Statistical Issues in Meta-Analysis

In Agricultural Research

Fernando E. Miguez

Iowa State University

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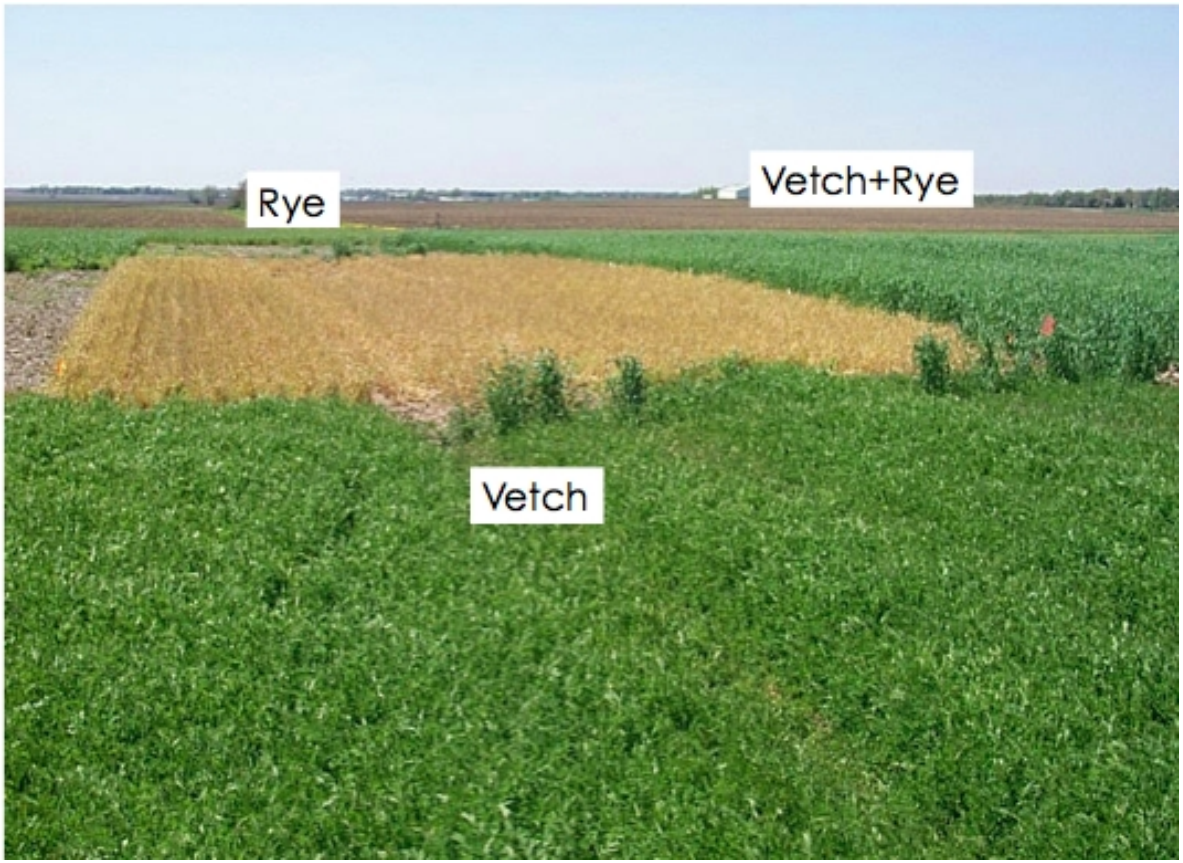
Reviewing Research on Cover Crops

Effect of cover crop on yields



Issues with individual studies

- Large environment effect (year/location)
- Environment $\times$ treatment interaction
- Length of experimentation

What is meta-analysis?

“ Meta-analysis is a quantitative method for research synthesis in which independent studies are combined to estimate treatment effects and their variability.”

