

Pros and Cons of Different Disease Assessment Ratings

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- General comments on measurements
- Types of disease intensity
- How to measure (assess) – scales, etc.
- Data analysis issues
- Agreement: accuracy, reliability

Disease assessment: measuring disease intensity

- Our ability to understand a phenomenon is proportional to our ability to measure it
 - *Lord Kelvin*
- “Without quantification of disease, no studies in epidemiology, no assessment of crop losses, and no plant disease surveys and their applications would be possible”
 - *Kranz (1988)*
- “The cornerstone of epidemic analysis”
 - *Campbell and Neher (1994)*

Types of disease intensity

- **Disease incidence**

- Proportion of plants (leaves, etc.) diseased, or the number diseased out of N plants (leaves, etc.) observed

- **Disease severity**

- Relative or absolute area of plant tissue affected by disease (sometimes called “intensity”)
 - For many fungal (and other) plant diseases, severity is the area of plant surface with lesions
 - Often represented as a proportion (percentage)
- *“Degree of infection”*

Types of disease intensity

(continued)

- Disease incidence
- Disease severity
- **Disease count**
 - Number of lesions (or other units of infection) per plant or per area of plant tissue
 - A type of *density*
 - Often considered to be a form of severity
 - When total diseased area is low:
 - ❖ *Number of lesions * lesion area = severity*

How to measure disease intensity

- **Incidence:**

Most useful when mean severity is low to moderate. Other advantages: very fast, and easier to train scouts (maybe more objective)

- Straightforward (other than sampling problems)

- Count the number with symptoms

- **Disease count (type of severity)**

- Also relatively straightforward (except for sampling problems)

- Count the lesions (or disease entities) per leaf, plant, etc.

- **Severity**

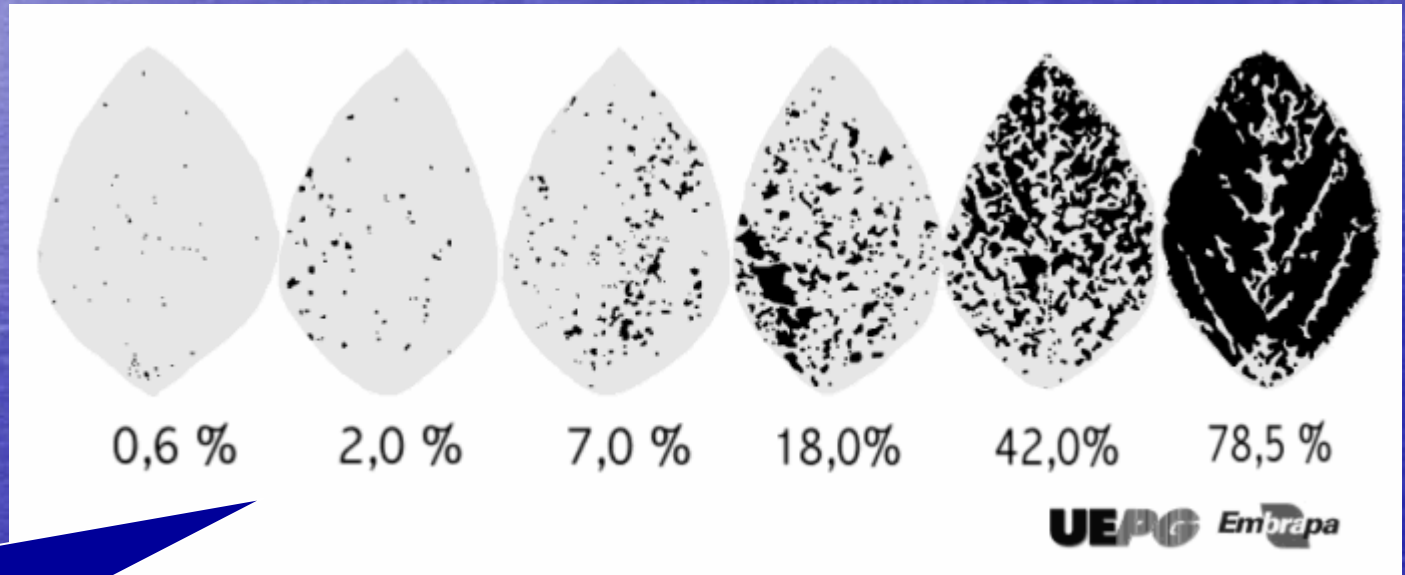
- A major challenge

Most useful when lesions are not too small, when counts are small, and sizes are similar

