Classification of Landforms using Topographic Position Index in Willamette Valley, Oregon

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Abstract

Geomorphological processes shape the landforms which define the terrain of a given area, and the landforms in turn support different ecological or geological processes. Accurate and detailed classification of landforms within a given area are necessary for land use planning, precision agriculture, habitat determination, landslide susceptibility, and more. This study examines the usage of a landform classification scheme based on Topographic Position Index (TPI) in the Willamette Valley of Oregon. Starting combining elevation of points to the neighborhood mean and the relative slope of the point, this method of landform determination then combines a large and small scale analysis to classify all points in a raster into one of ten landform types. These landforms, ranging from deeply incised canyons to small streams; plains to moderate slopes; and local ridges to mountain tops, were then cross-referenced with both the landcover and the lithology of the Willamette Valley. The model accurately separated rough, mountainous terrain from broad flat areas, but failed to recognize landforms on a large enough scale to encompass the entire valley.

Keywords: landform, topographic position index, geomorphology, landcover, lithology, willamette valley

# Landform Analysis of the Willamette Valley

Jordan Fink and Lana Jewell

Background

Geology → Landform → Landcover

- Landform classification: simplifies terrain into distinct landforms
  - Example landforms: mountains, plateaus, plains, channels, pits

- Topographic features are created by geologic and biologic processes

- Are landforms over a given area distinctly influenced by bedrock geology and do they influence landcover?

- Can we automatically classify landforms for an entire area, such as the Willamette Valley, starting with a DEM?
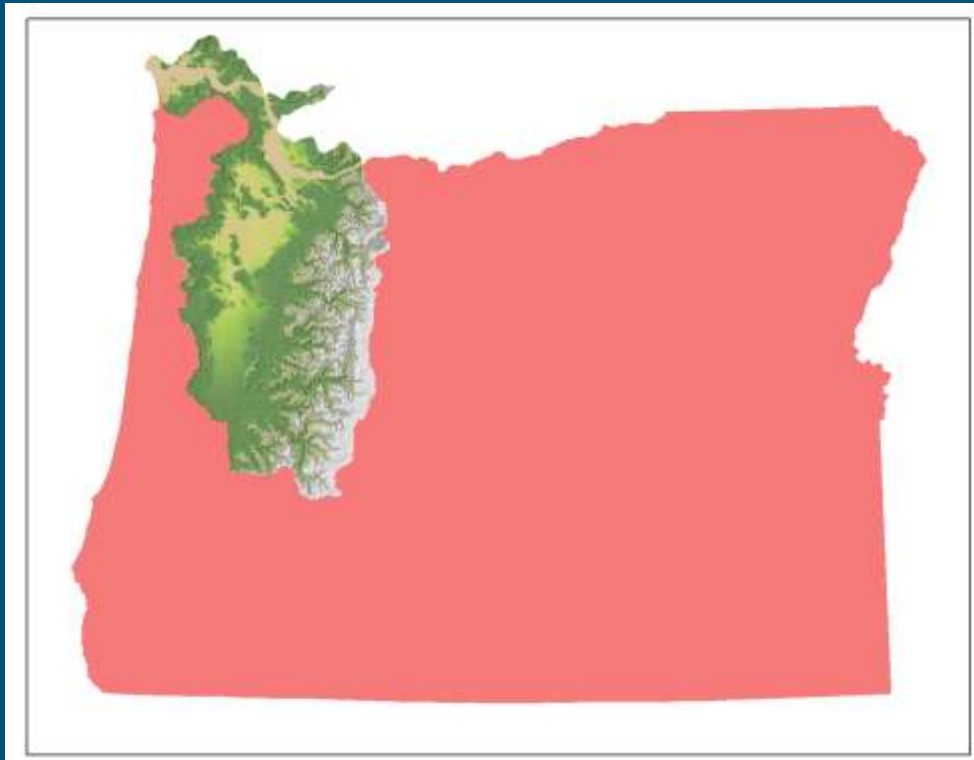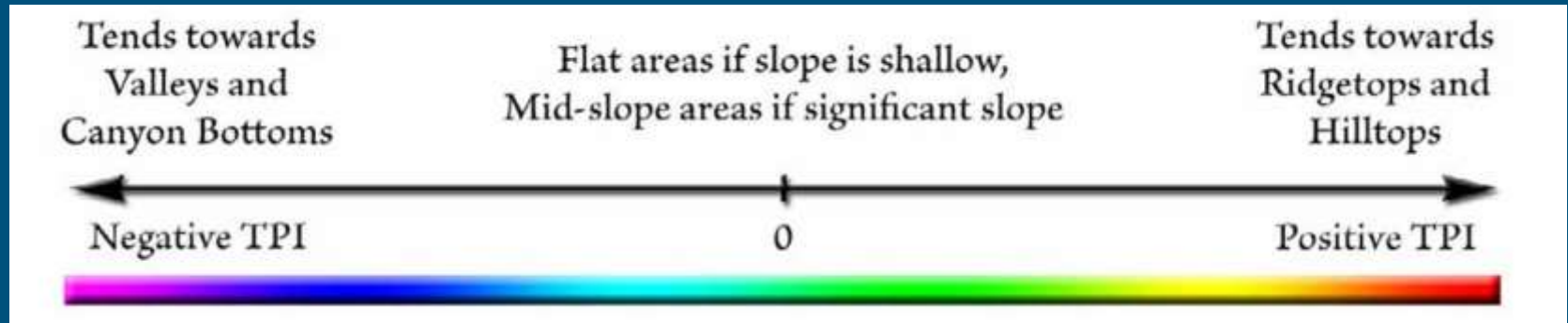
Regional Context--Willamette Watersheds
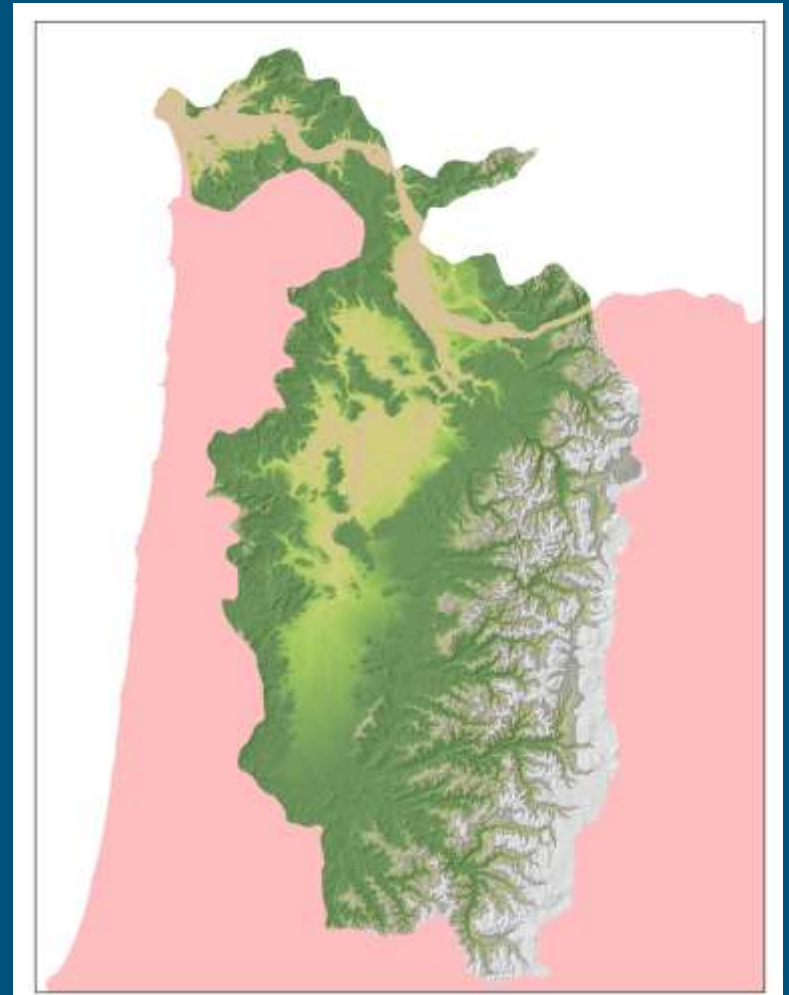
Topographic Position Index (TPI)