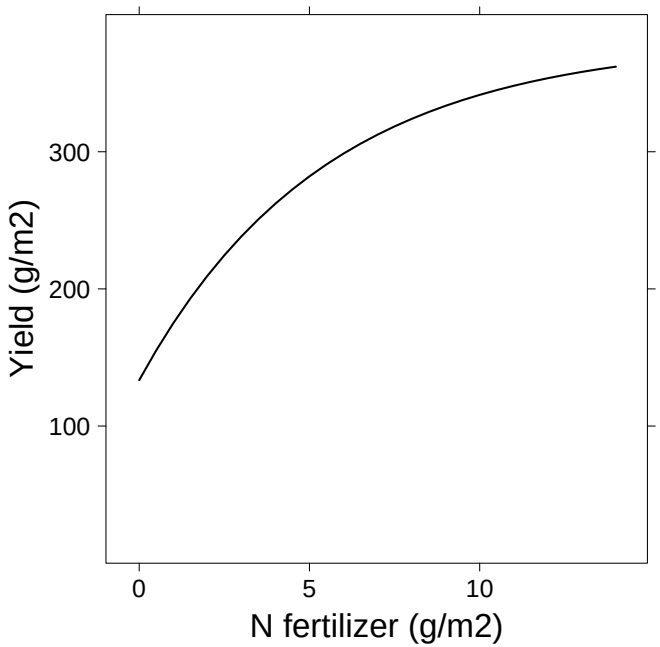
Issues in Meta-analysis

- Criteria for selecting publications
  - Exhaustive search
  - Source: Journal, Book, White paper, etc.
  - Pub Year
  - Methodology
  - "Publication bias"
- Should be continually updated
- Increased power and accuracy

Statistical Issues

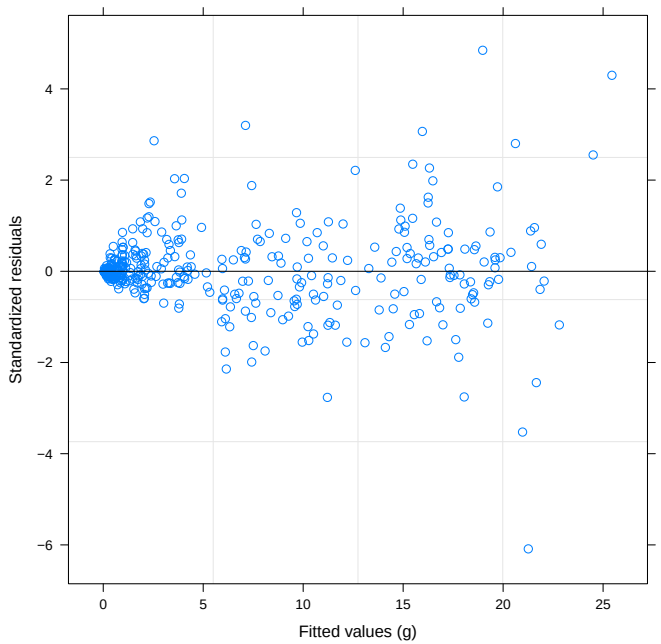
Mean Structure

- Linear
- Non-linear
- Transformations



Error structure

- normality
- variances
- independence (nesting)



How do these issues appear in meta-analysis?

For cover crops: linear model

$$yield = CoverCrop + Management + Environment$$

Response ratio

$$RR = \frac{Yield_{WCC}}{Yield_{NC}} = \frac{\bar{Y}_{WCC}}{\bar{Y}_{NC}}$$

How do these issues appear in meta-analysis?