Measuring disease severity

- **Visual estimation**
 - Direct estimation
 - (assign each specimen a severity value)
 - Direct, with aid of **disease diagrams**
 - Use of **disease scales**
 - Use of *ordinal* rating scales
- **Remote sensing and electronic methods**
 - Image analysis, etc.
- **Indirect methods**
 - Predict mean severity from incidence

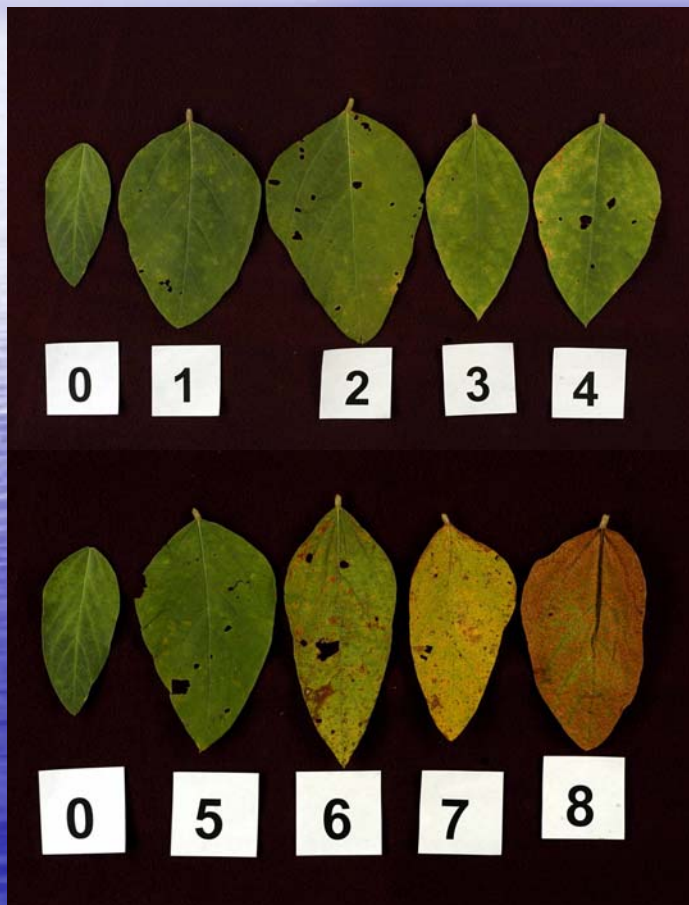
Direct estimation of severity, with aid of diagrams



Pictorial or graphic representation of selected levels of severity

Assign a severity value to a specimen based on closeness of perceived severity of the specimen to one of the values in the diagram

Direct estimation of severity, with aid of diagrams



Bayer Rating Scale

0	0
1	0-2.5%
2	2.5-5%
3	5-10%
4	10-15%
5	15-25%
6	25-35%
7	35-67.5%
8	67.5-100%

Assign a severity value to a specimen based on closeness of perceived severity of the specimen to one of the values in the diagram

Typically, unequal disease class intervals; major interpolation needed; USE MID-POINT OF RANGES

Direct estimation of severity, with use of a disease scale

"Disease Scale":

A partition of the continuous severity values from 0-100% into a finite number of classes—a "diagram" without the diagram

A rater observes a specimen and assigns it a class value (typically the mid-point)

Kemerait et al. (IL)

- 0 No disease
- 1 Trace to 5% infection
- 2 5-15%
- 3 15 to 35%
- 4 35 to 67.5%
- 5 67.5 to 100%

Generic (see Sinclair, ...)

- 0 No Disease (0%)
- 1 1-10%
- 2 11-20%
- 3 21-30%

...

Disease diagrams and scales *can* improve accuracy and speed

Estimation of severity using ordinal disease rating scales

"Ordinal Rating Scale":

Ordered categories (classes) of severity

Table 1. A 0-3 scale was employed for disease rating

Scale	Disease severity
0	no symptoms
1	light number of lesions (1-100)
2	moderate number of lesions (101-500)
3	heavy number of lesions (>500)

Vuong et al.

