# Field trials with biochar in the North Sea Region

Greet Ruysschaert
Victoria Nelissen

End Conference of the Interreg IVB North Sea Region project 'Biochar: climate saving soils'
Groningen, the Netherlands, 10th December 2013

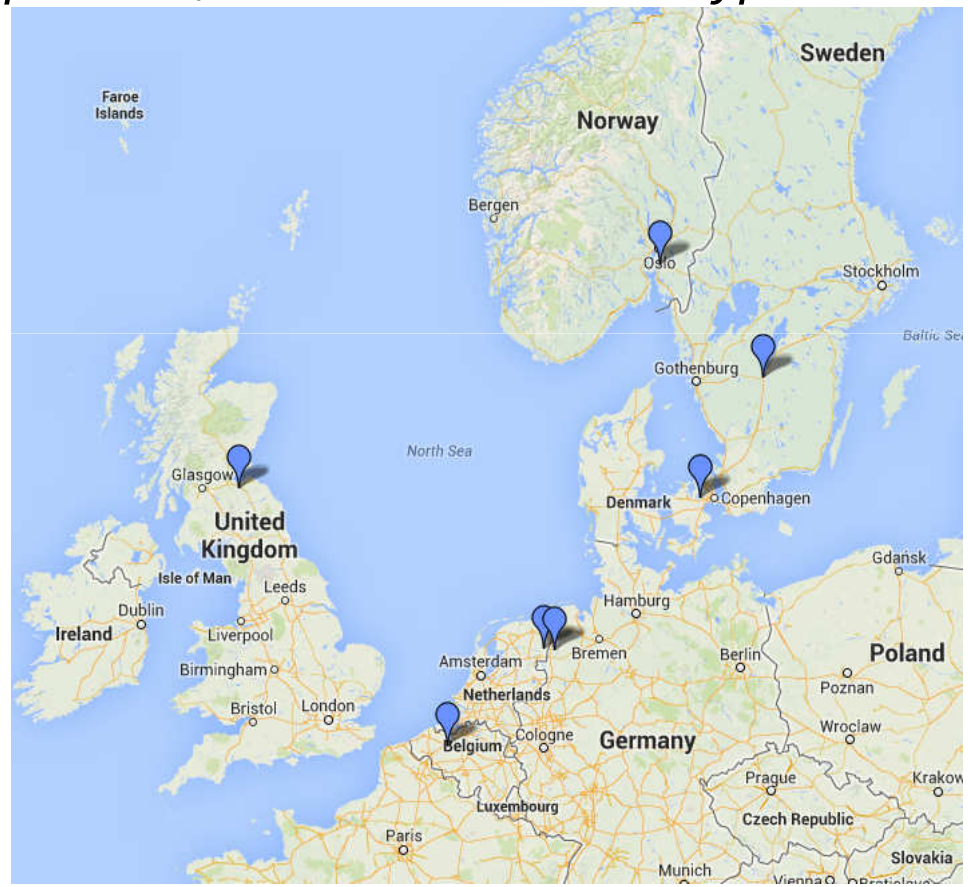
# Outline

1. Biochar North Sea ring trial
2. Details from the ILVO biochar trial
3. European biochar field experiments with pure biochar additions

# 1. Biochar North Sea ring trial

- Aim
  *"To test the effect of one wood based biochar on soil quality and crop growth according to a standard protocol, across different soil types and climates of the North Sea Region."*

- 7 countries



# 1. Biochar North Sea ring trial

- Romchar
  Wood mix – 480℃
  80% 0.5-8mm
  Small labile carbon fraction (0.4% over 381 days)

| C (%) | N (%) | pH-KCl | CEC ($cmol_c$/kg) |
|---|---|---|---|
| 69,4 | 0,37 | 8,6 | 46,3 |

- Treatments: 1) control 2) biochar 20 ton/ha
  3-4 replicates

- Biochar application: autumn 2011/spring 2012

- Crop
  - 2012: spring barley (DE: winter wheat)
  - 2013: free crop choice

- Mineral fertilizer


ILVO Instituut voor Landbouw- en Visserijonderzoek

The Interreg IVB North Sea Region Programme

European Union The European Regional Development Fund

BIOCHAR

# 1. Biochar North Sea ring trial

- Biochar application – Danish trial (Riso TDU, E. Bruun, H. Hauggaard-Nielsen)

# 1. Biochar North Sea ring trial

- Biochar application – Norwegian trial (A. O'Toole, Bioforsrk)

# 1. Biochar North Sea ring trial

- Biochar application – Belgian trial (V. Nelissen, G. Ruysschaert, ILVO)



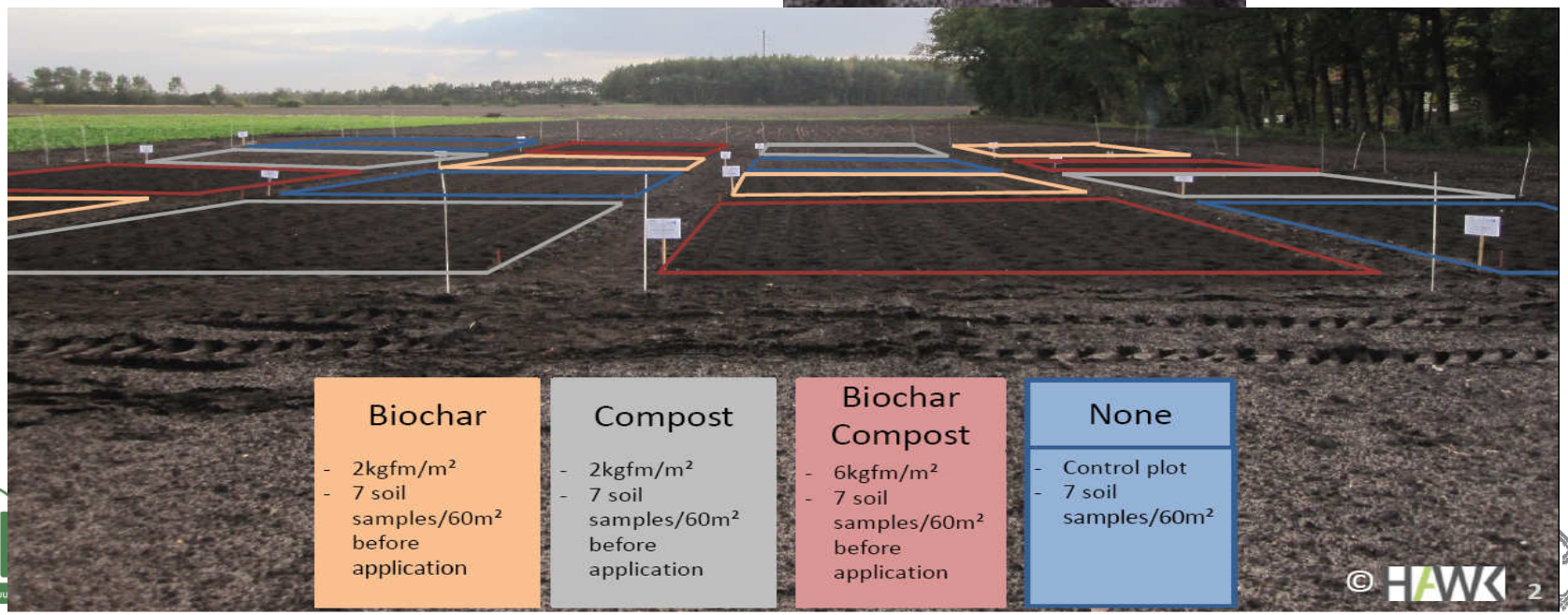



# 1. Biochar North Sea ring trial

- Biochar application – Scottish trial (J. Hammond, S. Shackley, UKBRC)