For cover crops: linear model

$$yield = CoverCrop + Management + Environment$$

Response ratio

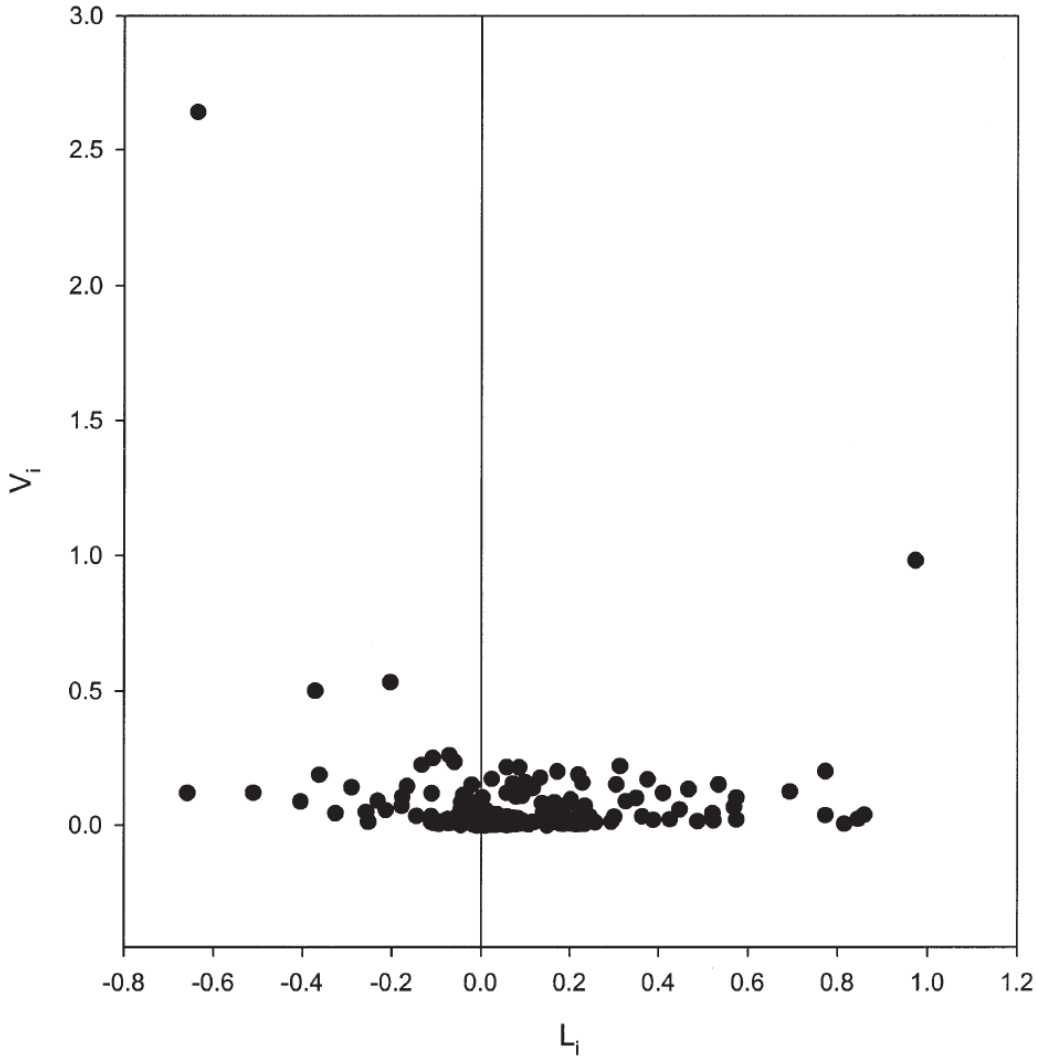
$$RR = \frac{Yield_{WCC}}{Yield_{NC}} = \frac{\bar{Y}_{WCC}}{\bar{Y}_{NC}}$$