Compares elevation of a cell to the mean elevation of the neighborhood around it
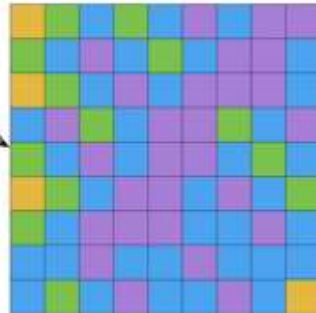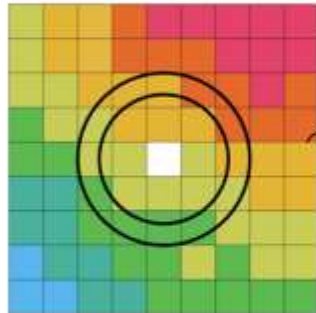
Takes slope into account

Tends towards Valleys and Canyon Bottoms — Flat areas if slope is shallow, Mid-slope areas if significant slope — Tends towards Ridgetops and Hilltops

Negative TPI — 0 — Positive TPI

Topographic Position Classification

TPI
int((dem - focalmean(dem, annulus, irad, orad)) + .5)
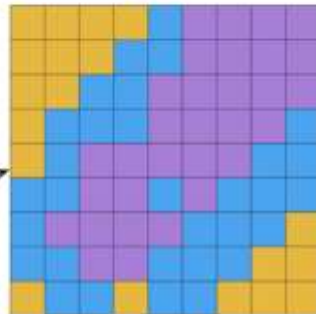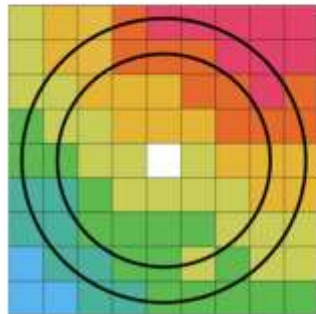
irad = inner radius of annulus in cells
orad = outer radius of annulus in cells

TpiSMSC
10-15 cell radius
(300-500 m)

Mean: 0.45451852
Sd: 23.886340

TpiLGSC:
62-67 cell radius
(1.86-2.1 km)

Mean:0.475822754
Sd: 81.63353566

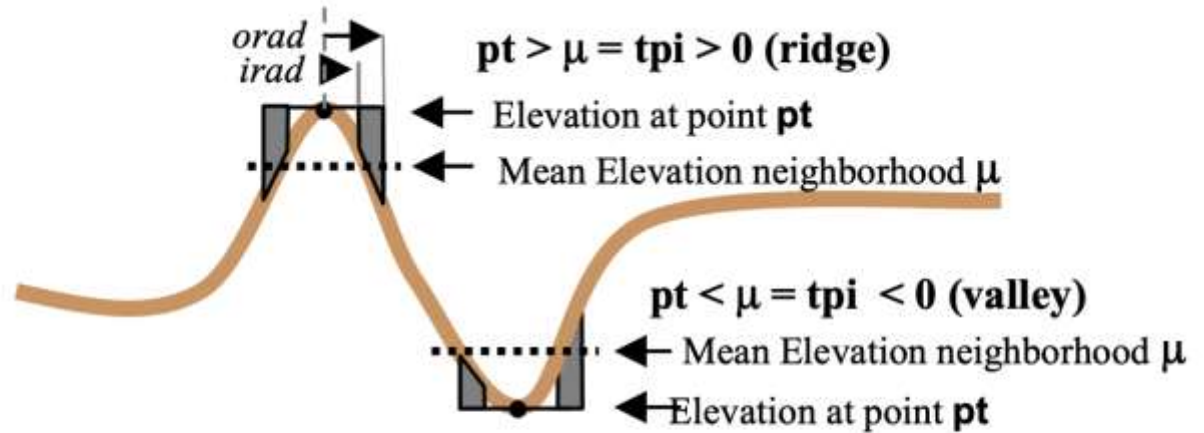Adjusts values based on distribution around the mean value of the raster

Standardize

Int((((TPI - mean)/sd)*100)+0.5)

Combine

Landform Classification

Each point is compared to the average value of the annulus.