"Classic (from 1923)"

0	No disease
0.75	Very slight disease
1	Slight
2	Moderate
3	Abundant

- 1 = No symptoms
- 2 = Isolated plants with very few symptoms (lesions) in the lower canopy
- 3 = 1 of 15 leaves with symptoms in the lower canopy
- 4 = Most or all plants with one or more leaves affected in the lower canopy
- 5 = Most or all plants with many leaves affected on plant, few leaves affected in the mid canopy
- 6 = Numerous lesions on most leaves in the mid canopy, limited defoliation in lower canopy
- 7 = Same as 6, but limited defoliation in mid canopy and severe defoliation in lower canopy
- 8 = Severe defoliation in mid canopy and limited defoliation in upper canopy
- 9 = Plants completely defoliated

Estimation of severity using ordinal disease rating scales

- Ordered categories of severity
- As with disease scales (and diagrams), one observes a specimen and assigns it a category (class) value (a score)
- Class values are only interpretable in terms of their *arrangement*, not in terms of their actual values
- The scores are only indicators of the order of the specimens, not the differences in the specimens (in terms of severity)
- Good points:
 - May be easy and rapid to use
- Bad points:
 - Arbitrary values, differences between scores do not have quantitative (physical) meaning, requires special statistical methods

Difference between scores do not make sense (in any quantitative or physical way)



By using ANOVA, one is assuming that the rating scores represent **equal** gradations on an underlying true disease severity scale

For all we know, the scale could look like this:



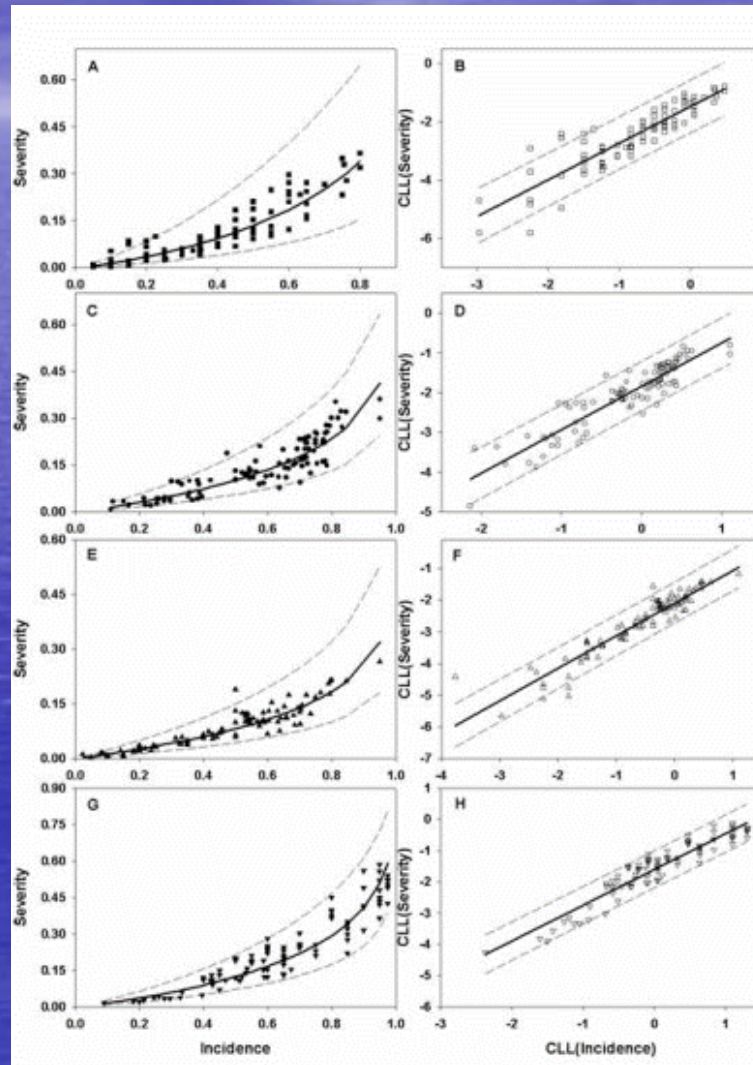
Or this: 1 2 3 4 5

Or even this: A B C D E

Estimation of severity using *indirect* methods

- Using the measurement of something other than severity to predict severity
 - Typically, predict mean severity using incidence
- The disease status of a single plant (leaf) tells you nothing about the severity of that single plant (leaf)
 - However, the disease incidence of a **population** does tell you something about the **mean severity** of the population
 - Concept based on epidemiological theory
 - There can be considerable variability

Example Severity-Incidence (S-I) relationship: (example: Fusarium Head Blight of Wheat)



