Development and Production of a Moderate Resolution Forest Type Map of the United States

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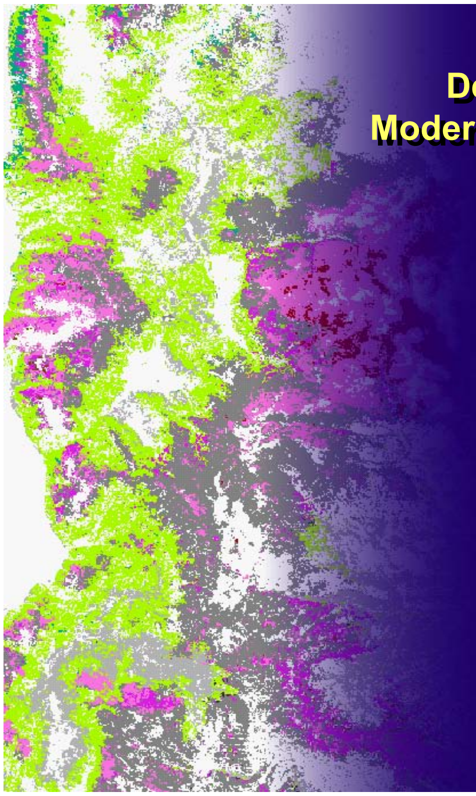
Zhu and Evans (1994) produced a forest group type map covering the entire United States (US) and Puerto Rico. This map was one of the key components for the development of the forest risk maps produced by the US Department of Agriculture Forest Service (USFS) Forest Health Monitoring (FHM) program. (Lewis 2002). The forest risk maps, which were actually produced in 2000, were non site-specific and only identified broad areas that had potential high risk of forest mortality or growth/volume loss from insects and diseases. The intent of these forest risk maps was to provide national information to policy makers to help determine national priorities. The forest risk mapping effort found 43 million hectares of forest land (14 percent of total forest lands) in danger of high tree mortality and growth/volume loss. According to Forest Health Protection (2004), tree mortality totaled 800,000 hectares in 2000. In 2003 tree mortality totaled over 4 million hectares. It is unknown how forest risk increased during this time period, but it is conceivable that forest risk also showed dramatic increases due to increases in climatic and anthropomorphic stresses and increases in globalization. Thus, there is a need to update and improve the forest risk maps. The improvements will allow the products to be used more specifically and at smaller scales. The forest group type map used for the forest risk mapping was produced in 1992 using AVHRR (Advanced Very High Resolution Radiometer) imagery with a spatial resolution of 1 km and, thus, the forest risk maps have a spatial resolution of 1 km as well (Zhu and Evans 1994). In 1999 the Moderate-resolution Imaging Spectroradiometer (MODIS) sensor with a spatial resolution of 250 meters became available. Additionally, other national remote sensing images and geographical information system (GIS) layers have become available since 1992.

These factors prompted Forest Health Monitoring (FHM), the Remote Sensing Applications Center (RSAC), and Forest Inventory and Analysis (FIA) to initiate the forest type and forest type group mapping effort described below.

Consistent national scale forest type information is important for modeling forest areas at risk of increased mortality due to insects and diseases. We used classification-trees to model forest type groups and forest types for the continuous United States (US) and Alaska. The modeling procedure used a geo-spatial dataset developed by the US Department of Agriculture Forest Service (USFS) for the predictor data and plot data from USFS Forest Inventory and Analysis (FIA) for the response data. The geo-spatial predictor dataset consisted of 269 remote sensing images and geographical information system (GIS) layers covering the continental US and 19 remote sensing images and GIS layers covering Alaska. The FIA plot data consisted of 78,127 forested plots covering the continuous US and 5,392 forested plots covering Alaska. Ten percent of the response data were separated from the modeling procedure and were used for accuracy assessment purposes. The overall accuracies for the continuous US for the forest type group and forest type were 69 percent and 50 percent, respectively. The overall accuracies for Alaska for the forest type group and forest type were 78 percent and 67 percent, respectively. To further verify the results, state summaries were derived from the final modeled products and compared to FIA state summary tables. For the continuous US, 95 percent of the forest type groups were within + 400,000 hectares of the FIA state summaries and 95 percent of the forest types were within + 290,000 hectares of the FIA state summaries. For Alaska, the forest type groups were within + 48,000,000 hectares of the FIA state summaries and the forest types were within + 27,000,000 hectares of the FIA state summaries; the FIA state summaries were only for southeast coastal Alaska whereas the state summaries derived from the modeled products included the whole state of Alaska.

Following the presentation of the background and reasons for development as well as the mapping methods and results the questions/issues below were discussed:

- Appropriate uses …
  - Scale
  - Applications
- Use of map and plots together
- Map unit descriptors
- Forest types and type groups
  - "Right" classifications for risk mapping?
  - Necessary but not sufficient?
  - What structural characteristics are needed?



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FIA Remote Sensing Band
All Regional Units

