of maps that describe forest condition, and treatment costs we need:

1) A Regional Classification System that unifies multiple levels of vegetation descriptions.:
The R1 Existing Vegetation Classification System

- The R1 EXVEG provides a **framework for summarizing inventory data**, and thus define map units
- The R1 EXVEG provides a **link** between *mapping* and *inventory*, can derive richly descriptive maps of existing forest condition
- Some forest conditions **cannot be described** with *mapping* or *inventory* **alone**.

2) A **defined set of treatments** for each considered forest condition, provided by silviculture experts

3) **Regionally Established Calculations** applied to selected forest conditions to reveal costs of:
- Harvest treatment
- Haul of materials
- *Non-commercial activities*

Goal: Generate a **map of** generalized
break-even delivered log prices per acre when desired treatments are applied

Databases: Why Vmap and FIA?

- Vmap is the most up-to-date, validated, spatial depiction of the R1 Existing Vegetation Classification System
- Vmap provides continuous coverage of the study area
- Vmap is being used in a fire modeling project in the SWCC
- FIA inventory data, in the R1 Summary database combined with Vmap provides a way to display wall to wall estimates for existing conditions including volume, basal area, etc. that cannot be directly mapped

Restoration Treatment Logic: Meet with **Silviculture/Fire** Experts

- Review the calculation inputs associated with each forest condition
  - This requires **agreement about treatments** that are acceptable and move towards stated restoration goals
  - This requires knowledge of **existing forest condition basal areas** (*provided by integrated database*)
  - This requires setting some **remaining basal area targets** after treatment for forest condition (*provided by treatment guidelines*)
  - This requires a **standard tons/MBF figure** for calculations (5.5 tons/mbf)
  - Validate estimated basal area and volume estimates provided by the integrated database
  - Future discussion of how non-saw volumes factor into cost calculations

BBER Cost Equations: Bureau of Business and Economic Research

BBER cost equations are based on Regional data and used to move through the gate system to appraisals

- Harvest
  - Ground – based (0-40%)

    Cost per ton = 35.079 - (0.805*average DBH(inches)) + (skid distance in 100' *0.083) – (0.835***volume per acre removed in MBF**).
  - Skyline – cable (41-60%)

    Cost per ton = 37.442 + (skid distance in 100' *0.558) - (0.671***volume per acre removed in MBF**)
  - Helicopter (>60%)

    Cost per ton = 72.379 - (skid distance *1.208) + (0.864***volume per acre removed in MBF**)

- Haul Cost (to Pyramid Lumber)
  - Cost per ton= 3.567 + (total haul distance*0.13)

Applying **logic** to estimate treatment products and costs

- In a spreadsheet we use the integrated database to estimate the amount of commercial material that would be generated as a byproduct of restoration treatments. This is part of the harvest cost equations for each yarding system.
  - **Percent reduction** desired = Existing basal area – Target basal area / Existing basal area (column AC)
  - This calculation defines the amount of **basal area that is removed** due to the treatment. From this removed basal area, the **estimated proportion of non-commercial material is subtracted** out and moved into the **non-saw CCF** in column AK.
  - The remaining percent reduction needed, associated with merchantable material, is multiplied with the average total board feet per acre from each forest condition. This gives a starting point for the **BF/acre Saw Comm** column.
  - See example row in Spreadsheet
  - See example VMAP polygon

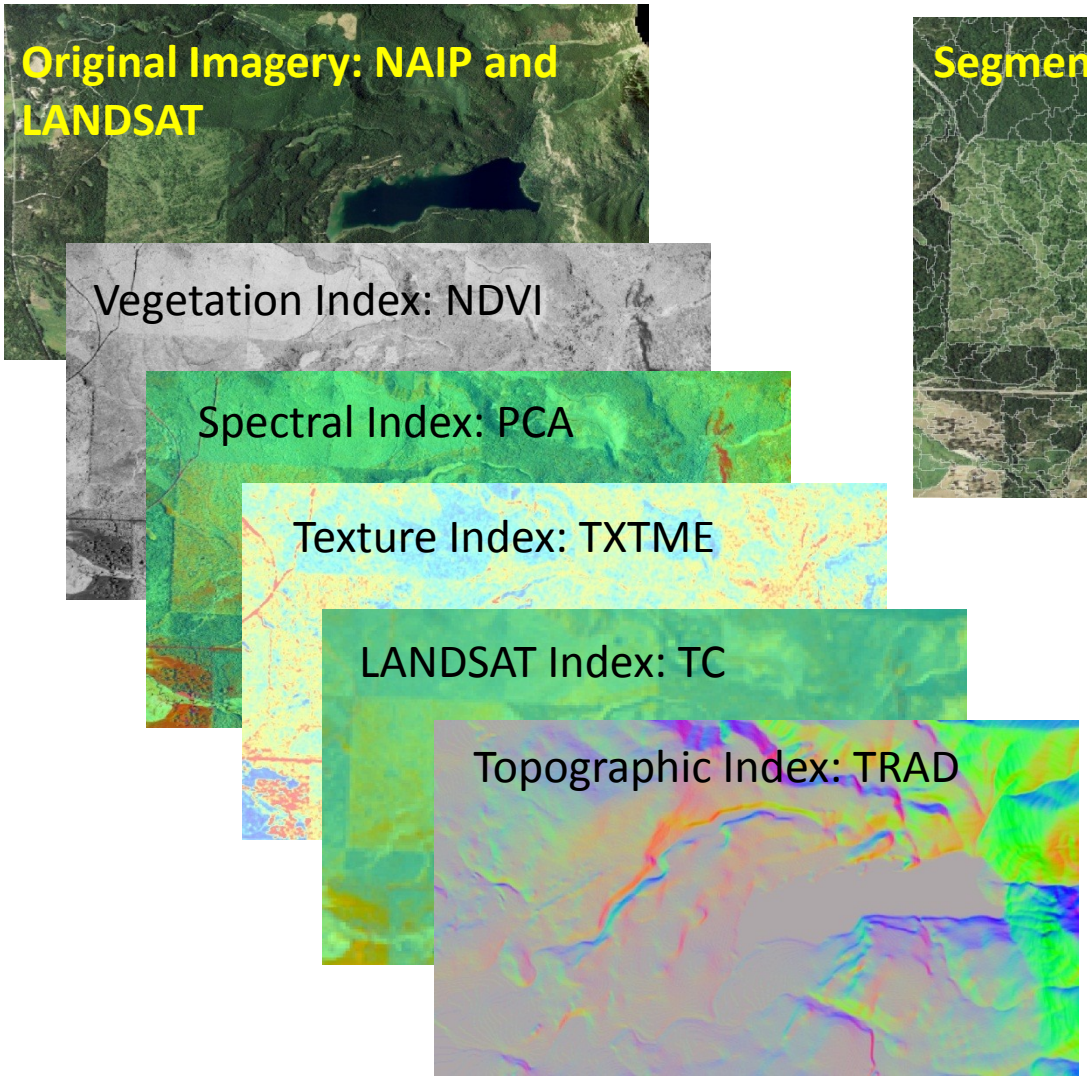
Building the Integrated Database: Part 1 the Vmap

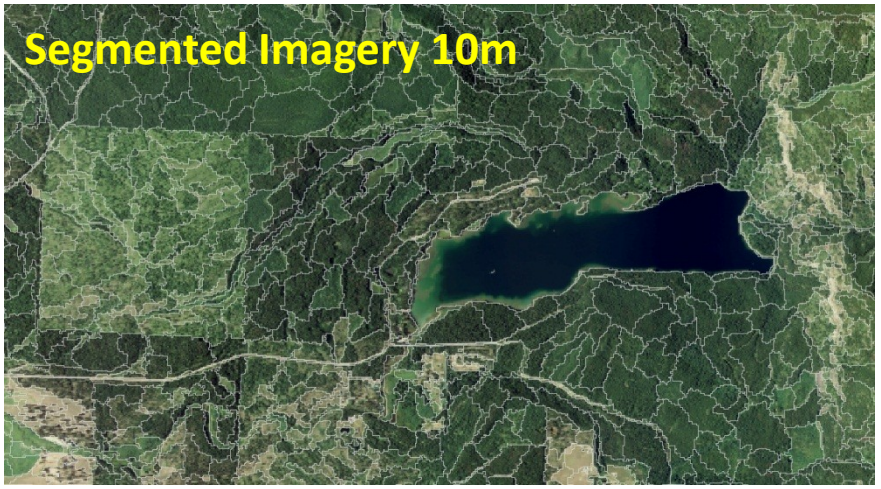
- Vmap is the Northern Region's Exiting Vegetation Spatial Database
- It is a spatial depiction of the R1 Existing Vegetation Classification System
- Vmap describes
  - Lifeform
  - Dominance type (many based on plurality)
  - Canopy Cover (4 classes based on percent cover)
  - Size (4 classes based on DBH classes
- Available for free at: http://www.fs.usda.gov/detailfull/r1/landmanagement/gis/?cid=stelprdb5331054&width=full

Vmap

Background and Production

Image Processing and Segmentation



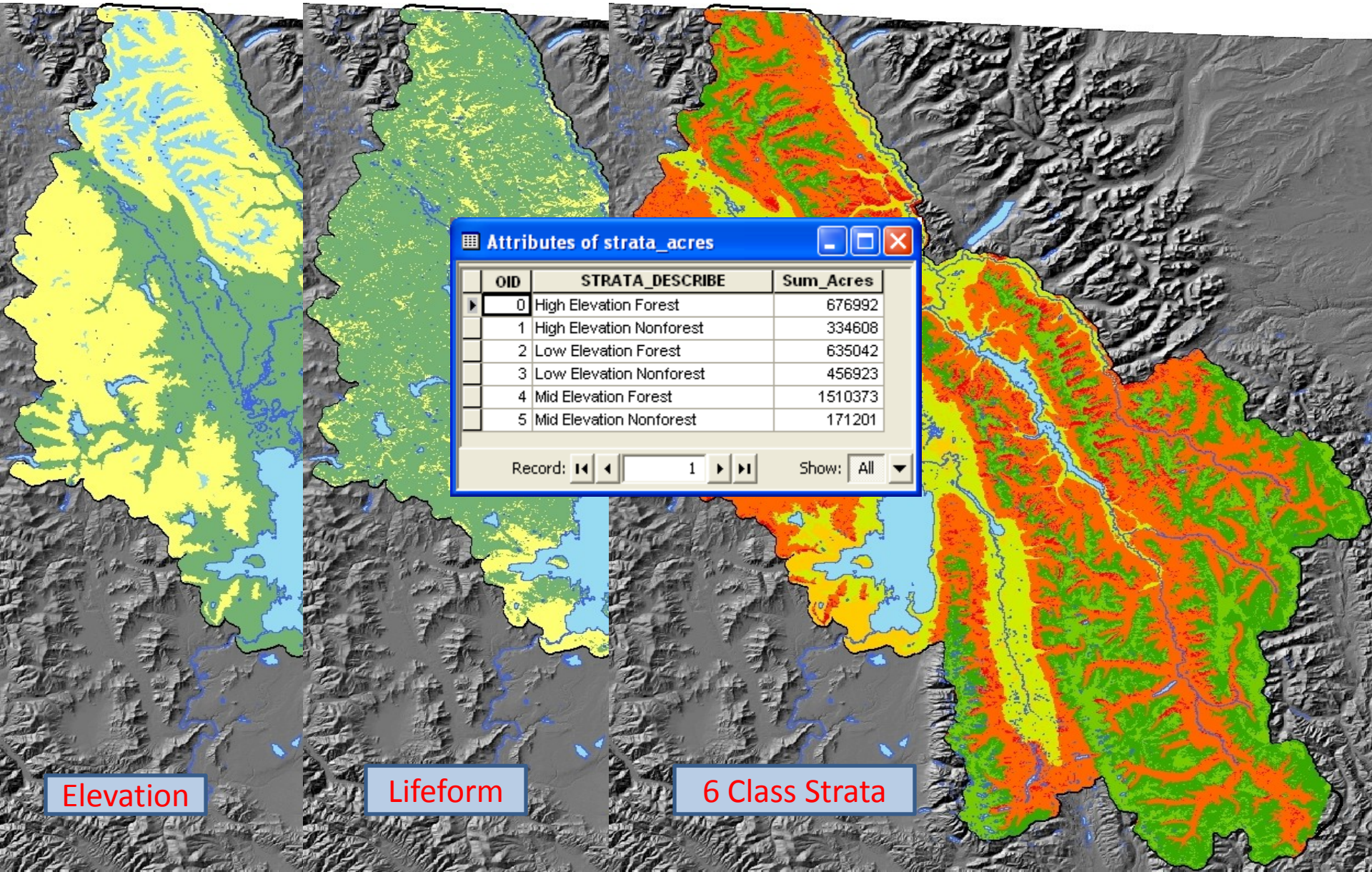


Processed imagery is segmented to generate polygons that are then sampled and classified

