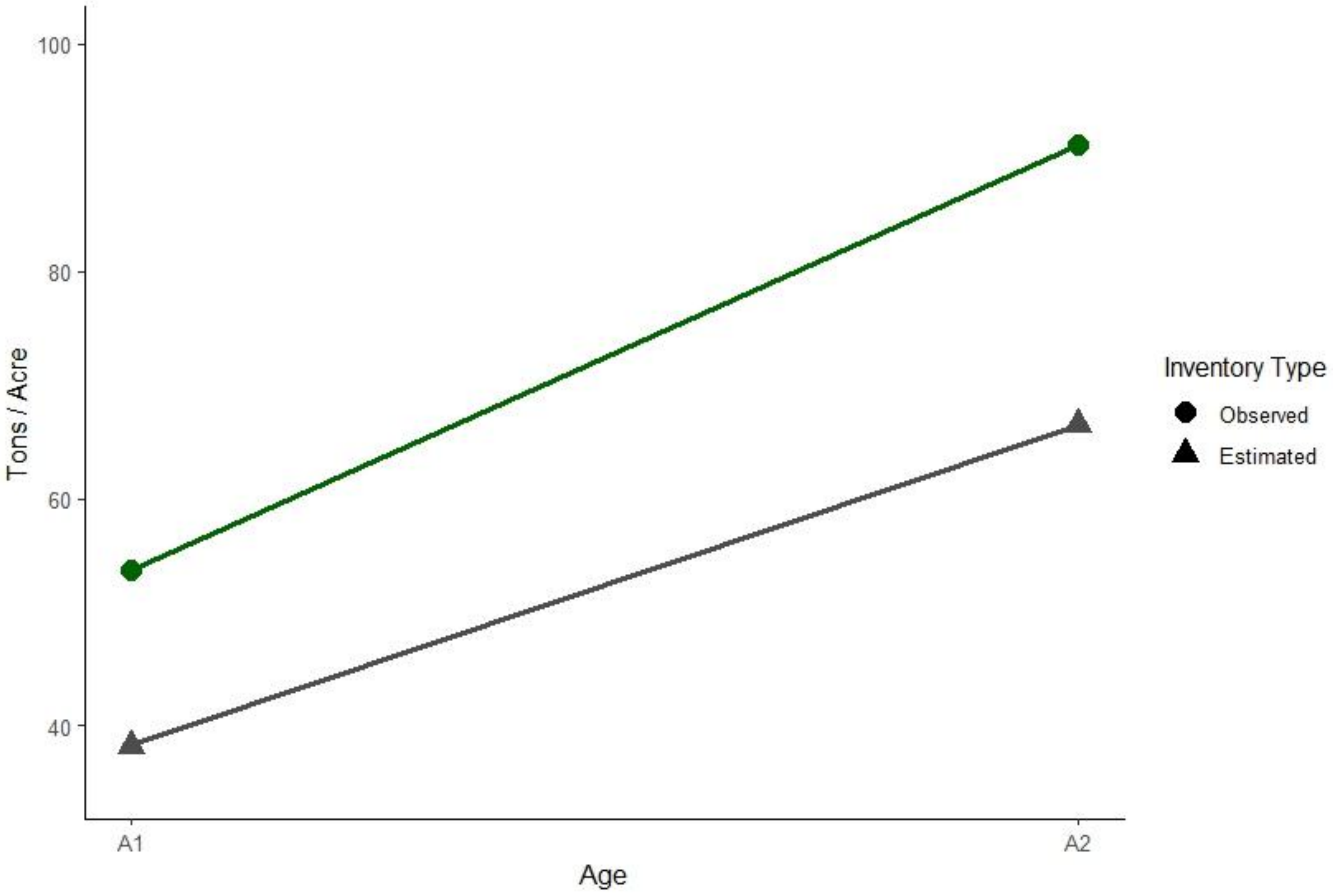
EXPIRATION DATES: FACT OR FICTION?

Extending the shelf-life of forest inventories

John Young | Biometrician | 4-16-2025



100
80
60
40
Tons / Acre
A1
A2
Age
Inventory Type
Observed
Estimated

IN THE BEGINNING

1910 - 1960

First Increase in Precision?

Permanent Sample Plot Design

- Introduced by Woolsey in 1910
- Stott & Ryan plot design (*pictured*) widely accepted after 1939 publication
- By 1947, Stott had standardized PSP procedure
- Barton 1960: Wrote the CFI guideline for US

This design become the foundation for:

Continuous Forest Inventory

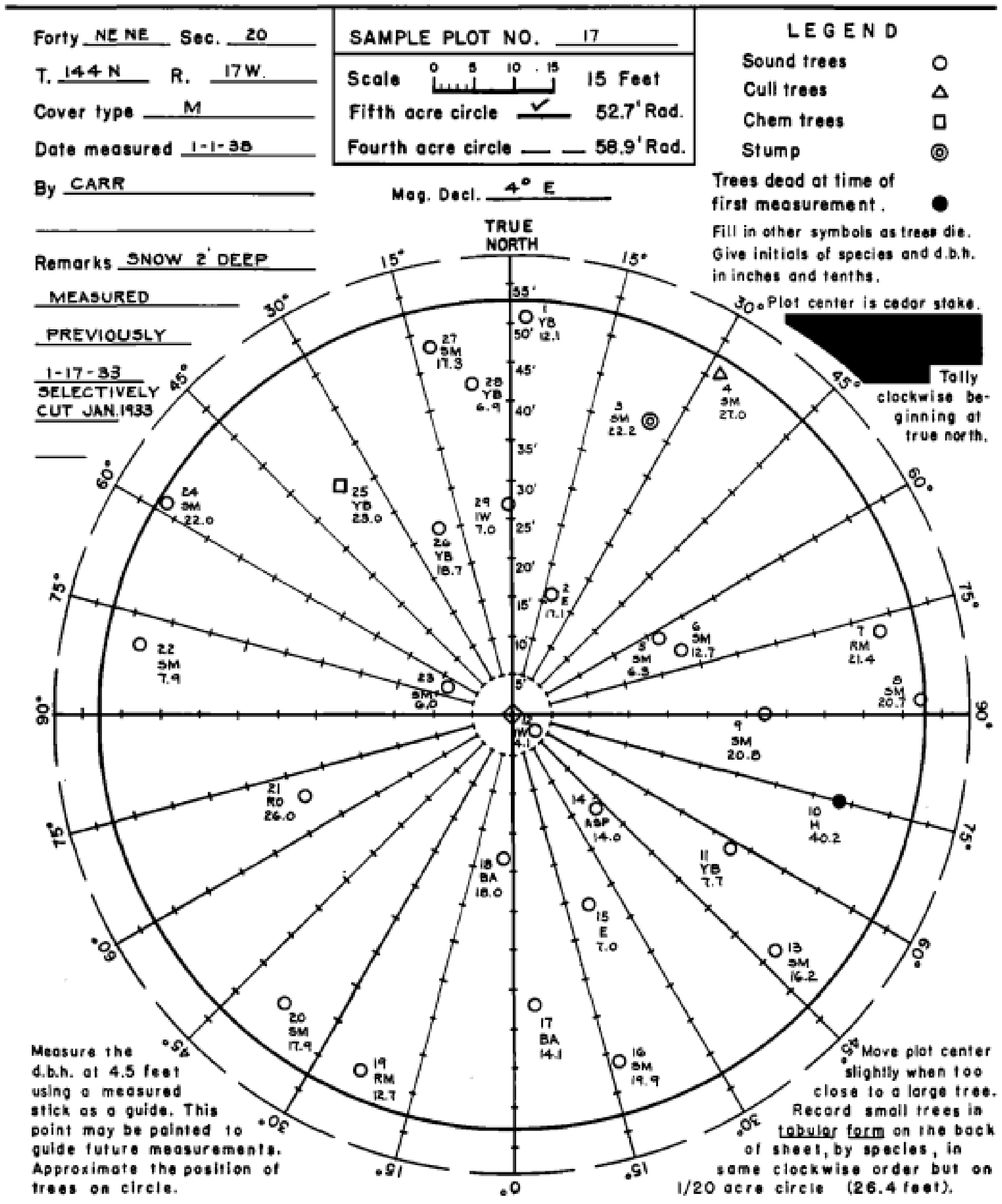


Fig. 1.—Growth measurement tally sheet.

Cracks in the Foundation

1942, Jessen comes along..

- Incomplete Matching

$$N_{t2} = 0.5n_{t1} + 0.5n_{t2}$$

- *Increased precision when combining two periodic surveys!*

TABLE 30. RELATIVE EFFICIENCY OF THE HALF MATCHED HALF UNMATCHED 1939 SAMPLE COMPARED WITH THAT OF A COMPLETELY UNMATCHED SAMPLE WHEN ITEM MEANS FOR 1939 ARE BEING ESTIMATED.

Item	Relative efficiency
	(%)
1. Acres in farms	145
2. Corn acres, harvested	145
3. Oat acres, grain	139
4. Barley acres, grain	131
5. Number of swine	137
6. Number of horses	142
7. Number of cattle	140
8. Number of sheep	143
9. Number of chickens	141
10. Receipts from sales of dairy products	136
11. Gross expenditures, operator	131
12. Gross receipts, operator	138
13. Net cash income, operator	122
14. Number of persons on farms	143

Estimated relative efficiencies on a group of items have been computed to show how much the incomplete matching as followed in the sample survey has increased efficiency over unmatched samples in estimating year means. These estimates appear in table 30.

It is clear that estimates of the 1939 means were substantially improved by the adoption of the above method of estimation (45). If correlations were perfect (± 1) the gain in relative efficiency would be 50 percent.

SPACE RACE

1960 - 2000

WE ARE NOT ALONE

Kalman (1960)

- Time-series predictions based on prior observations; "Bayes-derived"

- Drew heavily on systems theory

- Widely used for automation and navigation applications

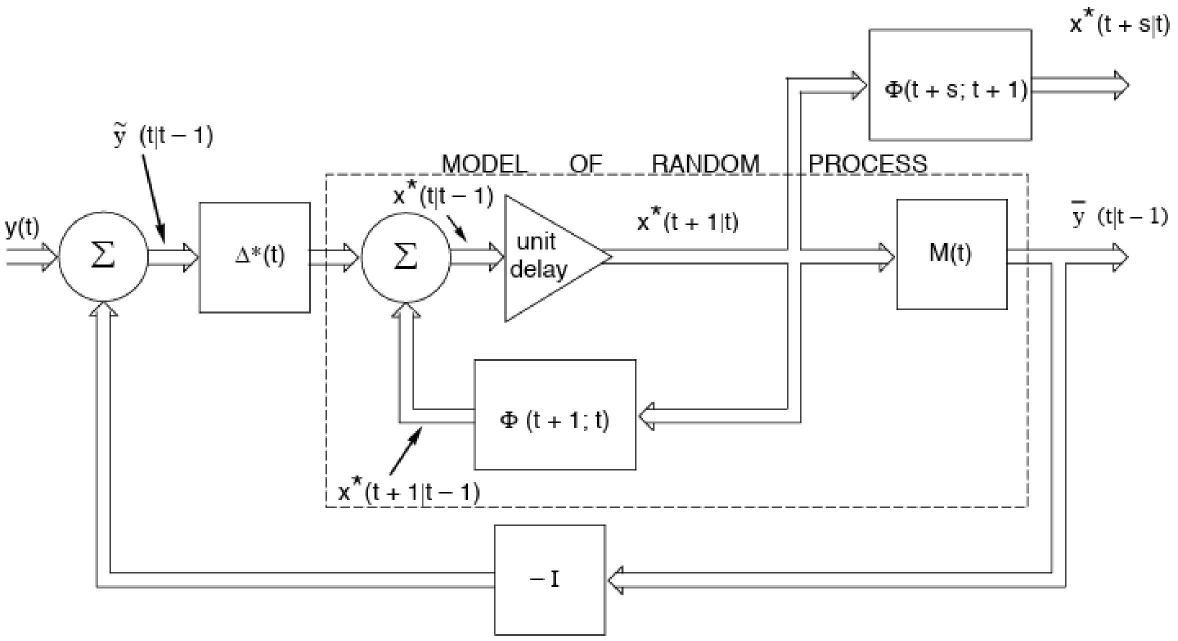


Fig. 3 Matrix block diagram of optimal filter

Took man to the moon!

