The Forest Inventory and Analysis Program: Current Research and Future Opportunities

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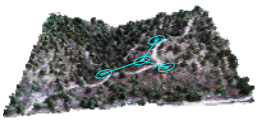


Outline

1. Brief Overview of the Forest Inventory and Analysis program (FIA)
2. General examples of current FIA research in the South
3. Specific research example: Physical constraints on timber availability
4. Future research directions and topics

Overview: The FIA Program

- Current comprehensive inventories and analyses of all US Forests
- Annual forest inventories in all States
- National core program that includes additional data beyond the core which are used to address specific regional/local needs
- QA programs to assess data quality and improve the FIA program
- Conduct inventories with State and Federal partners.

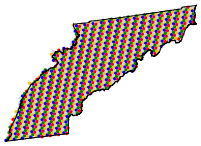
Overview: The FIA Program cont.

- Three phase program – Phase 1-remote sensing; Phase 2- forest mesuration plots; Phase 3-forest health plots
- Phase 3 is 1/16th of Phase 2
- One Phase 2 plot per 6000 ac
- Consistent core set of field measurements across the U.S.
- Rotating panel system - 10% of plots yr^{-1} in west, 15% of plots yr^{-1} in east
- States and FS forests can "buy down" to 20% of plots yr^{-1}.
- Annual data compilations
- 5-year state reports, FS forest reports

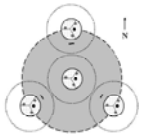
Overview: Sampling Hexagons and Plots

Truncated Icosohedron

North American Hexagon



248,832 area density intensification (1 plot / 6000 ac)



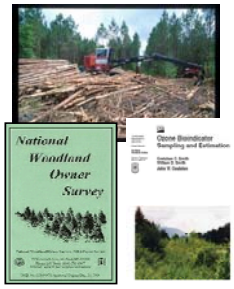
Large footprint plot layout

Overview: FIA – Past and Present

Past	Present
Timberland Inventory	Forestland Inventory
Timber Information	Forest and Forest Health Information
Aerial photography w/field sampling	Field sampling w/ remote sensing for stratification
Regional	National
Periodic	Annual
Tabular products	Tabular and some geospatial products

Overview: Additional Components of FIA

- Timber Product Output Surveys
- National Woodland Owner Survey
- Tropical Islands Inventory
- Utilization Studies
- Ozone biomonitoring



Current Research

- Status and trend reporting of southern forest resources including the extent, character and use of southern forests
  - Examples
    - assessment of the growth and removals of the hardwood resource in the Appalachian Hardwood Region (contact: Dr. Chris Oswalt)
    - development of the current status and utilization pressures of the southern cypress resource (contact: Mark Brown)
    - distribution of wood-processing mills in the South and the development of estimates of non-wood forest products in the United States (contact: Tony Johnson)
    - §Physical constraints on timber availability in the South: A multivariate approach. (contact: Dr. John Coulston)
- Forest health issue detection and monitoring
  - Examples
    - development of the Southern Nonnative Invasive Database and Tool (Contact: Dr. Chris Oswalt)
    - assessment of the oak regeneration pool in Virginia's forests, and the decline of dogwood populations in the Appalachian ecoregion (Contact: Anita Rose)

Current Research

- The development of techniques for implementing forest inventories and utilizing annual forest data
  - Examples
    - An alternative to traditional goodness-of-fit tests for discretely measured continuous data (contact: Dr. KaDonna Randolph)
    - detecting meaningful spatial clusters of forest health changes using FIA phase 3 data and spatial scan statistics (Contact: Dr. John Coulston)
    - Invasive forest pest surveillance: survey development and reliability (contact: Dr. John Coulston)
    - Increasing statistical power of components of change analysis (contact: Dr. Frank Roesch)
    - Exploiting correlations among phase 2 and phase 3 variables for prediction and estimation (contact: Dave Gartner)
- landscape level forest disturbance and change detection and characterization
  - Examples
    - determining the impacts of deforestation in Puerto Rico (contact: Dr. Tom Brandeis)
    - integrating Landsat derived disturbance maps with FIA inventory data (contact: Sonja Oswalt)
    - Mapping U.S. forest biomass using nationwide forest inventory data and moderate resolution information (Contacts: Dennis Jacobs, Dr. Dumitru Salajanu)

Specific Research Example

Physical constraints on timber availability in the South: A multivariate approach.