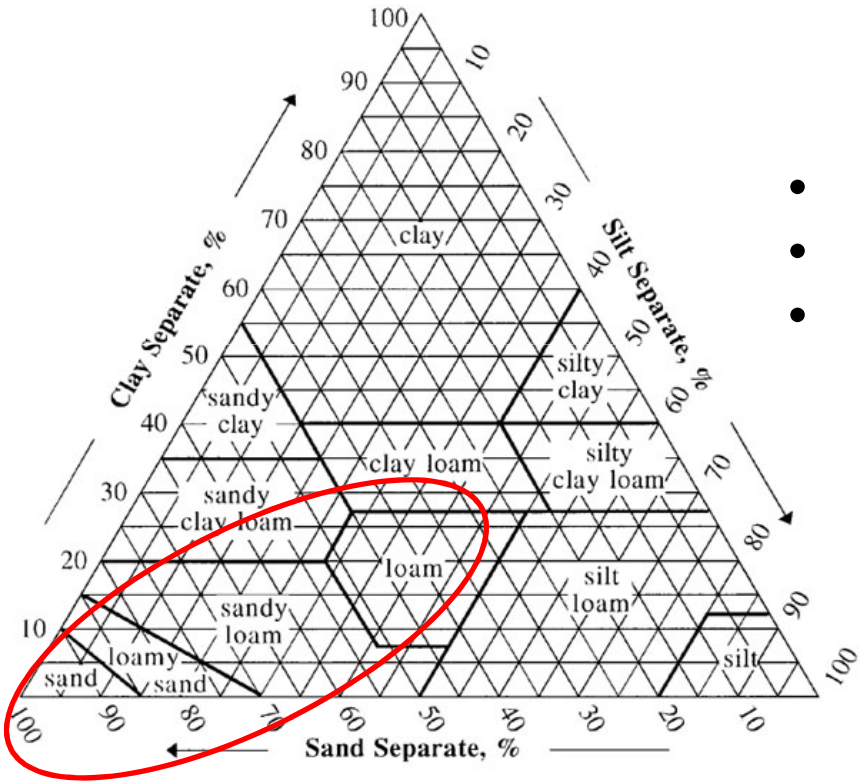
# 1. Biochar North Sea ring trial

- Biochar application – German trial (M. Rödger, HAWK)

