Yield gap analysis using boundary lines

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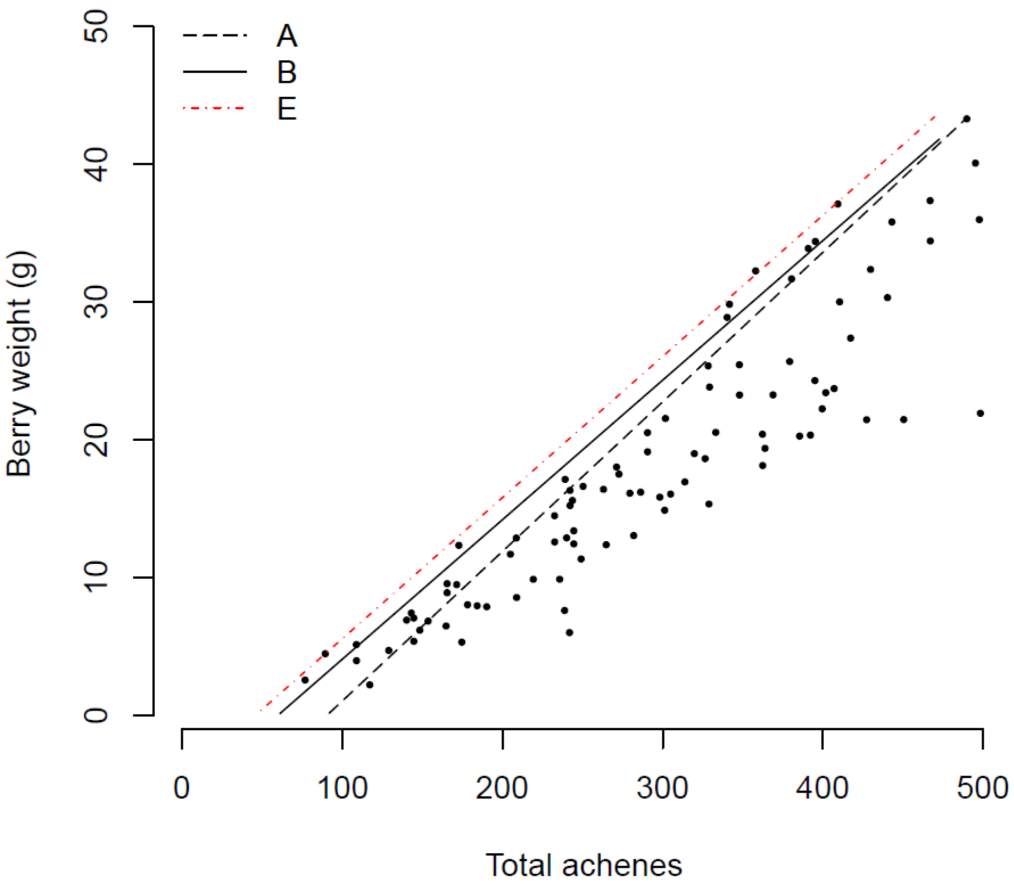
Background

- Biological response (e.g. yield) is affected by many factors in nature

- If the relationship of one factor and response is plotted in uncontrolled environments, a complex distribution is observed.

- Webb (1972) proposed a boundary line model for such data

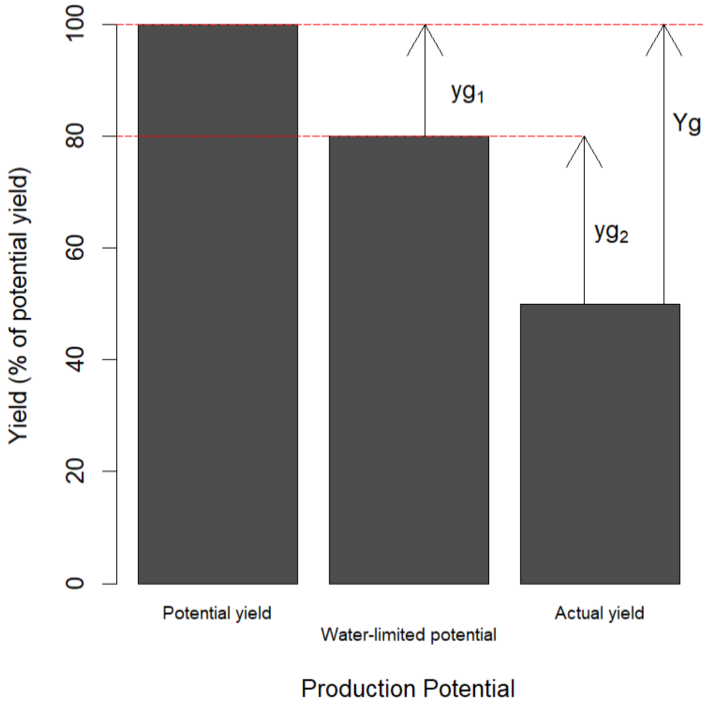
- The upper bounds are taken as the most efficient response when other factors are optimal