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Westminster, Colorado

July 26-28, 2005

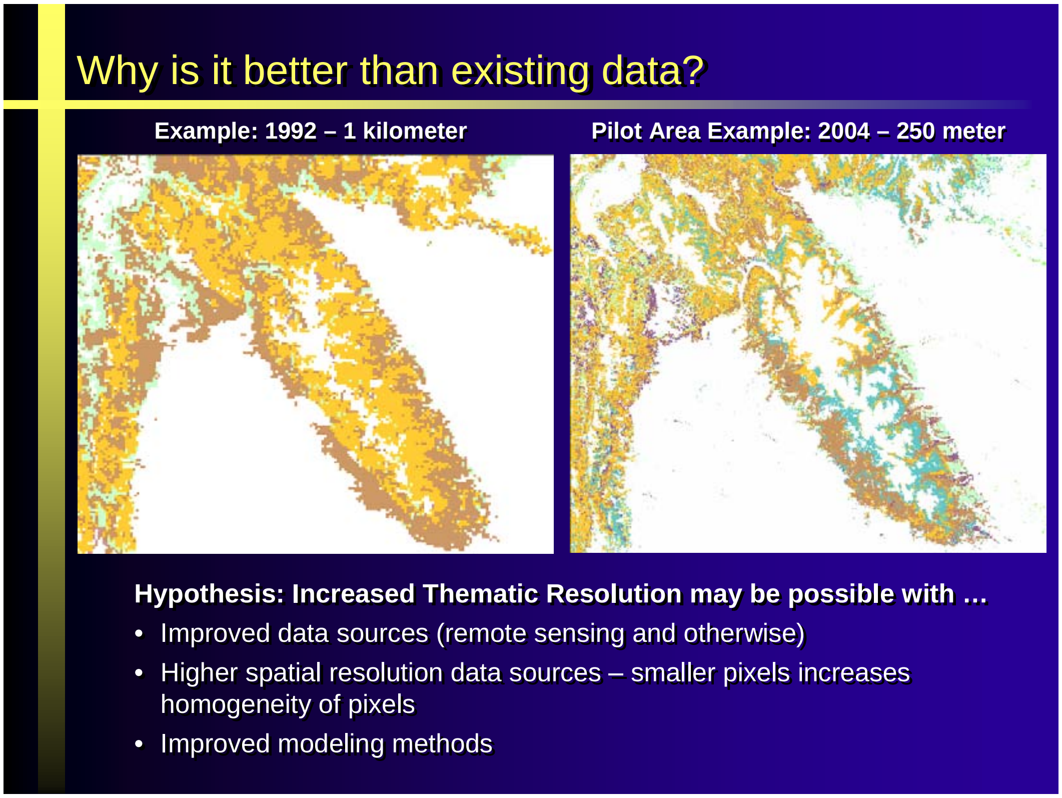
National Forest Type (NFT) Mapping Background

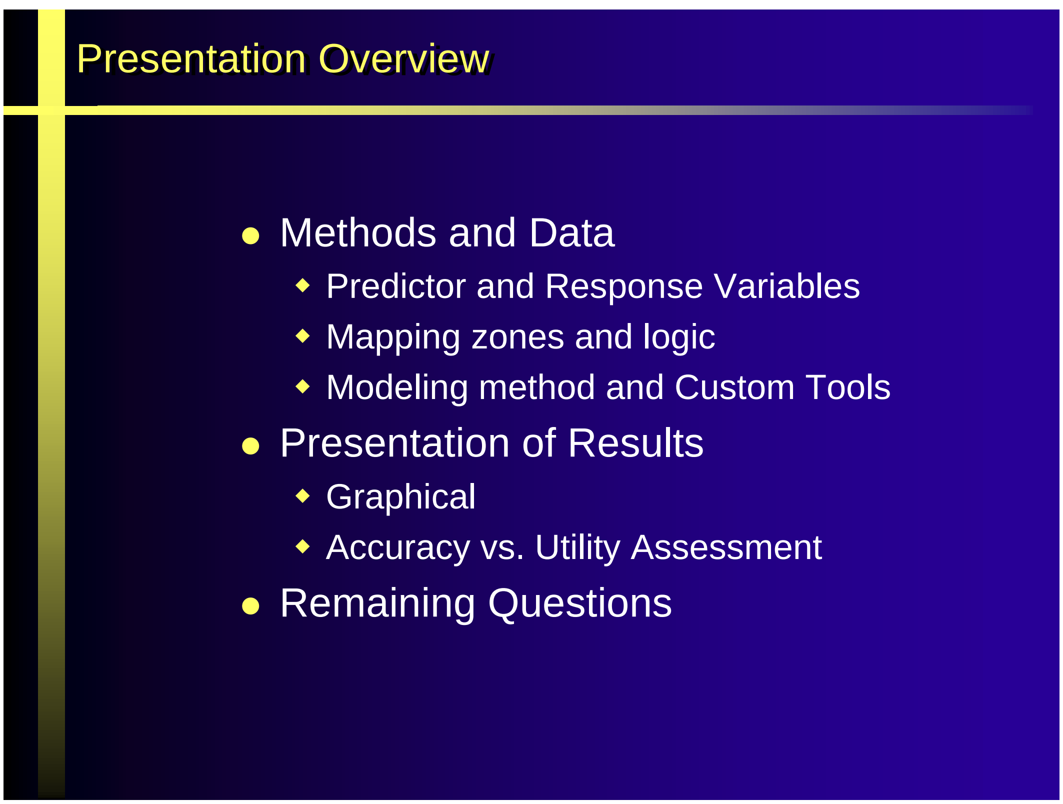
Impetus and Sponsorship

- ca. 2005 Forest Risk Map Revision (FHM)
- RSAC / FIA RSB Experience with National Mapping
- 12 Years since last map

What has changed in the last 10 years?

- Then …
  - 1993 Forest Type Group Map (Zhu and Evans) covered the entire U.S. including Alaska, Hawaii, and Puerto Rico
  - 1993 Forest Type Group Map - 1-km spatial resolution (FIA Plots, AVHRR, elevation data were primary data sources)
- Now …
  - Wide Availability of Nationwide Continuous Geospatial Data
  - New Satellite Imagery (MODIS, 250-m, 7-band)
  - New Modeling Techniques
  - Computing Environment Improvements

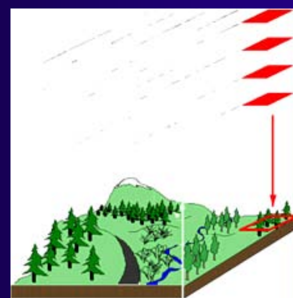

Why is it better than existing data?
Example: 1992 – 1 kilometer
Pilot Area Example: 2004 – 250 meter
Hypothesis: Increased Thematic Resolution may be possible with …
• Improved data sources (remote sensing and otherwise)
• Higher spatial resolution data sources – smaller pixels increases homogeneity of pixels
• Improved modeling methods


Presentation Overview
● Methods and Data
◆ Predictor and Response Variables
◆ Mapping zones and logic
◆ Modeling method and Custom Tools
● Presentation of Results
◆ Graphical
◆ Accuracy vs. Utility Assessment
● Remaining Questions

General Methodology – Spatial Modeling

-- Geospatial Predictor Layers --

MODIS imagery……
MODIS Veg indices
Elevation ………….
Aspect ……………..
Slope ……………….
STATSGO…………
Etc…………………..