Source: Paul et al. 2005. *Phytopathology* 95: 1049-1060

Type of variable determines the approach for proper data analysis

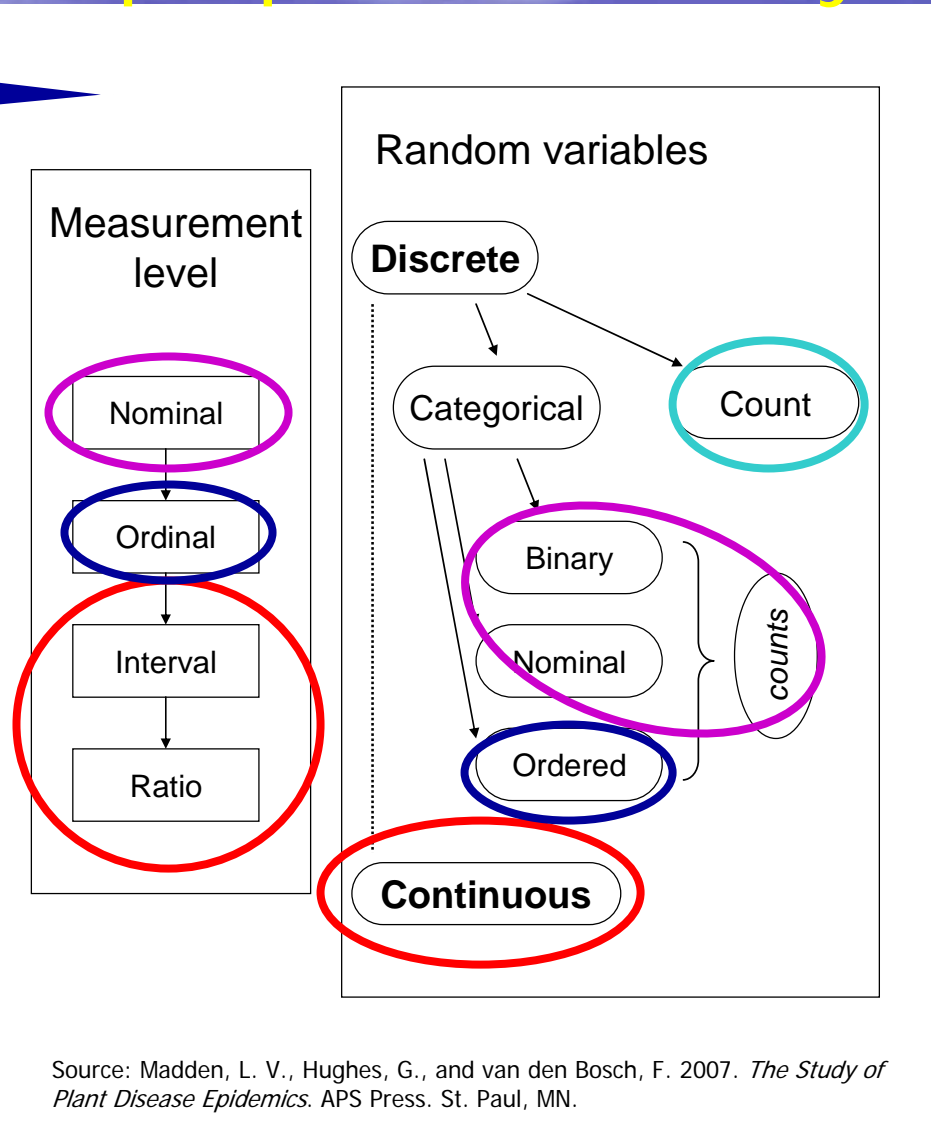
Two ways of looking at variables: information content or statistical properties

Incidence

Disease (lesion) count

Severity with ordinal scale

Severity (as a proportion or area)



Source: Madden, L. V., Hughes, G., and van den Bosch, F. 2007. *The Study of Plant Disease Epidemics*. APS Press. St. Paul, MN.

Data analysis: some valid approaches

- Disease incidence (binary or count of binary values)
 - ANOVA (linear models), only if properly transformed for unequal variances and nonlinear scale
 - For small samples, much better to use generalized linear models and generalized linear mixed models
- Disease counts (e.g., lesions per leaf)
 - ANOVA only if properly transformed
 - Better to use generalized linear (mixed) models
- Severity (as an area or proportion)
 - ANOVA, if transformed for unequal variances
- Severity from an ordinal scale – (do not use ANOVA)
 - Nonparametric analysis (especially the new “Marginal Effects” analysis of Brunner (see Shah & Madden, 2004))
 - Proportional odds (parametric) models and other generalized linear-type models

See: Garrett, Madden, Hughes, and Pfender (2004) *Phytopathology* 94: 999-1003.