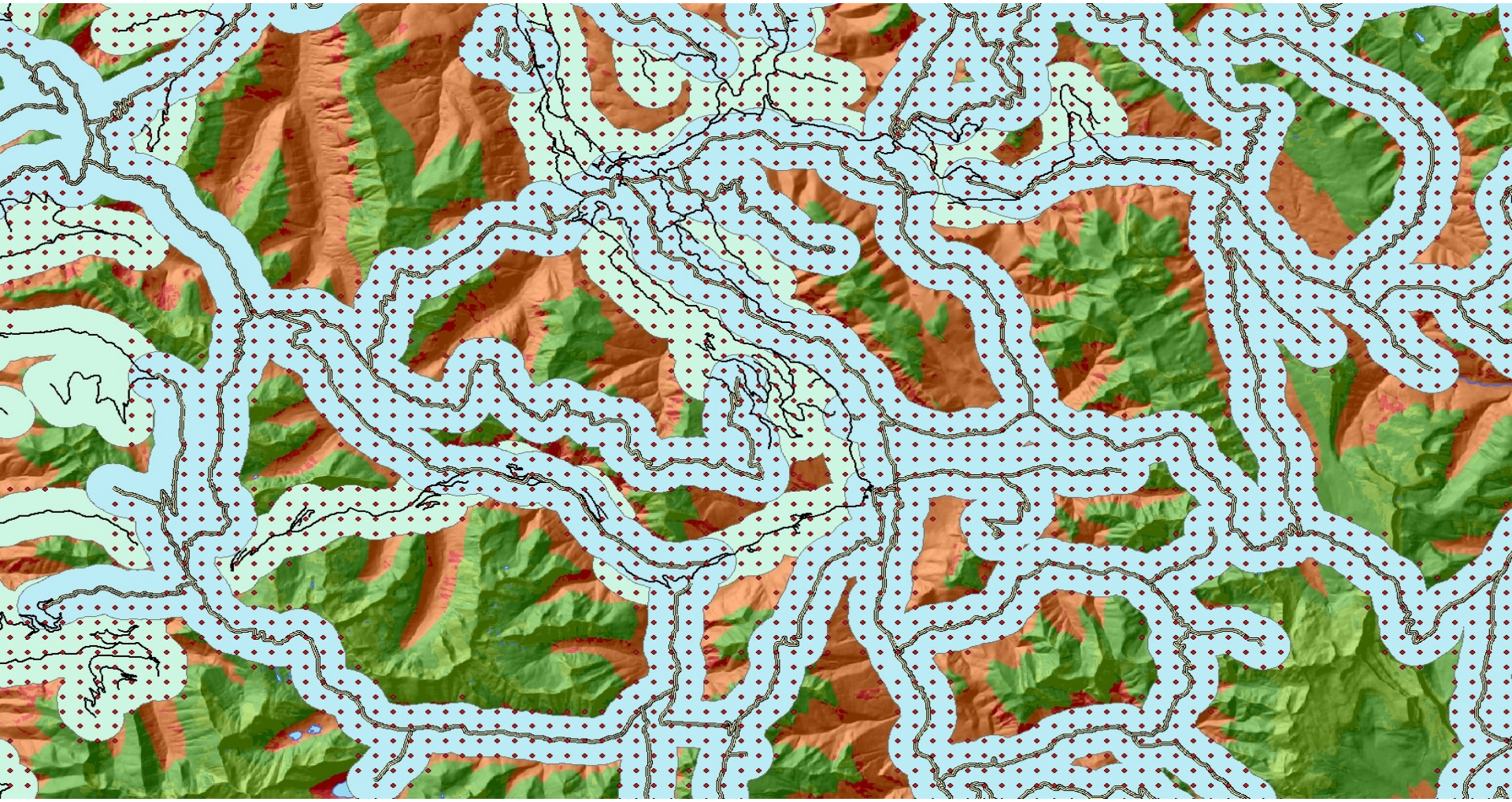
Sample Design

- Goal: capture landscape vegetation variability
- Stratify landscape based on lifeform,Elevation, and Access
- Randomly selected from a systematic grid of points with 500m spacing.

Sample Design



Sample Design

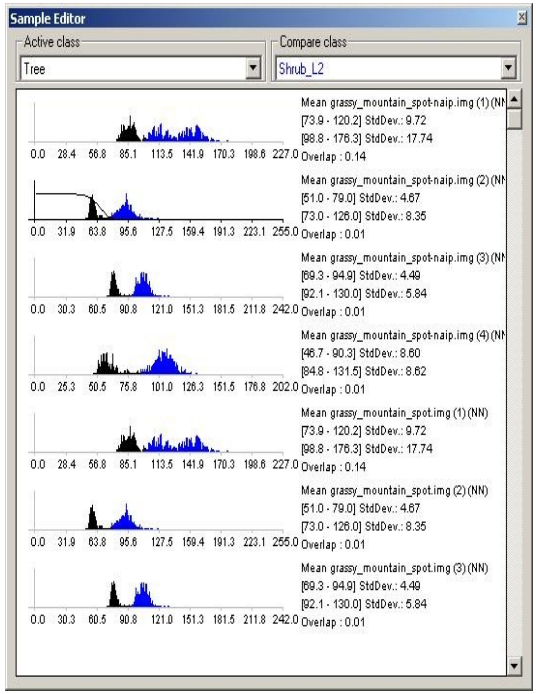


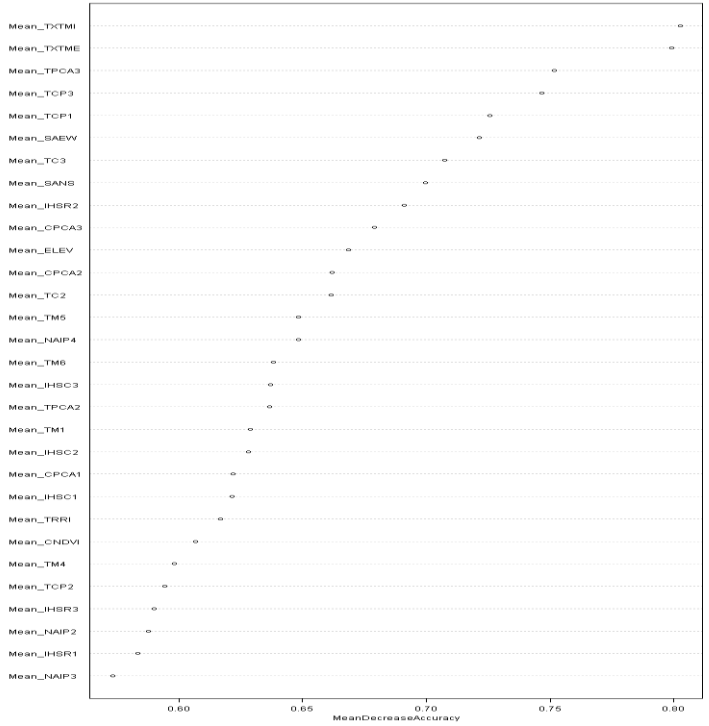
Training Data Collection

Image Classification

- **Lifeform:**
  classified with eCognition FUZZY LOGIC membership functions

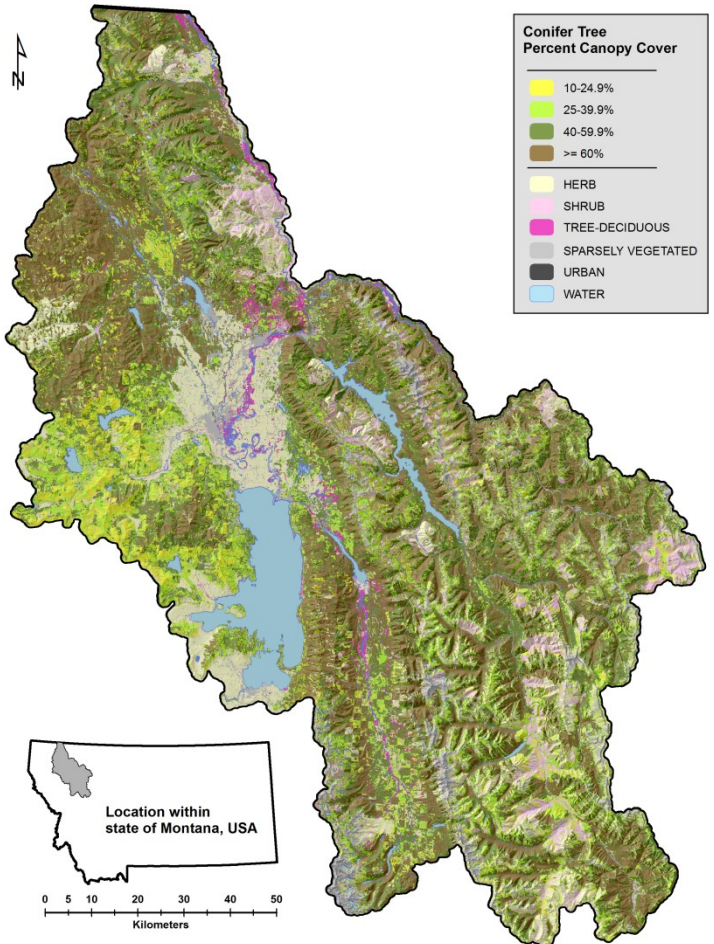
Dom Type, Canopy, Size:
classified with Data Mining ensemble methods using Random Forests algorithm





Map Review and Validation

- Maps are review and validated with an independent assessment
- Assessed accuracy has to meet national standard before published



Example CCV Accuracy Assessment

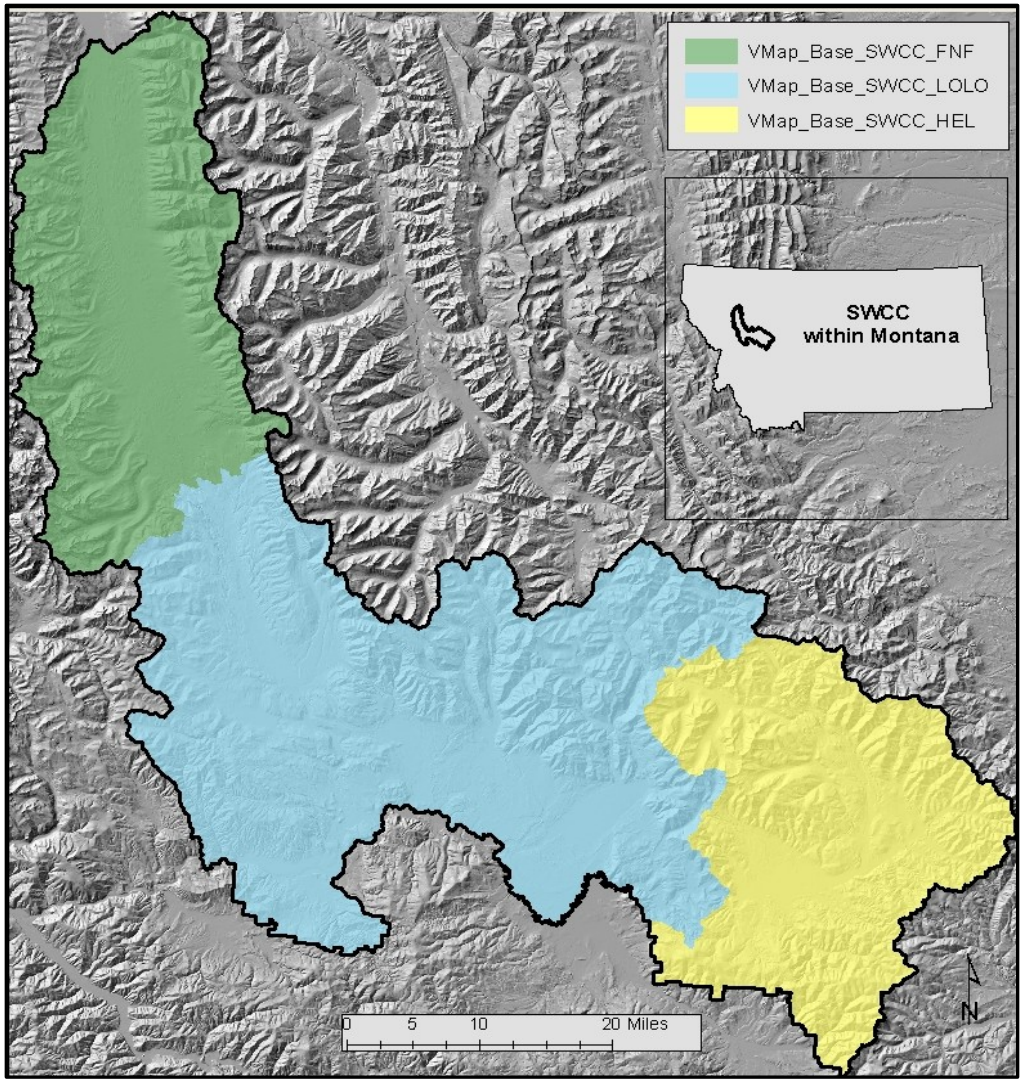
CCV_CLS	CCV_SAMP 4001	4002	4003	4004	Row Total	a+	User Accuracy
4001	30	6	3	1	40	0.066	*75*
4002	16	67	30	1	114	0.187	*59*
4003	1	19	138	34	192	0.315	*72*
4004		1	53	210	264	0.433	*80*
Column Total	47	93	224	246	**610**		
+a	0.077	0.152	0.367	0.403			
Producer Accuracy	*64*	*72*	*62*	*85*			