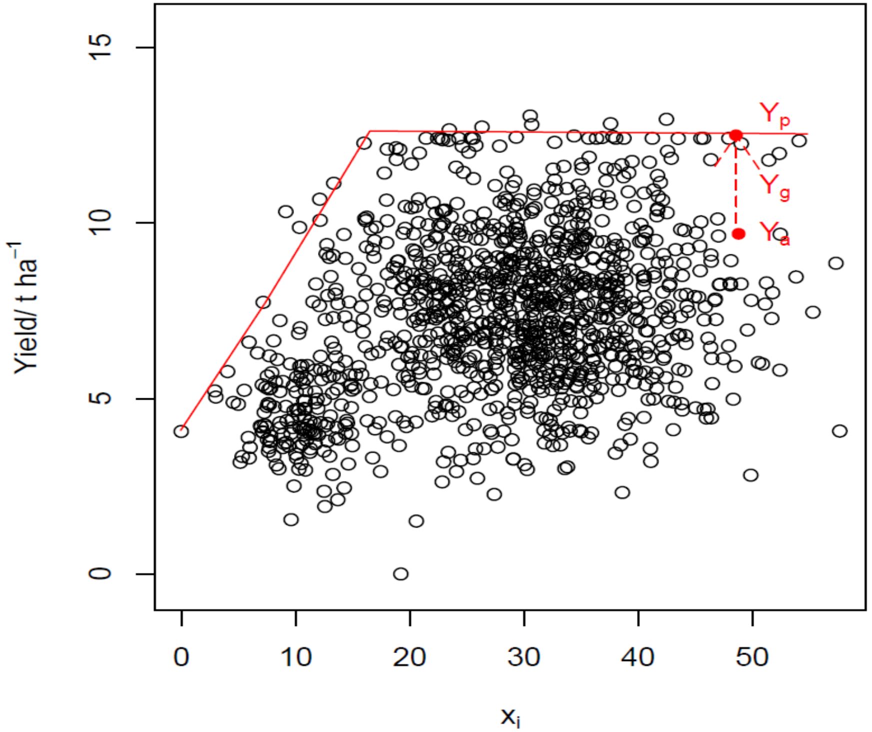


Source: Webb (1972)

Background

- The BL is taken as the maximum yield as function of factor x_i for that particular system
- Points below BL have a yield gap
- Used to *yield gap analysis* evaluate the *importance of production factors* on farm systems





Methods of implementing boundary line analysis

- Several methods are available in literature including ***heusteric*** or ***statistical*** methods

1. Heuristic methods

- ❑Visual assessment
- ❑BOLIDES algorithm
- ❑Binning
- ❑Quantile regression

Heuristic methods involve subjective discissions

2. Statistical methods

- ❑Censored bivariate model

Statistical methods follow strict statistical principles

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Yield gap analysis using binning methodology

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Yield gap analysis using boundary lines involves three steps

1. Selection of boundary points

2. Model fitting

3. Decomposition of identified yield gaps

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Yield gap analysis using binning approach

