Multi-Criteria Evaluation of the Current Large-Fire Probability on the Clearwater National Forest

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Research Question

Based on historical fire patterns, what areas of the Clearwater National Forest currently have the greatest probability of a large fire (>10 acres)?

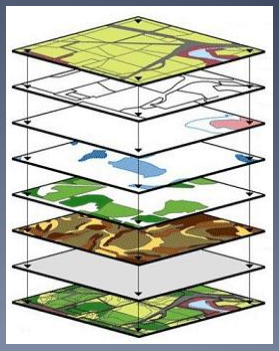
Introduction

http://www.fs.fed.us/r5/klamath/

- Fire Basics:
  - Fuels
  - Weather
  - Topography
- Frequency Ratio:
  - Usage -
    % of Frequency/ % of Area
  - Result
- Underlying Assumption:
  - Spatial relationships between variables and events

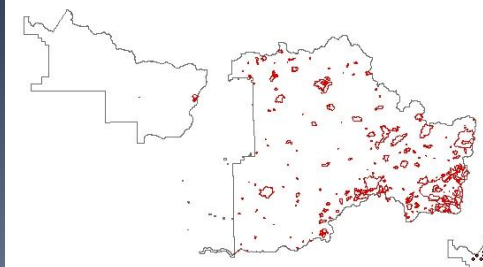
Data

- DEM (30m)
  - Generated Slope and Aspect
- Stream, Road and Trail features
- Management Unit polygons
  - National Forest is subdivided into 6 groups each with a different approach to fire fighting
- Fire History databases
  - Large Fire (>10 acres) polygons
  - Small Fire (0-10 acres) points



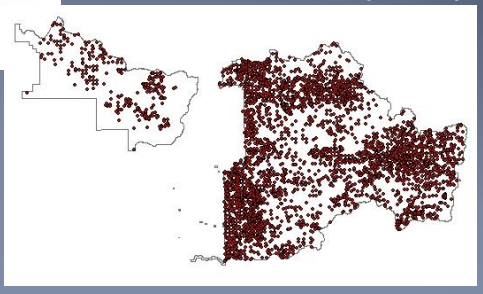
http://nhconnectworks.org/what_is_gis/

Data – Fire History (1970 – 2009)



Large Fires (above)

Small Fires (below)



Methods : Entire National Forest

Prepared Data and Performed Spatial Analyses

- DEM
- Aspect
- Slope

} Convert Raster attribute table to Integer

- Roads
- Streams
- Trails

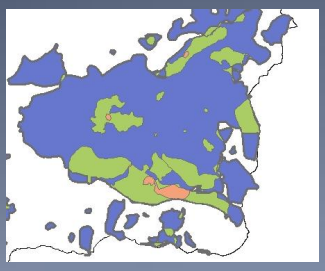
} Spatial Analyst: Euclidian Distance } Convert Raster to Integer

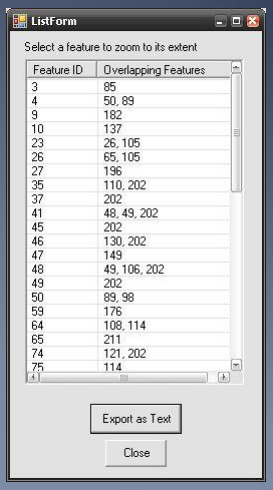
- Management Unit } Convert to Raster } Convert to Integer
- Large Fires (1907 – 2009) } Convert to Raster with Priority Field } Calculate Years Since Last Fire (pre-2010)