		95% Confidence interval	
Overall Agreement (Po)	0.730		
Chance Agreement (Pe)	0.324	*lower*	*upper*
Unweighted Kappa	**0.600**	***0.548***	***0.652***
Standard Error	0.027		
alpha level	0.05		
Kmax	0.936		
Percent of Kmax	64		

Building the SWCC Vmap

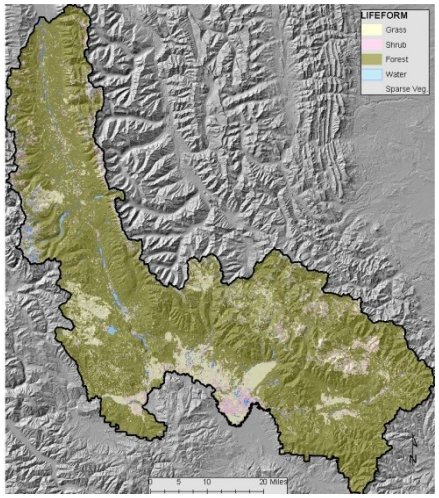
Composite SWCC Vmap

- *The SWCC is located in western Montana, USA.*
- *Composed of 3 Ranger Districts*
- *The region shown in green represents the Flathead NF data, the blue represents Lolo NF data, and the yellow represents Helena NF data.*

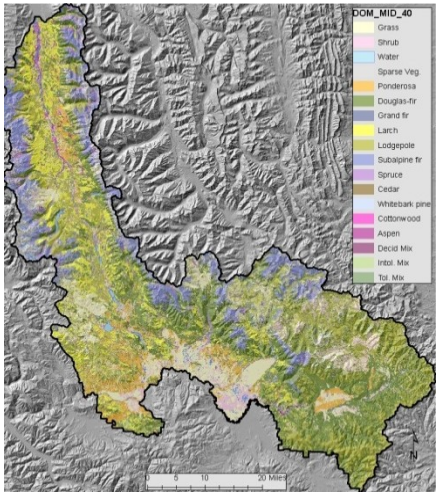


The SWCC Vmap

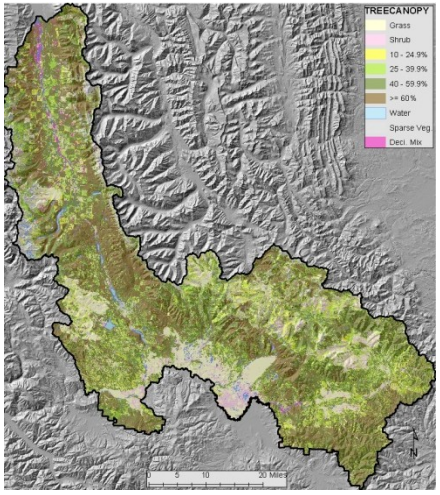
Lifeform



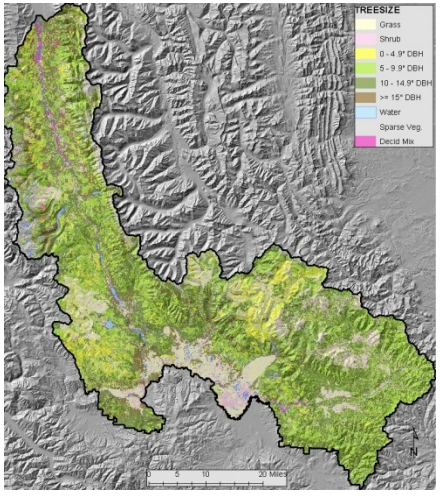
Dominance Type



Canopy Cover



Size Class



Forest Condition = Unique combination of DOM, Canopy, Size called STATLINK

DOM40_CLASS	CLASS DESCRIPTION
8015	Ponderosa pine
8025	Douglas-fir
8035	Grand fir
8045	Western larch
8055	Lodgepole pine
8065	Subalpine fir
8075	Engelmann spruce
8085	Western white pine
8095	Western red cedar
8125	Whitebark pine

CANOPY_CLASS	CANOPY CLASS DESCRIPTION
4001	10 - 24.9 %
4002	25 - 39.9 %
4003	40 - 59.9 %
4004	>= 60%

SIZE_CLASS	SIZE_CLASS_DESCRIPTION
4100	0 - 4.9 " DBH
4200	5 - 9.9 " DBH
4300	10 - 14.9 " DBH
4400	>= 15 " DBH

For example: Douglas fir with moderate canopy and medium size = 802540034300

FIA Inventory: The R1 Summary Database

- Plot-based inventory measurements are summarized to the same groups as Vmap data, following the R1 Existing Vegetation Classification System.
- Data are from across Northern Region, with total of ~14,000 records
- Not all records are relevant to SWCC, filtered to contain only type/canopy/size combinations found in SWCC Vmap
- Summary statistics computed for each STATLINK, called forest condition
- Summary statistics for BF_VOL ACRE, BASAL AREA, TREESACRE, AGE, etc.
- Summary statistics of mean and 95% CI joined to Vmap with STATLINK

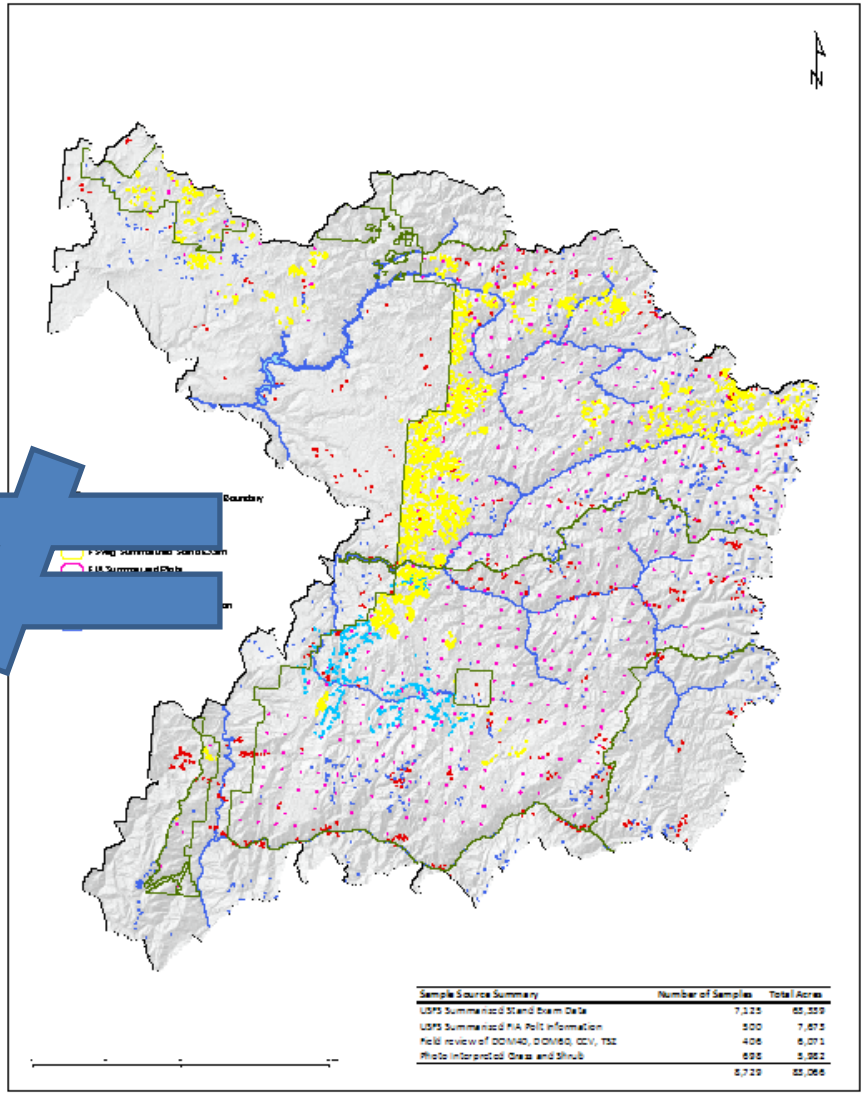
STATE	Number of Records	Relative Contribution
ID	3,181	38
MT	5,243	62
WA	19	< 1
	8,443	

Summary of relevant database records

DOM40_CLASS	CLASS DESCRIPTION	CANOPY_CLASS	CANOPY CLASS DESCRIPTION	SIZE_CLASS	SIZE_CLASS_DESCRIPTION
8015	Ponderosa pine	4001	10 - 24.9 %	4100	0 - 4.9 " DBH
8025	Douglas-fir	4002	25 - 39.9 %	4200	5 - 9.9 " DBH
8035	Grand fir	4003	40 - 59.9 %	4300	10 - 14.9 " DBH
8045	Western larch	4004	>= 60%	4400	>= 15 " DBH
8055	Lodgepole pine				
8065	Subalpine fir				
8075	Engelmann spruce				
8085	Western white pine				
8095	Western red cedar				
8125	Whitebark pine				