Natural Log

$$L_i = \ln(RR)$$

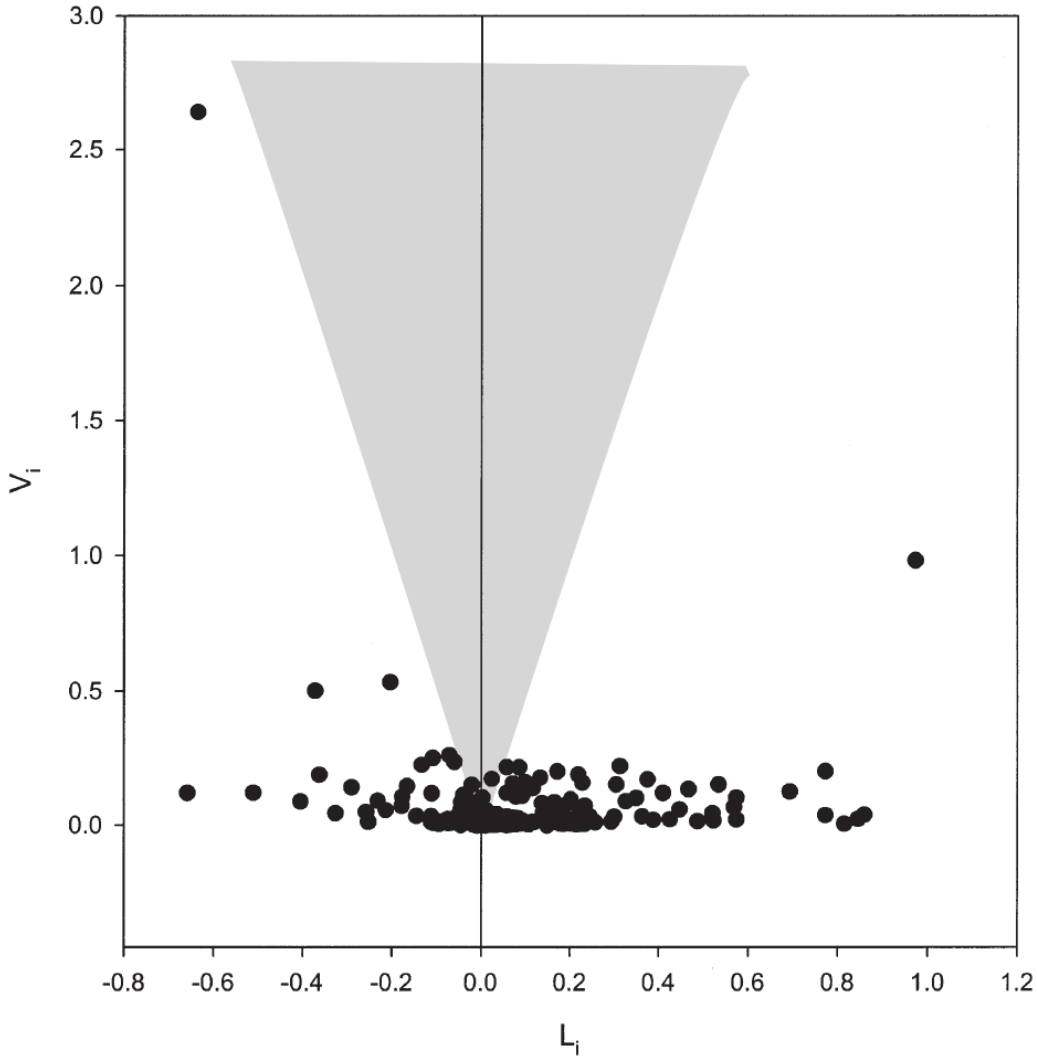
Bias and outliers

Funnel plot



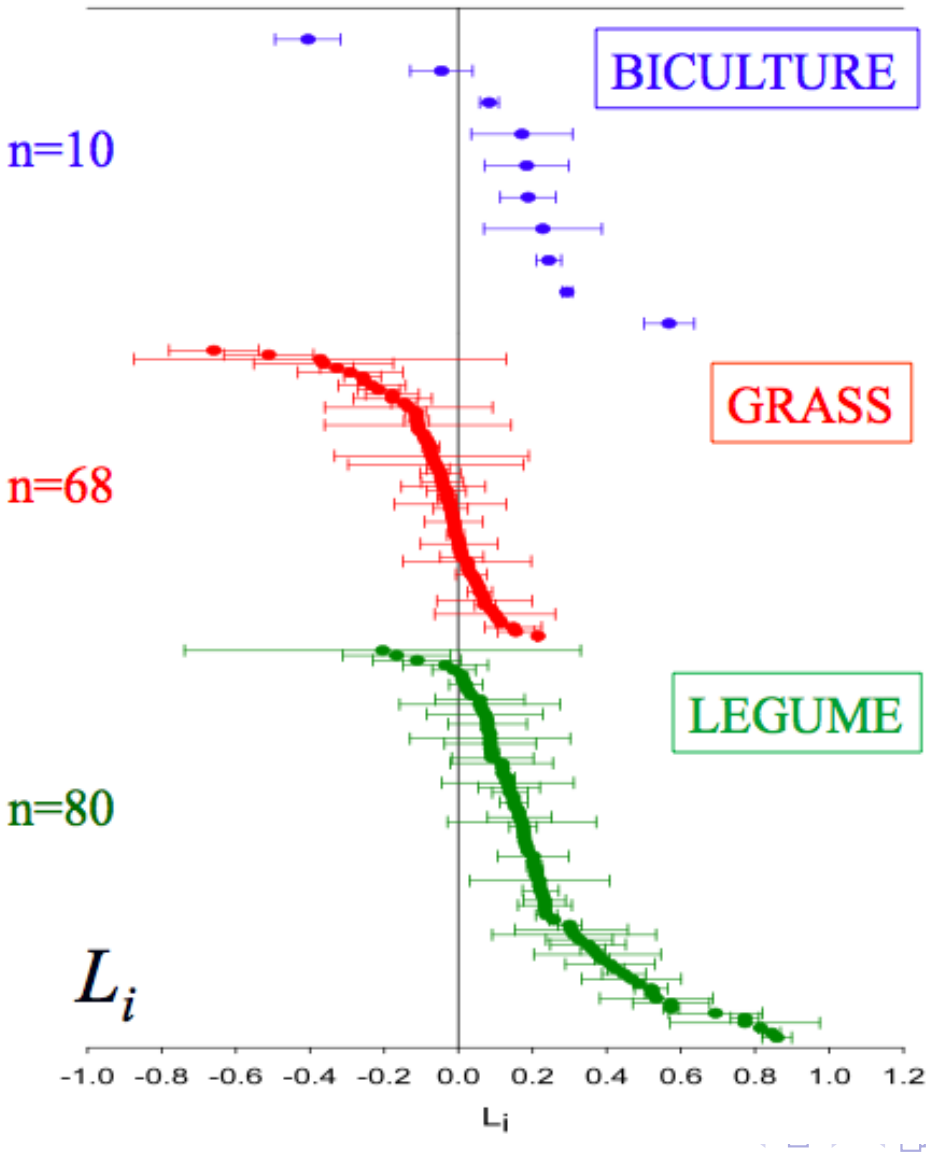
Bias and outliers

Funnel plot



Effect size, Grouping and Normality

'Forest plot'