# 1. Biochar North Sea ring trial

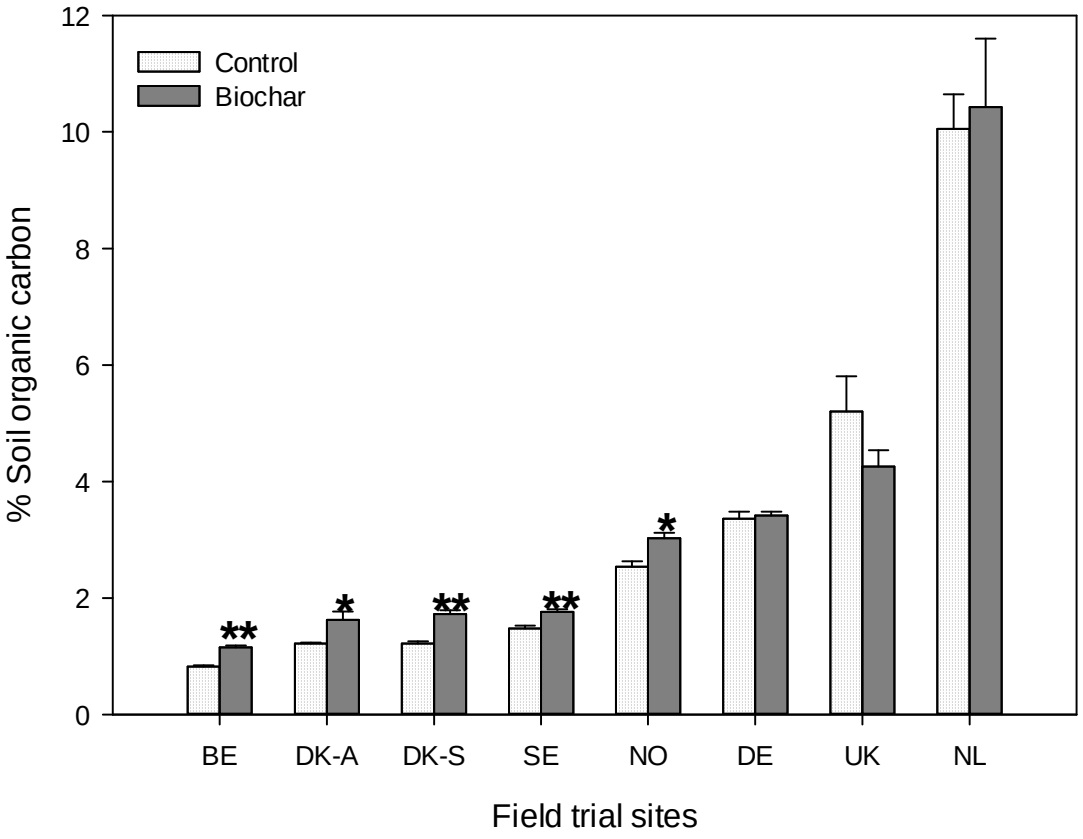
- Site characteristics



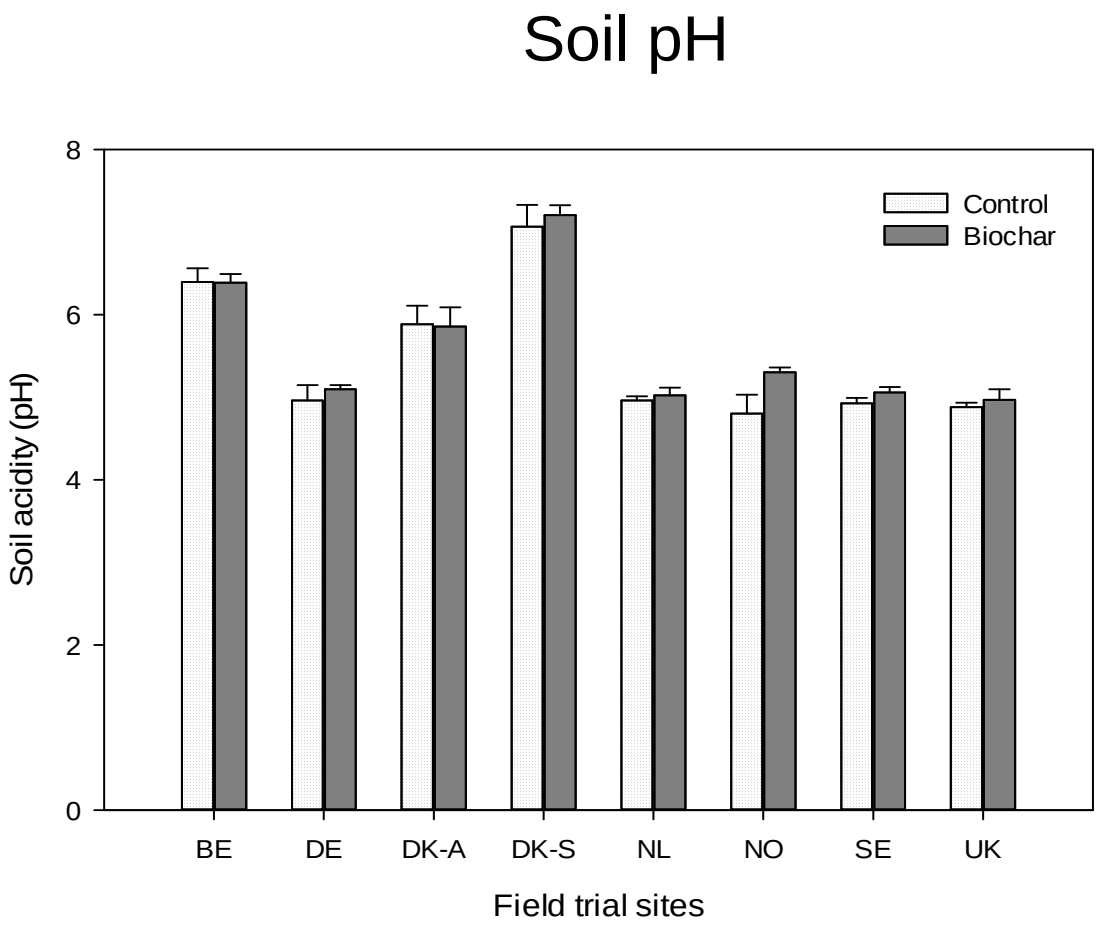

- Soil organic carbon contents: 0.9-9.8%
- C:N: 7.7-24.7
- pH-KCl: 4.9-7.1

# 1. Biochar North Sea ring trial

## Soil carbon content



# 1. Biochar North Sea ring trial

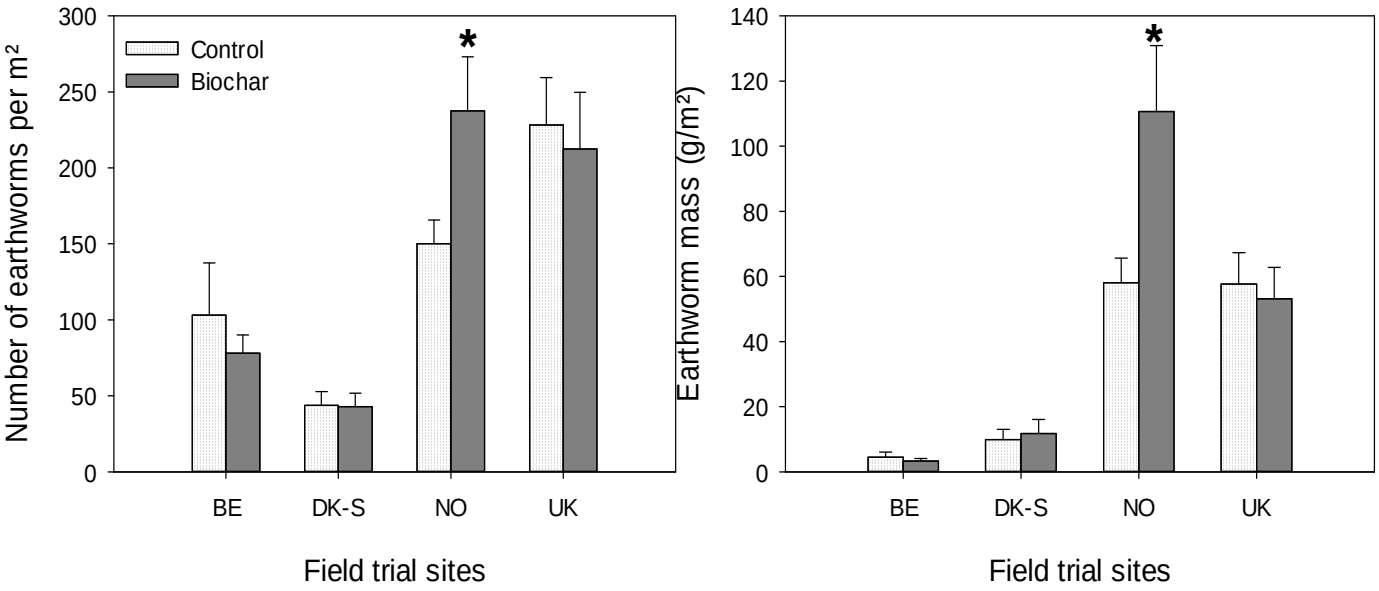


# 1. Biochar North Sea ring trial

- Nutrients
  - Soil mineral N: no effects
    =>Lower N availability in the short-term could not be proven.
  - Other plant available nutrients (AmLac): no effect or not consistent