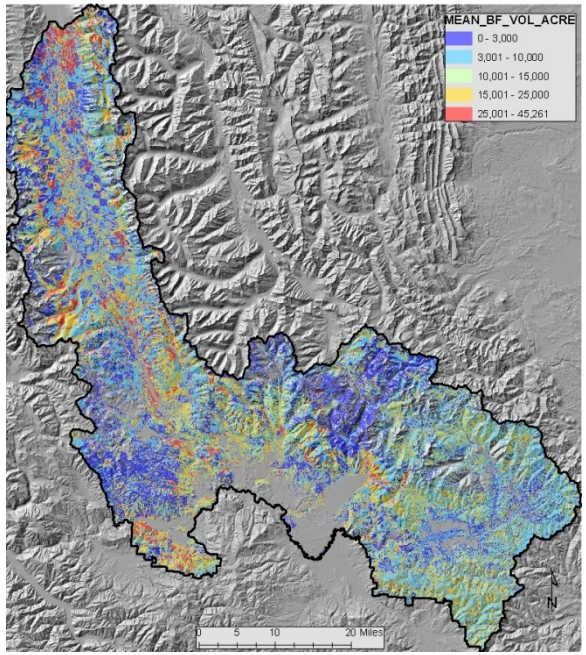
Associating Inventory with Spatial Data

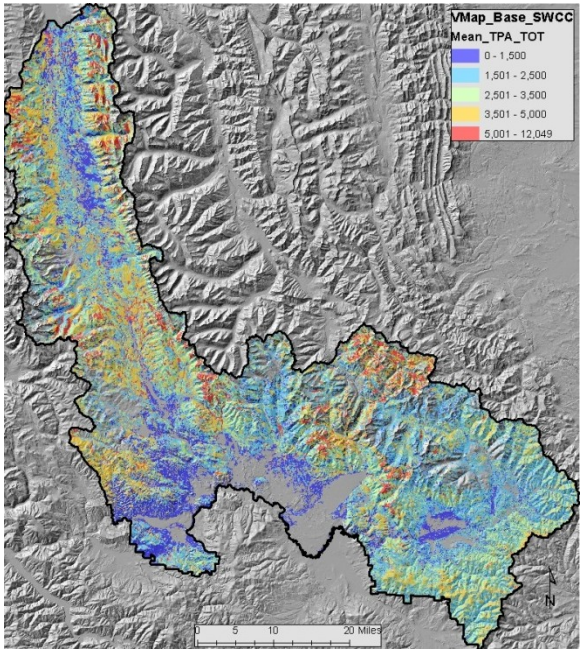
DOM40_CLASS	CCV_CLASS	TSZ_CLASS	Mean_BF_TOT	SD_BF_TOT	BF_TOT_N	CONF95	Low95MEAN_BF_TOT	High95MEAN_BF_TOT
8015	4001	4100	0	0	0	0	0	0
8015	4001	4200	576	598	17	284	292	861
8015	4001	4300	1728	933	23	381	1347	2110
8015	4001	4400	5512	3191	16	1564	3948	7075
8015	4001	4500	10325	4657	22	1946	8379	12271
8015	4002	4100	0	0	0	0	0	0
8015	4002	4200	1775	1649	27	622	1153	2397
8015	4002	4300	5603	3219	45	940	4663	6544
8015	4002	4400	11012	4928	32	1708	9304	12719
8015	4002	4500	24260	12043	14	6308	17952	30569
8015	4003	4100	0	0	0	0	0	0
8015	4003	4200	2412	2407	33	821	1591	3233
8015	4003	4300	8834	4935	36	1612	7222	10446
8015	4003	4400	24468	12059	27	4549	19919	29016
8015	4003	4500	39268	12785	20	5603	33665	44871
8015	4004	4100	0	0	0	0	0	0
8015	4004	4200	4876	4504	22	1882	2993	6758
8015	4004	4300	14949	8139	23	3326	11623	18275
8015	4004	4400	25405	10501	14	5501	19904	30905
8015	4004	4500	52759	20302	6	16245	36514	69004
8025	4001	4100	0	0	0	0	0	0
8025	4001	4200	430	525	57	136	293	566
8025	4001	4300	2581	1465	58	377	2204	2958
8025	4001	4400	4041	2742	49	768	3273	4809
8025	4001	4500	6906	3543	40	1098	5808	8004
8025	4002	4100	0	0	0	0	0	0
8025	4002	4200	1614	1681	83	362	1252	1976
8025	4002	4300	5051	2948	139	490	4561	5541
8025	4002	4400	8757	4316	123	763	7994	9520
8025	4002	4500	13030	6906	62	1719	11311	14749
8025	4003	4100	0	0	0	0	0	0
8025	4003	4200	3456	2981	183	432	3025	3888
8025	4003	4300	10474	6030	412	582	9892	11057
8025	4003	4400	17142	8272	249	1027	16115	18170
8025	4003	4500	26651	12966	61	3254	23398	29905
8025	4004	4100	0	0	0	0	0	0
8025	4004	4200	5869	4702	326	510	5359	6380
8025	4004	4300	16334	10703	382	1073	15261	17407
8025	4004	4400	28343	13473	122	2391	25952	30734
8025	4004	4500	39858	16334	18	7546	32312	47404

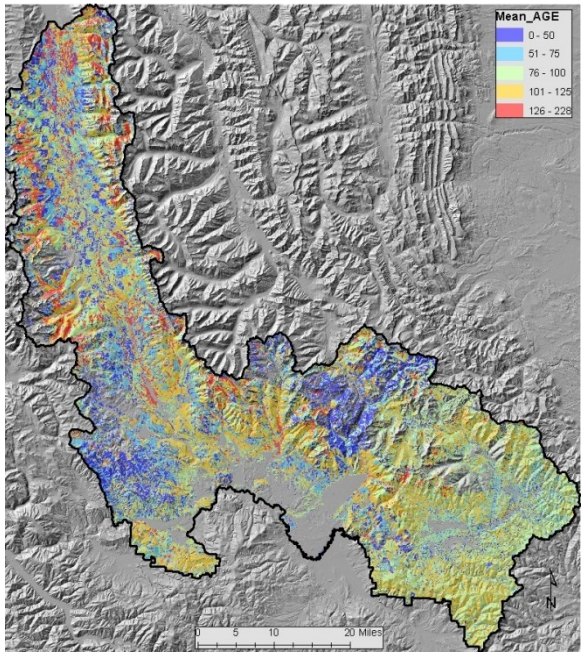


Associating Inventory with Spatial Data

- Many quantitative variables that are not possible to reliably map can be associated with map units with STATLINK
- For example: Board-foot Volume per acre, Trees per acres, stand age
- Are based on summary of all plot data in the region, and can be illustrated as mean or any other summary statistic







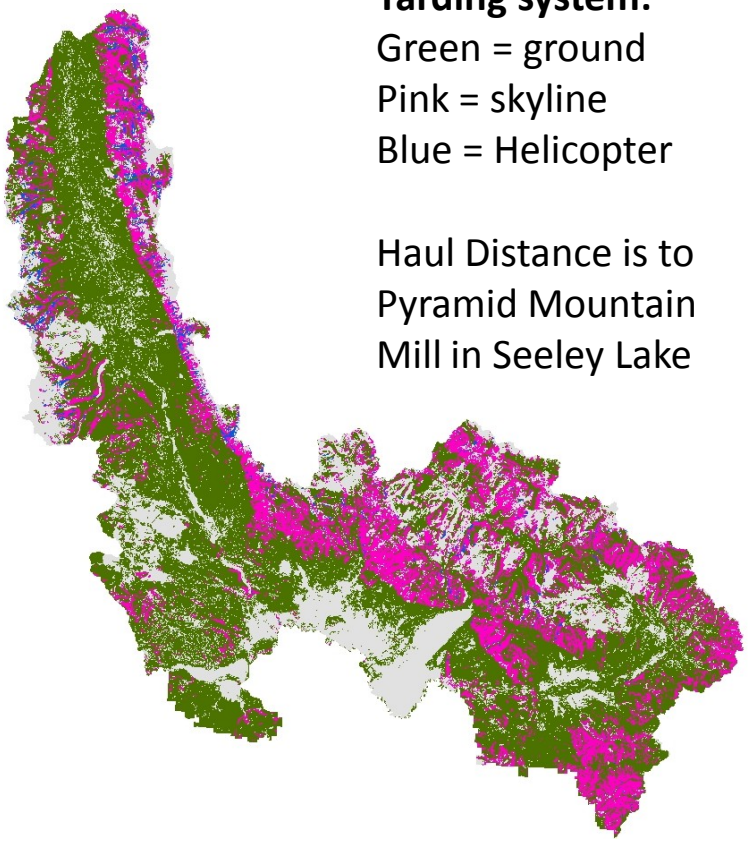
Computing Values and Costs with the Linked Spatial and Inventory Database

To satisfy Goal 1 of SWCC Pilot compute
Stump to Mill estimate

- Harvest Costs
  - Based on yarding system, skid distances, average DBH, volume removed
- Haul Cost
  - Based on volume of wood moved (per ton), haul distance X $0.13

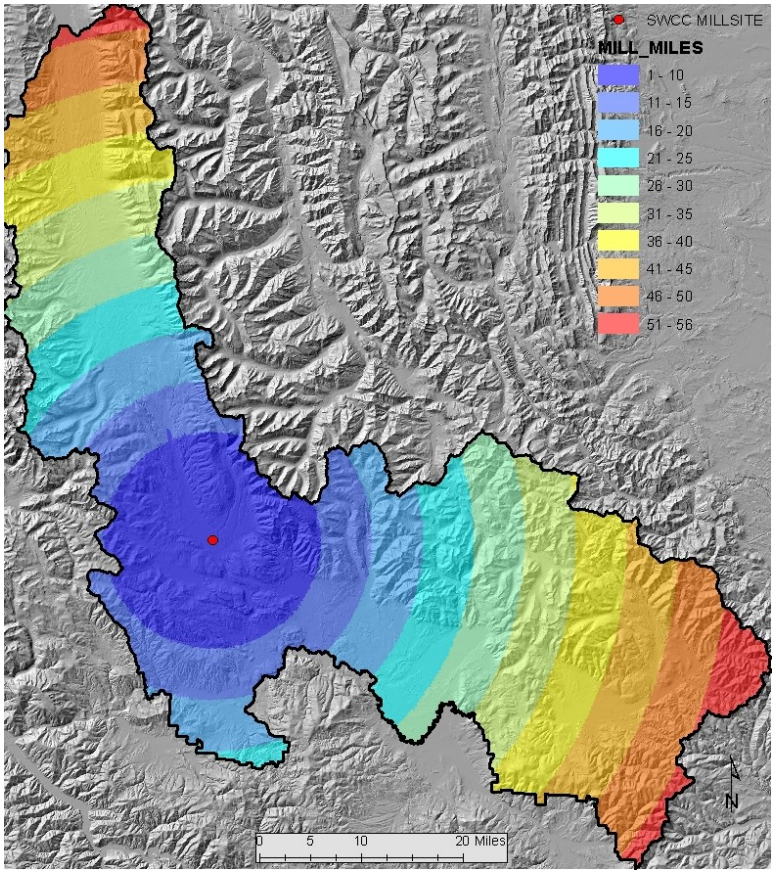
Computing Values and Costs with Additional Spatial Data

- For **Harvest Cost:** identify the yarding system based on rule set
- For **Haul Cost:** identify distance to mill for each stand



Yarding system:
Green = ground
Pink = skyline
Blue = Helicopter

Haul Distance is to Pyramid Mountain Mill in Seeley Lake



Computing Values and Costs with Defined Treatment Criteria 1

Species	Canopy Cover	Size Class	Mean_CUFT_TOT	Mean_CUFT_MERCH	Mean_CUFT_TOT	Mean_CUFT_MERCH	FIA Merch Portion	Basal Area Weighted DBH	Existing Basal Area / Acre	Mean_TPA_TOT	Comm__Trx	Target Basal Area / Acre
PIPO	10-24.9	0-4.9	-	-	-	-	0.00			379	NA	N/A
PIPO	10-249	5-9.9	265	129	265	129	0.49	7	20	884	Thin from Below	40
PIPO	10-24.9	10-14.9	504	396	504	396	0.79	12	31	469	Improv Harv (Thin from Below)	40
PIPO	10-24.9	15+	1,170	1,027	1,170	1,027	0.88	18	42	525	Improv Harv (Thin from Below)	40
PIPO	25-39.9	0-4.9	-	-	-	-	0.00			982	NA	N/A
PIPO	25-39.9	5-9.9	680	375	680	375	0.55	8	46	807	Thin from Below	40
PIPO	25-39.9	10-14.9	1,435	1,176	1,435	1,176	0.82	13	67	1,193	Thin from Below	60
PIPO	25-39.9	15+	2,374	2,087	2,374	2,087	0.88	17	87	1,203	Improv Harv (Thin from Below)	60
PIPO	40-59.9	0-4.9	-	-	-	-	0.00			1,065	NA	N/A
PIPO	40-59.9	5-9.9	948	501	948	501	0.53	7	66	1,167	Commercial Thin (from below)	40
PIPO	40-59.9	10-14.9	2,309	1,773	2,309	1,773	0.77	12	108	1,310	CT or Improv Harv (Thin from Below)	60
PIPO	40-59.9	15+	5,003	4,435	5,003	4,435	0.89	18	163	655	Improv Harv (Thin from Below)	70
PIPO	60+	0-4.9	-	-	-	-	0.00			2,411	NA	
PIPO	60+	5-9.9	1,981	1,053	1,981	1,053	0.53	7	126	1,340	Commercial Thin (from below)	70
PIPO	60+	10-14.9	3,883	3,000	3,883	3,000	0.77	12	176	1,476	CT or Improv Harv (Thin from below)	70
PIPO	60+	15+	5,626	4,908	5,626	4,908	0.87	17	219	935	Improv Harv (Thin from Below)	70
PSME	10-24.9	0-4.9	-	-	-	-	0.00		0	2,632	NA	N/A
PSME	10-249	5-9.9	180	89	180	89	0.50	6	13	1,514	Thin from Below	50
PSME	10-24.9	10-14.9	643	530	643	530	0.82	13	30	1,863	Thin from Below	60
PSME	10-24.9	15+	917	792	917	792	0.86	17	37	615	Thin from Below	80
PSME	25-39.9	0-4.9	-	-	-	-	0.00			3,205	NA	N/A
PSME	25-39.9	5-9.9	568	338	568	338	0.60	7	36	1,533	Thin from Below	50
PSME	25-39.9	10-14.9	1,283	1,036	1,283	1,036	0.81	13	59	1,245	Thin from Below	60
PSME	25-39.9	15+	1,930	1,674	1,930	1,674	0.87	17	76	1,234	Thin from Below	80
PSME	40-59.9	0-4.9	-	-	-	-	0.00			3,888	NA	N/A
~~PSME~~	~~40-59.9~~	~~5-9.9~~	~~1,133~~	~~728~~	~~1,133~~	~~728~~	~~0.61~~	~~8~~	~~72~~	~~1,828~~	~~Commercial Thin (from below)~~	~~60~~
PSME	**40-59.9**	**10-14.9**	**2,581**	**2,098**	**2,581**	**2,098**	**0.81**	**13**	**114**	**1,712**	**Commercial Thin (from below)**	**70**
~~PSME~~	~~40-59.9~~	~~15+~~	~~3,093~~	~~3,220~~	~~3,093~~	~~3,220~~	~~0.87~~	~~17~~	~~134~~	~~1,041~~	~~Improv Harv (Thin from Below)~~	~~70~~
PSME	60+	0-4.9	-	-	-	-	0.00			3,120	NA	N/A
PSME	**60+**	**5-9.9**	**2,156**	**1,211**	**2,156**	**1,211**	**0.56**	**8**	**128**	**2,726**	**Commercial Thin (from below)**	**60**
PSME	**60+**	**10-14.9**	**4,086**	**3,248**	**4,086**	**3,248**	**0.80**	**12**	**175**	**3,057**	**Commercial Thin (from below)**	**70**
PSME	60+	15+	6,120	5,312	6,120	5,312	0.87	17	221	1,806	Improvement Harvest	70