Methods : Large Fires

Selecting Fire Areas

- Determined Overlapping Fires:
  Generated Overlap Polygons





- Clipped each data layer by fire polygons

Methods : Small Fires

Selecting Fire Areas

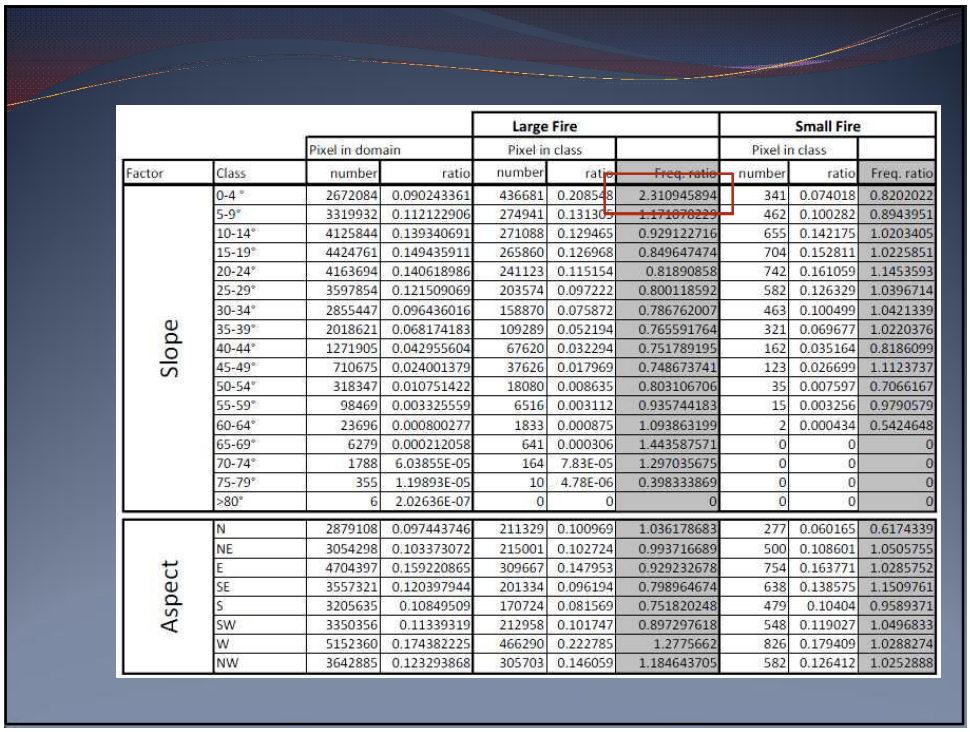
- Only point data available for fires < 10 acres

- Used Extract Value to Points for each data layer

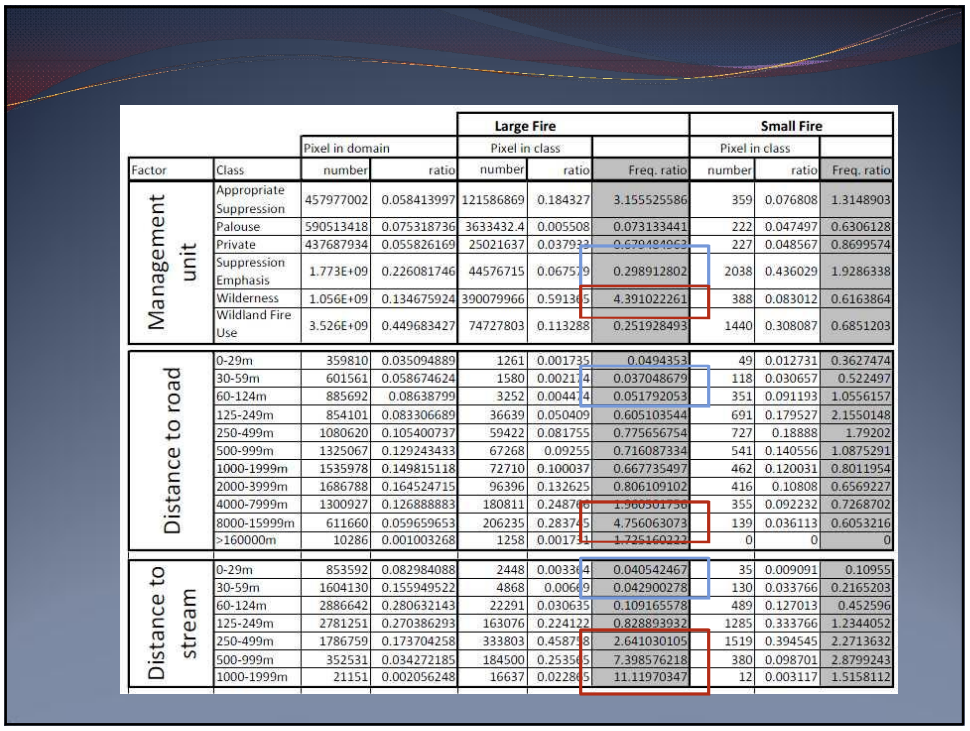
Methods – Data Crunching …

- Export attribute tables
- Summarize for each variable
- Calculate frequency ratios (POA/POF)
  - Large fires
  - Small fires