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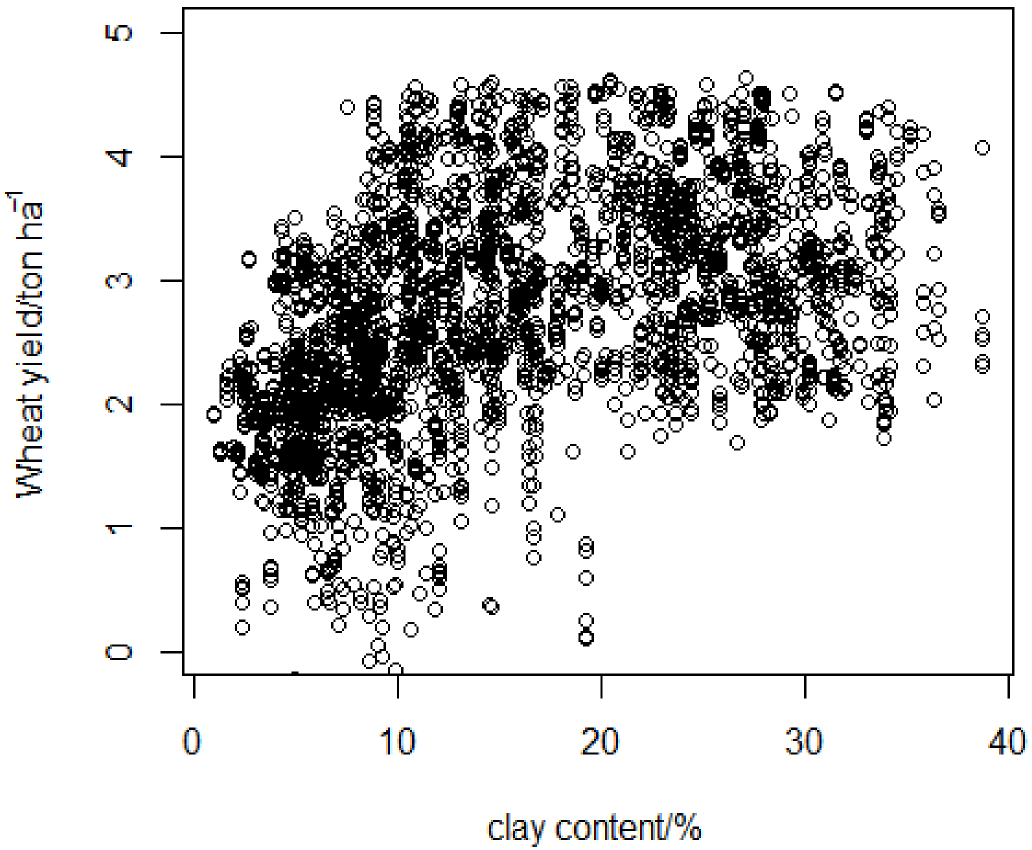
Yield gap analysis using binning approach

1. Selection of boundary points

- This follows a two step process

1. Dataset is divided into bins (group) of equal intervals based on the factor of interest

2. In each group, boundary point is selected corresponding to the ***maximum value*** or ***95 percentile*** of each group



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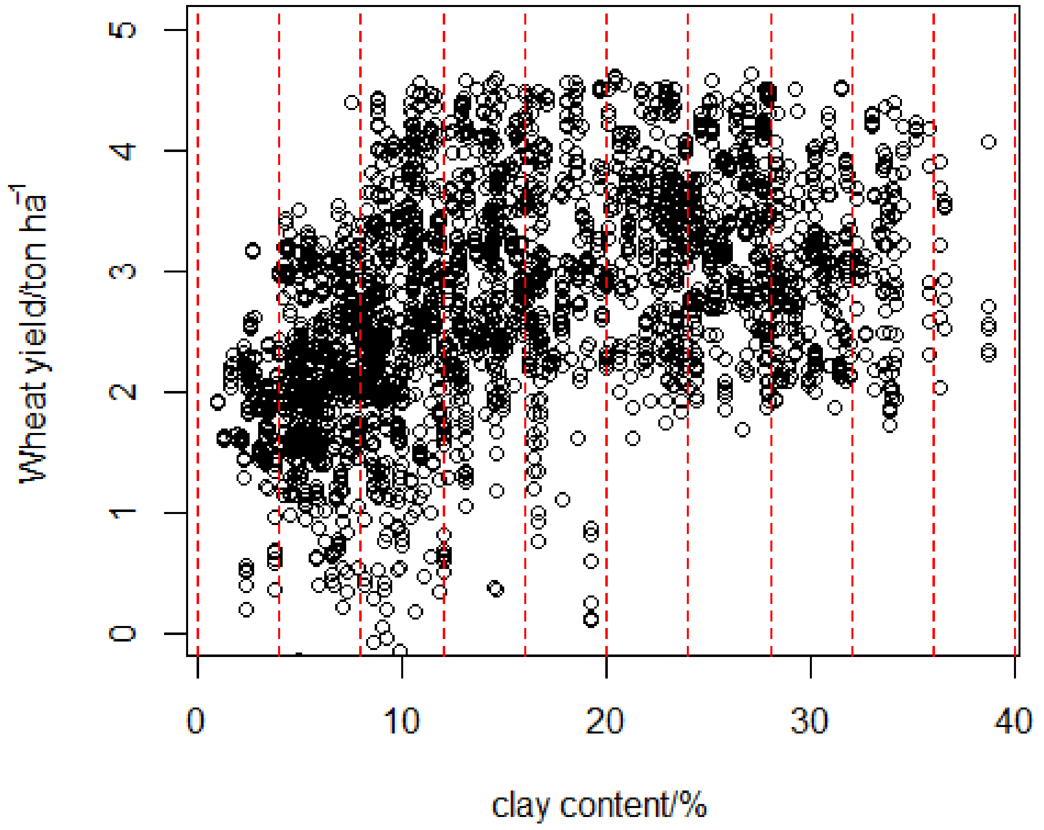