Error Structure
Main Sources of Variability

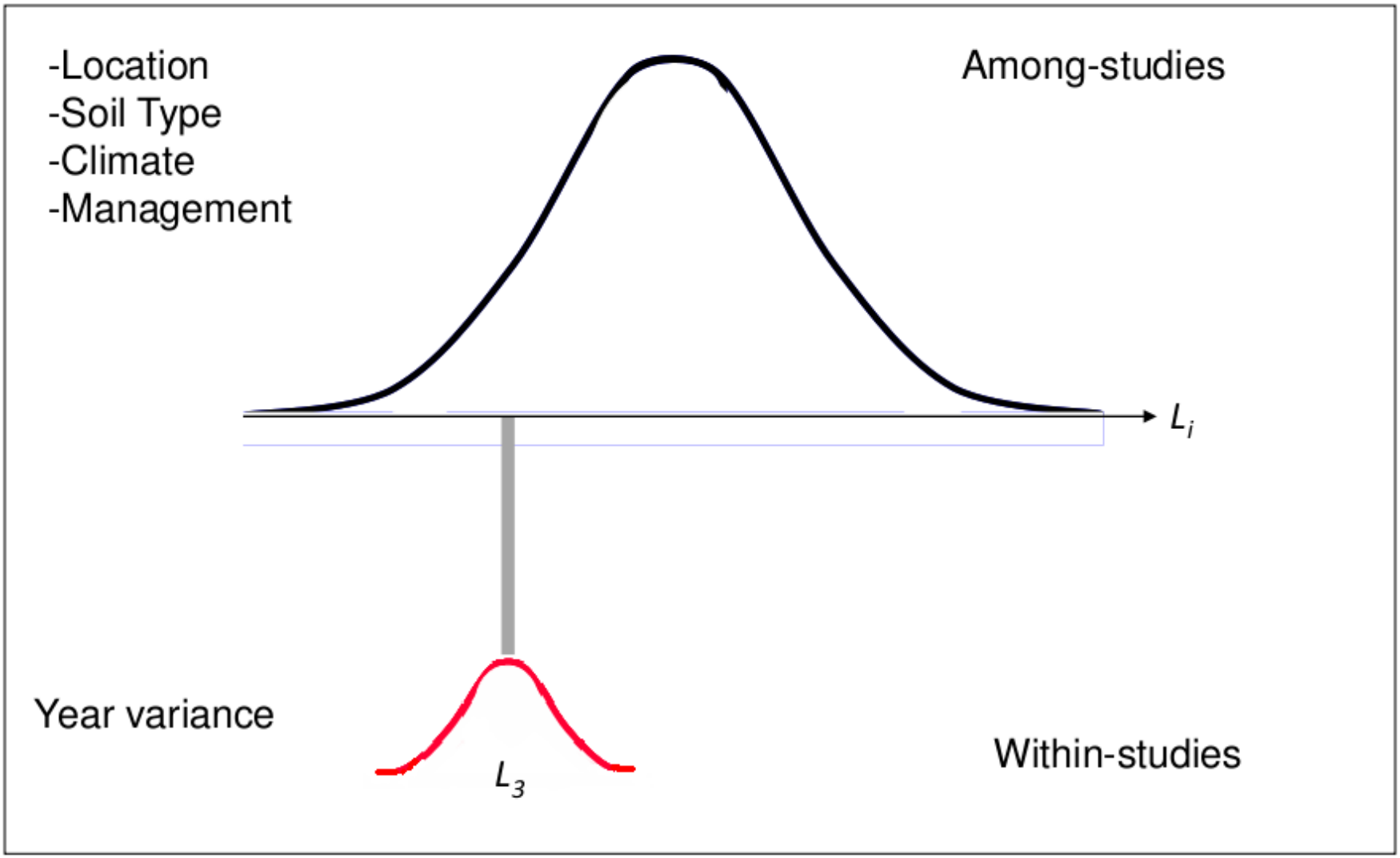
Within-studies

- Replication (n)
- Experimental error
- Design (RCBD)
- **Issue 1**: Lack of reporting
- **Issue 2**: Heterogeneous among studies

Among-studies

- Climate
- Soils
- Genetics
- Management
- **Issue 1**: Standards
- **Model**

Among-Within Variability



Year Factor in Agriculture