				Large Fire			Small Fire		
		Pixel in domain		Pixel in class			Pixel in class		
Factor	Class	number	ratio	number	ratio	Freq. ratio	number	ratio	Freq. ratio
Elevation	0-299m	10382	0.000350628	0	0	0	0	0	0
	300-399m	145692	0.004920405	664	0.000317	0.06444778	13	0.002822	0.5734879
	400-499m	226942	0.007664433	2195	0.001048	0.136771382	23	0.004992	0.6513728
	500-599m	367511	0.012411821	7673	0.003664	0.295236769	39	0.008465	0.6820416
	700-799m	630150	0.021281836	11532	0.005507	0.25878332	33	0.007163	0.3365787
	800-899m	2019615	0.068207753	16134	0.00770	0.112966339	98	0.021272	0.3118704
	900-999m	2878090	0.09720073	19208	0.009173	0.094374218	183	0.039722	0.4086611
	1000-1099m	3053726	0.103132424	291217	0.139078	1.348535068	408	0.088561	0.8587104
	1100-1199m	2505368	0.08461292	201059	0.096021	1.134821565	429	0.093119	1.1005313
	1200-1299m	2257890	0.076254932	157197	0.075073	0.984503039	457	0.099197	1.3008585
	1300-1399m	2339529	0.079012097	180071	0.085997	1.08840601	549	0.119166	1.5082056
	1400-1499m	2289988	0.077338966	185322	0.088505	1.14437763	447	0.097026	1.2545586
	1500-1599m	2126663	0.071823048	159434	0.076142	1.0601269	414	0.089863	1.2511757
	1600-1699m	1995751	0.067401803	135321	0.064626	0.958814141	347	0.07532	1.11748
	1700-1799m	1882197	0.063566783	139695	0.066715	1.04952158	298	0.064684	1.0175783
	1800-1899m	1702264	0.057489969	162740	0.07772	1.351895072	273	0.059258	1.0307477
	1900-1999m	1313697	0.044367031	150132	0.071699	1.616045744	232	0.050358	1.1350354
	2000-2099m	809712	0.027346121	116744	0.055754	2.03882327	159	0.034513	1.2620692
	2100-2199m	465836	0.015732517	66999	0.031997	2.033812258	64	0.013892	0.8830058
	2200-2299m	270244	0.009126856	37871	0.018086	1.981647028	67	0.014543	1.5934387
	2300-2399m	165114	0.005576338	24163	0.01154	2.069390939	42	0.009117	1.6348655
	2400-2499m	90614	0.003060275	13578	0.006485	2.118927465	15	0.003256	1.0639289
	2500-2599m	42281	0.001427941	8636	0.004124	2.888304462	14	0.003039	2.1281362
	2600-2699m	15565	0.000525671	4345	0.002075	3.947446417	2	0.000434	0.825843
	2700-2799m	4102	0.000138535	1405	0.000671	4.843466007	1	0.000217	1.5668267
	2800-2899m	762	2.57348E-05	509	0.000243	9.445792452	0	0	0
	>2900m	72	2.43163E-06	72	3.44E-05	14.14085236	0	0	0