Slope is used to separate broad open slopes from broad flat areas.

orad
irad

$pt > \mu = tpi > 0$ (ridge)

← Elevation at point **pt**

← Mean Elevation neighborhood μ

$pt < \mu = tpi < 0$ (valley)

← Mean Elevation neighborhood μ

←Elevation at point **pt**

$pt \sim \mu = tpi \sim 0$ (constant slope, flat area, or saddle)
Check slope of the point

Flat

Slope
Mean Elevation in
Neighborhood μ

Mean Elevation in neighborhood μ

Elevation at point **pt**

Elevation at point **pt**

■	Low Negative
■	Negative
■	Near Zero
■	Positive
■	High Positive
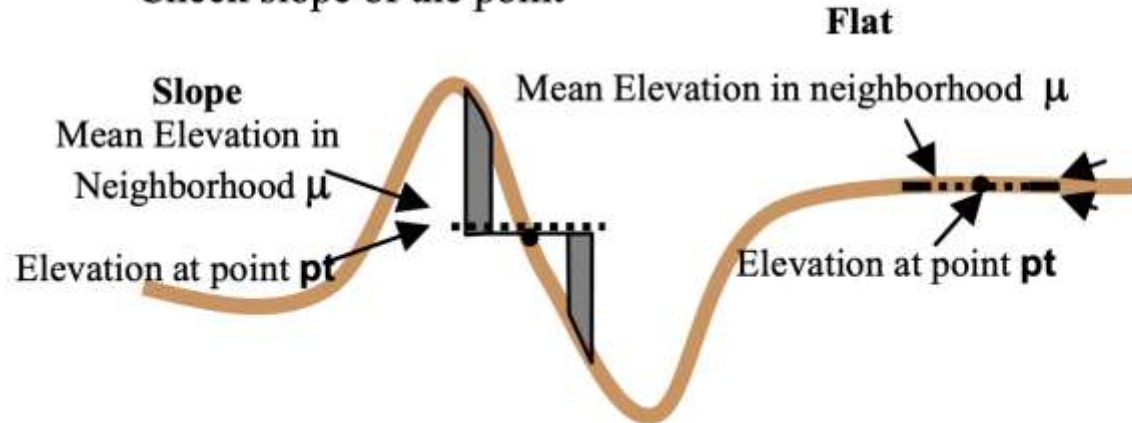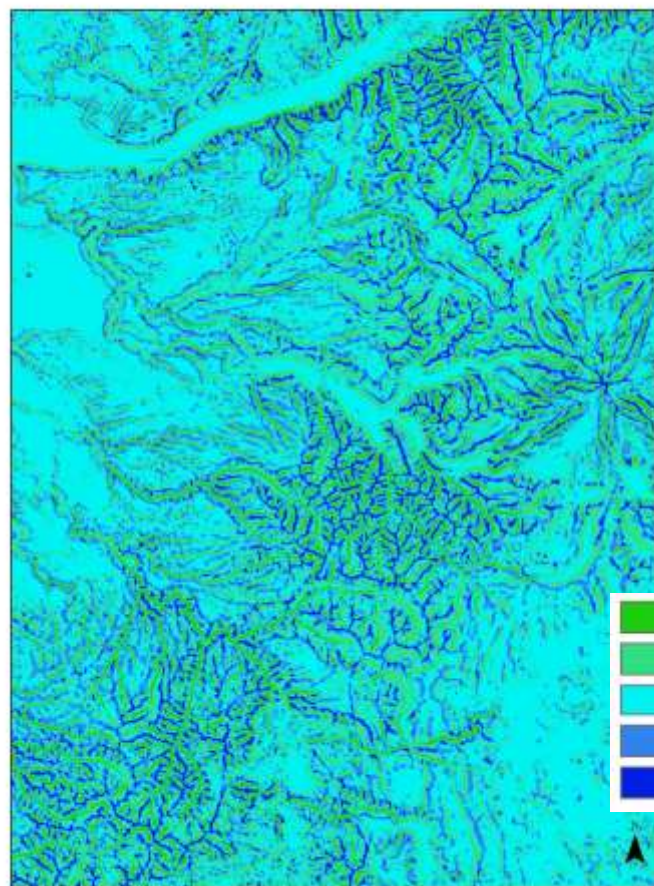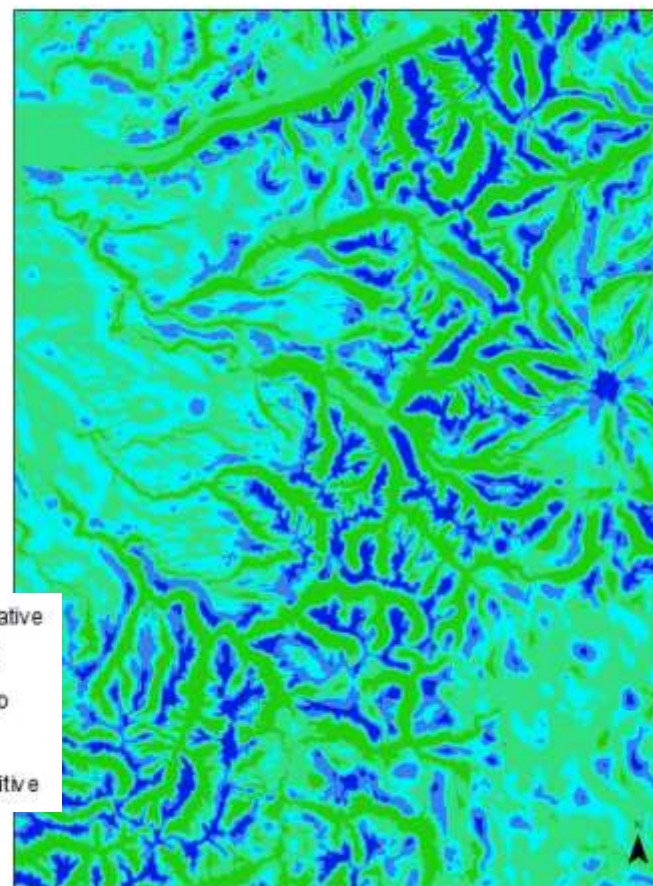
Landform Classification Scheme: Combine