Individual Experiment

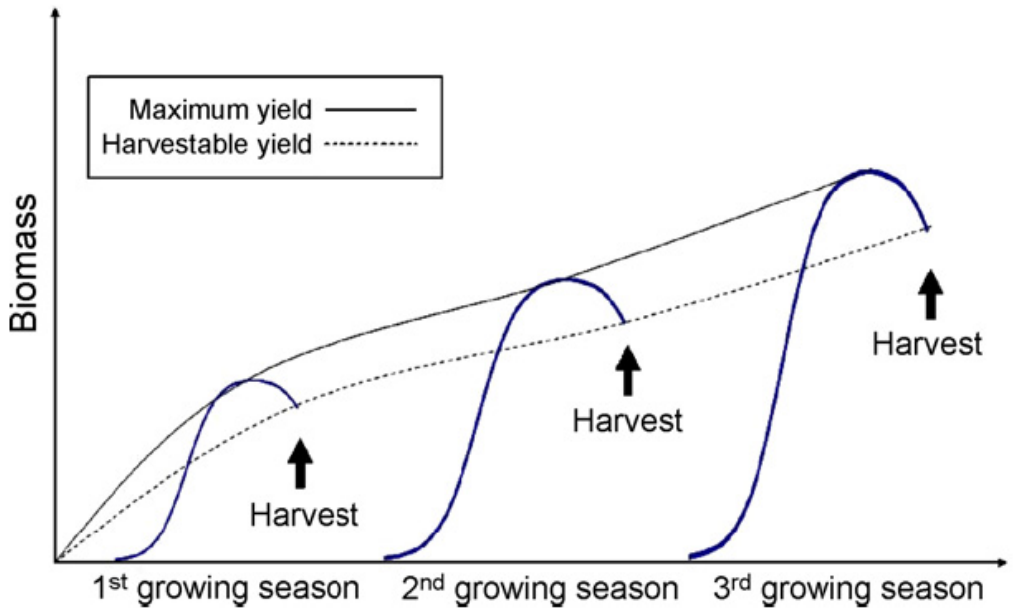
- **Year Fixed**
  - Software limitations (SAS GLM vs. MIXED)
  - Limited inference
- **Year Random**
  - Two or three years not enough
  - Poor variance estimate

Meta-analysis

- Larger number of observations
- Allows for better estimation of error

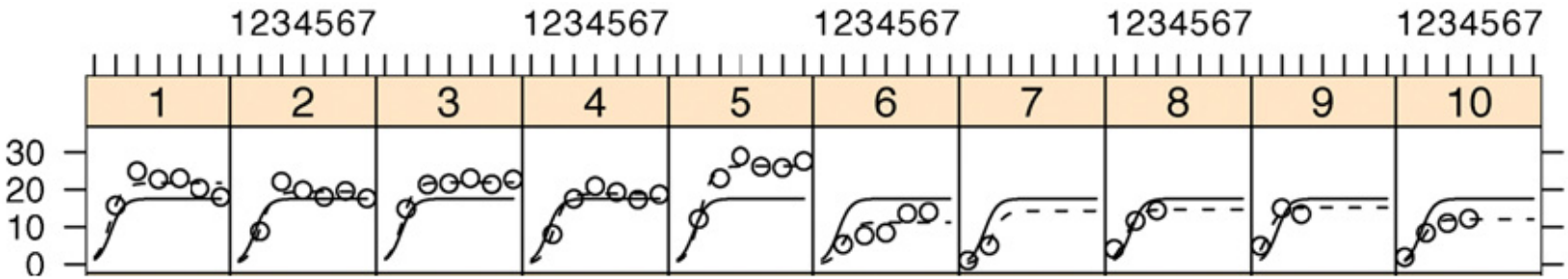
Source: Miguez and Bollero (2005)