Down to Earth

McEntire-Stennis takes effect 1962

Multiple Inventories on my Mind

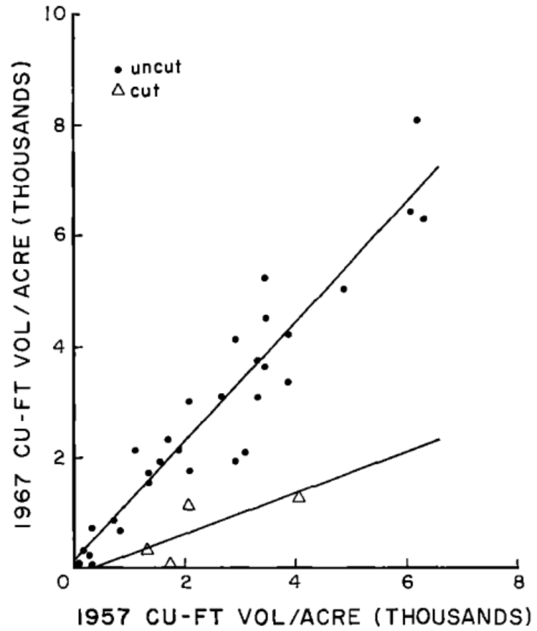
- Weighted Regression (*Cunia, Frayer*)

- Sampling with partial replacement

  Ware and Cunia (1962); Bickford et al (1963); Frayer and Furnival (1967)

TABLE 1. Comparison of regression and CFI estimates.

Item	Uncompahgre[a]		
	Standard error		Add'l plots needed[c]
	Regression	CFI	
	Pct	Pct	No.
Basal area, live trees	7.2	11.3	50
Net cu-ft volume	8.6	13.5	50
Board-ft volume			
Int ¼"	10.5	16.7	52
Scribner	10.7	16.9	51



Uncompahgre

Initial inventory:	Year	1957
Plots established		102
Reinventory:	Year	1967
Remeasured plots		34

Barnard 1975

Table 3.--Relative efficiency[a] of SPR when contrasted with complete remeasurement for inventory estimates

State	Forest area	Cubic-foot volume
Delaware	2.83	2.41
Rhode Island	8.89	2.38

[a] Relative efficiency is expressed by the ratio of the squared standard errors. A relative efficiency of 2.0 would show the one design to be twice as precise as the other under the conditions stated.

The relative efficiencies shown in table 3 reveal that SPR was always more than twice as efficient as the complete remeasurement sample it was contrasted against in estimating forest area and cubic-foot volume.

The difference in relative efficiency between the area estimators for the two states is striking. I examined the inventory data from these two states for possible explanations.

Another general trend in the Southeast is toward more in-place or location specific data. As pointed out by Campbell (1974) a comprehensive harvesting plan should answer two deceptively simple questions:

1. How much do we harvest annually in order to follow a predetermined wood flow strategy?
2. Where should this harvesting take place?

CFI systems and other extensive inventories may answer the "how much to cut" question but they cannot be used to determine "where to cut." Many CFI installations in the South were never remeasured, and several companies who performed one or more remeasurements have now abandoned their CFI plots, feeling that the costs were too great for the information gained.

Burkhart 1974

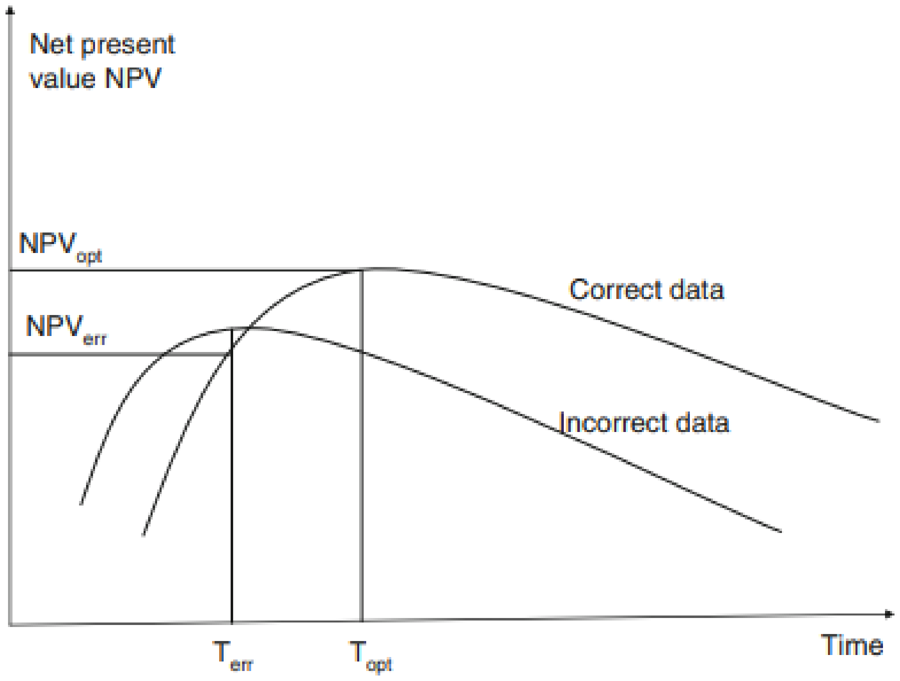


Fig. 1 The principle of cost-plus-loss analysis

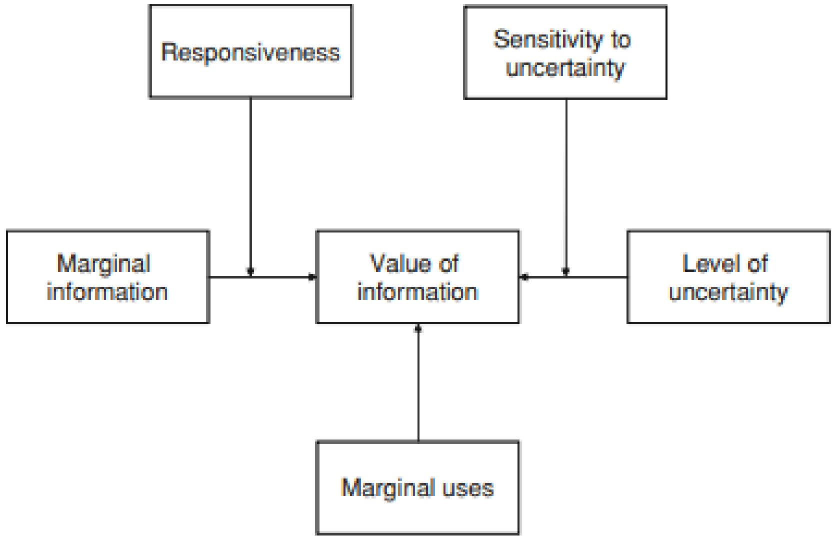


Fig. 6 The aspects affecting the value of information (Ketzenberg et al. 2007)

HAZARD WARNING

Important consideration: What is the actual benefit of additional information?