# 1. Biochar North Sea ring trial

## Earthworms




# 1. Biochar North Sea ring trial

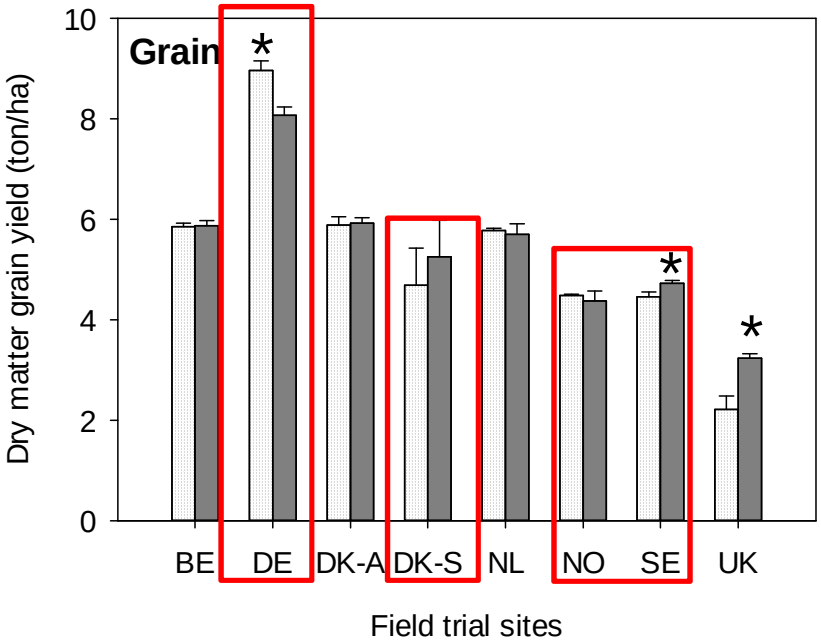
## Soil microbial community structure

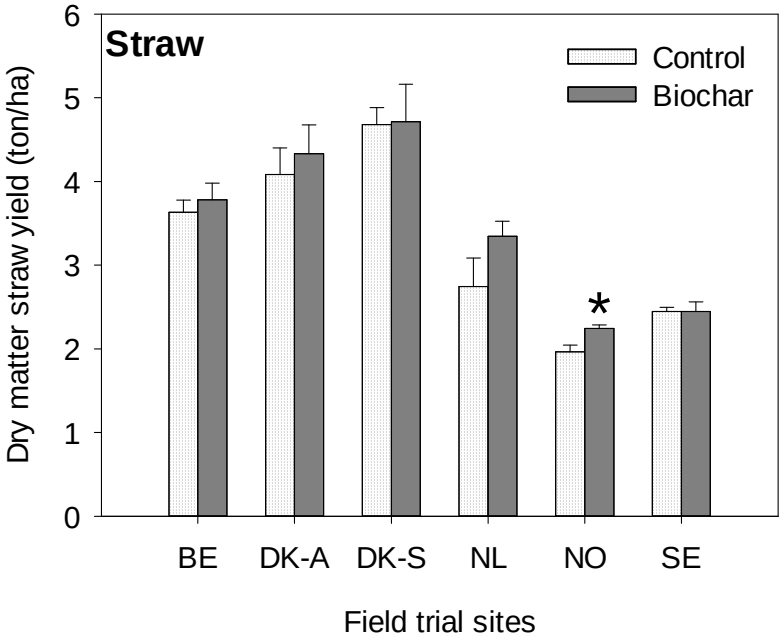
| Community | PLFA | Belgium | | Denmark | | Germany | | the Netherlands | | Norway | | Scotland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Control* | *Biochar* | *Control* | *Biochar* | *Control* | *Biochar* | *Control* | *Biochar* | *Control* | *Biochar* | *Control* | *Biochar* |
| Gram-positive bacteria | i-C14:0 | **1.22 ± 0.01** | **1.15 ± 0.02** * | 1.55 ± 0.04 | 1.60 ± 0.04 | 0.94 ± 0.05 | 0.93 ± 0.05 | 0.76 ± 0.06 | 0.86 ± 0.03 | 1.04 ± 0.12 | 1.06 ± 0.05 | 1.11 ± 0.08 | 1.15 ± 0.08 |
| | i-C15:0 | 10.33 ± 0.07 | 10.19 ± 0.08 | 8.90 ± 0.17 | 9.01 ± 0.17 | 11.33 ± 0.21 | 10.71 ± 0.24 | 12.06 ± 0.29 | 12.70 ± 0.21 | 9.33 ± 0.40 | 8.87 ± 0.20 | **10.89 ± 0.17** | **9.78 ± 0.07** *** |
| | a-C15:0 | 6.86 ± 0.12 | 6.91 ± 0.10 | **6.38 ± 0.10** | **6.69 ± 0.10** * | 6.99 ± 0.31 | 6.84 ± 0.23 | 6.49 ± 0.19 | 6.92 ± 0.10 | 7.45 ± 0.12 | 7.44 ± 0.18 | 9.45 ± 0.20 | 8.85 ± 0.24 |
| | i-C16:0 | 2.62 ± 0.03 | 2.59 ± 0.06 | 2.85 ± 0.10 | 3.02 ± 0.10 | 4.08 ± 0.22 | 3.89 ± 0.10 | 4.00 ± 0.16 | 4.21 ± 0.08 | 3.26 ± 0.20 | 3.10 ± 0.05 | 3.18 ± 0.09 | 3.06 ± 0.16 |
| | i-C17:0 | 1.97 ± 0.05 | 1.95 ± 0.02 | 1.92 ± 0.09 | 1.96 ± 0.09 | 2.34 ± 0.09 | 2.26 ± 0.06 | **2.35 ± 0.02** | **2.46 ± 0.03** * | 2.16 ± 0.06 | 2.03 ± 0.03 | 2.09 ± 0.05 | 2.05 ± 0.05 |
| | a-C17:0 | 1.30 ± 0.05 | 1.28 ± 0.03 | **1.38 ± 0.03** | **1.58 ± 0.03** ** | 1.40 ± 0.06 | 1.44 ± 0.06 | 1.39 ± 0.02 | 1.45 ± 0.02 | 1.43 ± 0.05 | 1.39 ± 0.03 | 1.58 ± 0.05 | 1.61 ± 0.06 |
| Gram-negative bacteria | C16:1ω7c | 8.82 ± 0.11 | 9.13 ± 0.09 | **8.81 ± 0.11** | **9.58 ± 0.11** * | 6.51 ± 0.44 | 6.27 ± 0.30 | **6.69 ± 0.05** | **7.28 ± 0.12** * | 8.07 ± 0.64 | 8.47 ± 0.19 | 8.74 ± 0.18 | 8.44 ± 0.09 |
| | C16:1ω7t | 1.69 ± 0.09 | 1.54 ± 0.03 | 1.27 ± 0.06 | 1.40 ± 0.06 | 0.98 ± 0.06 | 1.03 ± 0.07 | 1.17 ± 0.05 | 1.19 ± 0.04 | 1.28 ± 0.09 | 1.30 ± 0.01 | 1.52 ± 0.05 | 1.58 ± 0.14 |
| | C17:0cy | **4.67 ± 0.05** | **4.46 ± 0.07** * | 4.08 ± 0.08 | 4.33 ± 0.08 | 4.84 ± 0.15 | 4.91 ± 0.34 | **5.35 ± 0.07** | **5.83 ± 0.15** * | 3.99 ± 0.15 | 4.14 ± 0.08 | 4.45 ± 0.02 | 4.47 ± 0.09 |
| | C18:1ω7c | 10.53 ± 0.30 | 10.46 ± 0.19 | 14.76 ± 0.46 | 15.10 ± 0.46 | 6.87 ± 0.46 | 7.32 ± 0.51 | **8.85 ± 0.32** | **10.10 ± 0.32** ** | 12.23 ± 0.69 | 12.84 ± 0.23 | 12.40 ± 0.35 | 12.15 ± 0.26 |