Meta-Analysis: Miscanthus Management



Miscanthus

Meta-Analysis: Miscanthus Management



- Non-linear model
- Logistic

$$y = \frac{Asym}{1 + \exp((xmid - x)/scal)}$$

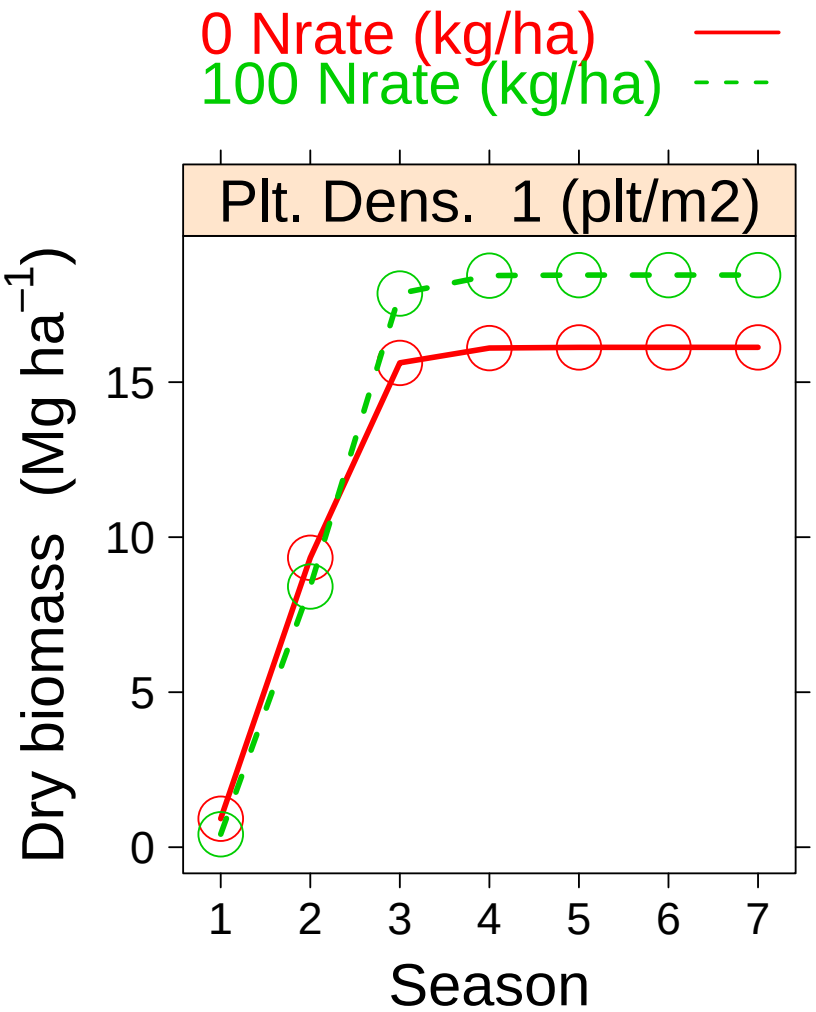
- Error structure (Mixed Model)

Non-linear Mixed Model

Specific Statistical Issues

- Choice of non-linear function
  - Interpretable
  - Fit criteria (LRT, AIC, BIC)
  - Parsimony
- Hierarchical structure of error
  - Covariance random
  - Covariance error
- State, Location and Experiment

Meta-analysis of Miscanthus (Miguez et al. 2008)