'Value of Information'

- Conklin 1977
- Burkhart et al 1978
- *Kangas 2010*
- *Makinen et al 2012*

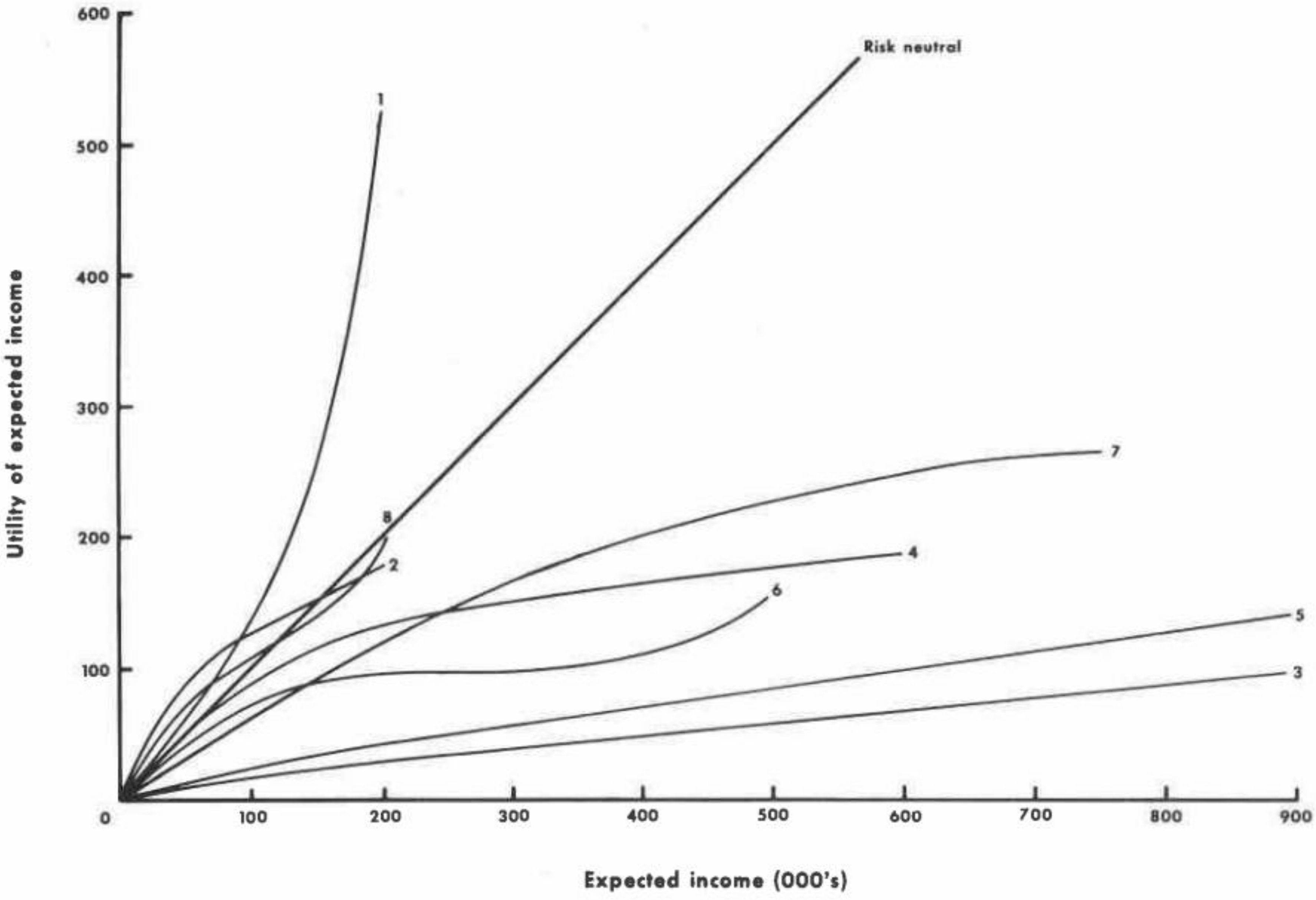


Figure 6. Utility function for eight orchardists, Jackson County, Oregon.

Running in Circles

Kalman Filter… in Forestry!

State-Space Estimation took off in the 1980s

- Variance reduction (Dixon and Howitt 1979)
- Stochastic Differential Equations (Garcia 1980)
- Localizing growth equations (Gertner 1984)
- Climate Impact Modelling (Van Deusen 1987; Visser 1986)

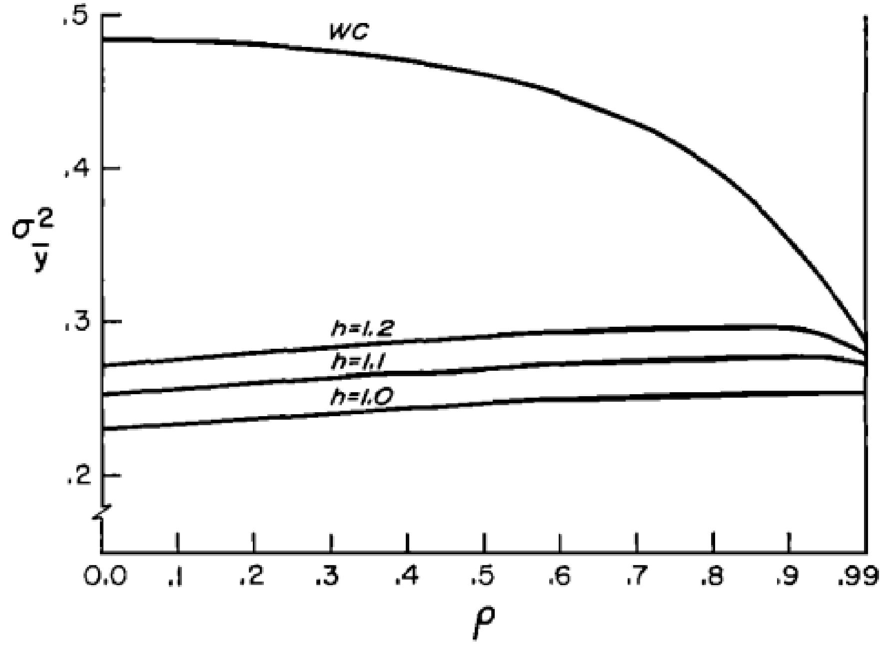


FIGURE 1. Comparisons of the variances of the Kalman and Ware and Cunia estimators for the second period population mean: parametric changes of the correlation coefficient between remeasured plots and changes in the a priori proportional change parameter, h, between the first and second period means. WC indicates the variance of the Ware and Cunia estimator. The curves labelled with an h denote Kalman variances for the corresponding value of h and $\omega = 0.04$. The population variance in the first period is 100 and then 121 in the second period. The sample sizes are $u = 200$, $m = 50$, and $n = 200$.