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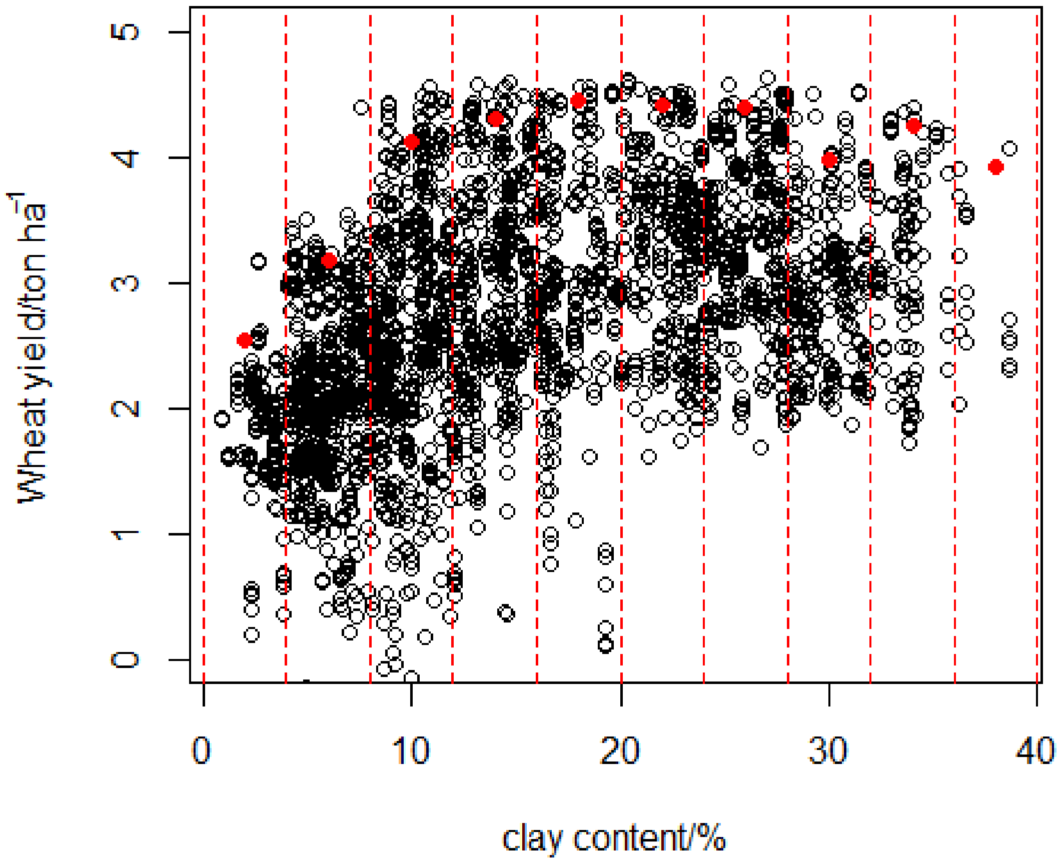

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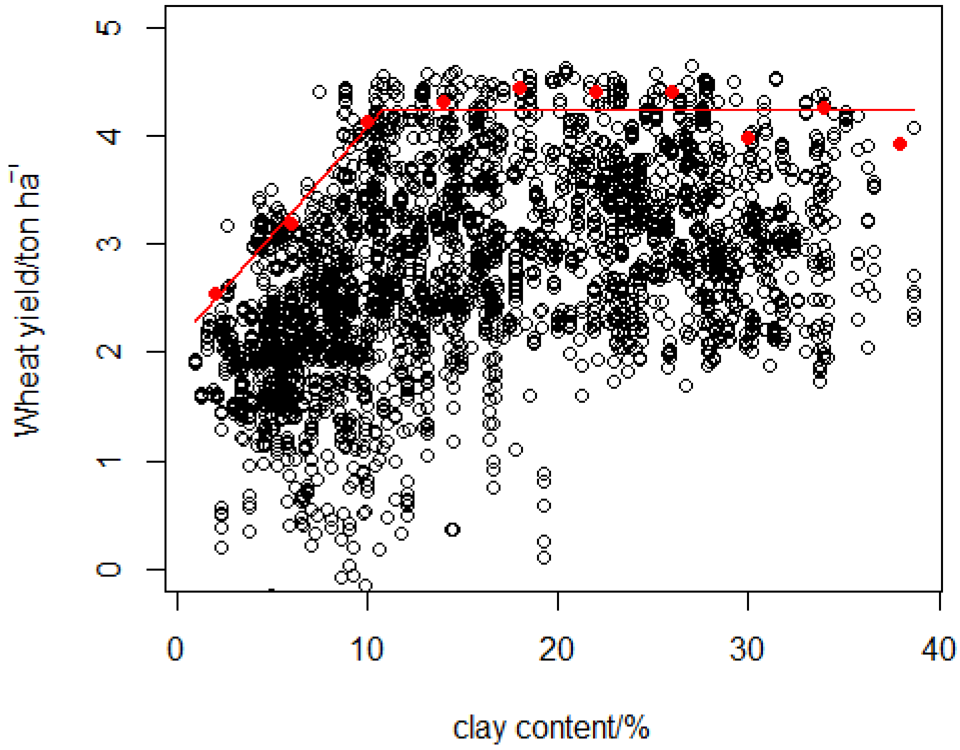
Yield gap analysis using binning approach