Landform Classification

1.	Canyons
2.	Shallow Valleys
3.	Upland Headwaters
4.	U-Shaped Valleys
5.	Plains
6.	Open Slopes
7.	Mesas
8.	Local Ridge
9.	Midslope Ridge
10.	Mountaintop

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Landcover Analysis

Open Water
Perennial Snow/Ice
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Herbaceuous
Hay/Pasture
Cultivated Crops
Woody Wetlands
Emergent Herbaceuous Wetlands

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Percent Area of Landcover Type per TPI Class

OBJECTID	Open Water	Perennial Snow Ice	Dev, Open SpaceDev low intensity	Dev Low intens	Dev med	Dev High	Barren	Decid Forest	Evergreen for	Mixed forest	Shrub/Scrub	Herbaceous	Hay/Pasture	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands
canyons, deeply incised streams	0.776733255	0.012925969	2.150411281	0.10987074	0.042303173	0.014688602	0.769682726	0.626321974	74.41715629	5.687426557	12.48178613	2.262632197	0.100470035	0.05640423	0.367802585	0.123384254
drainages, shallow valleys	0.302024684	0.055309047	1.642492263	0.209428639	0.085760095	0.019886399	0.709074412	1.231092385	63.30275799	9.705805586	17.48200902	3.629267808	0.712181662	0.249822887	0.579191369	0.083895746
upland drainages, headwaters	0.11500575	0.510025501	0.180009	0.0100005			1.485074254	0.120006	76.00880044	0.800040002	18.55092755	2.185109255	0.020001		0.0100005	0.00500025
u-shape valleys	1.981916117	0.00528511	2.195082205	0.248400153	0.112749006	0.060338335	0.768983453	0.532474797	71.64142293	3.380708469	12.56534818	3.855047059	1.144666664	0.640819544	0.63817699	0.228580992
plains	5.036962389	0.00036466	4.15876949	7.01150777	4.626172953	1.935070393	1.43995274	0.447164811	12.84124236	1.583537771	3.831213289	2.841069148	28.56621914	19.81017603	3.991116873	1.879456983
open slopes	0.107117815	0.033463536	2.530378078	1.464892179	0.452533957	0.080122746	0.905757884	1.372349977	53.99997068	7.818306797	17.19154683	5.799972574	5.286893764	2.42377774	0.465643384	0.067272058
mesas	0.017185822	0.192481203	0.83179377	0.262943072	0.046401719	0.003007519	0.915574651	0.299462943	71.29795918	1.884854995	18.36691729	4.464876477	0.878195489	0.5224489	0.01160043	0.004296455
local ridges/hills in valleys	0.006889425		0.227351016		0.006889425		0.275576989	0.013778849	85.84223217	0.675163624	10.12745436	2.824664141				
midslope ridges, small hills in plains	0.003536464	0.018861141	1.215954167	0.300599431	0.064245761	0.010609392	0.661908158	0.641278785	68.10522159	4.588561897	17.32395777	5.132587925	1.257212913	0.658371694	0.016503498	0.000589411
ridges	0.004411797	0.090993316	0.714711138	0.133456864	0.020404562	0.003308848	1.02022809	0.185846955	75.41195156	1.697990426	16.56078354	3.698188957	0.296141883	0.161030596	0.000551475	0

Evergreen forests present in all topographic positions

Hay and pasture dominant in plains

Percent Area of TPI Class per Landcover Type

OBJECTID	Open Water	Perennial Snow Ice	Dev, Open SpaceDev low intensity	Dev Low intens	Dev med	Dev High	Barren	Decid Forest	Evergreen for	Mixed forest	Shrub/Scrub	Herbaceous	Hay/Pasture	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands
canyons, deeply incised streams	2.102450739	1.743264659	3.995284255	0.194086083	0.126955019	0.111706881	3.645470989	3.916094192	7.896103443	6.185145428	4.979700524	2.683436694	0.044614903	0.038402919	1.198246655	0.942887931
drainages, shallow valleys	0.772913055	7.05229794	2.885119204	0.349770107	0.243330453	0.142984808	3.175177404	7.277469601	6.350335431	9.979297654	6.594047987	4.069402829	0.298998121	0.160812222	1.783971058	0.606142241
upland drainages, headwaters	0.03657819	8.082408875	0.039297878	0.002075787			0.826492278	0.088167224	0.947659591	0.102233809	0.869642673	0.304508397	0.001043623		0.003828264	0.004489943
u-shape valleys	7.156602363	0.950871632	5.440572876	0.585371929	0.451395624	0.612153709	4.858772784	4.441423901	10.14078677	4.904666973	6.687575596	6.099226535	0.678094344	0.582004235	2.773577321	2.330280172
plains	87.86876382	0.316957211	49.79696096	79.82438842	89.47683953	94.84361037	43.95436204	18.01917637	8.781296425	11.09875786	9.850871518	21.71555989	81.75380023	86.92660642	83.79878644	92.56465517
open slopes	1.975222252	30.74484945	32.02667889	17.62862095	9.251847019	4.151027703	29.22498956	58.4548694	39.03315157	57.92248121	46.72418966	46.86014912	15.99352953	11.2420544	10.33439887	3.502155172
mesas	0.063614243	35.49920761	2.113352546	0.635190817	0.190432529	0.031277927	5.930151663	2.560523126	10.34539296	2.803123243	10.02058076	7.241307226	0.533291588	0.486436969	0.051681565	0.044899425
local ridges/hills in valleys	0.001590356		0.036023055		0.001763264		0.111312091	0.007347269	0.776780376	0.062618208	0.344575399	0.285694377				
midslope ridges, small hills in plains	0.00016443	2.535657686	2.251986726	0.529325681	0.192195793	0.080428954	3.125086963	3.996914147	7.203484664	4.974313756	6.889632734	6.067869835	0.55651221	0.446833959	0.053595697	0.004489943
ridges	0.012722849	13.07448494	1.414723605	0.251170225	0.065240774	0.026809651	5.148184222	1.238014768	8.525008775	1.967361857	7.039183145	4.672845098	0.14010645	0.116808877	0.001914132	