Discovery of the Kalman Filter as a Practical Tool for Aerospace and Industry

Leonard A. McGee, Ames Research Center, Moffett Field, California
Stanley F. Schmidt, Analytical Mechanics Associates, Inc., Mountain View, California

November 1985

Reaching Nirvana?

By the early 1990s, Benefits of data assimilation were clearly demonstrated

- Czaplewski 1988; 1990
- Walters and Burkhart 1991

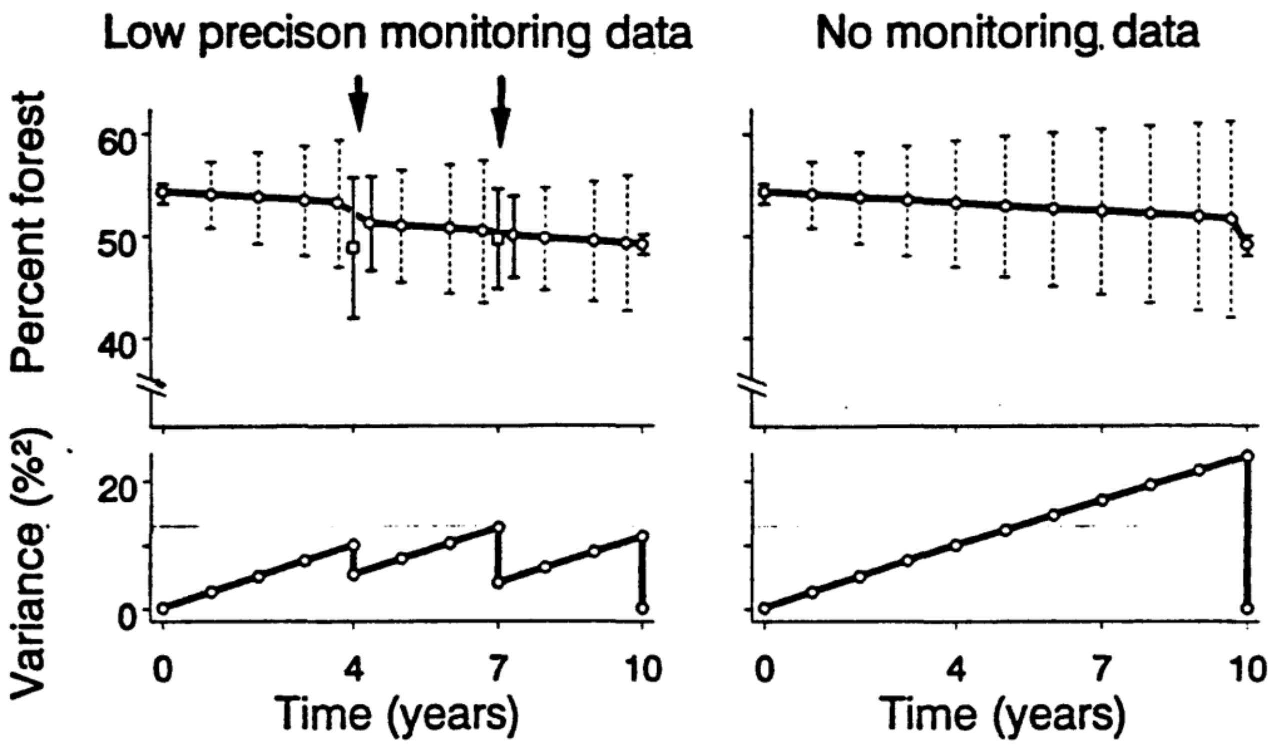


Figure 5. Kalman estimates and approximate 95% confidence intervals. Forest inventories were conducted in years 0 and 10; monitoring data were gathered in years 4 and 7. A time series of relatively imprecise (i.e., inexpensive) monitoring data can prolong utility of a previous, more expensive forest inventory.

Flying Under the Radar

Chip Scott (1998):

“I recommend a permanent-plot system (CFI) using a systematic grid.”

PRE-MODERN ERA

2000 – 2015

United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS–80

The Enhanced Forest Inventory and Analysis Program—National Sampling Design and Estimation Procedures

William A. Bechtold and
Paul L. Patterson, Editors

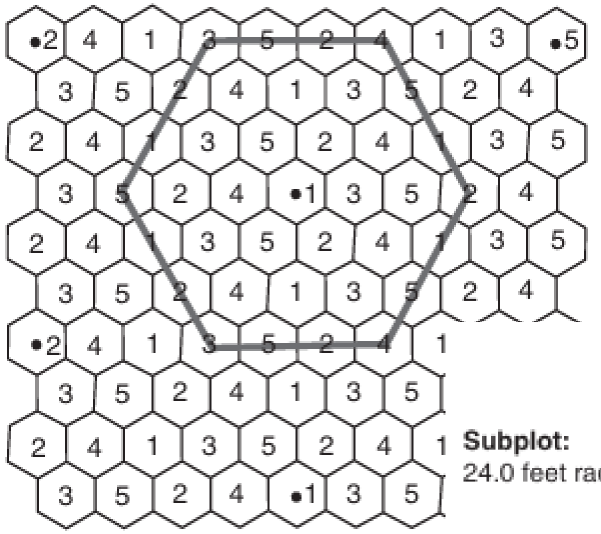


Figure 2.6—Assignment of hexagons to one o
(shown by number).