				Large Fire			Small Fire		
		Pixel in domain		Pixel in class			Pixel in class		
Factor	Class	number	ratio	number	ratio	Freq. ratio	number	ratio	Freq. ratio
Slope	0-4 °	2672084	0.090243361	436681	0.208548	2.310945894	341	0.074018	0.8202022
	5-9°	3319932	0.112122906	274941	0.131305	1.171078229	462	0.100282	0.8943951
	10-14°	4125844	0.139340691	271088	0.129465	0.929122716	655	0.142175	1.0203405
	15-19°	4424761	0.149435911	265860	0.126968	0.849647474	704	0.152811	1.0225851
	20-24°	4163694	0.140618986	241123	0.115154	0.81890858	742	0.161059	1.1453593
	25-29°	3597854	0.121509069	203574	0.097222	0.800118592	582	0.126329	1.0396714
	30-34°	2855447	0.096436016	158870	0.075872	0.786762007	463	0.100499	1.0421339
	35-39°	2018621	0.068174183	109289	0.052194	0.765591764	321	0.069677	1.0220376
	40-44°	1271905	0.042955604	67620	0.032294	0.751789195	162	0.035164	0.8186099
	45-49°	710675	0.024001379	37626	0.017969	0.748673741	123	0.026699	1.1123737
	50-54°	318347	0.010751422	18080	0.008635	0.803106706	35	0.007597	0.7066167
	55-59°	98469	0.003325559	6516	0.003112	0.935744183	15	0.003256	0.9790579
	60-64°	23696	0.000800277	1833	0.000875	1.093863199	2	0.000434	0.5424648
	65-69°	6279	0.000212058	641	0.000306	1.443587571	0	0	0
	70-74°	1788	6.03855E-05	164	7.83E-05	1.297035675	0	0	0
	75-79°	355	1.19893E-05	10	4.78E-06	0.398333869	0	0	0
	>80°	6	2.02636E-07	0	0	0	0	0	0
Aspect	N	2879108	0.097443746	211329	0.100969	1.036178683	277	0.060165	0.6174339
	NE	3054298	0.103373072	215001	0.102724	0.993716689	500	0.108601	1.0505755
	E	4704397	0.159220865	309667	0.147953	0.929232678	754	0.163771	1.0285752
	SE	3557321	0.120397944	201334	0.096194	0.798964674	638	0.138575	1.1509761
	S	3205635	0.10849509	170724	0.081569	0.751820248	479	0.10404	0.9589371
	SW	3350356	0.11339319	212958	0.101747	0.897297618	548	0.119027	1.0496833
	W	5152360	0.174382225	466290	0.222785	1.2775662	826	0.179409	1.0288274
	NW	3642885	0.123293868	305703	0.146059	1.184643705	582	0.126412	1.0252888



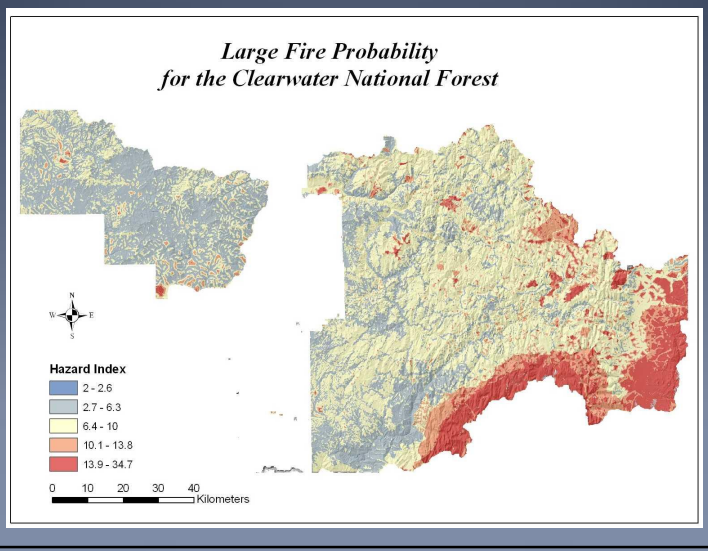
				Large Fire			Small Fire		
		Pixel in domain		Pixel in class			Pixel in class		
Factor	Class	number	ratio	number	ratio	Freq. ratio	number	ratio	Freq. ratio
Management unit	Appropriate Suppression	457977002	0.058413997	121586869	0.184327	3.155525586	359	0.076808	1.3148903
	Palouse	590513418	0.075318736	3633432.4	0.005508	0.073133441	222	0.047497	0.6306128
	Private	437687934	0.055826169	25021637	0.037933	0.679484063	227	0.048567	0.8699574
	Suppression Emphasis	1.773E+09	0.226081746	44576715	0.067579	0.298912802	2038	0.436029	1.9286338
	Wilderness	1.056E+09	0.134675924	390079966	0.59136	4.391022261	388	0.083012	0.6163864
	Wildland Fire Use	3.526E+09	0.449683427	74727803	0.113288	0.251928493	1440	0.308087	0.6851203
Distance to road	0-29m	359810	0.035094889	1261	0.001735	0.0494353	49	0.012731	0.3627474
	30-59m	601561	0.058674624	1580	0.002174	0.037048679	118	0.030657	0.522497
	60-124m	885692	0.08638799	3252	0.004474	0.051792053	351	0.091193	1.0556157
	125-249m	854101	0.083306689	36639	0.050409	0.605103544	691	0.179527	2.1550148
	250-499m	1080620	0.105400737	59422	0.081755	0.775656754	727	0.18888	1.79202
	500-999m	1325067	0.129243433	67268	0.09255	0.716087334	541	0.140556	1.0875291
	1000-1999m	1535978	0.149815118	72710	0.100037	0.667735497	462	0.120031	0.8011954
	2000-3999m	1686788	0.164524715	96396	0.132625	0.806109102	416	0.10808	0.6569227
	4000-7999m	1300927	0.126888883	180811	0.248768	1.960501756	355	0.092232	0.7268702
	8000-15999m	611660	0.059659653	206235	0.283745	4.756063073	139	0.036113	0.6053216
	>160000m	10286	0.001003268	1258	0.001731	1.725160222	0	0	0
Distance to stream	0-29m	853592	0.082984088	2448	0.003364	0.040542467	35	0.009091	0.10955
	30-59m	1604130	0.155949522	4868	0.006693	0.042900278	130	0.033766	0.2165203
	60-124m	2886642	0.280632143	22291	0.030635	0.109165578	489	0.127013	0.452596
	125-249m	2781251	0.270386293	163076	0.224122	0.828893932	1285	0.333766	1.2344052
	250-499m	1786759	0.173704258	333803	0.458758	2.641030105	1519	0.394545	2.2713632
	500-999m	352531	0.034272185	184500	0.253565	7.398576218	380	0.098701	2.8799243
	1000-1999m	21151	0.002056248	16637	0.022865	11.11970347	12	0.003117	1.5158112