-- Response Variables –
(FIA Plot Data)

Predictive models developed for Forest Type using data from FIA plots and Geospatial Predictor Layers

Figure Courtesy of Interior West FIA

National Geospatial Predictors Database

- Elevation, slope, and aspect
- Ecological region layers
  - USGS Mapping Zones, Bailey's Ecoregions, and Unified Ecoregions for Alaska
- STATSGO data layers (Lower 48)
  - Available water capacity, soil bulk density, soil permeability, soil ph, soil porosity, soil plasticity, depth to bedrock, rock volume, soil types, and soil texture
- MODIS Vegetation Indices such as EVI, NDVI
- MODIS Vegetation Continuous Fields
  - Percent tree cover, percent herbaceous cover, and percent bare ground
- MODIS fire points developed from the MODIS Active Fire Maps
- MODIS 8-day composites
  - Multiple dates from the spring, summer, and fall
- All MODIS 32-day composite imagery that are cloud-free between the years 2001-2003
- USGS NLCD layers
- PRISM temperature and precipitation
  - Minimums, maximums, and averages

Over 200 national predictor layers

Response Variables – FIA Plot Data

- 80,948 forested* FIA plots** for continental United States
- 5,392 forested FIA plots for Alaska
- Data collected between 1978 - 2004 – majority of the data collected between 2000 - 2004
- FIA variables – Forest Type and Forest Type Group

* The response variables included all FIA plots that were at least 50% forested. A forested plot is defined as being greater than 0.4 ha (1 acre) in size, greater than 120 feet in width, with greater than 10% stocking, and an undisturbed understory.

** FIA plots occur throughout the U.S. at an intensity of approximately one per 6,000 acres

Response Variables – 141 FIA Forest Types

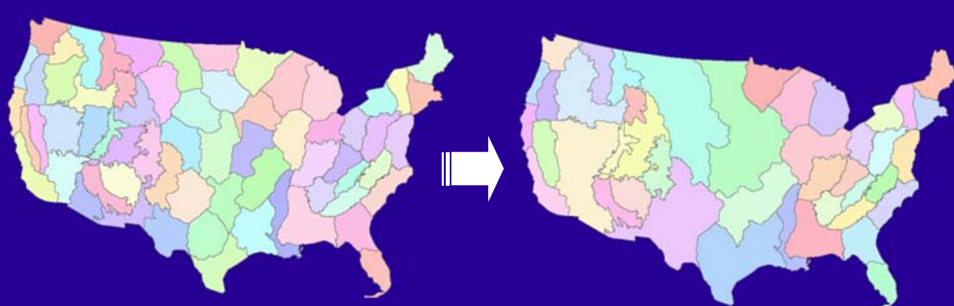
Jack Pine
Red Pine
Eastern White Pine
Eastern White Pine/Eastern Hemlock
Eastern Hemlock
Balsam Fir
White Spruce
Red Spruce
Red Spruce/Balsam Fir
Black Spruce
Tamarack
Northern White-cedar
Longleaf Pine
Slash Pine
Loblolly Pine
Shortleaf Pine
Virginia Pine
Sand Pine
Table Mountain Pine
Pond Pine
Pitch Pine
Spruce Pine
Eastern Redcedar
Rocky Mountain Juniper
Western Juniper
Juniper Woodland
Pinyon Juniper Woodland
Douglas-fir
Port-Orford-Cedar
Ponderosa pine
Incense Cedar
Jeffrey Pine/Coulter Pine/Bigcone Douglas-fir
Sugar Pine
Western White Pine
White Fir
Red Fir
Noble Fir
Pacific Silver Fir
Engelmann Spruce
Engelmann Spruce/Subalpine Fir
Grand Fir
Subalpine Fir
Blue Spruce
Mountain Hemlock
Alaska-Yellow-Cedar
Lodgepole Pine
Western Hemlock
Western Redcedar
Sitka Spruce
Western Larch
Redwood
Giant Sequoia
Knobcone Pine
Southwest White Pine
Bishop Pine
Monterey Pine
Foxtail Pine/Bristlecone Pine
Limber Pine
Whitebark Pine
Misc. Western Softwoods
California Mixed Conifer
Scotch Pine
Australian Pine
Other Exotic Softwoods
Norway Spruce
Introduced Larch
Eastern White Pine/Northern Red Oak/White Ash
Eastern Redcedar/Hardwood
Longleaf Pine/Oak
Shortleaf Pine/Oak Virginia Pine/Southern Red Oak
Loblolly Pine/Hardwood
Slash Pine/Hardwood
Other Pine/Hardwood
Post Oak/Blackjack Oak
Chestnut Oak
Red Oak/White Oak/Hickory
White Oak
Northern Red Oak
Yellow-popular/White Oak/Northern Red Oak
Sassafras/Persimmon
Sweetgum/Yellow-poplar
Bur Oak
Scarlet Oak
Yellow Poplar
Black Walnut
Black Locust
Southern Scrub Oak
Chestnut Oak/Black Oak/Scarlet Oak
Red Maple/Oak
Mixed Upland Hardwoods
Swamp Chestnut Oak/Cherrybark Oak
Overcup Oak/Water Hickory
Atlantic White-cedar
Baldcypress/Water Tupelo
Sweetbay/Swamp Tupelo/Red Maple
River Birch/Sycamore
Cottonwood
Willow
Sycamore/Pecan/American Elm
Sugarberry/Hackberry/Elm/Green Ash
Red Maple/Lowland
Cottonwood/Willow
Oregon Ash
Sugar Maple/Beech/Yellow Birch
Black Cherry
Cherry/Ash/Yellow-poplar
Hard Maple/Basswood
Elm/Ash/Locust
Red Maple/Upland
Aspen
Paper Birch
Balsam Poplar
Red Alder
Bigleaf Maple
Gray Pine
California Black Oak
Oregon White Oak
Blue Oak
Deciduous Oak Woodland
Coast Live Oak
Canyon Live Oak/Interior Live Oak
Tanoak
California Laurel
Giant Chinkapin
Pacific Madrone
Mesquite Woodland
Cercocarpus Woodland
Intermountain Maple Woodland
Misc. Western Hardwood Woodlands
Stable Palm
Mangrove
Other Tropical
Paulownia
Melaluca
Eucalyptus

Response Variables – 28 FIA Forest Type Groups

- White/Red/Jack Pine Group
- Spruce/Fir Group
- Longleaf/Slash Pine Group
- Loblolly/Shortleaf Pine Group
- Pinyon/Juniper Group
- Douglas-fir Group
- Ponderosa Pine Group
- Western White Pine Group
- Fir/Spruce/Mountain Hemlock Group
- Lodgepole Pine Group
- Hemlock/Sitka Spruce Group
- Western Larch Group
- Redwood Group
- Other Western Softwoods Group
- California Mixed Conifer Group
- Exotic Softwoods Group
- Oak/Pine Group
- Oak/Hickory Group
- Oak/Gum/Cypress Group
- Elm/Ash/Cottonwood Group
- Maple/Beech/Birch Group
- Aspen/Birch Group
- Alder/Maple Group
- Western Oak Group
- Tanoak/Laurel Group
- Other Western Hardwoods Group
- Tropical Hardwoods Group
- Exotic Hardwoods Group

Modeling Performed on Mapping Zones

For production purposes and to prevent anomalies, such as loblolly pine occurring in California, the continental U.S. was divided into the 65 USGS mapping zones. Alaska was not divided into mapping zones.