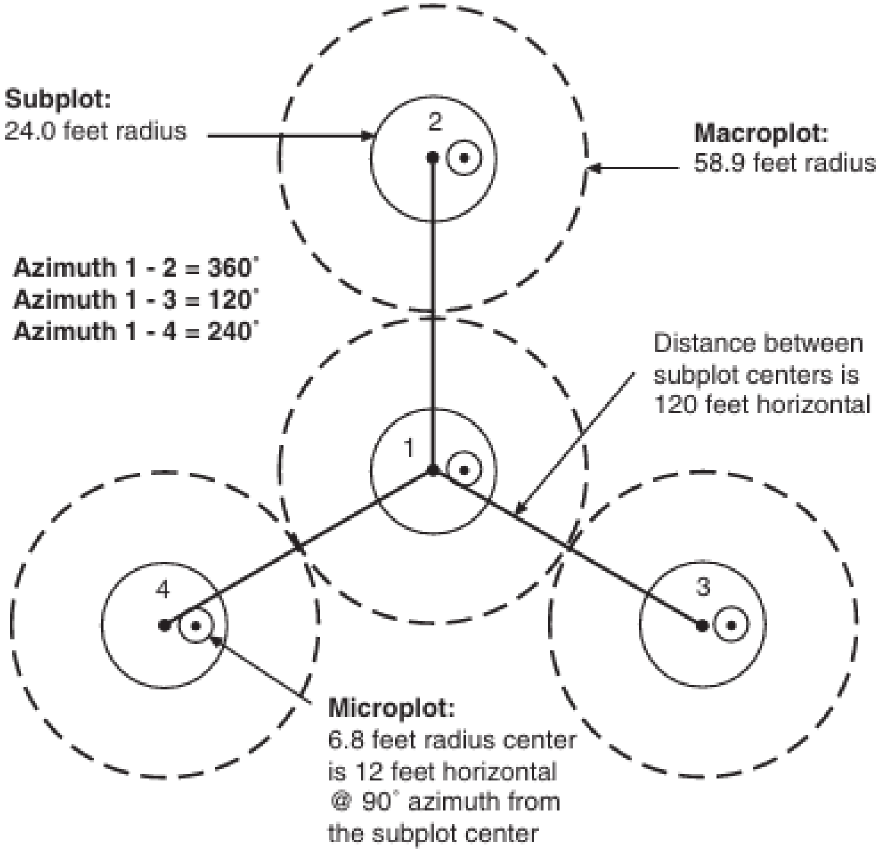


Figure 3.1—FIA plot design.

FIAs and NFIs

Annual plot design necessitates a robust, easily interpretable design

Frayer and Furnival (2000)

New challenges:

- Multiple resource questions
- Diverse, public customers
- Various domain needs

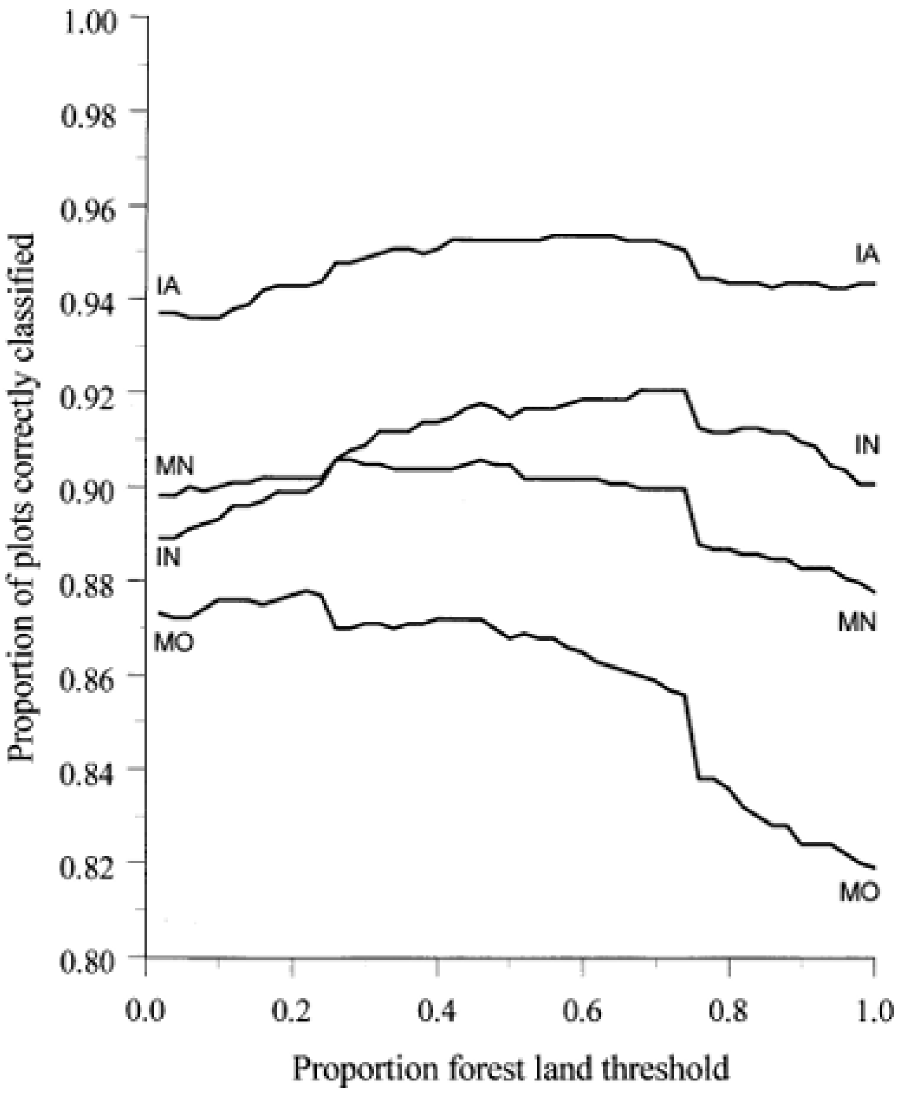


Fig. 2. Correspondence between NLCD-based forest and nonforest strata and proportion forest land observed by field crews.