				Large Fire			Small Fire		
		Pixel in domain		Pixel in class			Pixel in class		
Factor	Class	number	ratio	number	ratio	Freq. ratio	number	ratio	Freq. ratio
Distance to trail	0-29m	110160	0.011036768	316	0.000444	0.040238425	10	0.002621	0.2374377
	30-59m	210560	0.021095696	1042	0.001464	0.069417611	26	0.006813	0.3229767
	60-124m	426086	0.042688928	6782	0.009531	0.223274094	115	0.030136	0.7059505
	125-249m	614208	0.061536593	41042	0.05768	0.93732643	259	0.067872	1.1029554
	250-499m	1146036	0.114819656	106768	0.15005	1.306834717	558	0.146226	1.2735312
	500-999m	1917707	0.192132235	188536	0.264966	1.379081242	854	0.223795	1.1647944
	1000-1999m	2297289	0.230161996	235705	0.331257	1.439232569	1024	0.268344	1.1658911
	2000-3999m	1587625	0.159061807	121785	0.171155	1.076028285	711	0.186321	1.1713733
	4000-7999m	888486	0.089016102	5542	0.007789	0.087497118	228	0.059748	0.6712092
	8000-15999m	760615	0.076204895	3781	0.005314	0.069729991	30	0.007862	0.1031644
	>160000m	22411	0.002245325	249	0.00035	0.155853273	1	0.000262	0.1167112
Time since last burn	1-5 years	2760154	0.008654298	2760154	0.008654	2.574562241	84	0.019631	2.2683244
	6-15 years	2322321	0.007281499	2322321	0.007281	8.28357164	43	0.010049	1.3800836
	16-30 years	1197754	0.003755486	1197754	0.003755	4.635213579	29	0.006777	1.8046358
	31-80 years	87585723	0.274619794	87585723	0.27462	0.142279418	702	0.164057	0.5973969
	>80 years	225068535	0.705688924	225068535	0.705689	1.21997721	3421	0.799486	1.1329154