| | C19:0cy | 4.09 ± 0.28 | 4.09 ± 0.26 | 3.67 ± 2.04 | 1.41 ± 2.04 | 6.82 ± 0.52 | 8.93 ± 2.14 | **12.14 ± 1.44** | **6.05 ± 1.53** * | 4.52 ± 0.66 | 3.92 ± 0.47 | **2.66 ± 0.95** | **5.85 ± 0.13** ** |
| Actinomycetes | 10Me-C16:0 | 2.91 ± 0.14 | 2.68 ± 0.15 | **3.99 ± 0.15** | **4.46 ± 0.15** * | 4.49 ± 0.20 | 3.15 ± 0.99 | 3.88 ± 0.56 | 4.39 ± 0.02 | 2.90 ± 0.56 | 2.98 ± 0.37 | 4.22 ± 0.11 | 4.00 ± 0.17 |
| | 10Me-C17:0 | 0.19 ± 0.04 | 0.15 ± 0.02 | 0.56 ± 0.03 | 0.62 ± 0.03 | 0.34 ± 0.03 | 0.28 ± 0.02 | 0.54 ± 0.04 | 0.54 ± 0.03 | 0.32 ± 0.03 | 0.27 ± 0.02 | 0.28 ± 0.01 | 0.30 ± 0.01 |
| | 10Me-C18:0 | 1.33 ± 0.09 | 1.01 ± 0.19 | 2.16 ± 0.16 | 2.14 ± 0.16 | 1.48 ± 0.07 | 1.59 ± 0.10 | **1.16 ± 0.03** | **1.33 ± 0.04** * | 2.11 ± 0.09 | 2.05 ± 0.14 | 2.09 ± 0.14 | 2.37 ± 0.21 |
| Fungi | C18:1ω9c | 5.88 ± 0.21 | 5.95 ± 0.26 | 9.33 ± 0.32 | 9.39 ± 0.32 | 5.36 ± 0.08 | 5.51 ± 0.31 | 5.25 ± 0.09 | 5.24 ± 0.12 | 7.77 ± 0.34 | 7.77 ± 0.39 | 7.03 ± 0.03 | 6.96 ± 0.15 |
| | C18:2ω6,9c | 6.26 ± 0.24 | 6.59 ± 0.32 | 4.67 ± 0.45 | 3.64 ± 0.45 | 2.10 ± 0.30 | 1.89 ± 0.24 | 2.36 ± 0.06 | 2.40 ± 0.34 | 4.20 ± 0.09 | 3.76 ± 0.39 | 1.53 ± 0.04 | 1.84 ± 0.19 |
| AM Fungi | C16:1ω5c | 5.84 ± 0.17 | 5.65 ± 0.11 | 5.56 ± 0.20 | 6.02 ± 0.20 | 3.14 ± 0.20 | 3.19 ± 0.16 | 3.00 ± 0.03 | 3.51 ± 0.26 | 4.68 ± 0.41 | 5.22 ± 0.19 | 5.04 ± 0.11 | 4.90 ± 0.32 |
| Non-specific bacteria | C14:0 | 1.40 ± 0.04 | 1.39 ± 0.03 | 1.09 ± 0.03 | 1.09 ± 0.03 | 1.81 ± 0.08 | 1.79 ± 0.02 | 1.41 ± 0.10 | 1.49 ± 0.03 | 1.35 ± 0.04 | 1.38 ± 0.04 | 1.56 ± 0.08 | 1.36 ± 0.03 |
| | C15:0 | 0.82 ± 0.05 | 0.82 ± 0.02 | 0.67 ± 0.01 | 0.68 ± 0.01 | 1.06 ± 0.01 | 1.08 ± 0.03 | 0.78 ± 0.02 | 0.85 ± 0.03 | 0.77 ± 0.02 | 0.74 ± 0.01 | 0.81 ± 0.02 | 0.78 ± 0.02 |
| | C16:0 | **18.32 ± 0.18** | **19.10 ± 0.14** * | 13.27 ± 0.28 | 13.89 ± 0.28 | 22.93 ± 0.37 | 22.55 ± 0.72 | 17.21 ± 0.23 | 17.90 ± 0.79 | 18.05 ± 0.27 | 18.10 ± 0.70 | 16.30 ± 0.31 | 15.40 ± 0.22 |
| | C17:0 | 0.60 ± 0.02 | 0.58 ± 0.01 | 0.65 ± 0.16 | 0.54 ± 0.16 | 0.74 ± 0.02 | 0.79 ± 0.03 | **0.54 ± 0.01** | **0.62 ± 0.02** * | 0.57 ± 0.03 | 0.59 ± 0.01 | 0.65 ± 0.00 | 0.67 ± 0.05 |
| | C18:0 | 2.35 ± 0.04 | 2.33 ± 0.05 | 2.48 ± 0.73 | 1.87 ± 0.73 | 3.43 ± 0.09 | 3.63 ± 0.08 | 2.62 ± 0.06 | 2.66 ± 0.01 | 2.51 ± 0.03 | 2.57 ± 0.05 | 2.43 ± 0.06 | 2.43 ± 0.05 |