2. Model fitting

Considerations

1. Selection of model form
   - Agronocally plausible

2. Fitting model to boundary points
   - Least squares
   - Low root mean square error for the boundary points

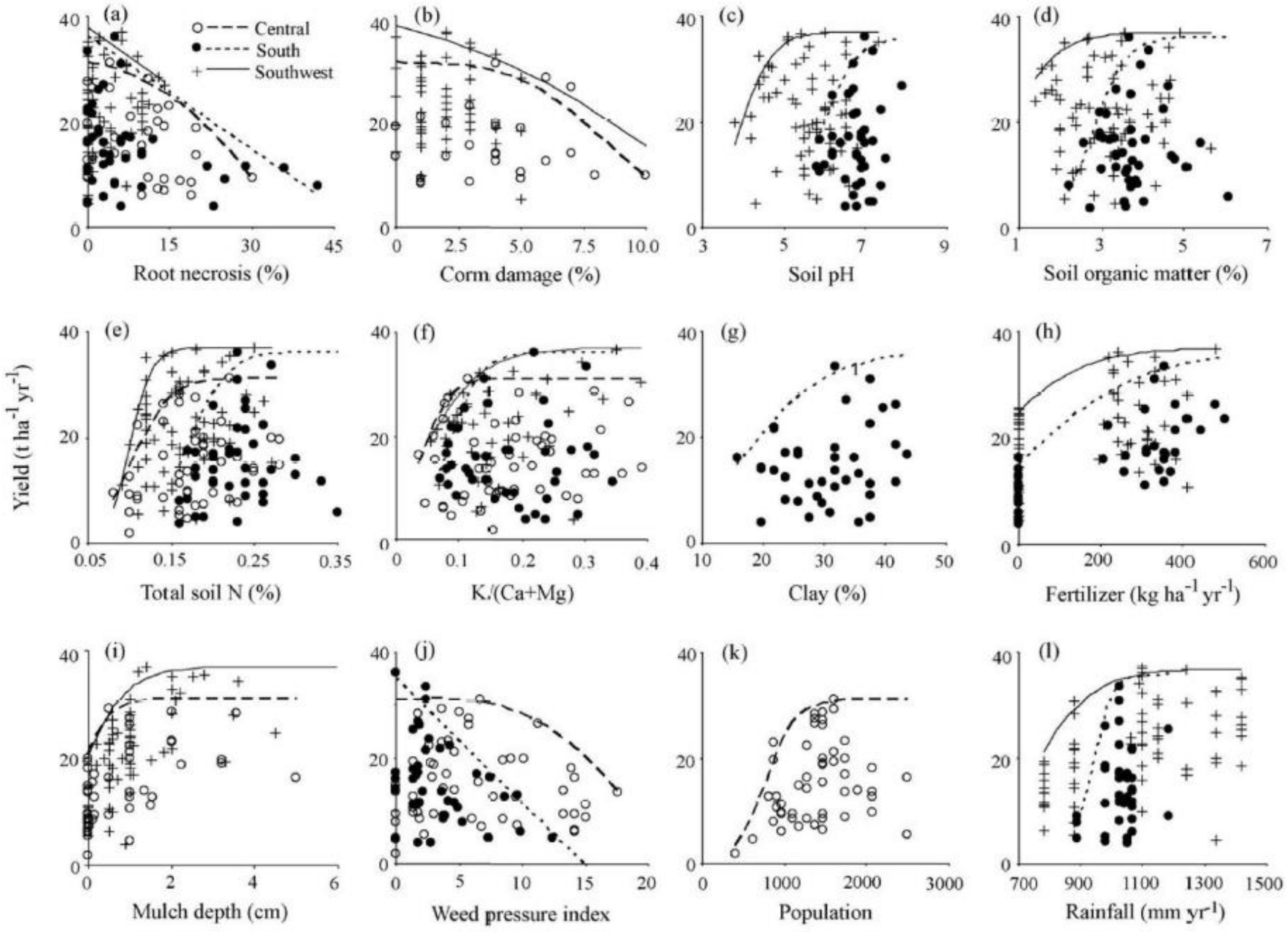


Yield gap analysis using binning approach

2. Model fitting

Fit boundary lines to all variables

- *Bio-physical factors*
- *Management factors*



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Yield gap analysis using binning approach