Because of the paucity of forest land in some mapping zones, several mapping zones were combined together creating a total of 43 mapping zones.

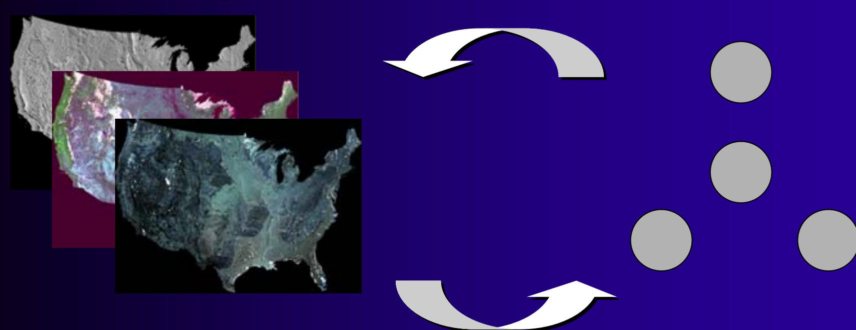
Modeling Using Cubist / See5

What is Cubist / See5? (www.rulequest.com)

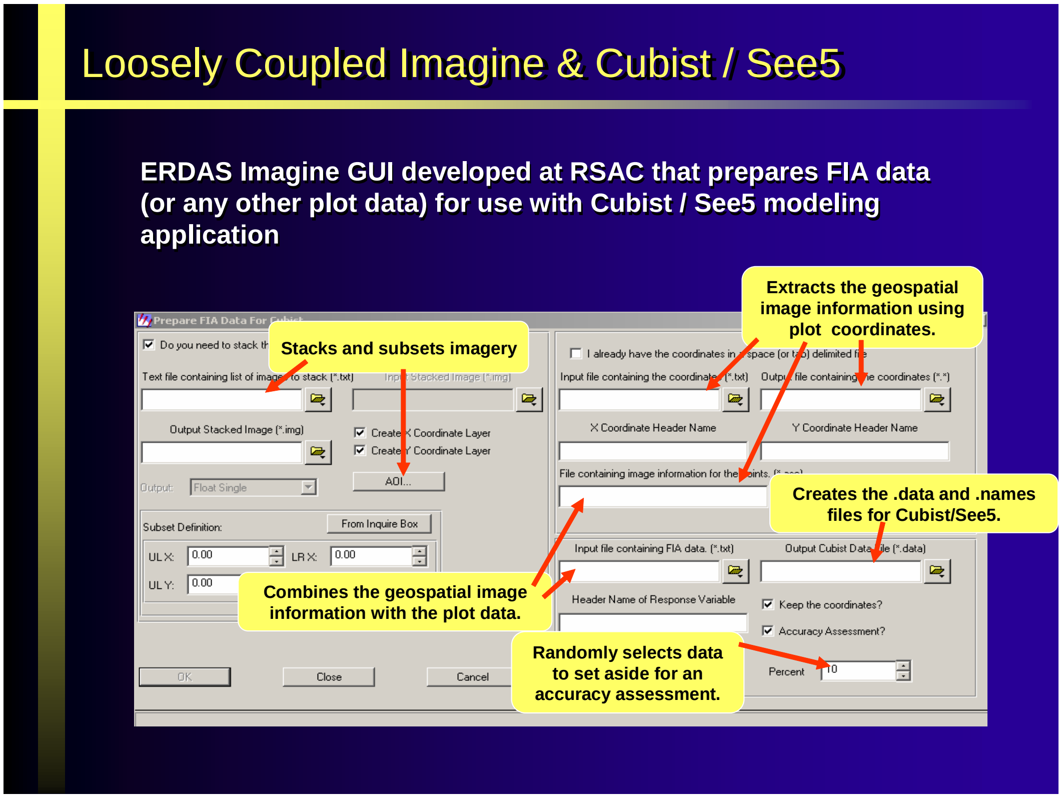
- Powerful tool for generating rule-based models
  - Software helps determine which variables are important for modeling
- No assumptions about the data distribution (non-parametric models)
- Handles numeric and categorical data
- Handles large databases
- Able to incorporate both Remote Sensing and GIS data layers
- Easy to understand and efficient to run
- Easy to generate predictions based upon the models