# 1. Biochar North Sea ring trial

## 2012 crop yield

Spring barley (Germany winter wheat)

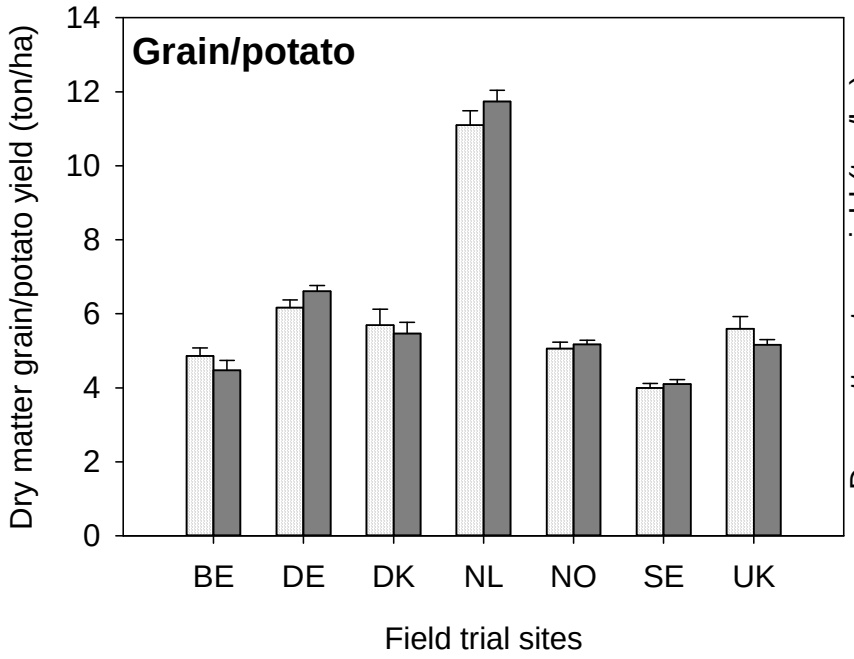


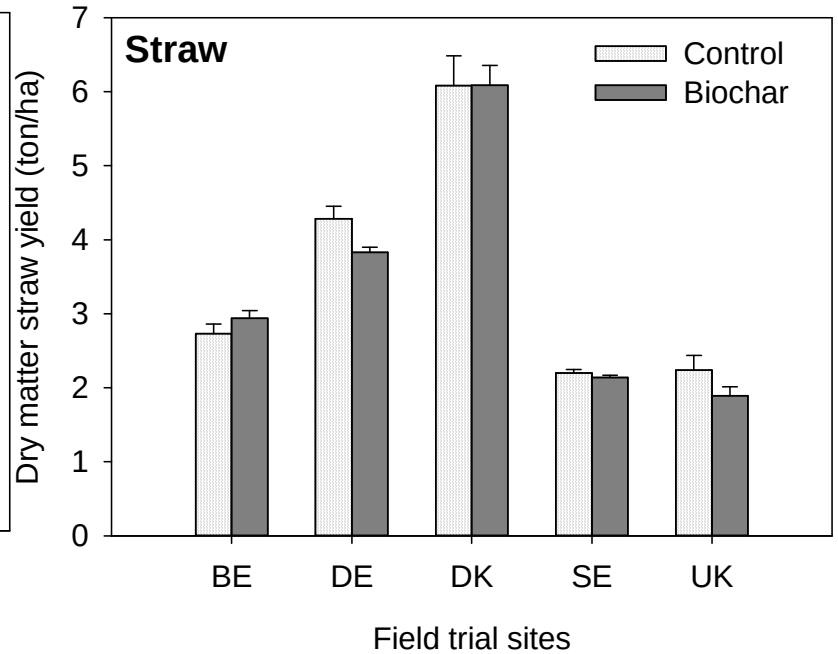




- Mostly no differences in N and P uptake
- Time of application

# 1. Biochar North Sea ring trial

## 2013 crop yield




=> No significant differences

# Outline

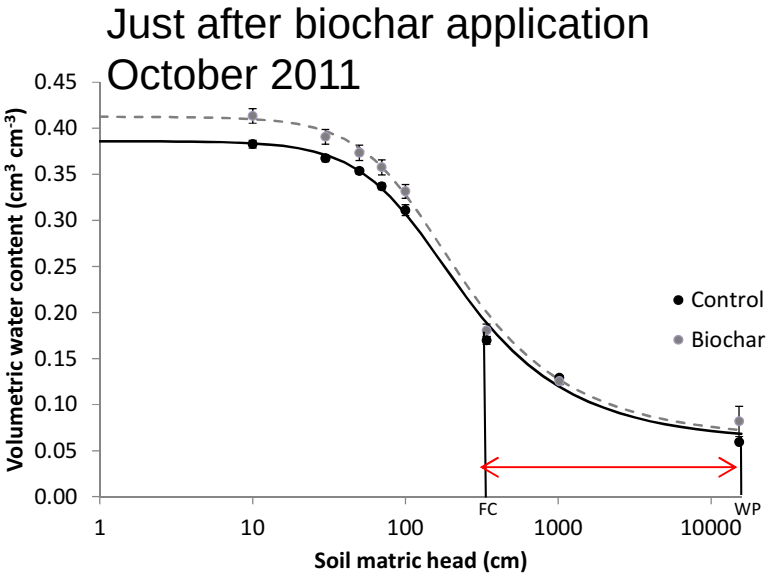
1. Biochar North Sea ring trial
2. Details from the ILVO biochar field trial
3. European biochar field experiments with pure biochar additions

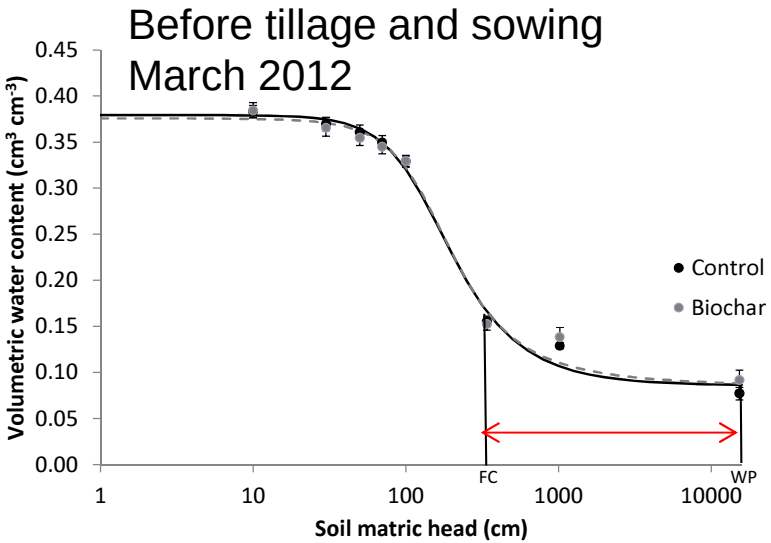
# 2. Details from the ILVO biochar field trial

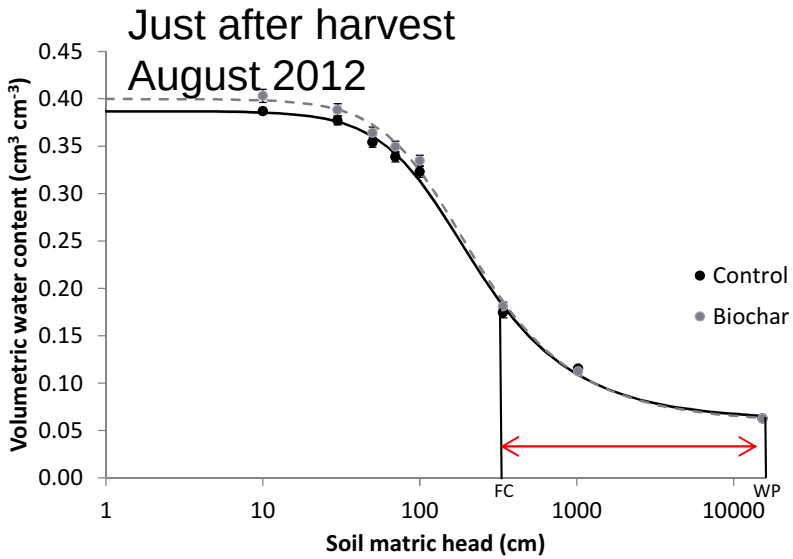
- Sandy loam soil
- %C: 0.9
- C:N 11.4
- pH-KCl: 6.4

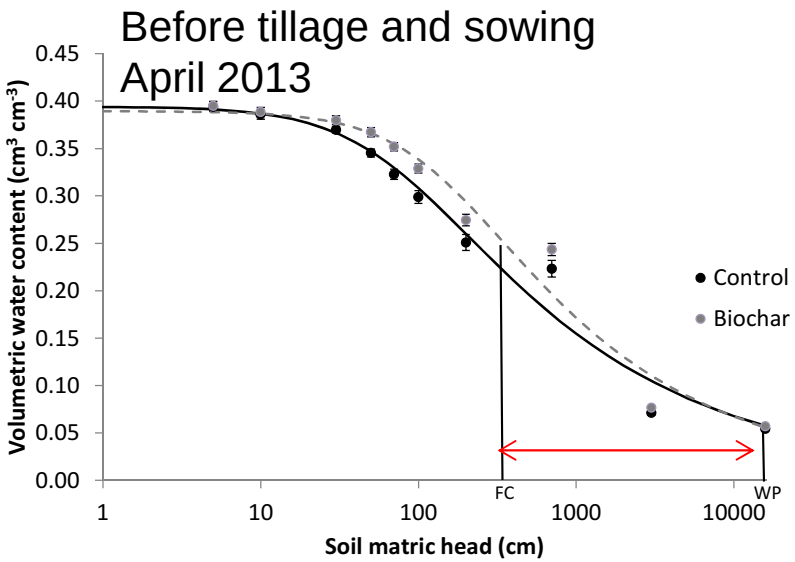
| | | | pH-KCl | OC | TN | C:N | Mg | Ca | Mn | Na | P | Fe | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | - | % | % | | mg kg $^{-1}$ | mg kg $^{-1}$ | mg kg $^{-1}$ | mg kg $^{-1}$ | mg kg $^{-1}$ | mg kg $^{-1}$ | mg kg $^{-1}$ |
| After biochar application | 21/10/2011 | Control | 6.38 ± 0.15 | **0.85 ± 0.03** | 0.074 ± 0.001 | **11.4 ± 0.2** | 185 ± 22 | 1006 ± 100 | 110 ± 10 | 25 ± 6 | 231 ± 17 | 463 ± 71 | 179 ± 5 |
| | | Biochar | 6.41 ± 0.15 | **1.11 ± 0.04** | 0.077 ± 0.002 | **14.4 ± 0.8** | 149 ± 11 | 1002 ± 105 | 124 ± 3 | 19 ± 0 | 233 ± 7 | 450 ± 23 | 194 ± 5 |