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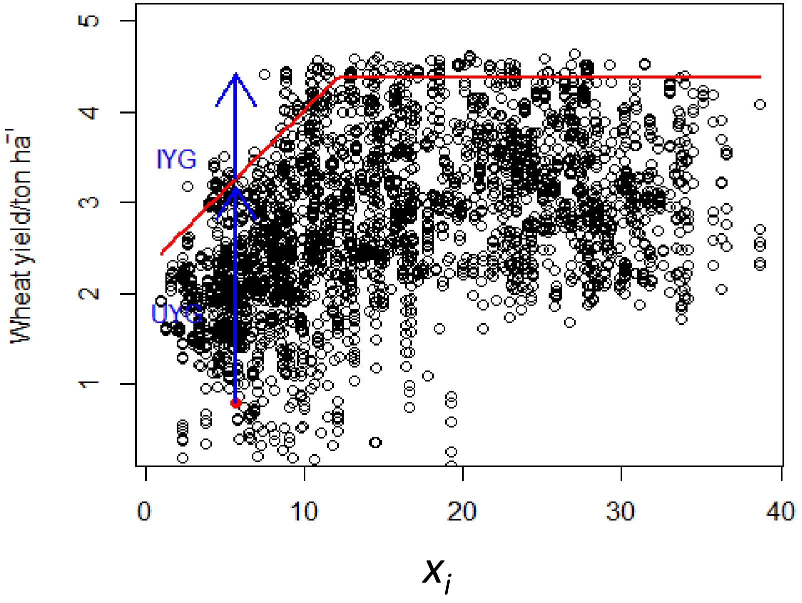
3. Decomposition of identified yield gaps

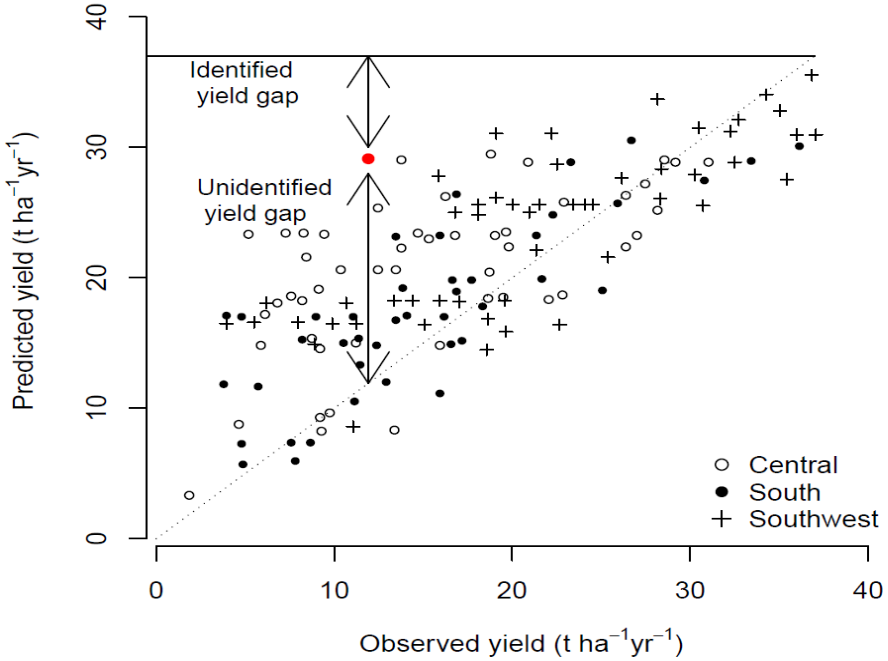
- Based on the principle of van Liebig's law of minimum