Motivation

- The are approximately 215 million acres of forest land with 325 billion cubic feet of timber in the South. However, the availability of this resource differs by:
  - Management constraints
  - Physical constraints
  - Economic constraints
  - Other

Physical Constraint examples

- Proximity to roads
- Population density
- Slope
- Topographic position
- Soil wetness
- Tract size
- Percent forest

Physical Constraints

- Traditionally, expert opinion has been used to identify plots that are unlikely to be harvested
  - Remove stands on slopes greater than 40%
  - Remove stands within a certain proximity to urban or built-up areas
- Another alternative is to let the data determine the likelihood of harvest

Modeling Complications

- Response variable is problematic
  - e.g. harvest = $x_1+x_2+\ldots+x_n+\varepsilon$
  - To build, for example, a logistic model we would want harvest to be binomial.
  - While selecting harvest=1 from the data is easy, properly selected harvest=0 requires more information than is available.
- Many explanatory variables are correlated.
  - Slope is correlated with soil wetness
  - Road proximity is correlated with population density.

Multivariate Alternatives

- Examine the set of explanatory variables from harvested plots to explain the correlation among variables in fewer uncorrelated dimensions.
  - Singular value decomposition
  - Principal components
  - Factor analysis
  - Latent class analysis

Continuous variables

Categorical variables

Principal Components (PCA)

- Used with continuous variables.
- Seeks to explain the covariance (or correlation) among variables in terms of uncorrelated linear combinations.
- Based on characteristic roots (eigenvalues) and characteristics vector (eigenvector) of the covariance matrix
- Used to reduce dimensionality and aid in interpretation.
- Multivariate normality is not required.
- Has generally been used in psychometrics and market analysis

Available variables

- FIA plot variables
  - Tract size (continuous)-NIPF
  - Percent forest of tract (continuous)-NIPF
  - Slope (continuous)
  - Distance to road (ordinal)
  - Operability class (categorical)
  - Physiographic class (categorical)
- GIS variables (all continuous)
  - Percent forest in surrounding ~160 ac.
  - Connectivity of forest in surrounding 160 ac.
  - Distance to nearest road.
  - Terrain relative moisture index
  - Topographic scale
  - Slope
  - Population density
  - Night-time light saturation

Variables used

- FIA plot variables
  - Tract size (continuous)-NIPF
  - Percent forest of tract (continuous)-NIPF
  - Slope (continuous)
  - Distance to road (ordinal)
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Basic Steps

- Extract all current plot and condition level data from FIADB (~35,000 plots)
- Identify which plots had been harvested (~4,000 plots)
- Attach GIS variables to plot
- Remove 200 harvested plots for testing
- Run PCA on remaining harvested plots
- Create likelihood model in feature space
- Apply linear combinations from PCA to test plots and examine likelihood model in feature space
- Apply linear combinations to all plots that were not harvested

Results from PCA

Eigenvectors

	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7	Prin8
Terrain Relative Moisture Index	0.001	**-0.676**	-0.047	0.042	-0.028	0.111	0.725	-0.002
Slope	0.165	**0.415**	0.181	0.523	-0.581	-0.147	0.369	-0.014
Topographic Scale	-0.034	**0.596**	-0.031	-0.289	0.466	0.156	0.564	-0.001
Percent Forest	**0.644**	-0.031	0.152	-0.242	-0.051	0.058	-0.016	0.705
Connectivity of Forest	**0.647**	-0.041	0.148	-0.226	-0.015	0.052	-0.027	-0.709
Population Density	-0.174	-0.028	**0.692**	0.132	0.035	0.681	-0.092	-0.001
Light Saturation	-0.183	-0.080	**0.661**	-0.248	0.097	-0.667	0.088	0.000
Distance to Nearest Road	0.272	-0.074	0.061	0.673	0.657	-0.167	-0.053	0.026
eigen value	2.03	1.40	1.18	0.95	0.89	0.76	0.66	0.14
Cummulative Percent Variance Explained	25.4%	42.9%	57.7%	69.5%	80.7%	90.1%	98.3%	100.0%