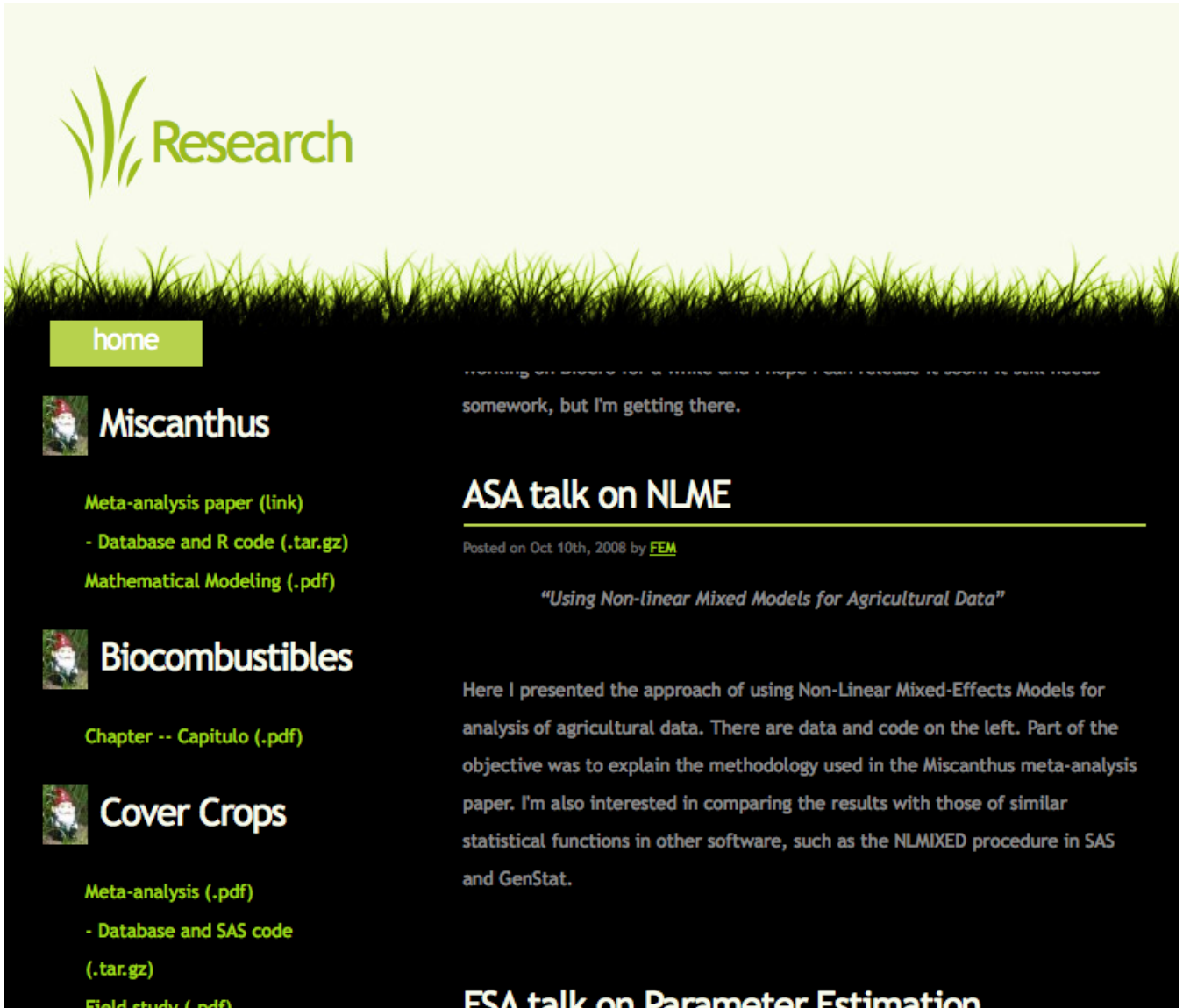
Objective Summarize the European literature

Method combined 31 studies

Results Learned about the agronomic management practices (N fertilizer and planting density)

Outcome Average; Recommendation; Prediction

Website: Data and code (https://netfiles.uiuc.edu/miguez/www)



References

- "Integrating Quantitative Findings from Multiple Studies Using Mixed Model Methodology". 2001. J. Dairy Sci. N. R. St-Pierre.
- "Review of Corn Yield Response under Winter Cover Cropping Systems Using Meta-Analytic Methods". 2005. Crop Science. Miguez and Bollero.
- "Meta-analysis of the effects of management factors on Miscanthus x giganteus growth and biomass production". 2008. Agr. For. Meteor. Miguez, Villamil, Long, Bollero.

Questions ?