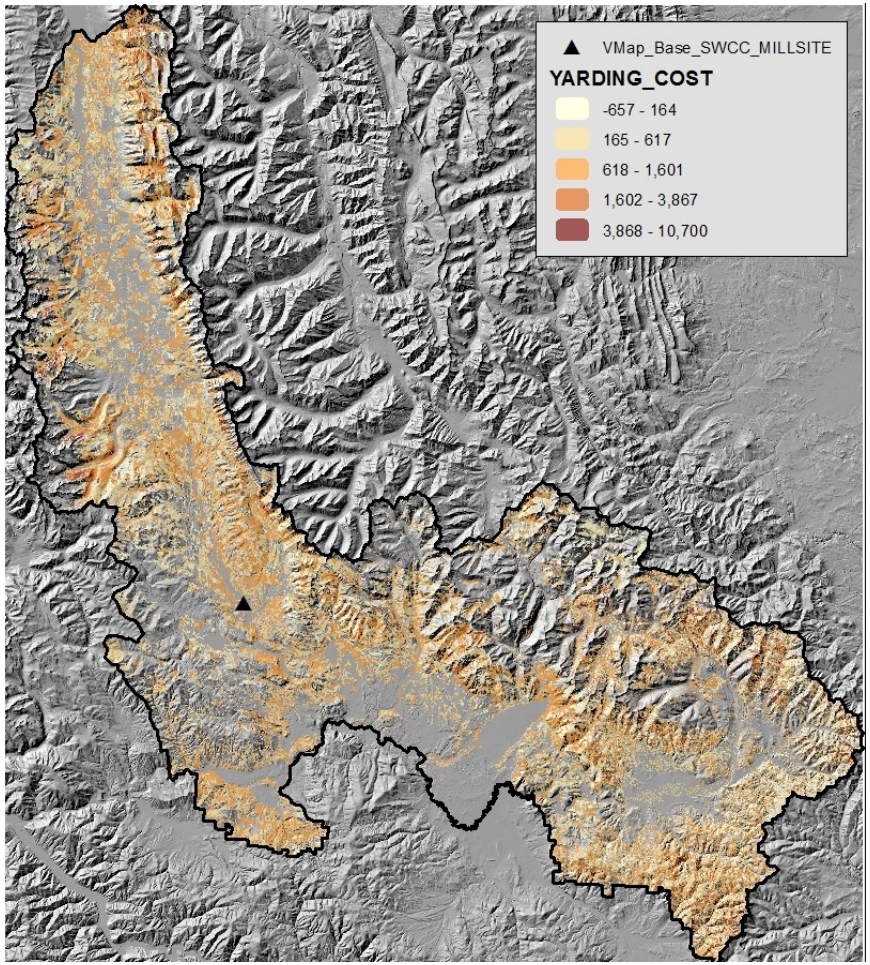
Computing Values and Costs with Defined Treatment Criteria 2

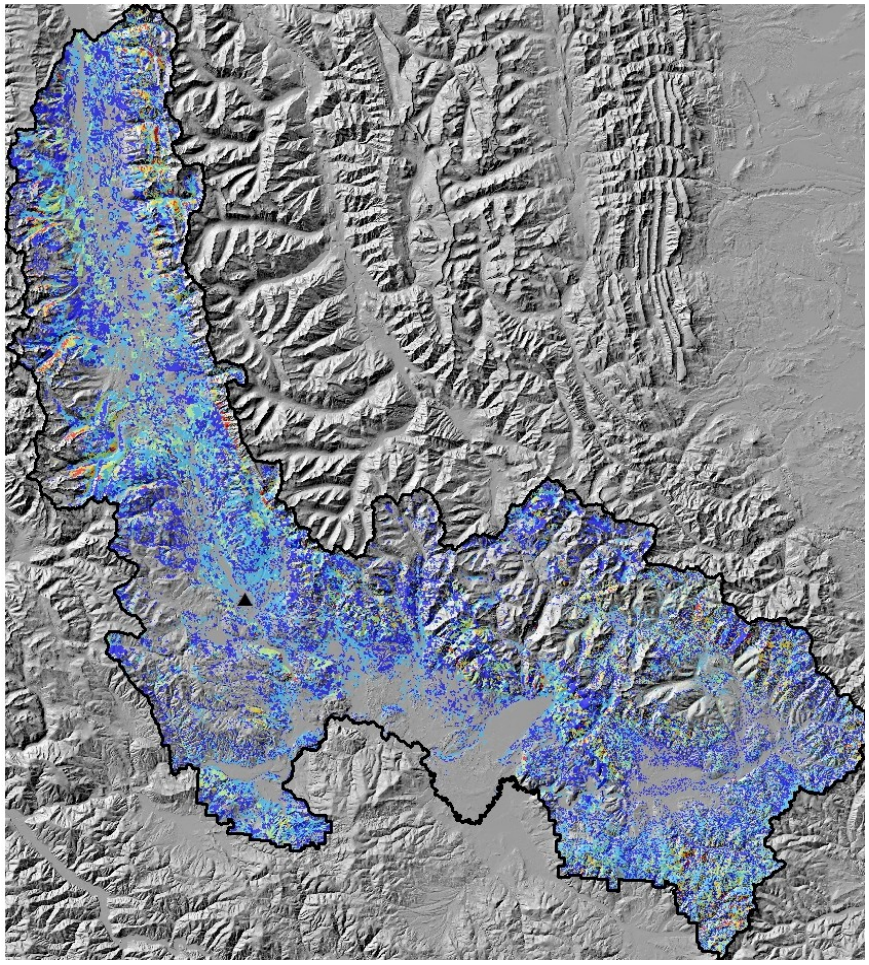
Reduction Needed	Reduction Needed from Merch	Mean_BF_ TOT	BF/acre Saw Comm	Observed / Expected BF / Acre	Ton /BF Conversion	Ton/acre Saw Comm	Dominant Saw Comm Species	NonSaw CCF	NonComm Veg TRx	Non Comm Veg TRx Cost	Non Comm Fire Trx	Non Comm Fire Trx Cost	Non Comm Weed Costs
0.00	0.00	-	-	-	0.005500	-	PSME, PICO	-	PCT/Thin for Fuels	130			
0.00	0.00	576	-	-	0.005500	-	PSME, PICO	136	PCT/Thin for Fuels	170			
0.00	0.00	1,728	-	-	0.005500	-	PSME, PICO	108	Slashing/pullback	265	Underburn	360	
0.04	0.00	5,512	-	-	0.005500	-	PSME, PICO	143	Slashing/pullback	265	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, PICO	-	PCT/Thin for Fuels	170			
0.13	0.00	1,775	-	-	0.005500	-	PSME, PICO	304	PCT/Thin for Fuels	170			
0.11	0.00	5,603	-	-	0.005500	-	PSME, PICO	258	Slashing/pullback	265	Underburn	360	
0.31	0.19	11,012	2,112	2,112	0.005500	11.6	PSME, PICO	287	Slashing/pullback	265	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, PICO	-	PCT	170			
0.40	0.00	2,412	-	-	0.005500	-	PSME, PICO	447	PCT	130			
0.45	0.21	8,834	1,892	1,892	0.005500	10.4	PSME, PICO	536	BoxaxSlashing/pullba	273	Underburn	360	
0.57	0.46	24,468	11,206	11,206	0.005500	61.6	PSME, PICO	568	Borax/Slashing	138	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, PICO	-	PCT	215			
0.45	0.00	4,876	-	-	0.005500	-	PSME, PICO	927	PCT	130			
0.60	0.37	14,949	5,589	5,589	0.005500	30.7	PSME, PICO	883	Borax/Slashing	138	Underburn	360	
0.68	0.55	25,405	14,024	14,024	0.005500	77.1	PSME, PICO	718	Borax/Slashing	138	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, ABGR, PICO	-	PCT	215			
0.00	0.00	430	-	-	0.005500	-	PSME, ABGR, PICO	91	PCT	170			
0.00	0.00	2,581	-	-	0.005500	-	PSME, ABGR, PICO	113	PCT	170			
0.00	0.00	4,041	-	-	0.005500	-	PSME, ABGR, PICO	125	Slash	130	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, ABGR, PICO	-	PCT	260			
0.00	0.00	1,614	-	-	0.005500	-	PSME, ABGR, PICO	229	PCT	170			
0.00	0.00	5,051	-	-	0.005500	-	PSME, ABGR, PICO	247	PCT	170			
0.00	0.00	8,757	-	-	0.005500	-	PSME, ABGR, PICO	256	Slash	130	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, ABGR, PICO	-	PCT	260			
0.17	**0.00**	**3,456**	**-**	-	0.005500	**-**	PSME, ABGR, PICO	**471**	PCT	170			
0.39	**0.20**	**10,474**	**2,083**	2,083	0.005500	**11.5**	PSME, ABGR, PICO	**483**	**PCT**	170			
0.48	0.35	17,142	5,990	5,990	0.005500	32.9	PSME, ABGR, PICO	473	Slashing/pullback	265	Underburn	360	
0.00	0.00	-	-	-	0.005500	-	PSME, ABGR, PICO	-	PCT	260			
0.53	**0.09**	**5,869**	**546**	546	0.005500	**3.0**	PSME, ABGR, PICO	**945**	PCT	215			
0.60	**0.40**	**16,334**	**6,452**	6,452	0.005500	**35.5**	PSME, ABGR, PICO	**837**	Slashing	130			
0.68	0.55	28,343	15,624	15,624	0.005500	85.9	PSME, ABGR, PICO	808	Slashing/pullback	265	Underburn	360	