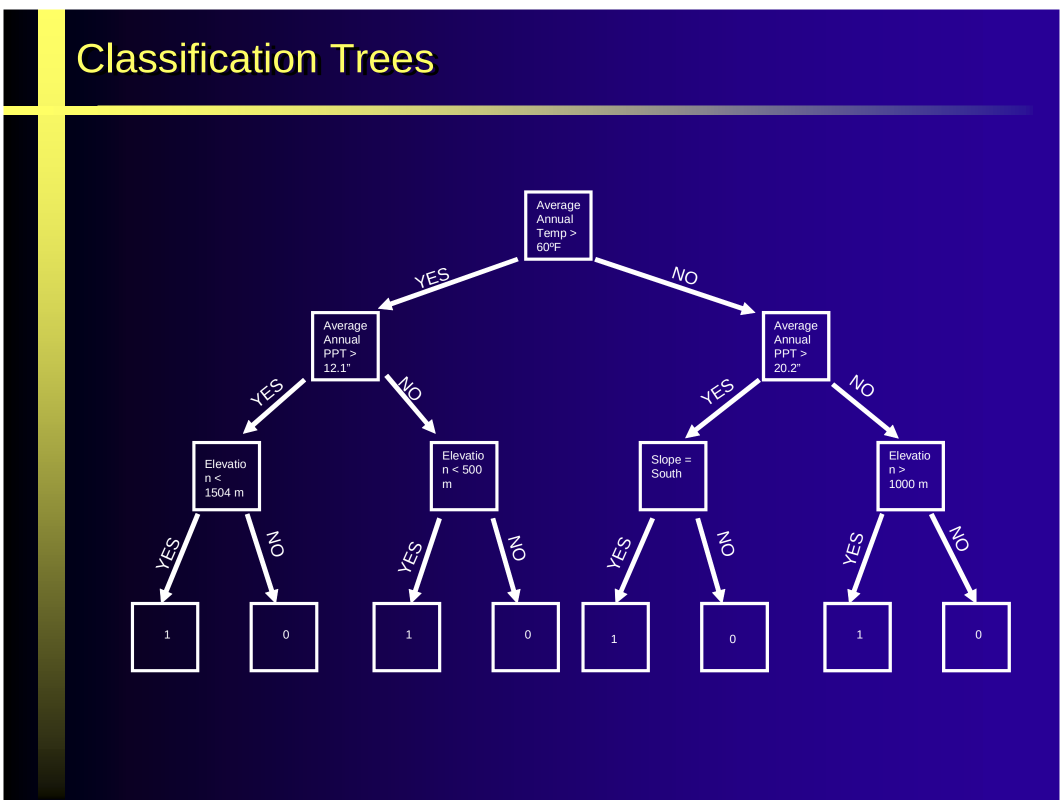
Modeling / Mapping Tools

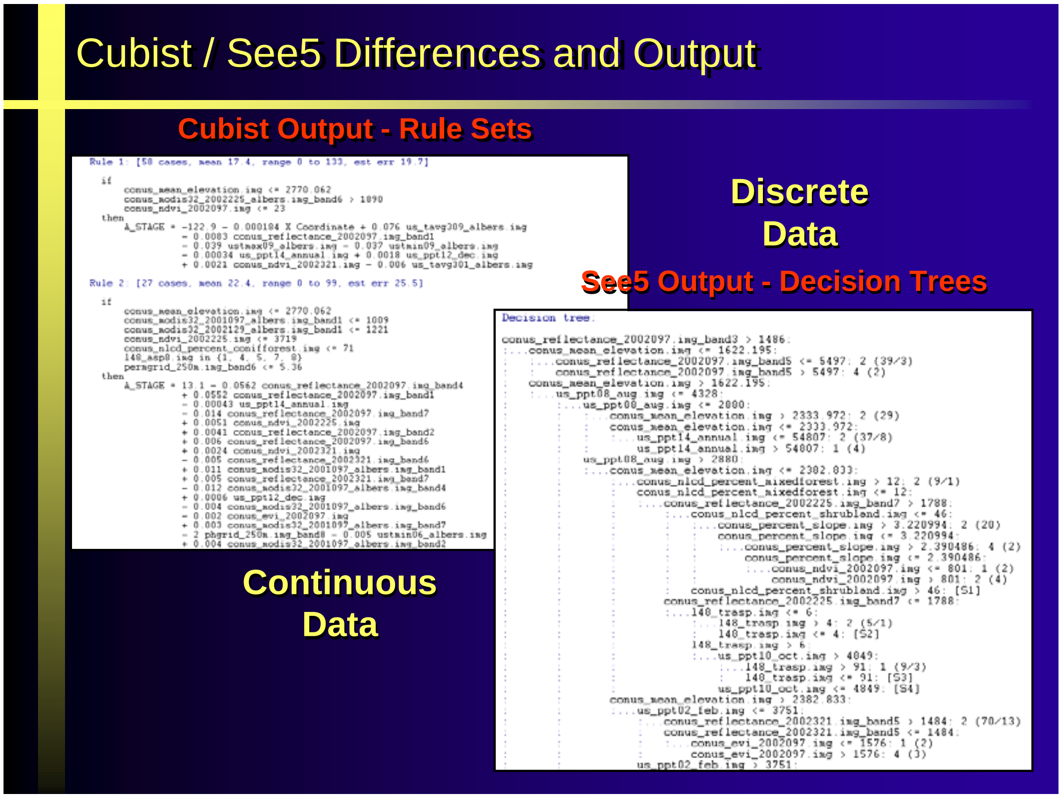
Remote Sensing/GIS Data | **FIA Plot Data**