Enter: SAE / SDE

Changing landscape = changing demands

- New markets consuming data (Prisley et al 2021)
- Renewed focus on auxiliary data incorporation (LeMay & Temesgen 2005; McRoberts et al. 2002)

Research Efforts concurrent with FIA annual inventory

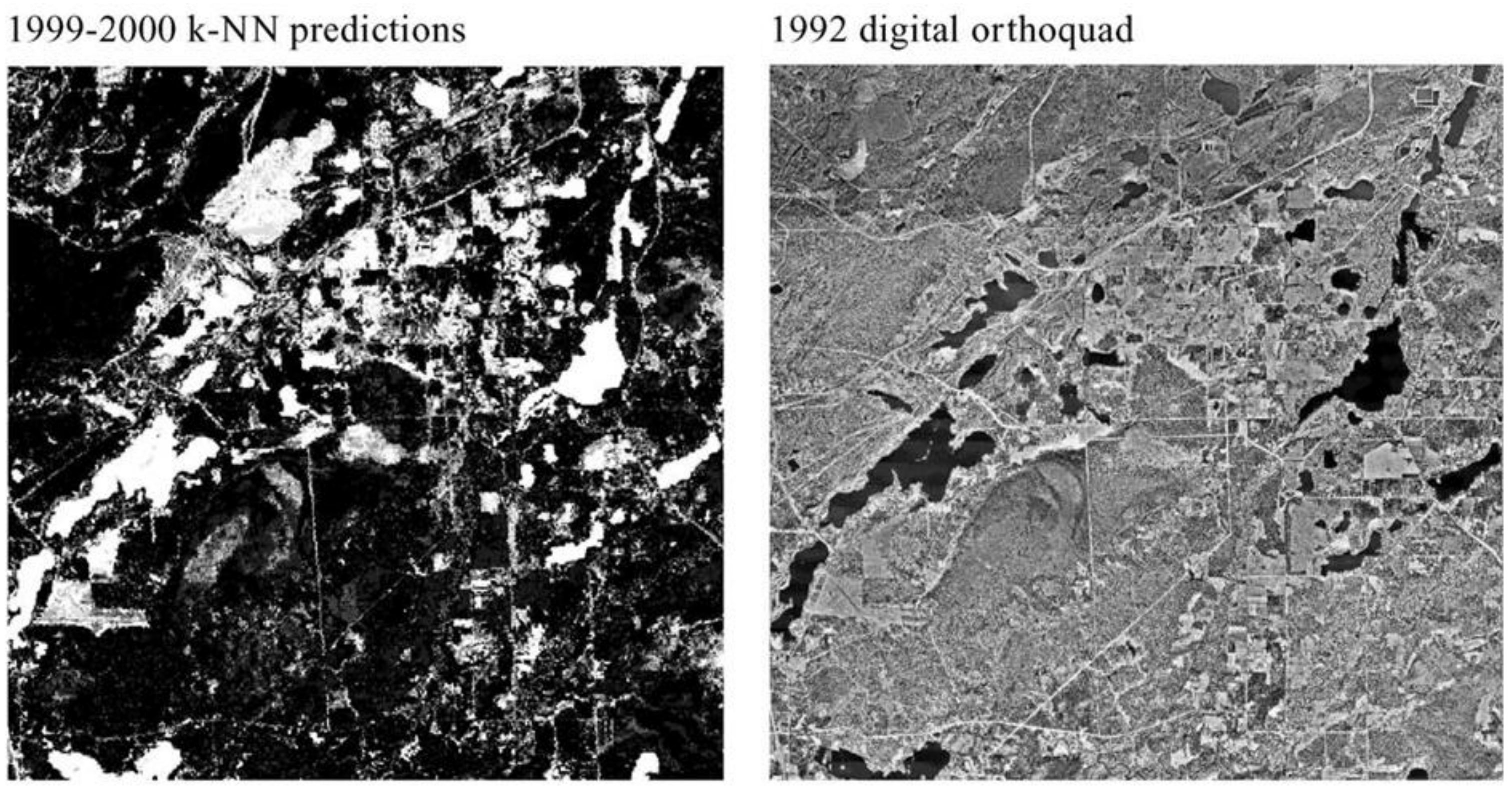


Fig. 6. Predicted forest land proportion and aerial photograph for the 15 × 15 km center of the St. Louis study area.

Composite Estimation 2.0?

Auxiliary data… alternative inventory… sound familiar?

Research primarily associated with (Guildin 2021):

- Remotely sensed auxiliary data
- Spatially-defined domains

Are there others?

MODERN ERA

2015 – Present

Where are we now?

Composite Estimation

- **SAE methods more relevant than ever**

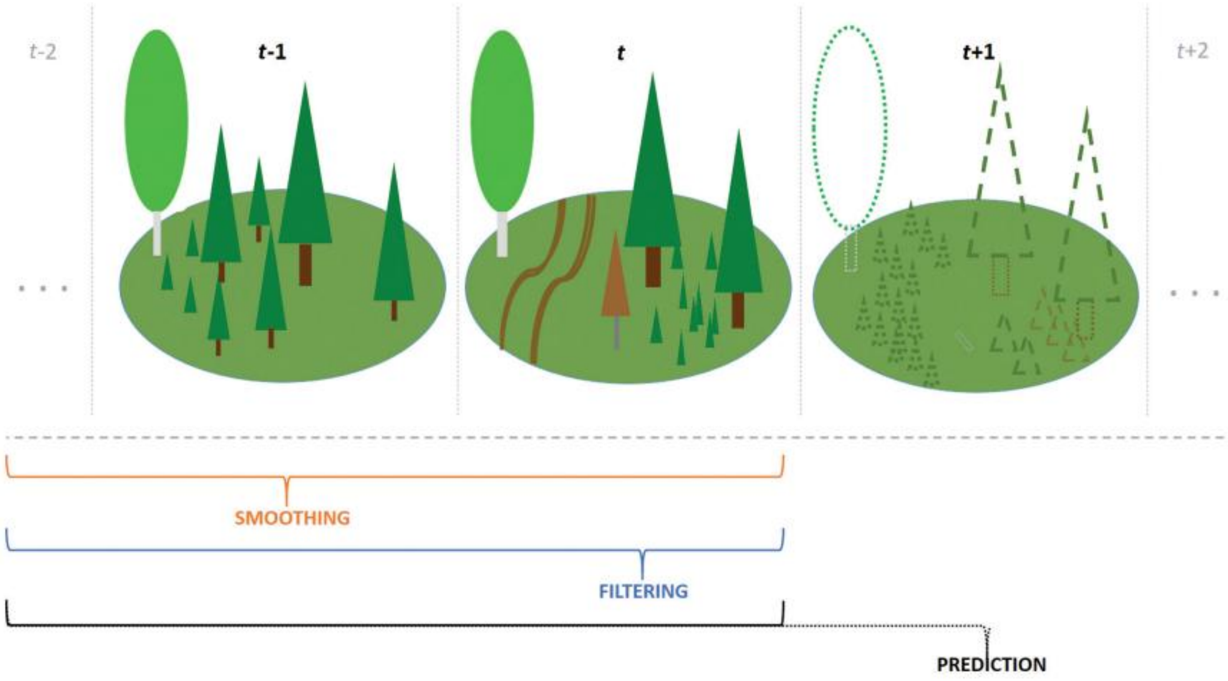
  Prisley 2021; Guildin 2021; Dettman 2022

- **Data Assimilation methods more relevant than ever**

  Nystrom et al 2015; Eyvindson et al 2017; Kangas 2020; Mohamedou et al 2022

- **Classical regression estimators not obsolete**

  McConville et al 2020



Where are we now?