| Before sowing | 20/03/2012 | Control | 6.32 ± 0.12 | **0.86 ± 0.02** | 0.079 ± 0.002 | **10.9 ± 0.2** | 149 ± 14 | 956 ± 44 | 115 ± 9 | 19 ± 0 | 239 ± 19 | 461 ± 73 | 187 ± 9 |
| | | Biochar | 6.39 ± 0.11 | **1.10 ± 0.05** | 0.080 ± 0.003 | **13.9 ± 0.7** | 139 ± 11 | 941 ± 85 | 127 ± 6 | 21 ± 2 | 237 ± 7 | 437 ± 37 | 214 ± 16 |
| After harvest | 23/08/2012 | Control | 6.39 ± 0.17 | **0.83 ± 0.02** | 0.077 ± 0.002 | **10.8 ± 0.2** | 193 ± 29 | 1025 ± 115 | 111 ± 12 | 9 ± 1 | 223 ± 14 | 421 ± 63 | 148 ± 8 |
| | | Biochar | 6.39 ± 0.11 | **1.15 ± 0.03** | 0.080 ± 0.001 | **14.5 ± 0.4** | 145 ± 10 | 953 ± 78 | 118 ± 7 | 10 ± 1 | 228 ± 5 | 430 ± 32 | 165 ± 1 |
| Before sowing | 2/04/2013 | Control | 6.22 ± 0.03 | **0.92 ± 0.04** | 0.080 ± 0.002 | 11.5 ± 0.4 | 171 ± 18 | 959 ± 56 | 143 ± 6 | 19 ± 0 | 269 ± 12 | 551 ± 51 | 163 ± 4 |
| | | Biochar | 6.15 ± 0.07 | **1.06 ± 0.07** | 0.079 ± 0.002 | 13.4 ± 0.7 | 143 ± 7 | 913 ± 69 | 144 ± 7 | 19 ± 0 | 247 ± 8 | 492 ± 33 | 171 ± 7 |
| After harvest | 14/08/2013 | Control | 6.50 ± 0.09 | **0.88 ± 0.03** | 0.077 ± 0.002 | **11.4 ± 0.2** | NDA | NDA | NDA | NDA | NDA | NDA | NDA |
| | | Biochar | 6.36 ± 0.09 | **1.17 ± 0.07** | 0.081 ± 0.002 | **14.5 ± 0.8** | | | | | | | |