$$y\_pred = min(x_i, x_2, x_3, x_4)$$



Decomposition of yield gap

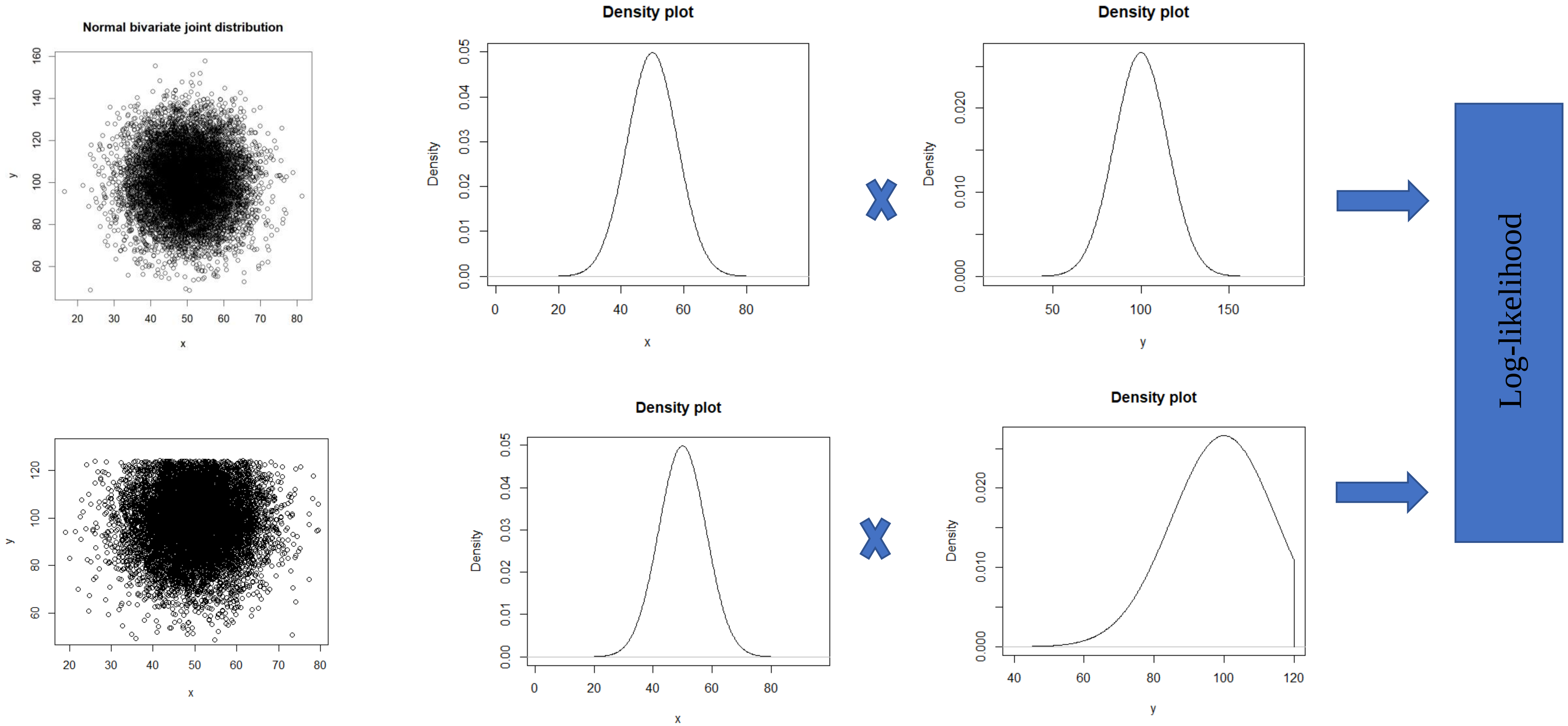
- *Unexplained = predicted yield – actual yield*
- *Identified = maximum yield – predicted yield*