Perennial snow on slopes, mesas, and ridges

Plains are dominant for development, hay, pasture, crops, and wetlands

Open slopes for forest

Lithology Analysis

Legend (left map):
1. Canyons
2. Shallow Valleys
3. Upland Headwaters
4. U-Shaped Valleys
5. Plains
6. Open Slopes
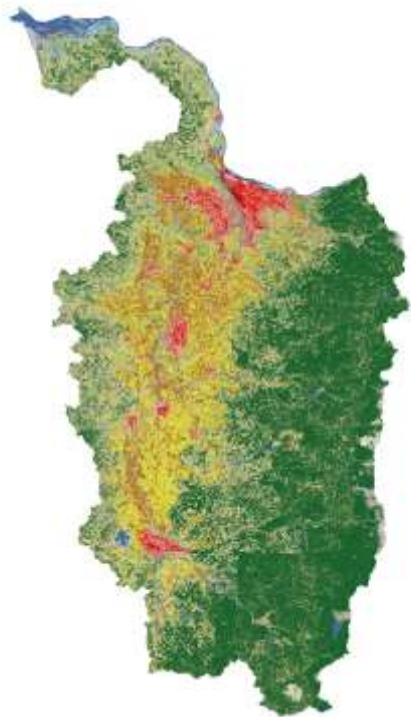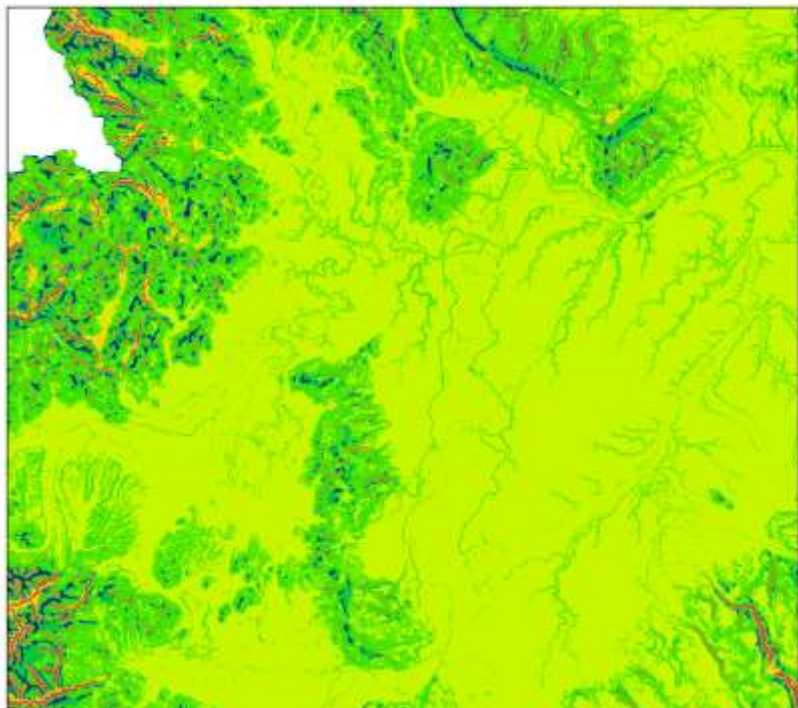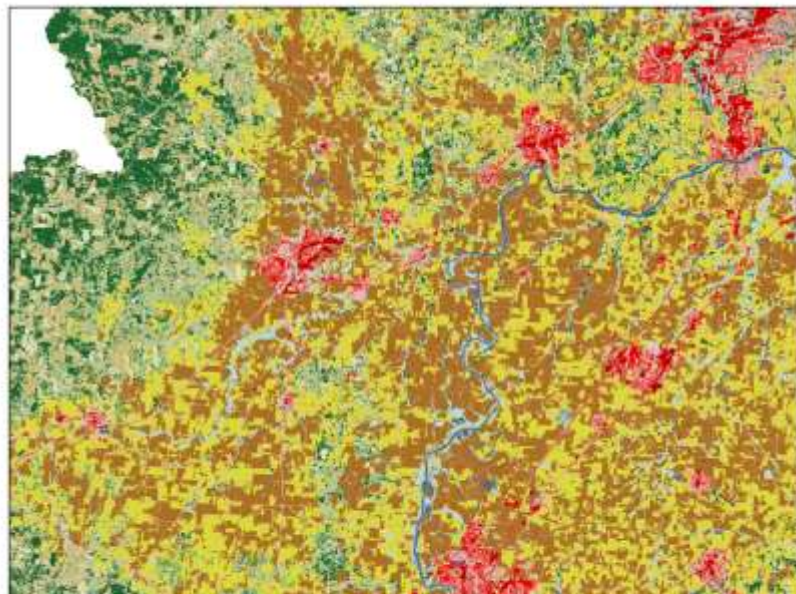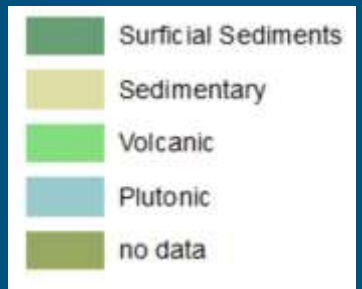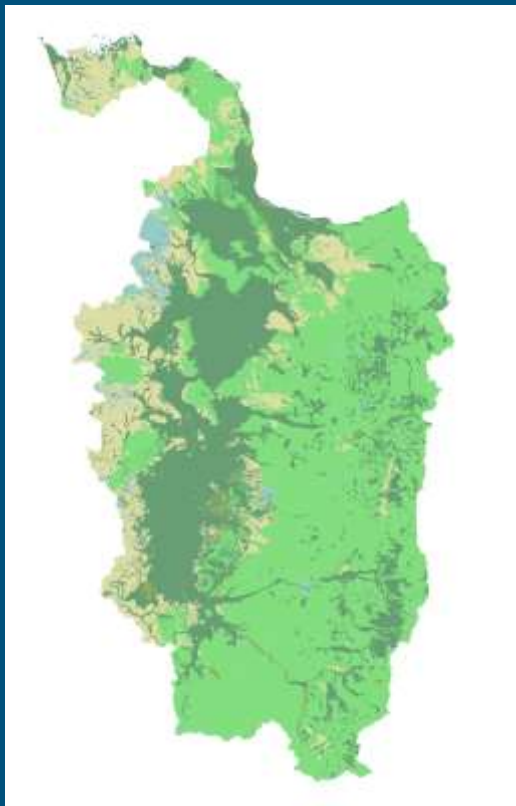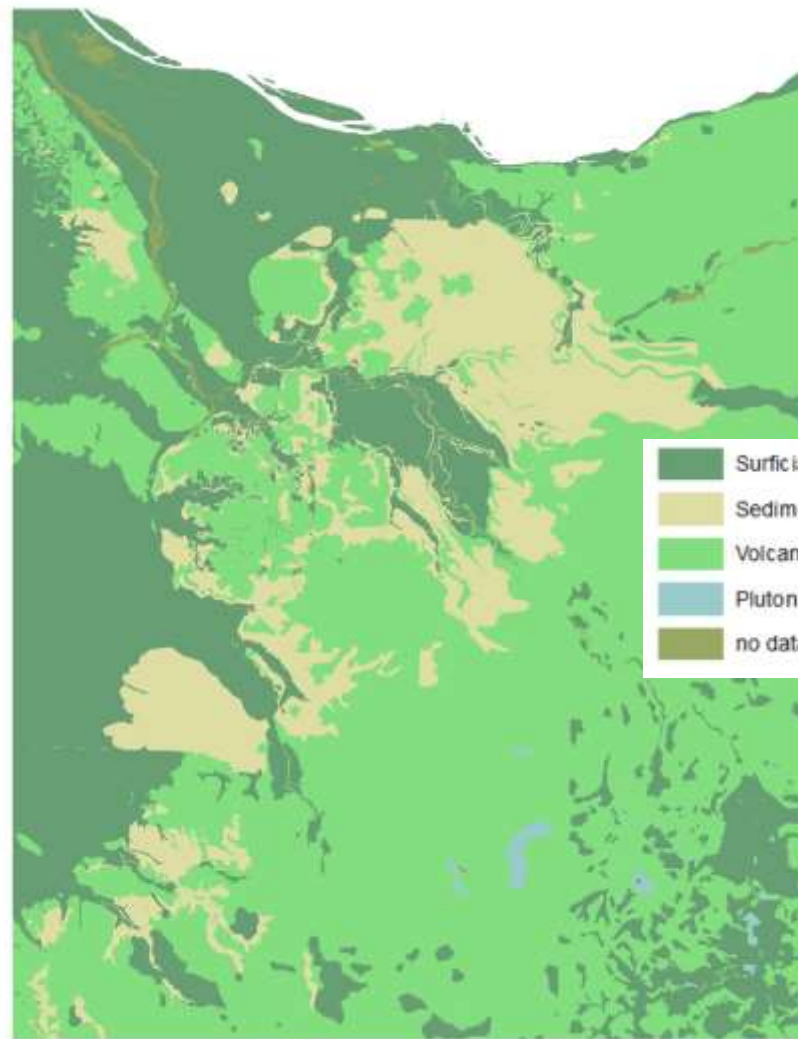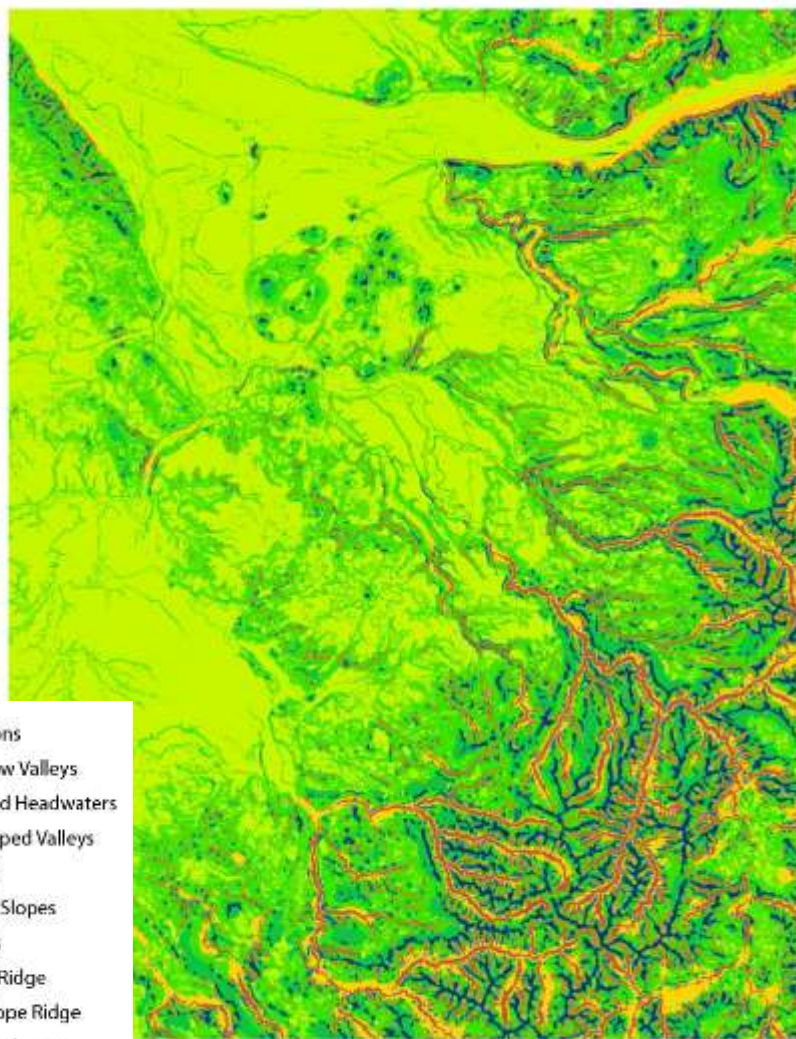7. Mesas
8. Local Ridge
9. Midslope Ridge
10. Mountaintop