Computing Values and Costs with Defined Treatment Criteria 3

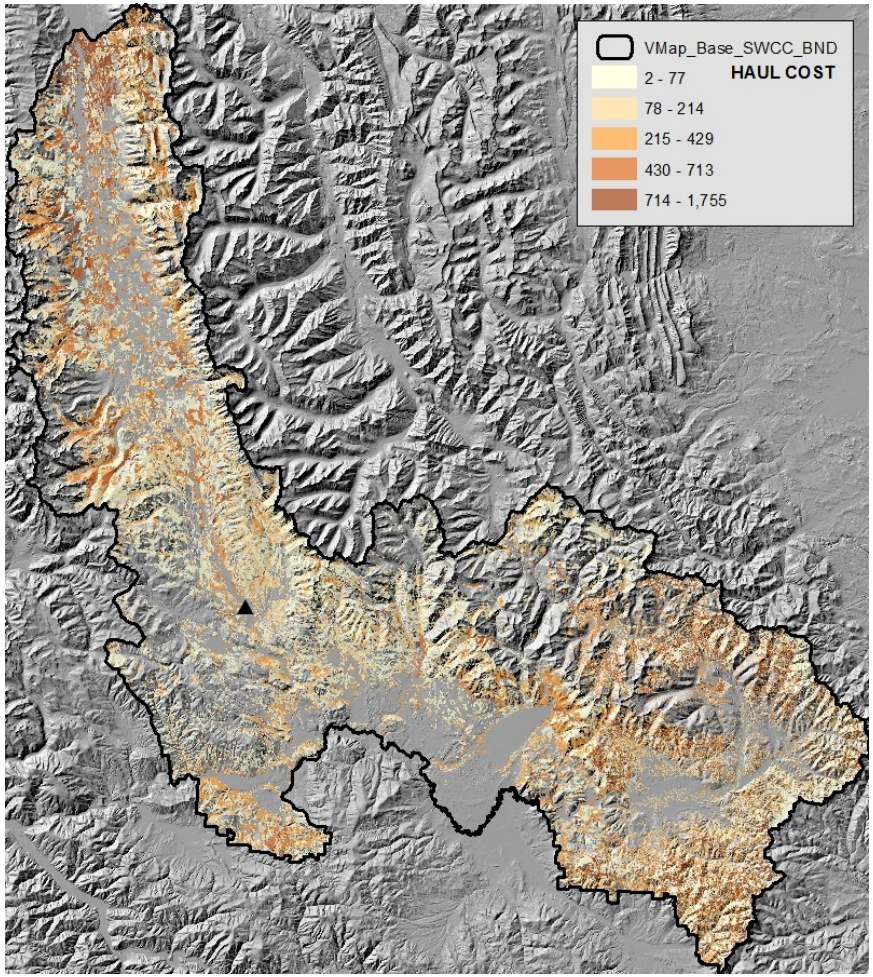
Ground Costs per ton	Skyline Costs per ton	Helicopter Costs per ton	Ground Costs per mbf	Skyline Costs per mbf	Helicopter Costs per mbf	Ground Costs per acre	Skyline Costs per acre	Helicopter Costs acre	Erosion Cost per MBF	Snow plow per MBF	Road Costs per MBF	Refores tation Costs per acre	Rough Revenue per MBF	STATLINK	Estimated Revenue per acre
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540014100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540014200	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540014300	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540014400	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540024100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540024200	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540024300	0.00
20.36	41.61	100.75	111.99	228.83	554.15	236.50	483.22	1,170.21					$ 361.25	801540024400	762.86
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540034100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540034200	0.00
24.53	41.75	100.94	134.89	229.64	555.19	255.19	434.43	1,050.32					$ 361.25	801540034300	683.41
12.07	35.50	92.90	66.37	195.27	510.94	743.73	2,188.07	5,725.31					$ 361.25	801540034400	4048.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540044100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	801540044200	0.00
21.23	39.27	97.75	116.77	215.99	537.62	652.68	1,207.28	3,005.00					$ 361.25	801540044300	2019.18
10.23	33.61	90.46	56.25	184.87	497.54	788.85	2,592.52	6,977.42					$ 361.25	801540044400	5066.07
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540014100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540014200	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540014300	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540014400	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540024100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540024200	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540024300	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540024400	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540034100	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	**802540034200**	0.00
23.91	41.62	100.78	131.51	228.93	554.29	273.94	476.88	1,154.60					$ 361.25	**802540034300**	752.50
17.02	39.00	97.40	93.63	214.51	535.72	560.91	1,285.02	3,209.16					$ 361.25	802540034400	2164.03
0.00	0.00	0.00	0.00	0.00	0.00	-	-	-					$ 361.25	802540044100	0.00
29.22	42.66	102.11	160.73	234.61	561.59	87.68	127.98	306.35					$ 361.25	**802540044200**	197.07
20.52	38.69	97.00	112.83	212.81	533.52	728.02	1,373.08	3,442.39					$ 361.25	**802540044300**	2330.85
9.11	32.54	89.08	50.12	178.96	489.94	783.00	2,796.03	7,654.62					$ 361.25	802540044400	5644.01