Statistical approach

Statistical approach

- Based on the censored bivariate normal distribution

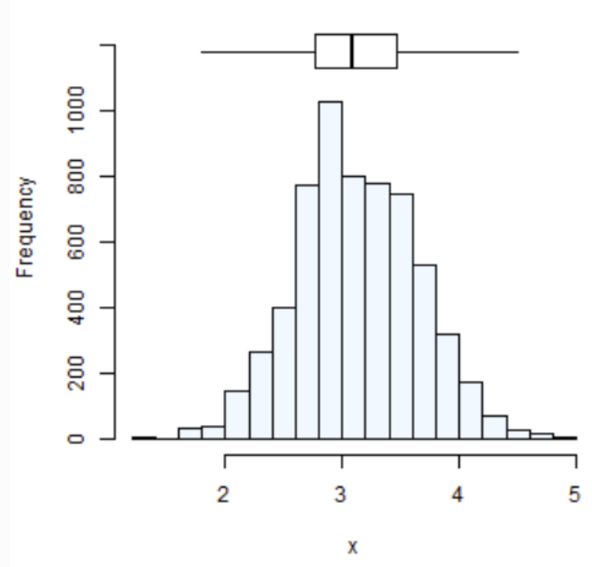


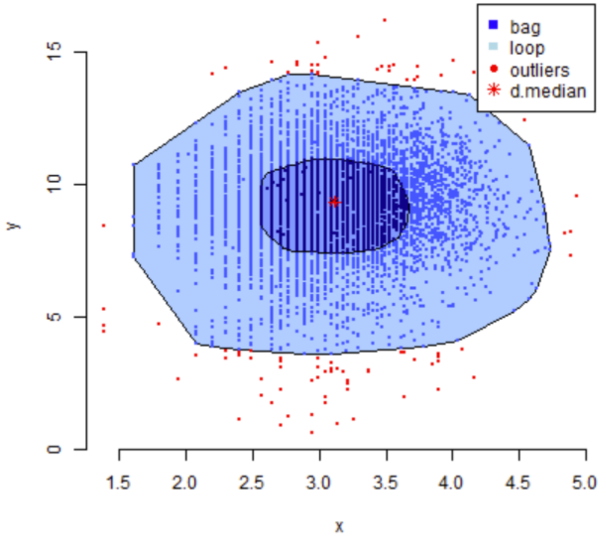
Statistical approach

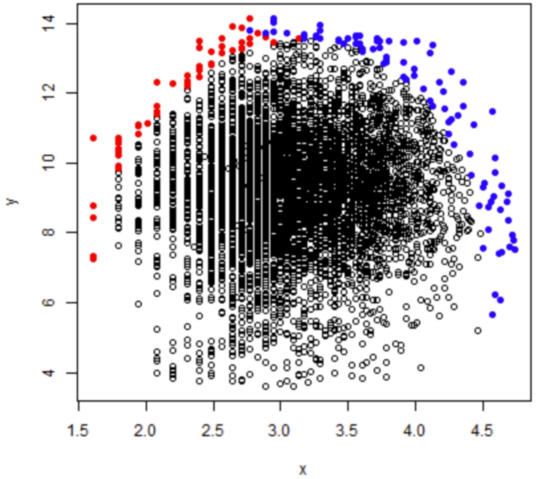
Process of fitting boundary line

1. ***Check the distribution of variables***
2. ***Check for outliers***
3. ***Check for evidence of boundary***
4. ***Fit the model (maximum likelihood)***

- ❑ *Select model form to describe relation (agronomically plausible)*
- ❑ *Initial starting values*
  - ❑ *Parameters of bivariate normal distribution*
  - ❑ *Parameters of censor (BL)*



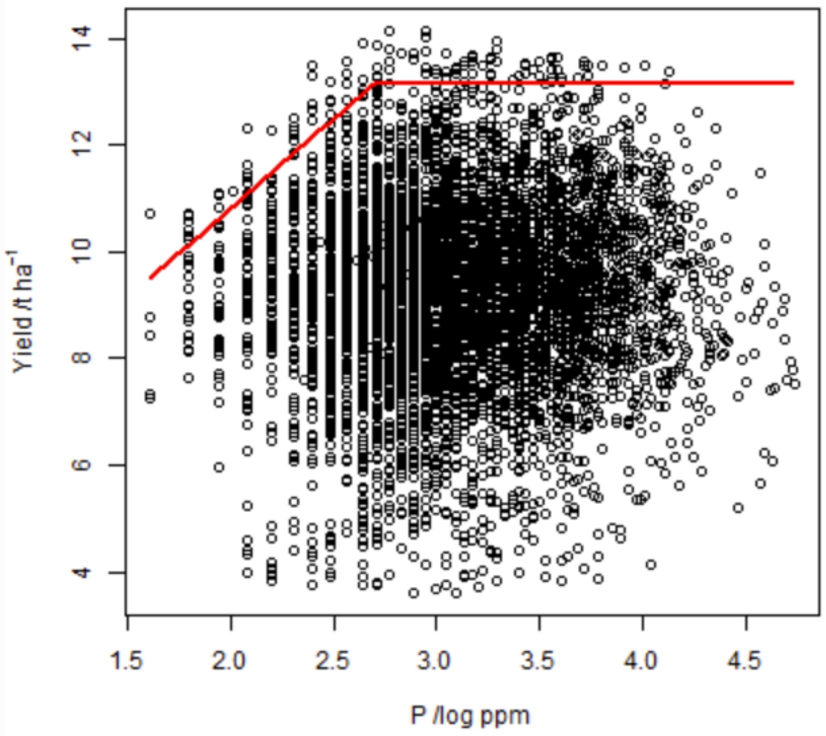




Index	Section	value
sd	Rise	1.045711
sd	Fall	1.115379
Mean sd	Rise	1.180385
Mean sd	Fall	1.271274
p_value	Rise	0.018000
p_value	Fall	0.017000

Statistical approach

```
cbvn(vals,theta,sigh,model = "lp", xlab=expression("P /log ppm"), ylab=expression("Yield /t ha"^{-1}))
```




```
model1
## $estimates
##          Estimate  Standard error
## beta0 13.17142480    0.134120445
## beta1  4.09776732    1.002709032
## beta2  3.36047473    0.457647238
## mux    3.12596783    0.006451127
## muy    9.29811648    0.022643136
## sdx    0.50053427    0.004561592
## sdy    1.61780277    0.017865349
## rcorr  0.03053177    0.014139952
##
## $AIC
##
## constant max 32431.55
## mvn          32429.55
## BL           32397.87
```

Thankyou