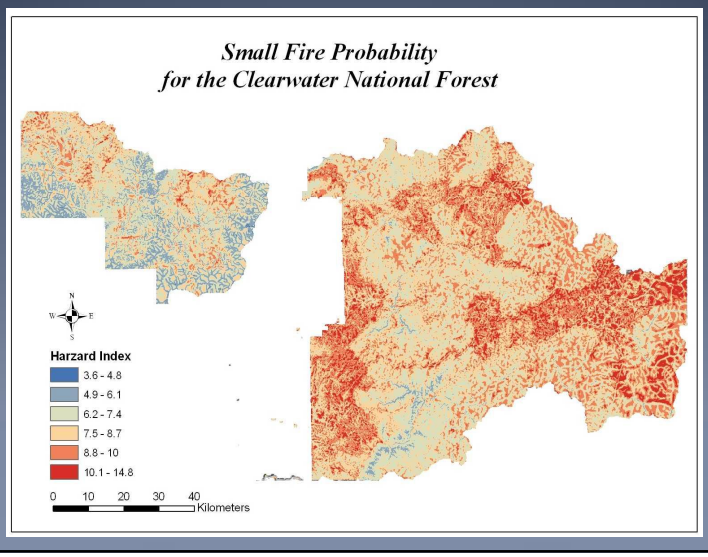
Results

- Frequency ratios from eight variables were summed to create:
  - A predicted fire hazard map generated from large fires
  - A predicted fire hazard map generated from small fires
- Hazard Index
  - > 8 indicates above average fire probability (association)
  - = 8 indicates average fire probability
  - < 8 indicates below average fire probability (avoidance)

Results – Prediction from Large Fires



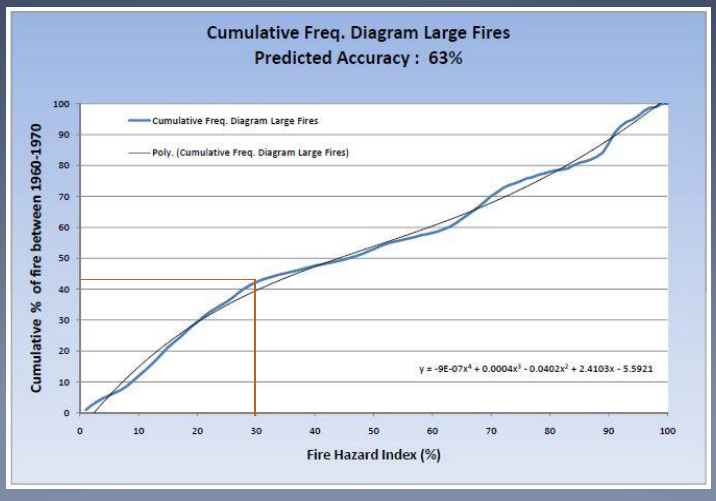
Results – Prediction from Small Fires



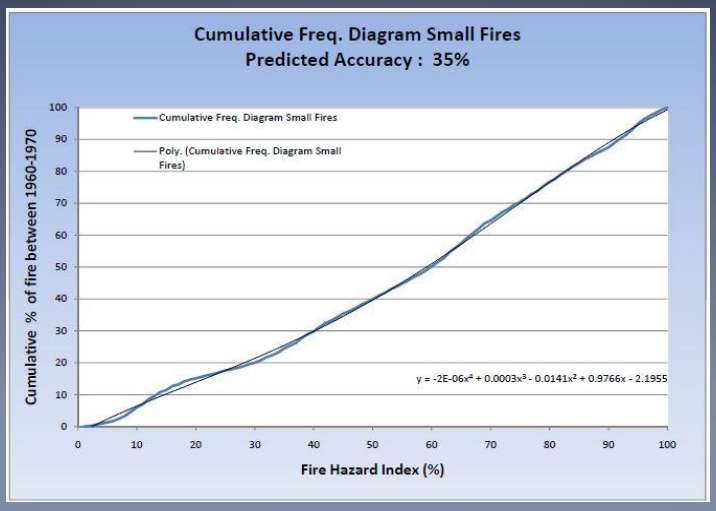
Accuracy Assessment

- Both maps were verified through an accuracy assessment using a separate dataset containing known large fires between 1960 – 1970
- Hazard map was divided into 100 equal areas and the value for each area was calculated
- Ratio of area under curve to total graph area provides an accuracy prediction