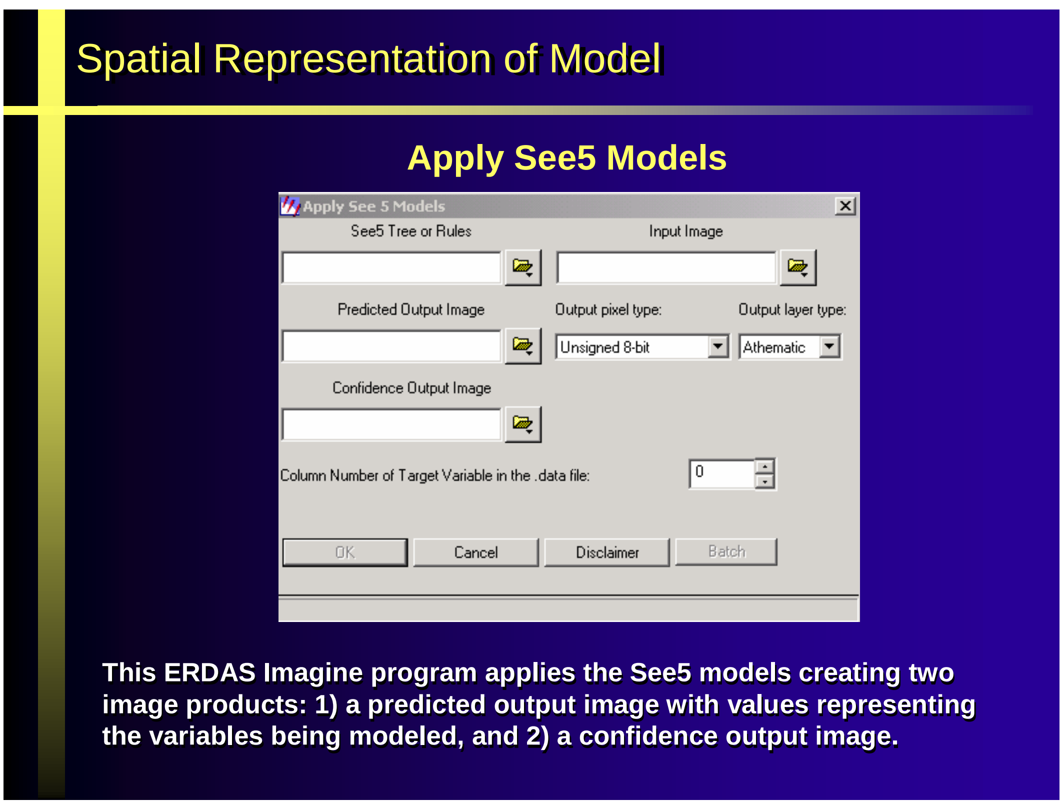


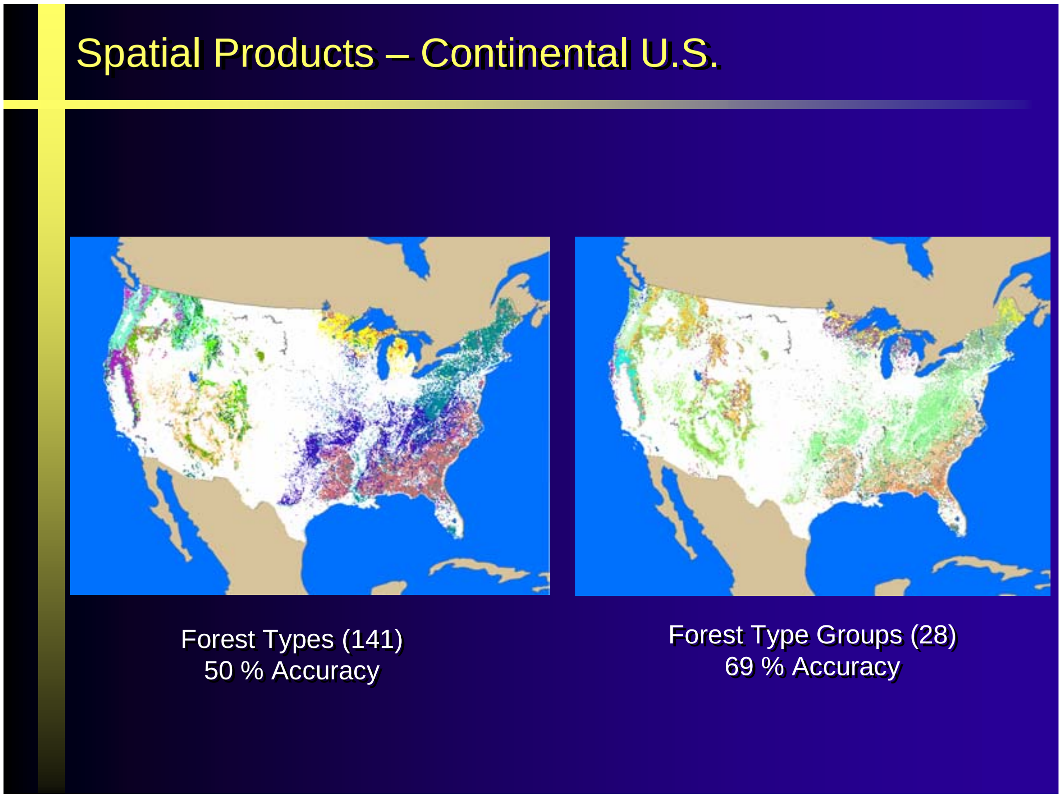
Challenge:
How to combine Remote Sensing & GIS data with FIA plot data to produce a forest type geospatial product?