Composite Estimation

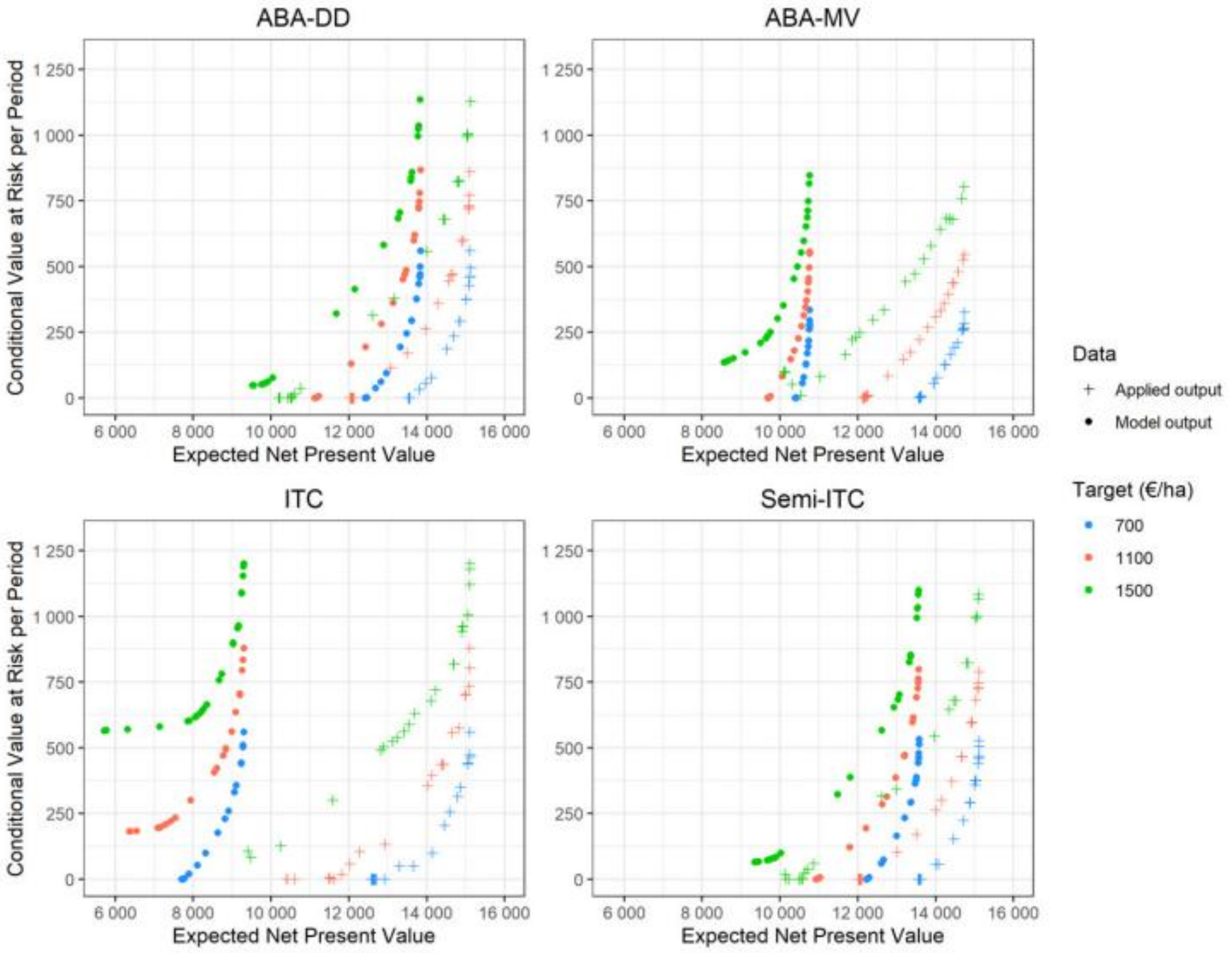
Value of Information

- **Objective criteria for inventory value**

  Nahorna et al 2024

- **Multi-resource inventories**

  Guldin 2021; Ferretti et al 2024



STATE OF THE ART

The state of the art of inventory systems in use throughout the Eastern and Southern U.S. was presented by Breeman (1974). Breeman conducted a telephone survey of companies and divisions of companies which own and manage from 60,000 to 600,000 acres of forest lands to determine their practices. The most common practices he found were:

1. No inventory system. Inventory data limited to acquisition cruises. Harvesting areas are selected by employers and owners from personal knowledge about the land.

2. Continuous Forest Inventory (CFI). Broad inventory information used to determine allowable cut. No system used to select harvest areas.

3. Updating of previous inventory cruises and reinventory of about 20% of the ownership each year. Data are mostly maintained on a tract basis and updating is done by hand.

4. Stand data inventory systems more or less maintained by hand and containing basic data such as age, species, basal area, etc. Some use university or data processing computing centers to develop reports annually. Reinventory is every 5 to 10 years.

5. Sophisticated inventory systems involving computers, management models, growth projections, etc. All of these systems use either stand data or cutting area data.

Of the 22 companies surveyed, 2 had no inventory system, 4 possessed CFI data only, 8 relied on updating previous inventory cruises, 3 used stand data inventory systems, and 5 employed highly sophisticated systems involving computers, management models, and growth projection systems (Breeman, personal communication). One can conclude from these results that the state of the art in forest management inventories is, in general, considerably behind the research results that are available.

MY OBSERVATIONS

Increased precision is a long-standing objective but distracted by organizational challenges

Research foci have shifted through time, resulting in a ‘moving target’

Data availability and computing power are just now cost-favorable

SO, WHAT'S THE QUESTION?

How can we derive a value-driven approach to optimize the lifespan of forest inventory data?

What are the institutional barriers to making complex designs standard practice?

How do we maximize the value of information for increasing precision?

Where can we focus research efforts to guide implementation of advanced inventory techniques?

Others?

QUESTIONS?

CITATIONS

CITATIONS

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