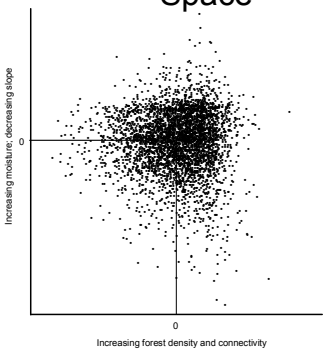
Results from PCA

- Retain first two components from PCA
- Use principal factor analysis which allows rotation of the components for more defined structure of the first two dimensions.
- Calculate the factor score for each observation

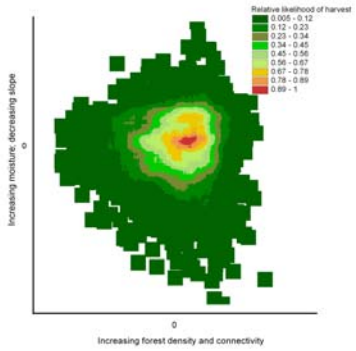
Standardized Scoring Coefficients

Variable	Factor1	Factor2
Terrain Relative Moisture Index	0.024	**0.571**
Slope	0.102	**-0.355**
Topographic Scale	-0.044	**-0.502**
Percent Forest	**0.452**	0.008
Connectivity of Forest	**0.455**	0.017
Population Density	-0.121	0.029
Light Saturation	-0.126	0.073
Distance to Nearest Road	0.193	0.055

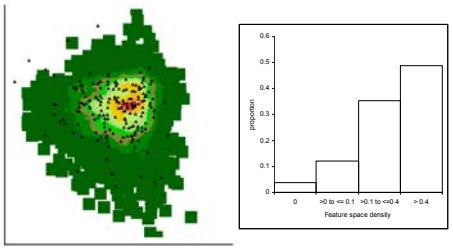
Harvested Plots in Feature Space



Relative Likelihood of Harvest



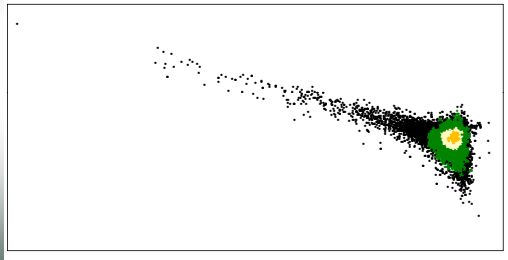
Test of Feature Space Model Based on 200 Observations Withheld from Analysis



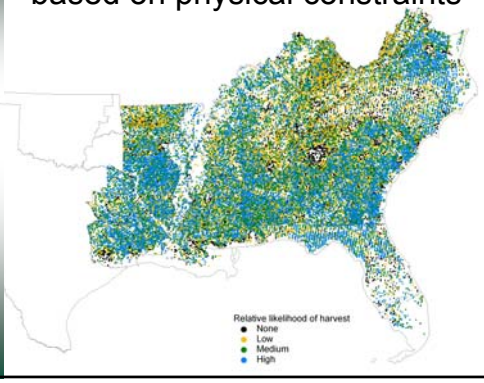
Application of the Model

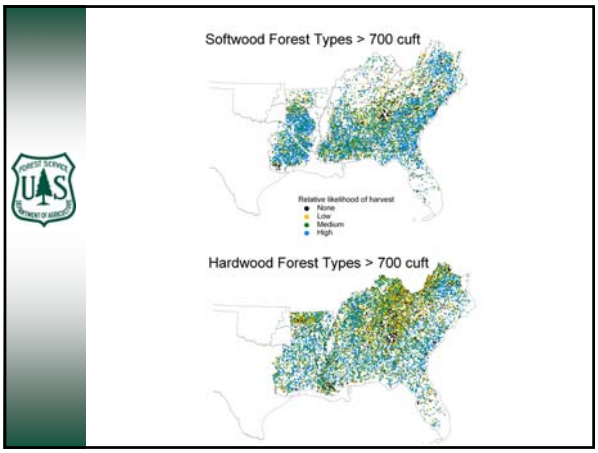
- We have a model the describes the general condition where we have observed harvest.
- The linear combination from the multivariate analysis can be applied to the all FIA plots in the south.
- Plots with little or no chance of being harvested will fall outside our model space.
- Plots inside our model space will be assigned a relative harvest likelihood score.