Legend (right map):
- Surficial Sediments
- Sedimentary
- Volcanic
- Plutonic
- no data

	Plutonic	Sedimentary	Volcanic	Surficial Sediment	No Data
Canyons, Deeply Incised Streams	3.032975435	5.376543537	73.43907521	17.50374105	0.647664769
Drainages, Shallow Valleys	3.418231323	15.94796808	69.54899622	10.83894485	0.245859523
Upland Drainages, Headwaters	2.512416527	1.533776497	89.59720331	6.350781444	0.005822225
U-shaped Valleys	1.757401999	6.353453505	61.14071814	29.49251269	1.255913667
Plains	0.498931491	10.59022913	18.26303533	68.99432205	1.653481998
Open Slopes	3.468805688	23.35035879	58.64167445	13.94606647	0.593094593
Upper Slopes, Mesas	4.219262791	5.43925187	84.56405931	5.441444845	0.335981188
Local Ridges, Hills Within Valleys	2.652896753	1.126534526	88.02774825	8.138282721	0.054537749
Midslope Ridges, Small Hills in	4.869384094	16.74586667	73.37818385	4.542695253	0.463870128
Mountain Tops, High Ridges	5.152506601	5.046727979	87.52010786	2.055762642	0.224894913

Percent Area of TPI Class per Lithology Type

Landscape is predominantly volcanic in all areas except "plains", where surface sediment dominates. Sediment collects in depressed landforms--valleys and canyons. Plutonic rocks seen mostly on ridges.

Most rocks found on open slopes, most sediment found on plains.

	Canyons	Shallow Valleys	Upland Drainages	U-Shaped Valleys	Plains	Open Slopes	Mesas	Local Ridges	Midslope Ridges	Mountain Tops
Plutonic	5.830784307	6.214397575	0.568093358	4.49552165	5.9601436	45.47568732	11.12278143	0.437131383	9.348040607	10.54741877
Sedimentary	1.89459727	5.314453353	0.063569062	2.97902735	23.18872237	56.1110653	2.628280144	0.034024504	5.892639103	1.893621544
Volcanic	7.099320898	6.357991981	1.018718162	7.864498566	10.97034515	38.65780458	11.20970476	0.729361368	7.08345339	9.008801156
Surficial Sediments	2.886270783	1.690179001	0.123169548	6.470962195	70.69313948	15.68191661	1.230379734	0.115019777	0.748011493	0.360951385
No Data	3.590362321	1.288886101	0.003796181	9.264002958	56.95674994	22.42090739	2.554004806	0.025913064	2.567869121	1.327508121