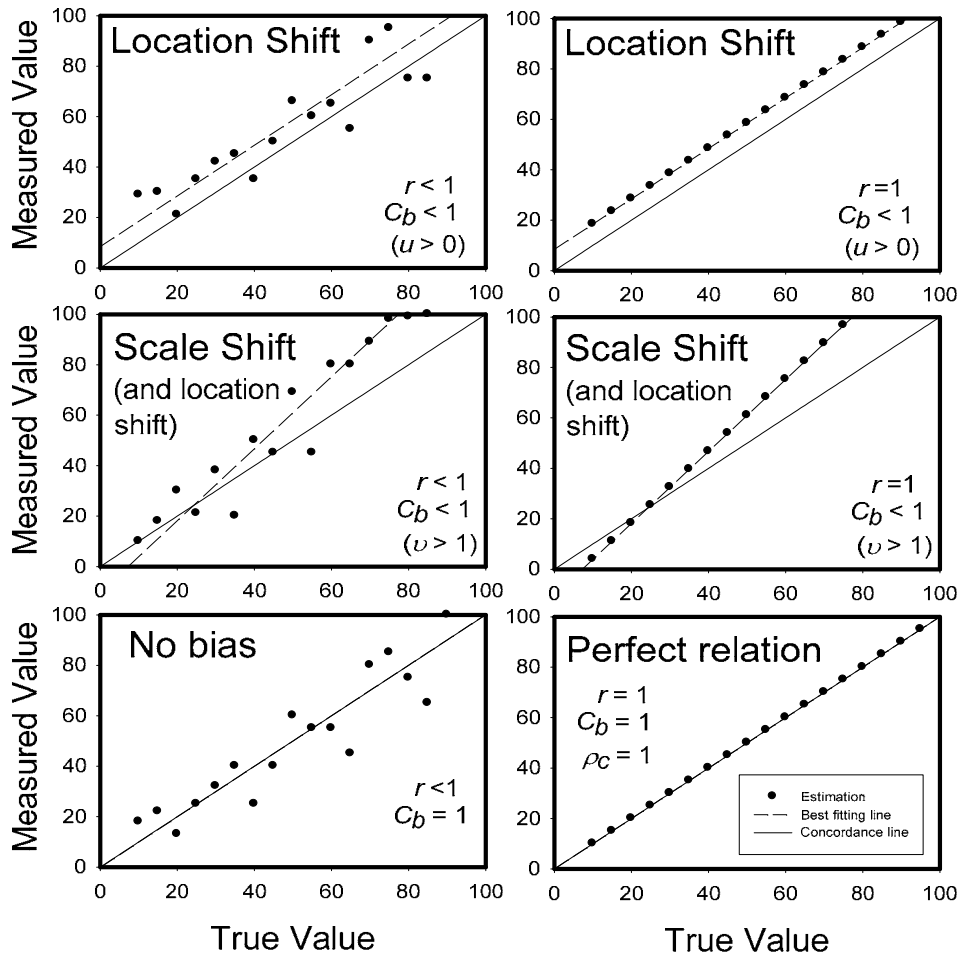
Assessing severity:

- *Measurements need to be reliable and accurate*
- **Reliability:**
 - The extent to which the same measurements of specimens obtained under different conditions yield similar results
 - Different raters (inter-rater reliability)
 - Different times (intra-rater reliability)
 - “Reproducibility”, “Repeatability”, “Precision”
- **Accuracy:**
 - Degree of conformity or closeness of measured values to recognized standard (“true value”, “gold standard”)
 - Precision: variability of measurements
 - Bias: Difference between expected (mean) value of measurements and true value

Correlations

Accuracy

- Regression (and correlation) analysis is commonly used to quantify accuracy and reliability
 - However, there are some flaws with this approach (precision affects measure of bias)
- Preferred approach:
 - Concordance coefficient analysis
- Training can improve accuracy and reliability
 - See articles by Nutter and colleagues



Source: Madden, L. V., Hughes, G., and van den Bosch, F. 2007. *The Study of Plant Disease Epidemics*. APS Press. St. Paul, MN.

Conclusions

- Measurement of plant disease intensity is a continuing problem in epidemiology, crop loss assessment, and disease management
- Investigators should carefully consider the type of disease variable to use, depending on the objectives of the study and type of disease
- When possible, measurement accuracy (bias and precision) and reliability should be considered
- When possible, one should match the data-analysis with the type of variable used for disease intensity
- Many more details in new book:
 - Madden, L. V., Hughes, G., and van den Bosch, F. (2007). *The Study of Plant Disease Epidemics*. APS Press.