Accuracy Assessment – Large Fires



Accuracy Assessment – Small Fires

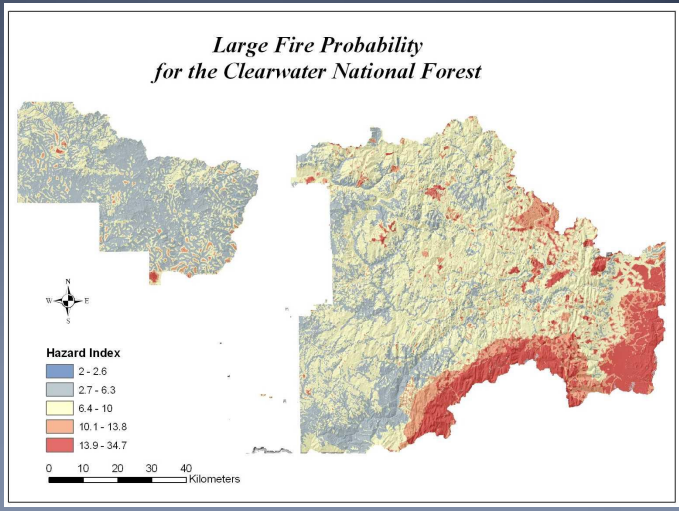


Conclusions

- Fire probabilities generated from large and small fires differ in their spatial distribution
- Most concentrated, highest large fire probability occurs in the Selway-Bitterroot Wilderness
- Some areas of predicted high probability have not had recent large fires
- Validation fires (historic, known) were better predicted using large fire history - higher prediction accuracy
- Gentle slope of accuracy assessment curve means still lots of room for improvement

Conclusions

Based on historical fire patterns, what areas of the Clearwater National Forest currently have the greatest probability of a large fire (>10 acres)?



Limitations

- Small fire data not available pre-1970
- Small fire data only available as points
- Possible changes to variables (roads, trails, management policy, etc…) over time
- Logging history not considered
- Sample of data used for accuracy assessment was to small

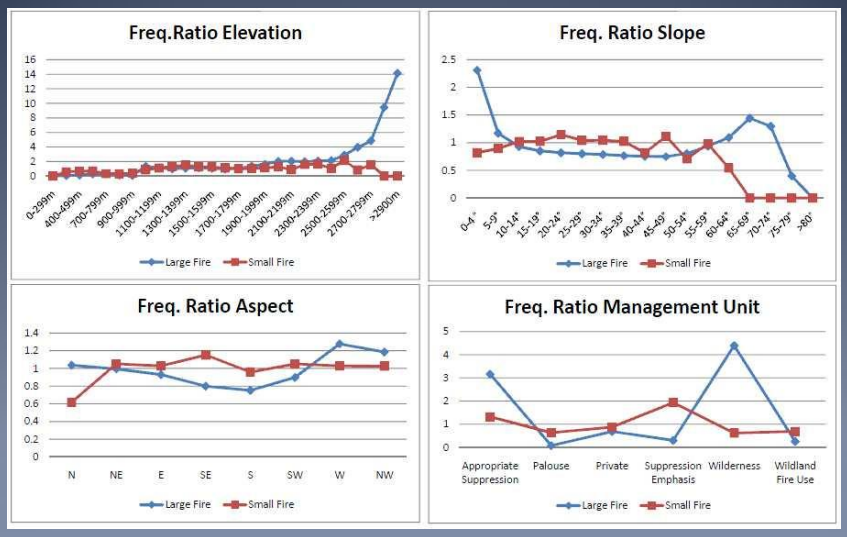
Sources

- http://www.fs.fed.us/r1/clearwater/gis/library.htm
- http://arcscripts.esri.com/details.asp?dbid=15198
- Lee Padhan: Landslide hazard mapping at Selangor, Malaysia using frequency ratio and logistic regression (2006)
- Stickney, P. F. 1986. First decade plant succession following the Sundance forest fire, northern Idaho. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report, INT-97.
- Oliver, C.D. 1980. Forest development in North America following major disturbances. *Forest Ecology and Management* 3: 153–168.
- Huff, M. H. 1995. Forest age structure and development following wildfires in the Western Olympic Mountains, Washington. *Ecological Applications* 5(2): 471-483.

Questions?

Photo by Dave Hansen http://www.alumni.umn.edu/Playing_With_Fire.html

Results – FR Comparison Graph



Results – FR Comparison Graph