Percent Area of Lithology Type per TPI Class
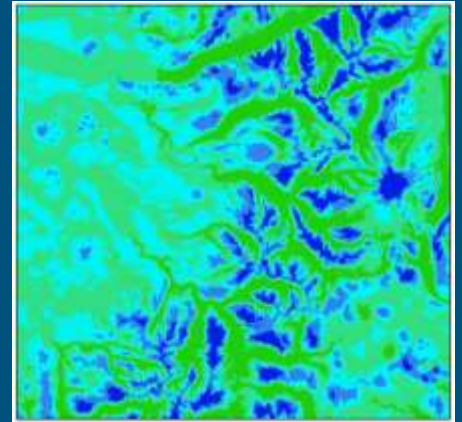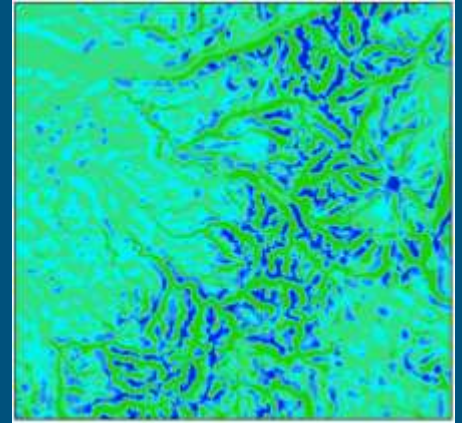
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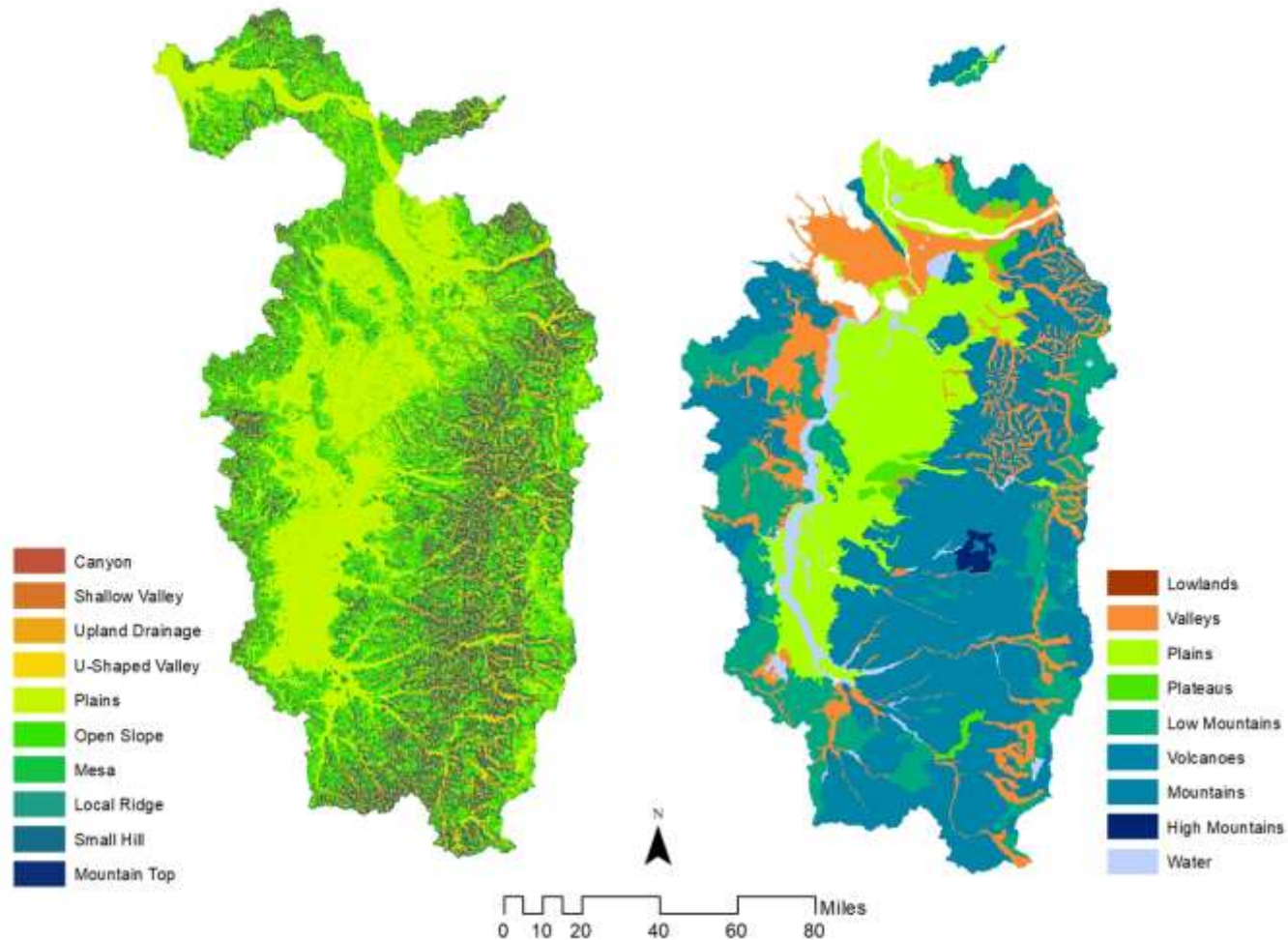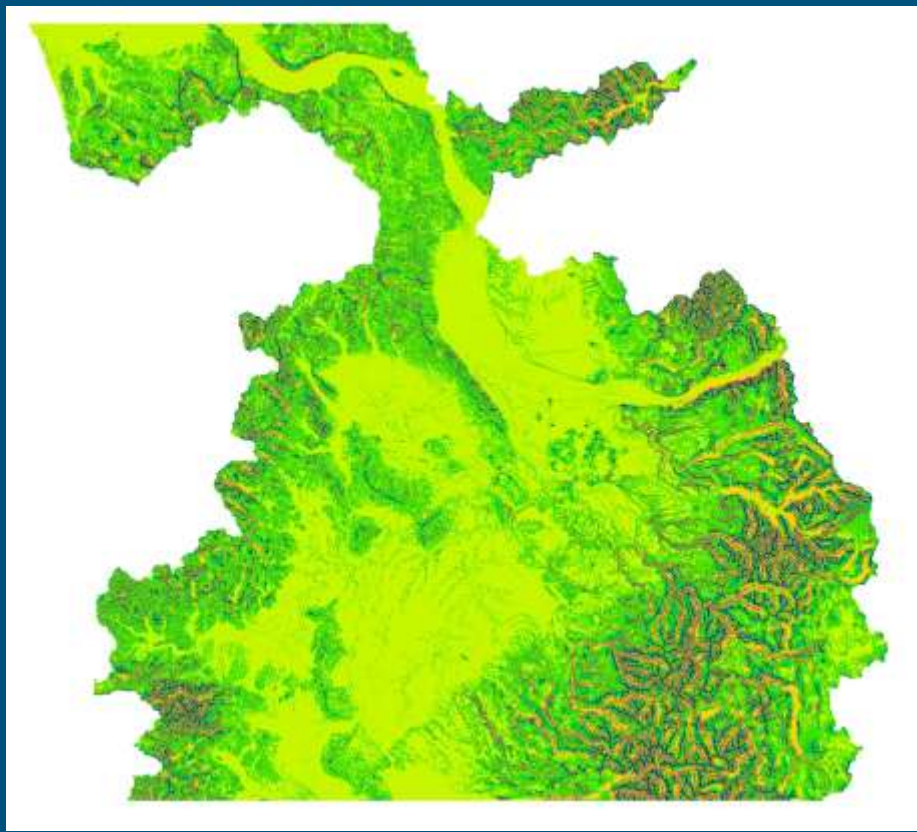
Erwin Raisz--Landforms of the Northwestern United States

Errors & Accuracy

- TPI has limitations on heterogeneous landscapes
  - Large scale analysis of broad mountains/river valleys not possible
- Attempted scale of analysis larger than previous uses of TPI to classify landforms
- There is no standard method for determining sizes other then trying multiple scales and testing for desired sensitivity
- Original DEM from DOGAMI has strange artifact, not sampled well--this proved an issue with detailed analysis

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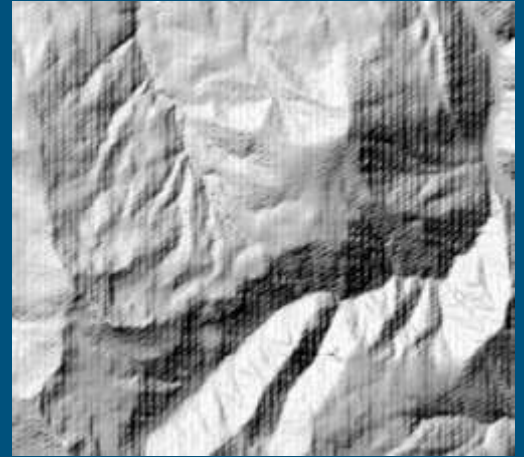
Discussion & Future Applications

- TPI is great for detailed, small scale landform classification
- Landform classification set in terms of immediate relationships, then contextualized within larger relationships
- Possible Uses:
  - Landslide susceptibility on local scales
  - Watershed development and management
  - Agricultural analysis and planning based on landform shape
- Next steps:
  - Finer resolution DEM
  - Smaller scale analysis to provide more useful landforms
  - More detailed geological analysis
  - 3 scale combination of TPI to classify more specific landforms

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