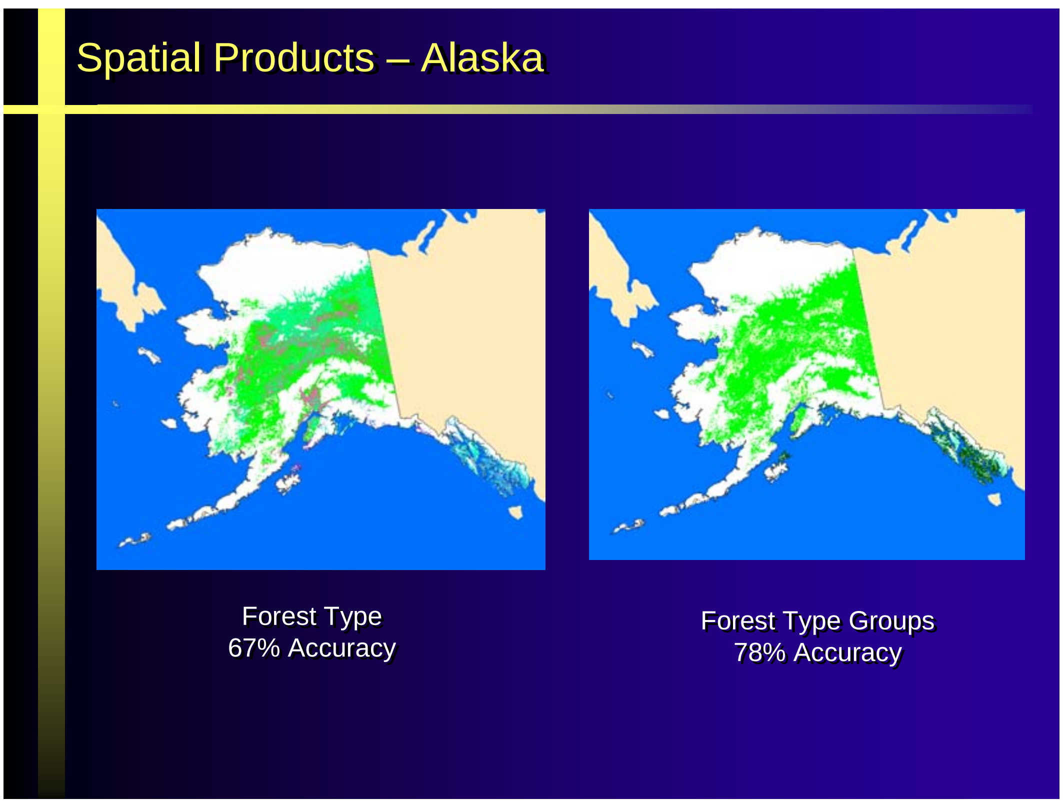

Loosely Coupled Imagine & Cubist / See5
ERDAS Imagine GUI developed at RSAC that prepares FIA data (or any other plot data) for use with Cubist / See5 modeling application
Extracts the geospatial image information using plot coordinates.
Stacks and subsets imagery
Creates the .data and .names files for Cubist/See5.
Combines the geospatial image information with the plot data.
Randomly selects data to set aside for an accuracy assessment.
Output Stacked Image (*.img)
Create X Coordinate Layer
Create Y Coordinate Layer
AOI...
Subset Definition:
From Inquire Box
X Coordinate Header Name
Y Coordinate Header Name
Input file containing FIA data. (*.txt)
Header Name of Response Variable
Keep the coordinates?
Accuracy Assessment?
Percent
OK
Close
Cancel


Classification Trees
Average Annual Temp > 60°F
YES
NO
Average Annual PPT > 12.1"
Average Annual PPT > 20.2"
Elevation < 1504 m
Elevation < 500 m
Slope = South
Elevation > 1000 m
1
0

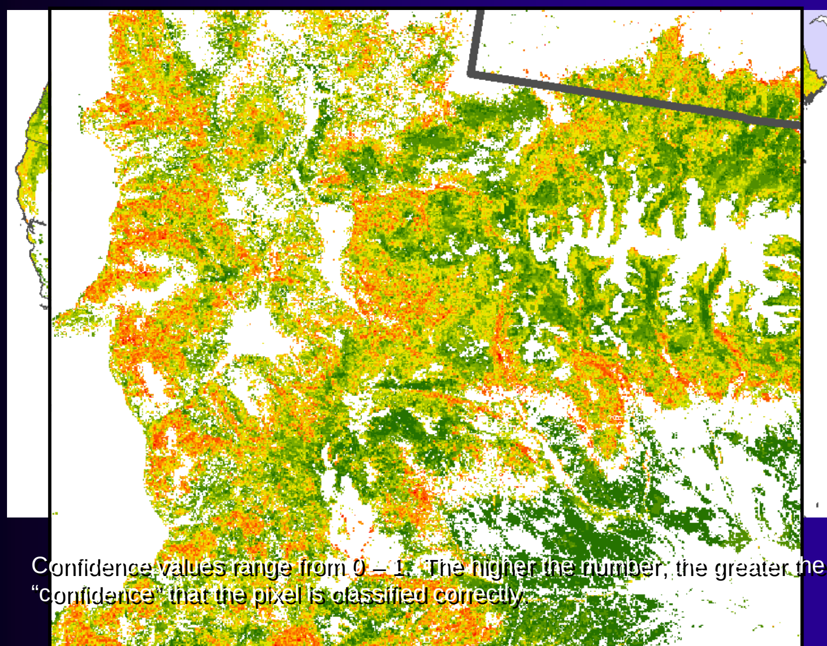

Cubist / See5 Differences and Output
Cubist Output - Rule Sets
Discrete Data
See5 Output - Decision Trees
Decision tree:
Continuous Data


Spatial Representation of Model
Apply See5 Models
Apply See 5 Models
See5 Tree or Rules
Input Image
Predicted Output Image
Output pixel type:
Output layer type:
Unsigned 8-bit
Athematic
Confidence Output Image
Column Number of Target Variable in the .data file:
0
OK
Cancel
Disclaimer
Batch
This ERDAS Imagine program applies the See5 models creating two image products: 1) a predicted output image with values representing the variables being modeled, and 2) a confidence output image.


Spatial Products – Continental U.S.
Forest Types (141)
50 % Accuracy
Forest Type Groups (28)
69 % Accuracy

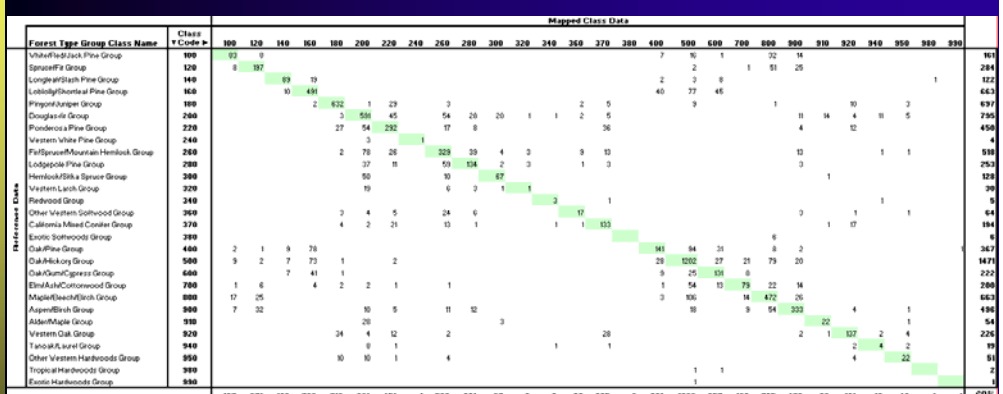

Spatial Products – Alaska
Forest Type
67% Accuracy
Forest Type Groups
78% Accuracy

Classification Confidence – Forest Type Groups



Accuracy Assessment

- Source – Random 10% Holdout of FIA Plots (~ 8100)



Mapped Class Data (columns); Reference Data (rows)