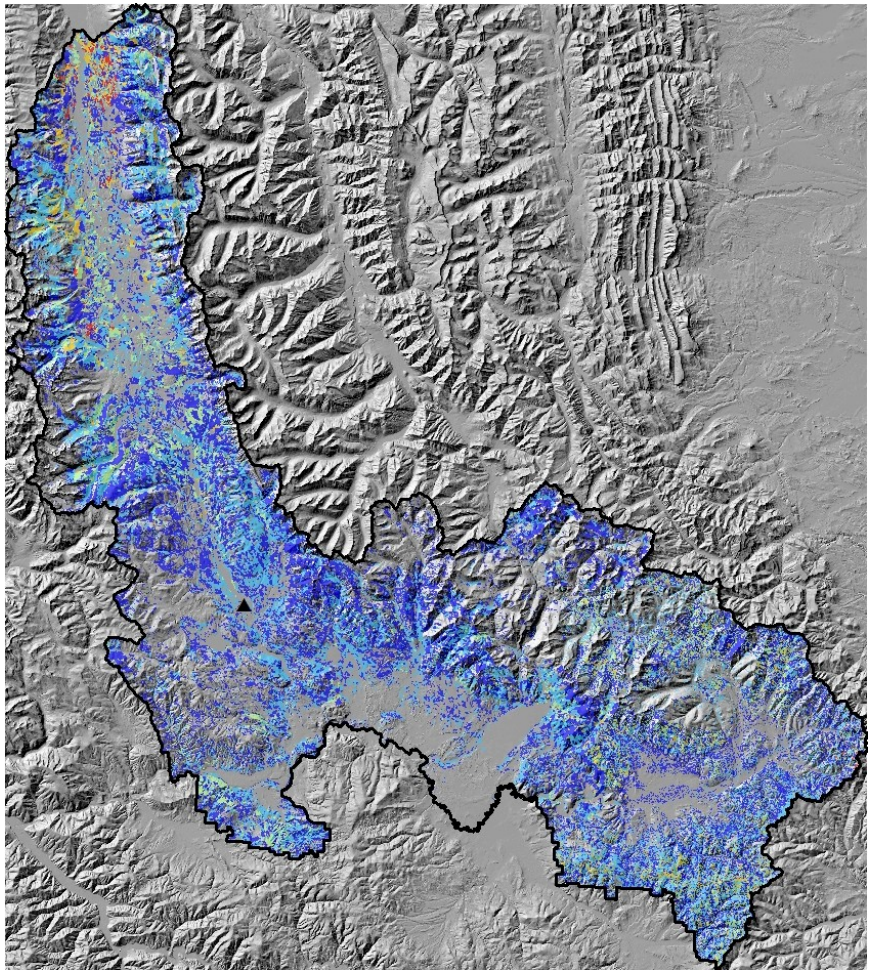
Estimated Harvest Cost



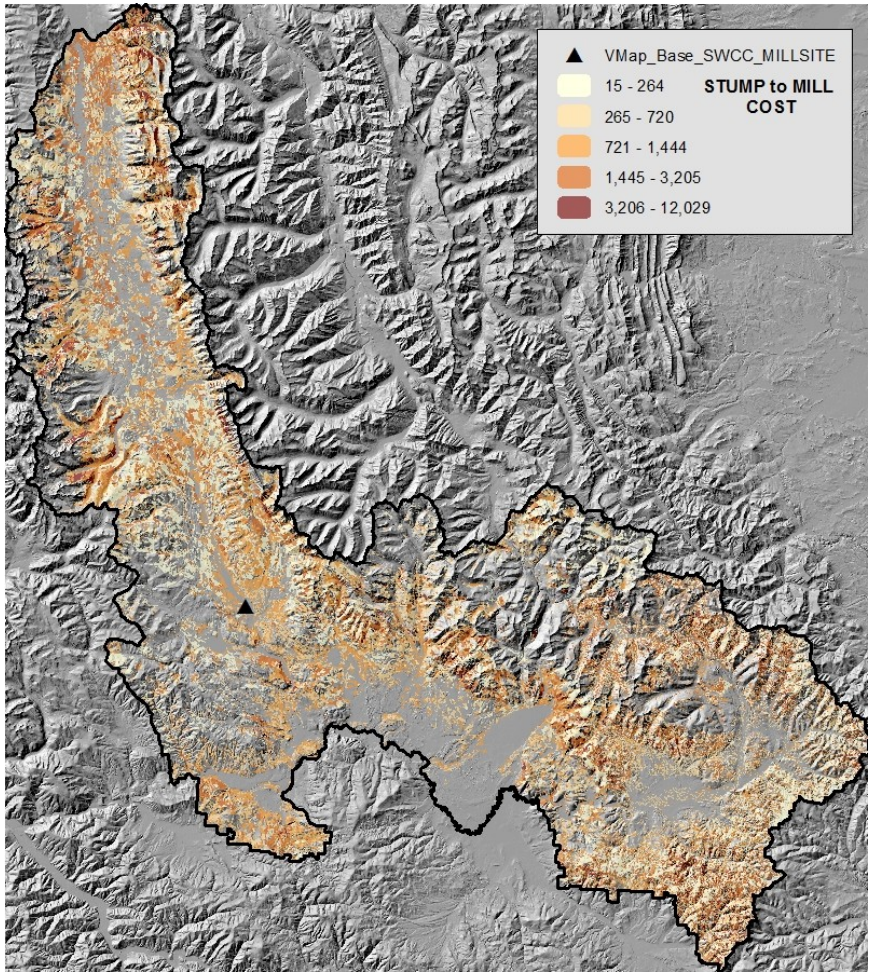


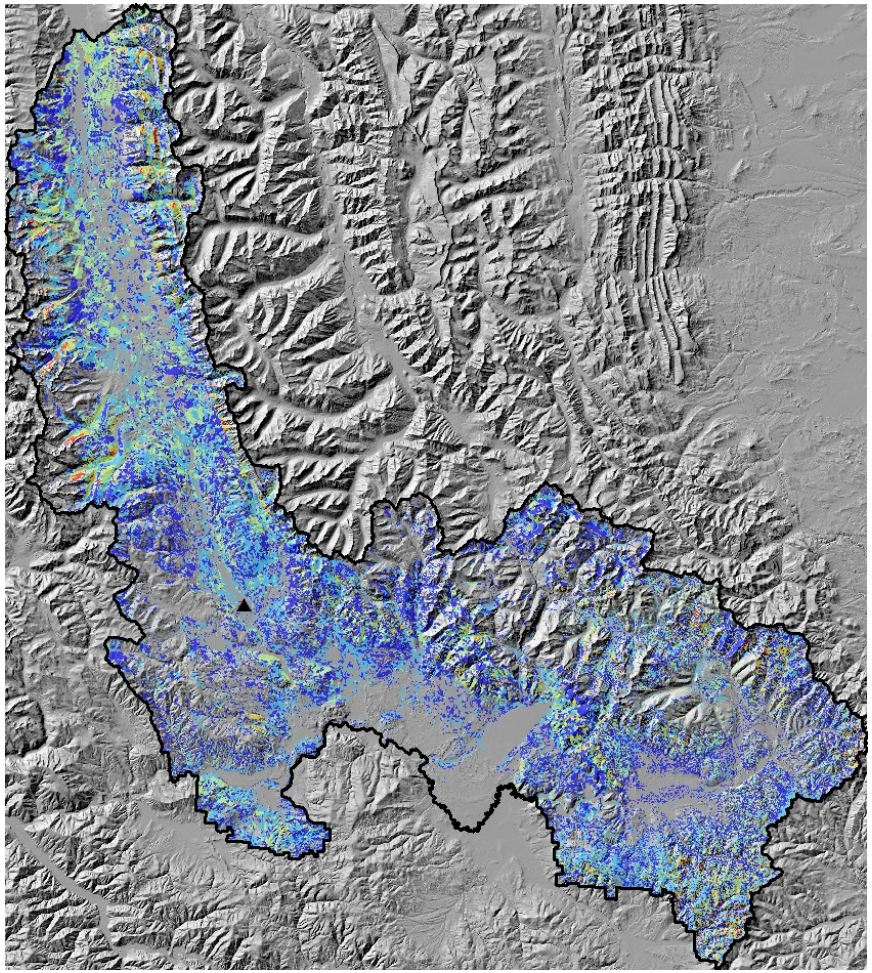
Estimated Haul Cost



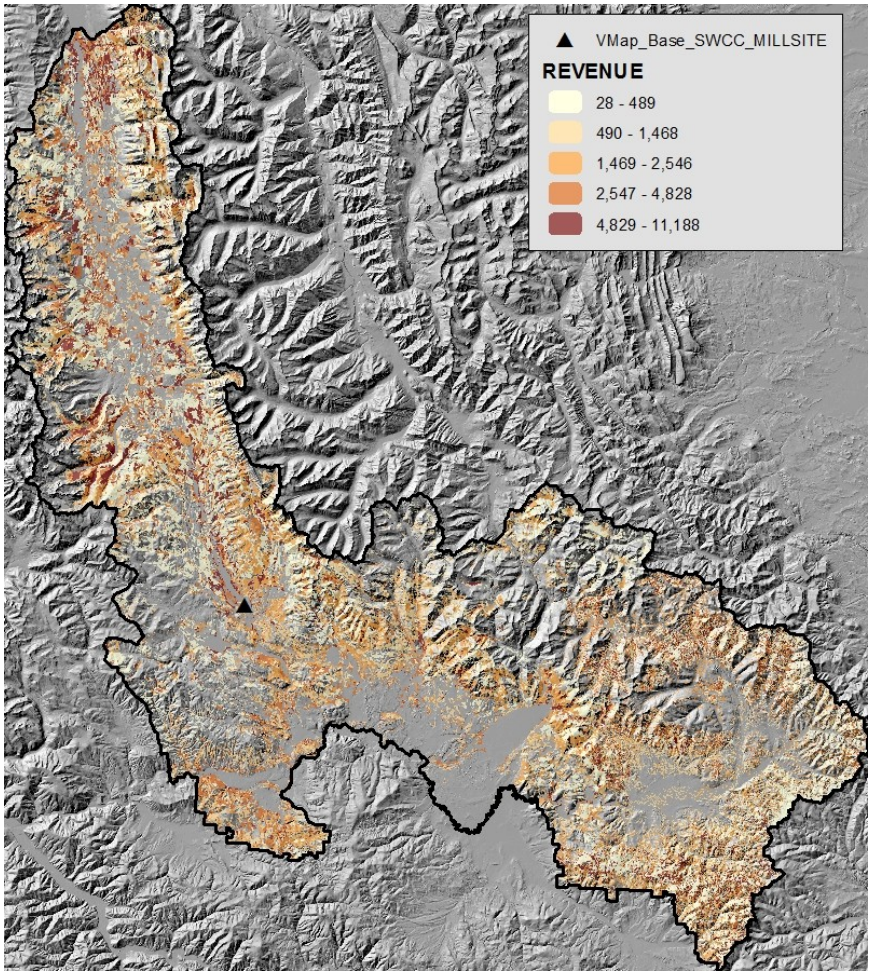


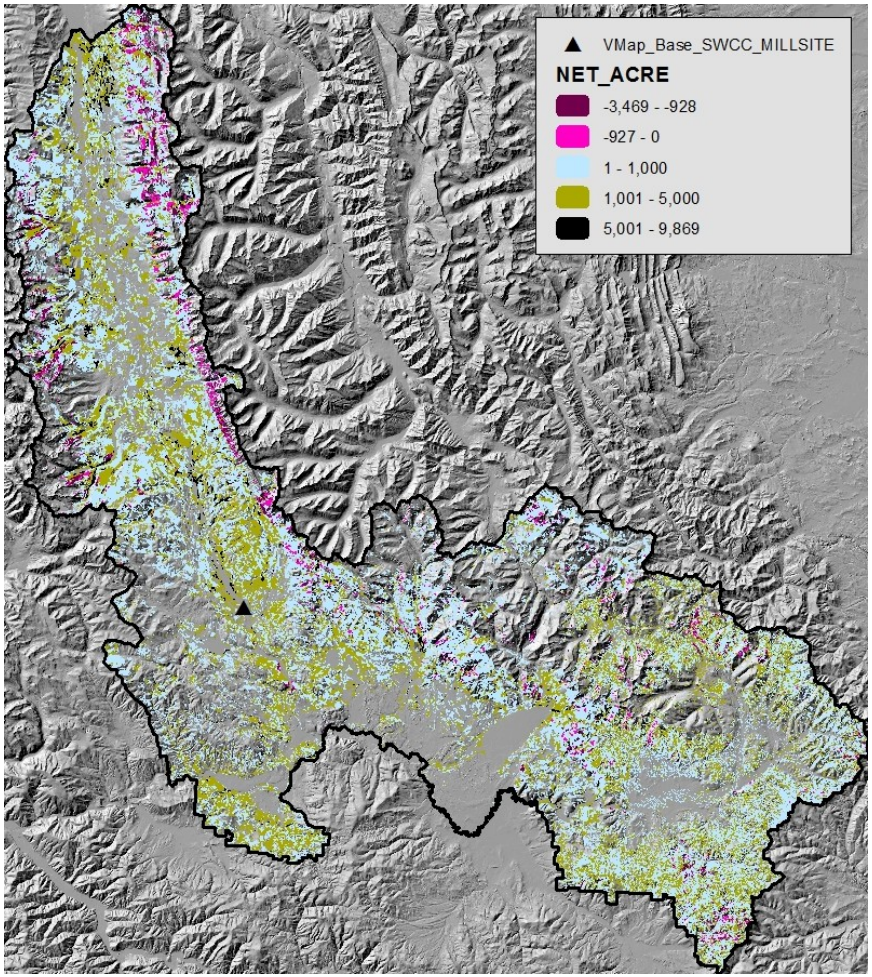
Estimated Stump to Mill Cost



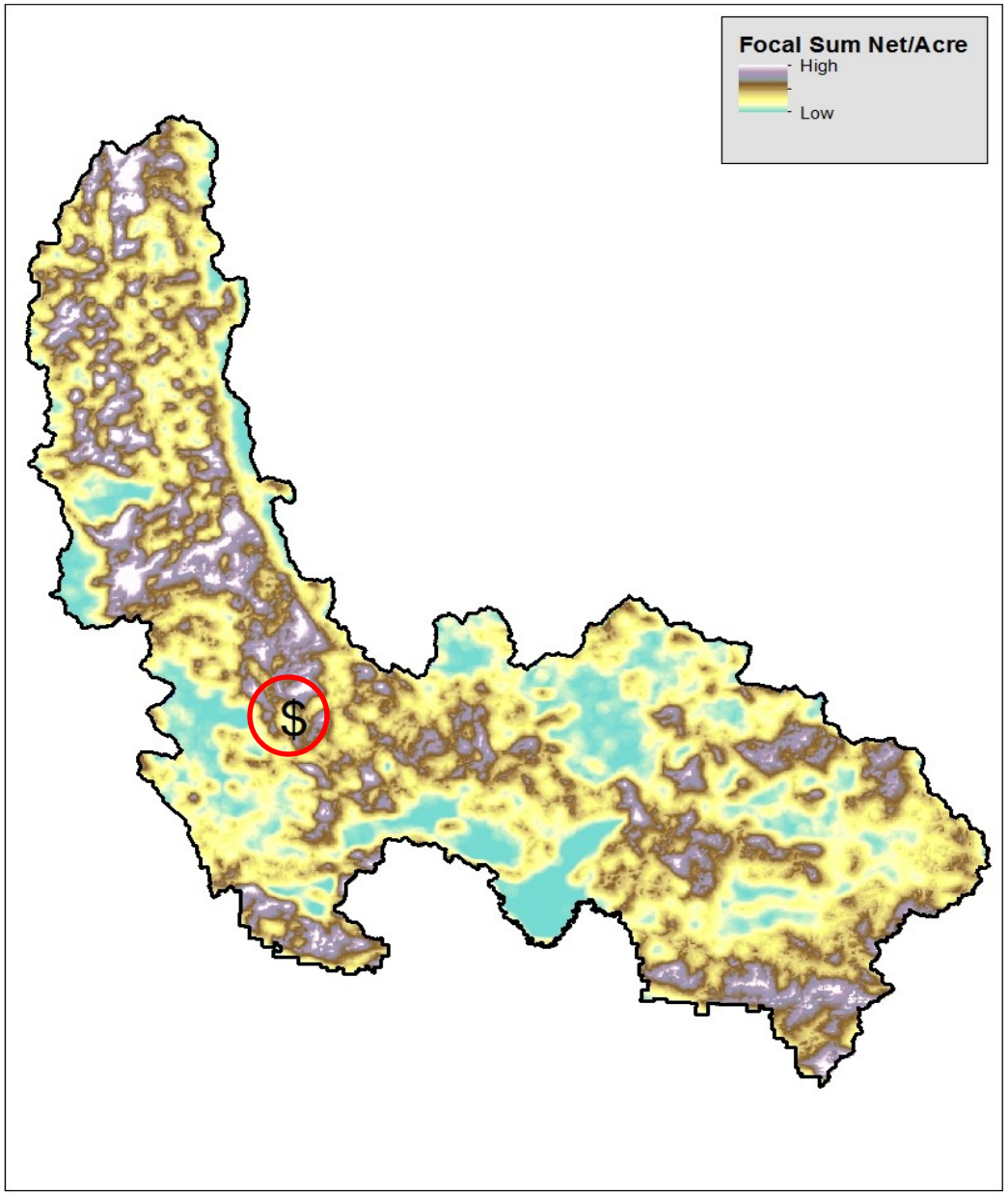


Estimated Revenue



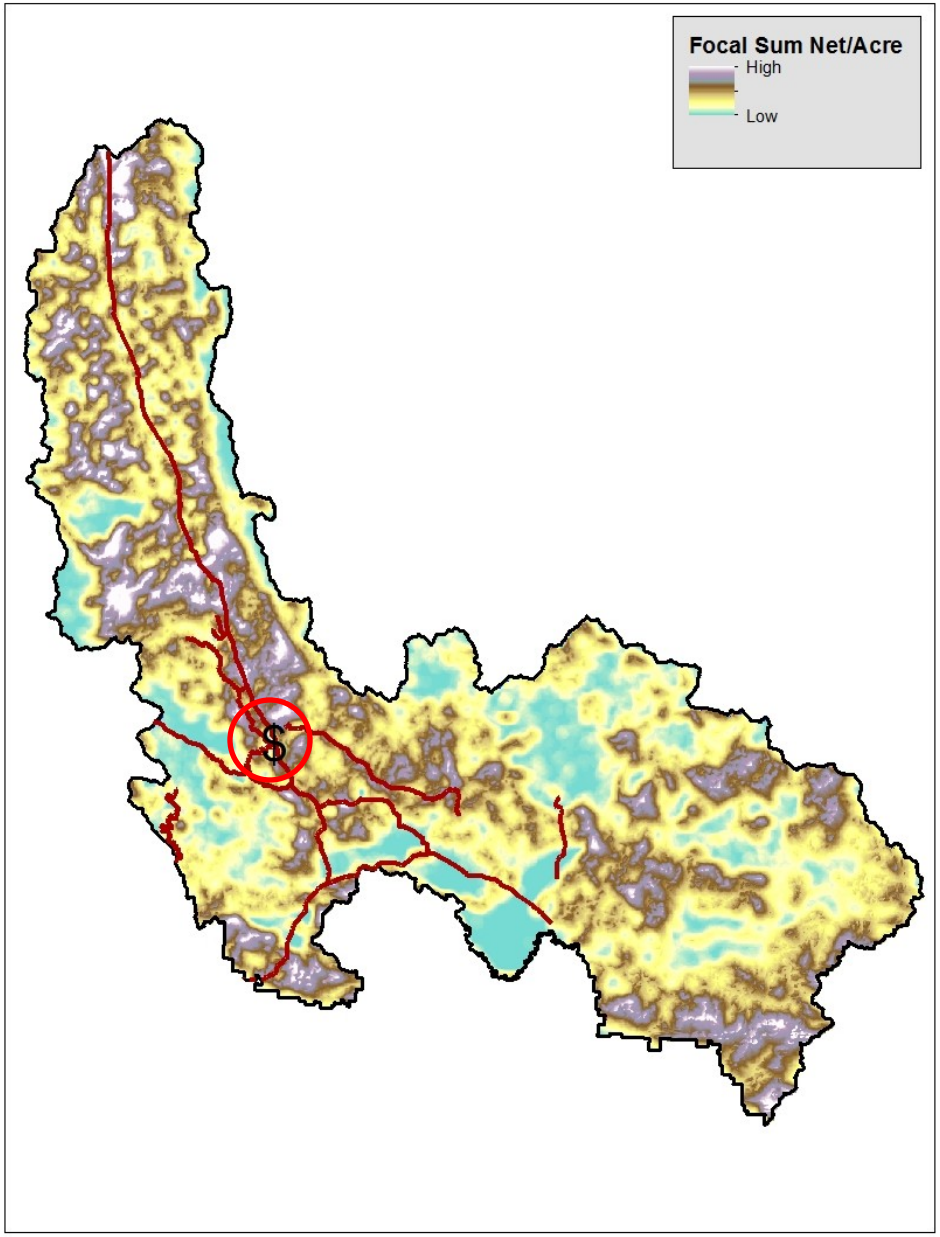


Another look at Estimated Net Revenue



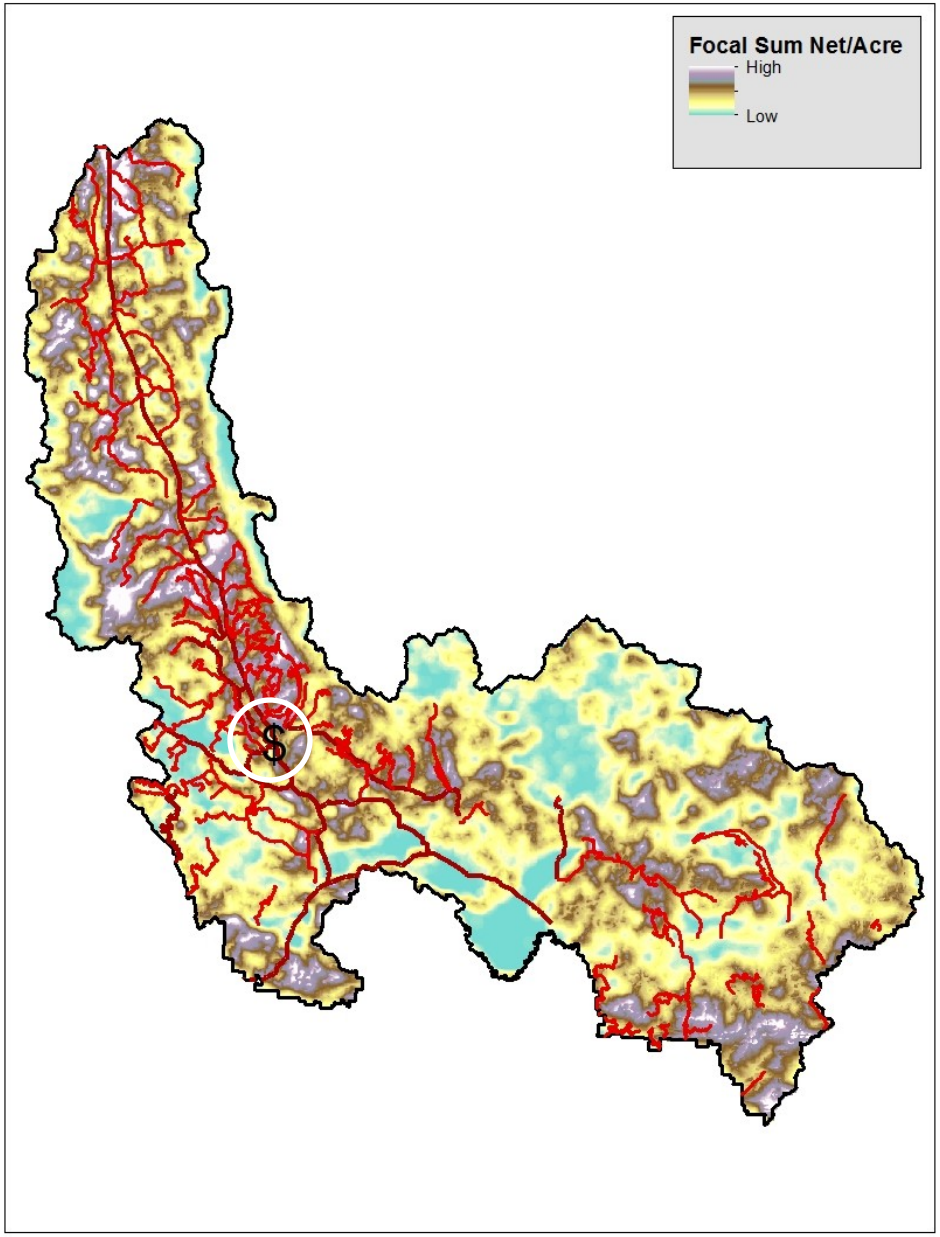
- A purpose of the analysis is to **communicate information**
- The circled area represents the mill location
- If we consider high and low levels of net revenue as peaks and valleys, can you see the **Mountains of Opportunity**?

Another look at Access to Opportunities



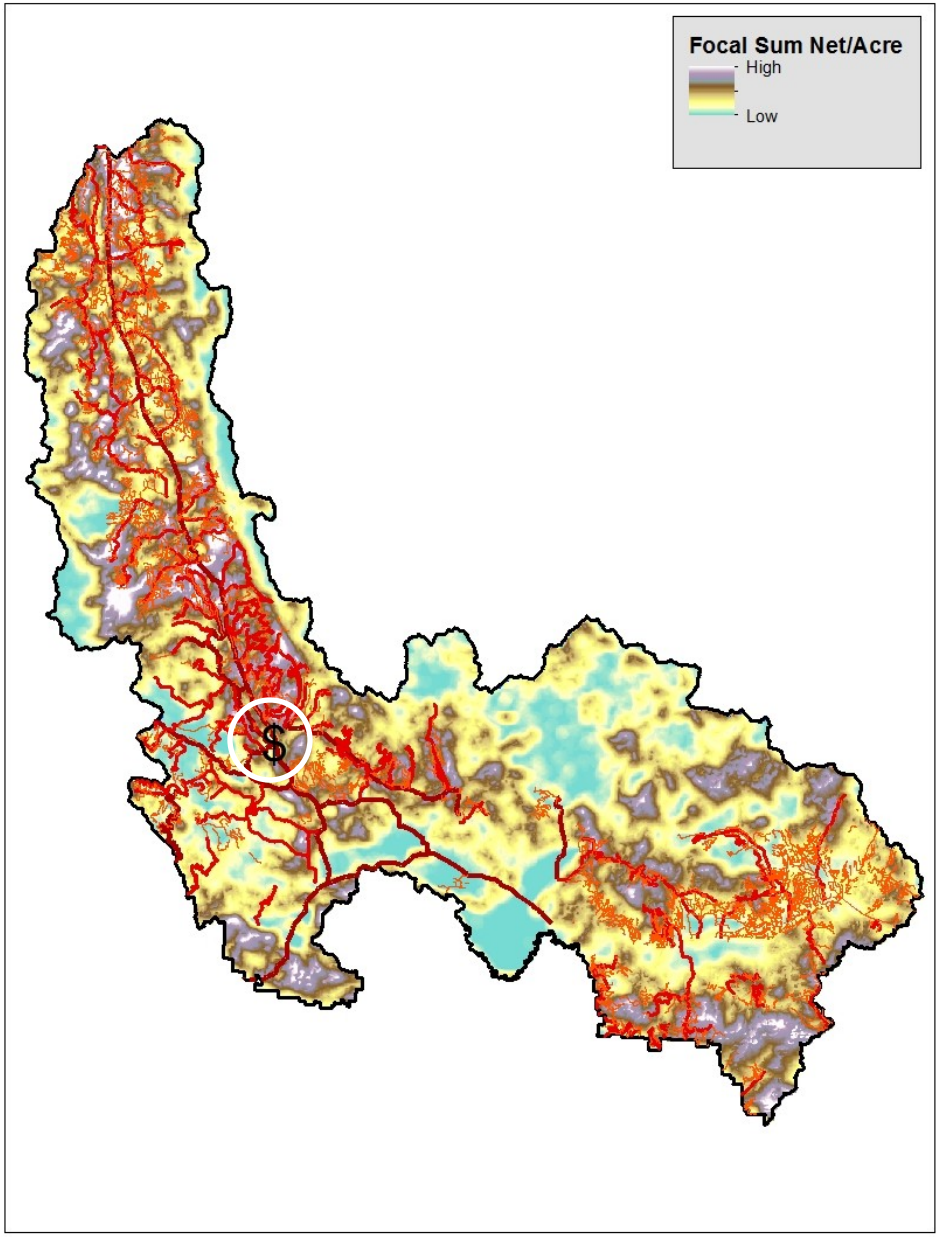
- A purpose of the analysis is to **communicate information**
- The circled area represents the mill location
- Do we have infrastructure to access our estimated **Mountains of Opportunity**?
- Arterial roads are shown

Another look at Access to Opportunities



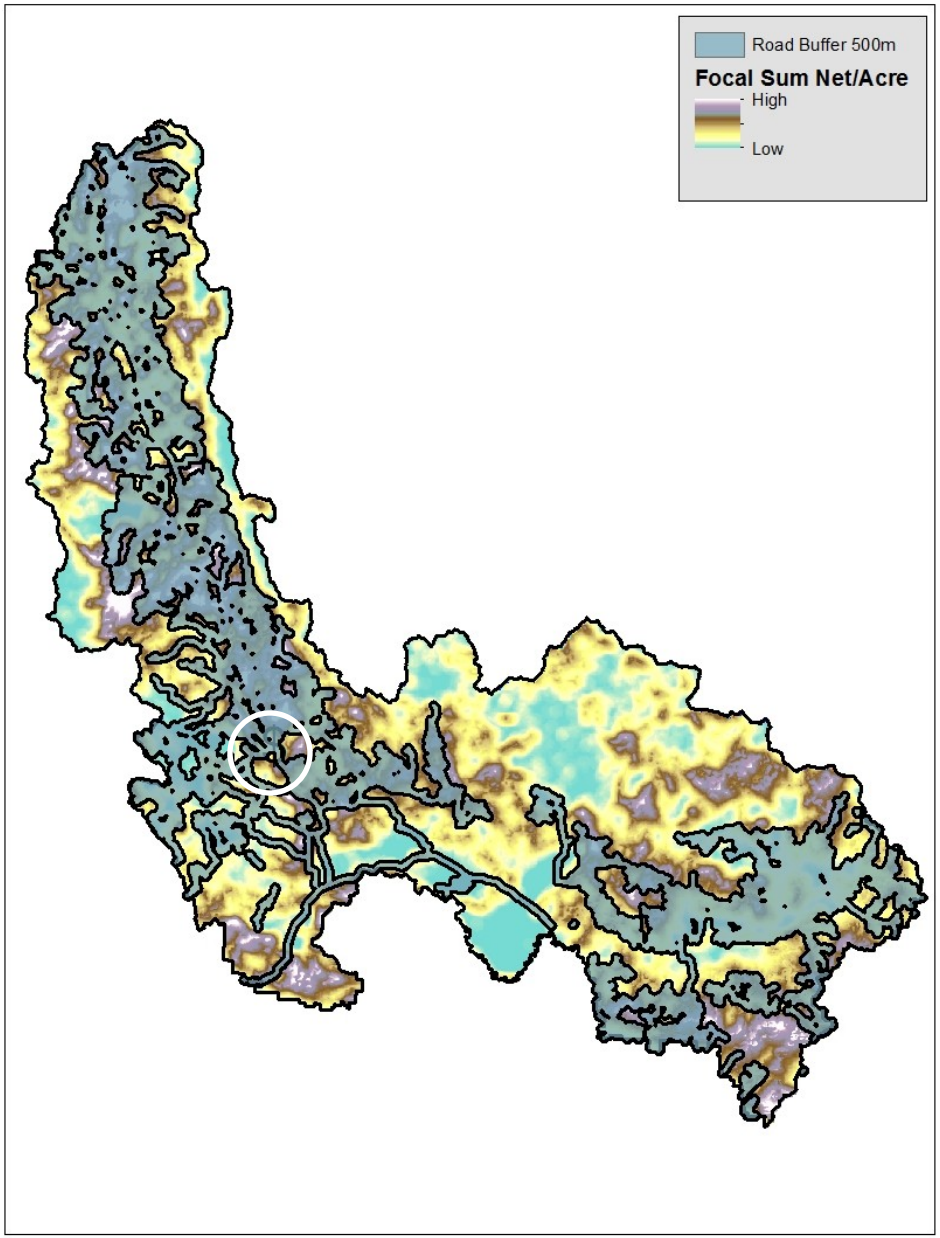
- A purpose of the analysis is to **communicate information**
- The circled area represents the mill location
- Do we have infrastructure to access our estimated **Mountains of Opportunity**?
- Arterial and Connector roads are shown

Another look at Access to Opportunities



- A purpose of the analysis is to **communicate information**
- The circled area represents the mill location
- Do we have infrastructure to access our estimated **Mountains of Opportunity**?
- Arterial, Connector and Local roads are shown

Another look at Access to Opportunities



- A purpose of the analysis is to **communicate information**
- The circled area represents the mill location
- Do we have infrastructure to access our estimated **Mountains of Opportunity**?
- Composite roads with 500m buffer are shown

Do we have access to opportunity?

Additional Costs to Consider

To be realistic, additional treatment costs should be considered

Presented is a summary of costs, obtained from real, recent projects

While cost are variable and site-specific, ranges provide upper and lower limits of opportunity