Feature Space Model Applied to All FIA Plots in the South



Relative likelihood of harvest based on physical constraints

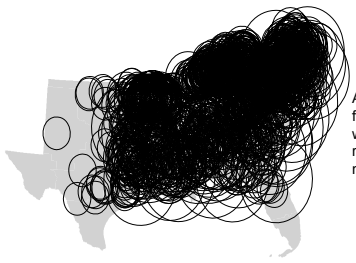




Utility of model

- Now that we have a model for physical constraints we can ask more direct questions about availability.
  - E.g. How much hardwood area and volume in non-industrial private ownership are available for harvest.
    - Constraints
      - Volume greater than 700 cuft/ac.
      - Stand falls within the draw radius of a hardwood mill
      - Hardwood forest type**
      - Stand classified in medium or high likelihood of harvest category.

Southern Hardwood Mills Draw Radii



All hardwood forest land is within the draw radius of one or more mills

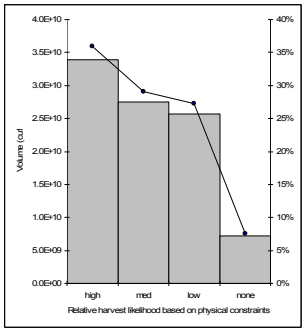
Hardwoods

Constraints
•Non-industrial private ownership
•Volume greater than 700 cuft/ac.
•Stand falls within the draw radius of a hardwood mill
•Hardwood forest type**

Result

•Approx. 34 billion cuft of hardwood volume was in the 'high' category.

•Approx. 65% of the hardwood volume in non-industrial private ownership was in the high & med category.



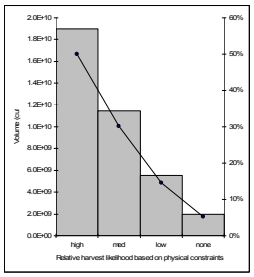
Softwoods

Constraints
•Non-industrial private ownership
•Volume greater than 700 cuft/ac.
•Stand falls within the draw radius of a softwood mill
•softwood forest type**

Result

•Approx. 19 billion cuft of softwood volume was in the 'high' category.

•Approx. 80% of the softwood volume in non-industrial private ownership was in the high & med category.



Summary

- Multivariate techniques can be used to classify the likelihood that a plot can be harvest based on physical constraints and observed harvest patterns.
- This is a plausible alternative to expert opinion models.
- The multivariate approach can be extended to include management and economic constraints.
- Other techniques that include the use of categorical and ordinal data should be investigated and incorporated.

Outline revisited

- Brief Overview of the Forest Inventory and Analysis program (FIA)
- General examples of current FIA research in the South
- Specific research example: Physical constraints on timber availability
- Future research directions and topics

FIA: Past, Present, and Future

Past	Present	Future
Timberland Inventory	Forestland Inventory	All Treed land Inventory
Timber Information	Forest and Forest Health Information	Forest, rangeland, and urban forest
Aerial photography w/field sampling	Field sampling w/ remote sensing for stratification	Increased reliance on remote sensing
Regional	National	National
Periodic	Annual	Annual
Tabular products	Tabular and some geospatial products	Increased geospatial products

Drivers and Future Directions

- Carbon, biomass, biofuel, and climate change
  - Expand FIA to urban, rangeland, and riparian areas
    - Urban pilot study – Tennessee
    - Rangeland Pilot – Oregon
- Increased cost of *in situ* measurements
  - Increased reliance on remotely sensed data
    - LIDAR research
    - Large-scale photography
- Increased use of GIS and spatial analysis
  - Expansion of FIA products to the spatial domain
    - Imputation techniques
    - Interpolation techniques

Take Home Messages

- FIA conducts a variety of research
- FIA data and sampling intensity is appropriate to address forest resources as broad spatial scales (e.g. multiple counties)
- FIA data and tools are available online - http://fia.fs.fed.us/
- Students and faculty are also invited to use the spatial data services located at SRS FIA headquaters in Knoxville for more complex spatial analysis using actual FIA coordinates

Questions / Comments