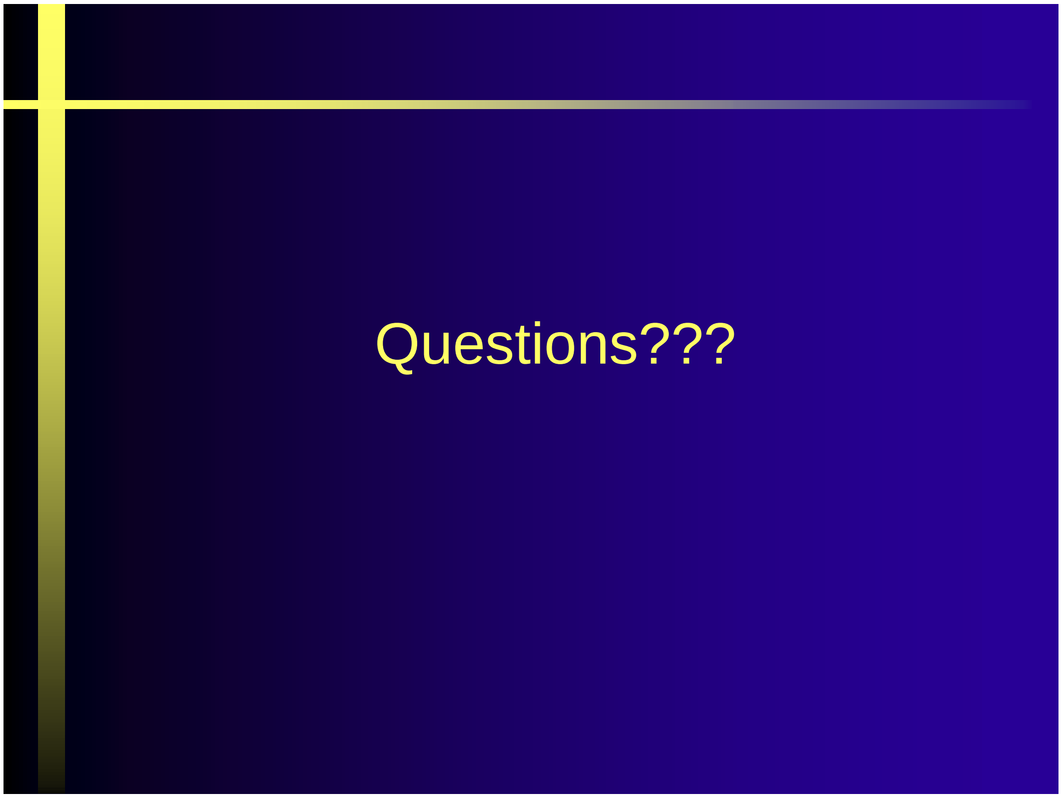
Forest Type Group Class Name	Class Code	100	120	140	160	180	200	220	240	260	280	300	320	340	360	370	380	400	500	600	700	800	900	910	920	940	950	980	990	
White/Red/Jack Pine Group	100	93	0															7	16	1		32	14							161
Spruce/Fir Group	120	8	197																2		1	51	25							284
Longleaf/Slash Pine Group	140			89	19													2	3	8								1		122
Loblolly/Shortleaf Pine Group	160			10	491													40	77	45										663
Pinyon/Juniper Group	180				2	632	1	29		3					2	5			9			1			10		3			697
Douglas-fir Group	200					3	586	45		54	20	20	1	1	2	5							11	14	4	11	5			795
Ponderosa Pine Group	220					27	54	292		17	8					36							4		12					450
Western White Pine Group	240						3		1																					4
Fir/Spruce/Mountain Hemlock Group	260					2	78	26		329	39	4	3		9	13							13			1	1			518
Lodgepole Pine Group	280						37	11		59	134	2	3		1	3							3							253
Hemlock/Sitka Spruce Group	300						50			10		67												1						128
Western Larch Group	320						19			6	3	1	1																	30
Redwood Group	340													3		1										1				5
Other Western Softwood Group	360					3	4	5		24	6				17								3		1		1			64
California Mixed Conifer Group	370					4	2	21		13	1			1	1	133								1	17					194
Exotic Softwoods Group	380																					6								6
Oak/Pine Group	400	2	1	9	78													141	94	31		8	2						1	367
Oak/Hickory Group	500	9	2	7	73	1		2										28	1202	27	21	79	20							1471
Oak/Gum/Cypress Group	600			7	41	1												9	25	131	8									222
Elm/Ash/Cottonwood Group	700	1	6		4	2	2	1		1								1	54	13	79	22	14							200
Maple/Beech/Birch Group	800	17	25															3	106		14	472	26							663
Aspen/Birch Group	900	7	32				10	5		11	12								18		9	54	333		4		1			496
Alder/Maple Group	910						28					3												22			1			54
Western Oak Group	920					34	4	12		2						28							2	1	137	2	4			226
Tanoak/Laurel Group	940						0	1						1		1									2	4	2			19
Other Western Hardwoods Group	950					10	10	1		4															4		22			51
Tropical Hardwoods Group	980																		1	1										2
Exotic Hardwoods Group	990																		1											1
		127	271	122	708	719	901	451	1	533	231	97	8	6	32	225	0	231	1608	257	132	725	470	39	191	19	40	1	1	69%

Accuracy Assessment

Producer's	User's	Forest Type Group Class Name	# of AA Plots
65%	52%	White/Red/Jack Pine Group	161
73%	69%	Spruce/Fir Group	284
73%	73%	Longleaf/Slash Pine Group	122
69%	74%	Loblolly/Shortleaf Pine Group	663
88%	91%	Pinyon/Juniper Group	697
66%	74%	Douglas-fir Group	795
65%	65%	Ponderosa Pine Group	450
100%	25%	Western White Pine Group	4
62%	64%	Fir/Spruce/Mountain Hemlock Group	518
58%	53%	Lodgepole Pine Group	253
69%	52%	Hemlock/Sitka Spruce Group	128
13%	3%	Western Larch Group	30
50%	60%	Redwood Group	5
53%	27%	Other Western Softwood Group	64
59%	69%	California Mixed Conifer Group	194
0%	0%	Exotic Softwoods Group	6
61%	38%	Oak/Pine Group	367
75%	82%	Oak/Hickory Group	1471
51%	59%	Oak/Gum/Cypress Group	222
60%	40%	Elm/Ash/Cottonwood Group	200
65%	71%	Maple/Beech/Birch Group	663
71%	67%	Aspen/Birch Group	496
56%	41%	Alder/Maple Group	54
72%	61%	Western Oak Group	226
21%	21%	Tanoak/Laurel Group	19
55%	43%	Other Western Hardwoods Group	51
0%	0%	Tropical Hardwoods Group	2
0%	0%	Exotic Hardwoods Group	1

Discussion Items : Accuracy vs. Utility

- Appropriate uses …
  - Scale
  - Applications
- Use of map and plots together
- Map unit descriptors
- Forest types and type groups
  - “Right” classifications for risk mapping?
  - Necessary but not sufficient?
  - What structural characteristics are needed?


Questions???