# 2. Details from the ILVO biochar field trial



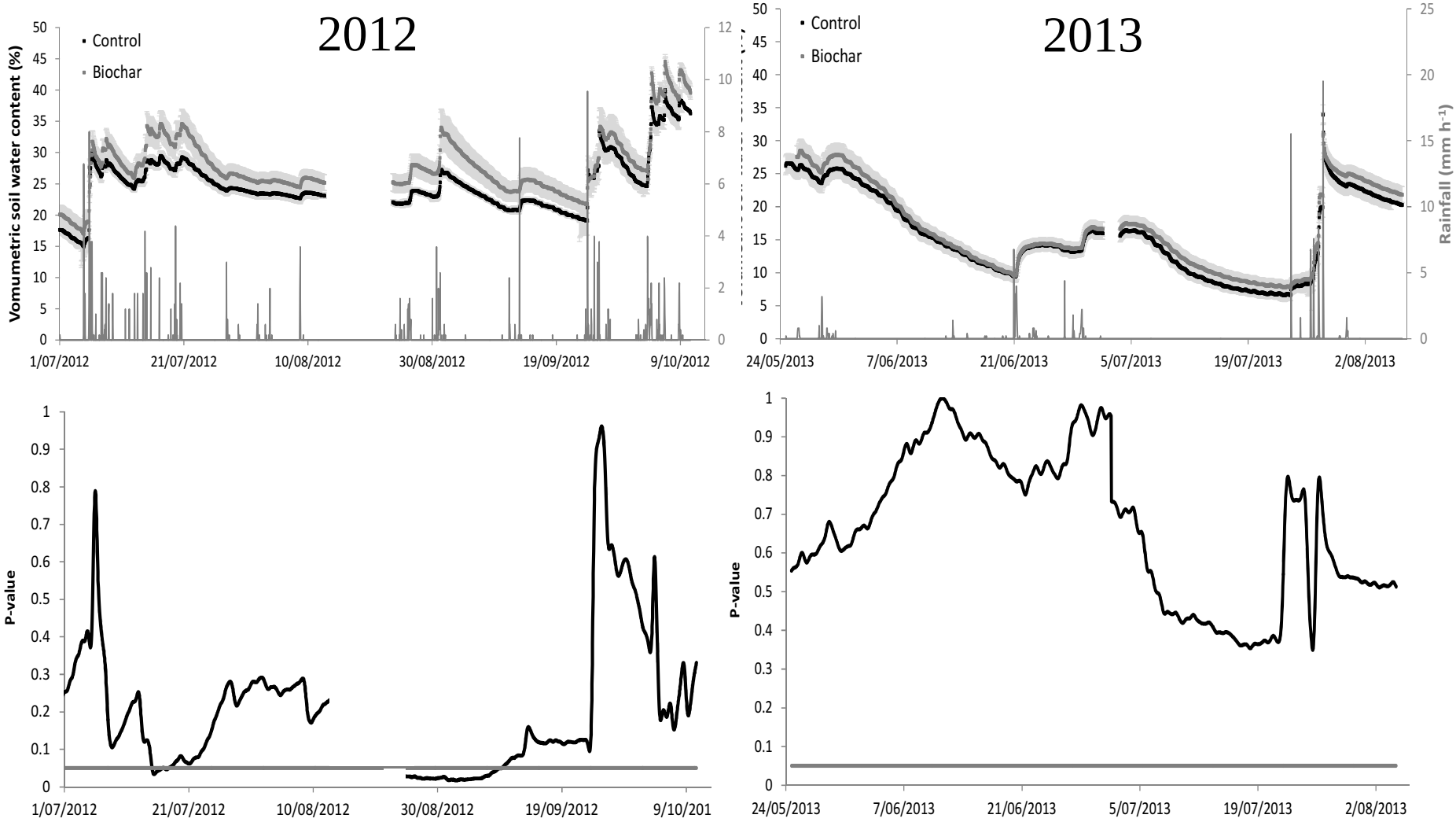




Plant available moisture

# 2. Details from the ILVO biochar field trial

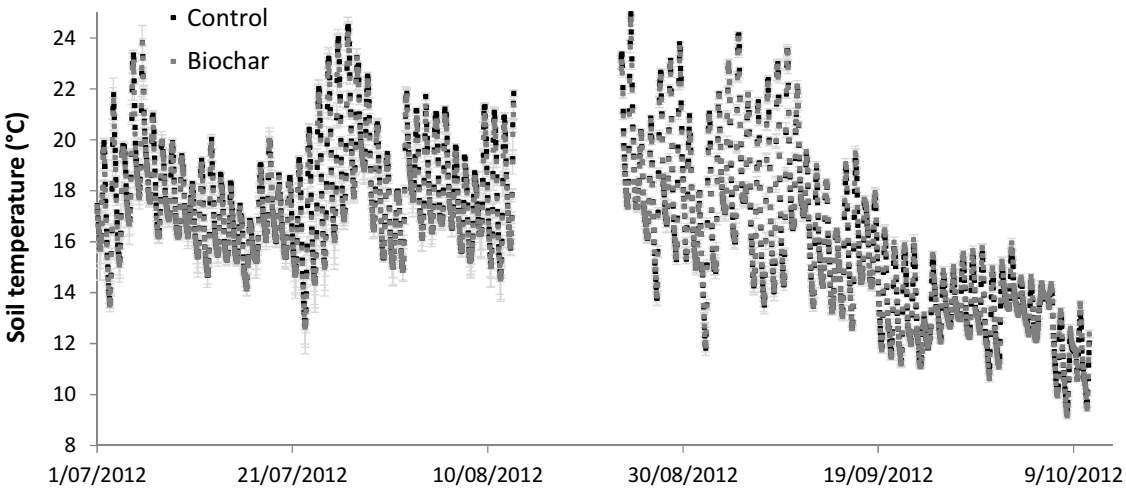


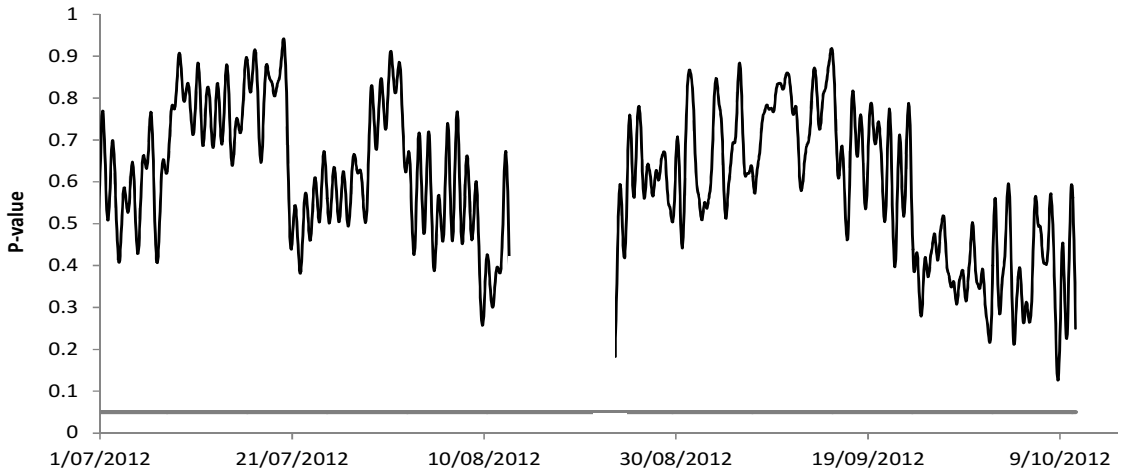

ILVO Instituut voor Landbouw- en Visserijonderzoek

The Interreg IVB North Sea Region Programme

European Union The European Regional Development Fund

# 2. Details from the ILVO biochar field trial



# Outline

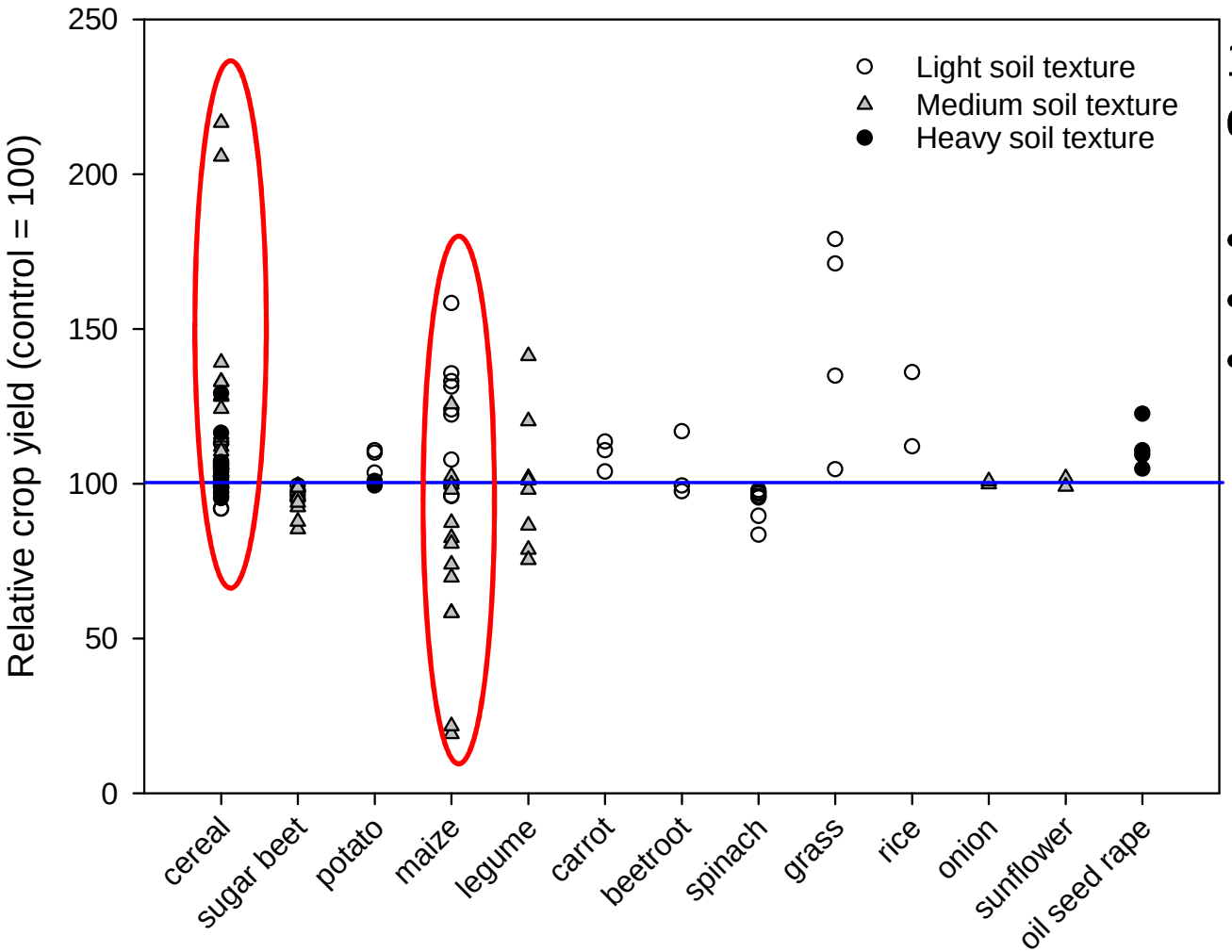
1. Biochar North Sea ring trial
2. Details from the ILVO biochar field trial
3. European biochar field experiments with pure biochar additions

# 3. European biochar field experiments

- Global meta-data analysis
  - +10% yield increase in first 3 years (Jeffrey et al., 2011)
  - Mostly tropical soils

- European biochar field trials – facts and figures
  - First established in 2007
  - 25 trial sites with pure biochar amendments documented
    - North and NorthWest Europe: 19
    - Austria: 2
    - Italy: 4
  - 21 biochar types
    - most are wood based
    - 14 slow pyrolysis, 1 flash pyrolysis, 1 activated carbon, 1 torrefaction, 2 gasification, 2 hydrochars
  - 56 site - biochar type – dose combinations
  - 127 site - biochar type – dose – year combinations

# 3. European biochar field experiments




127 site - biochar type – dose – year combinations

- 75% not significant
- 17% positive effect
- 9% negative effect

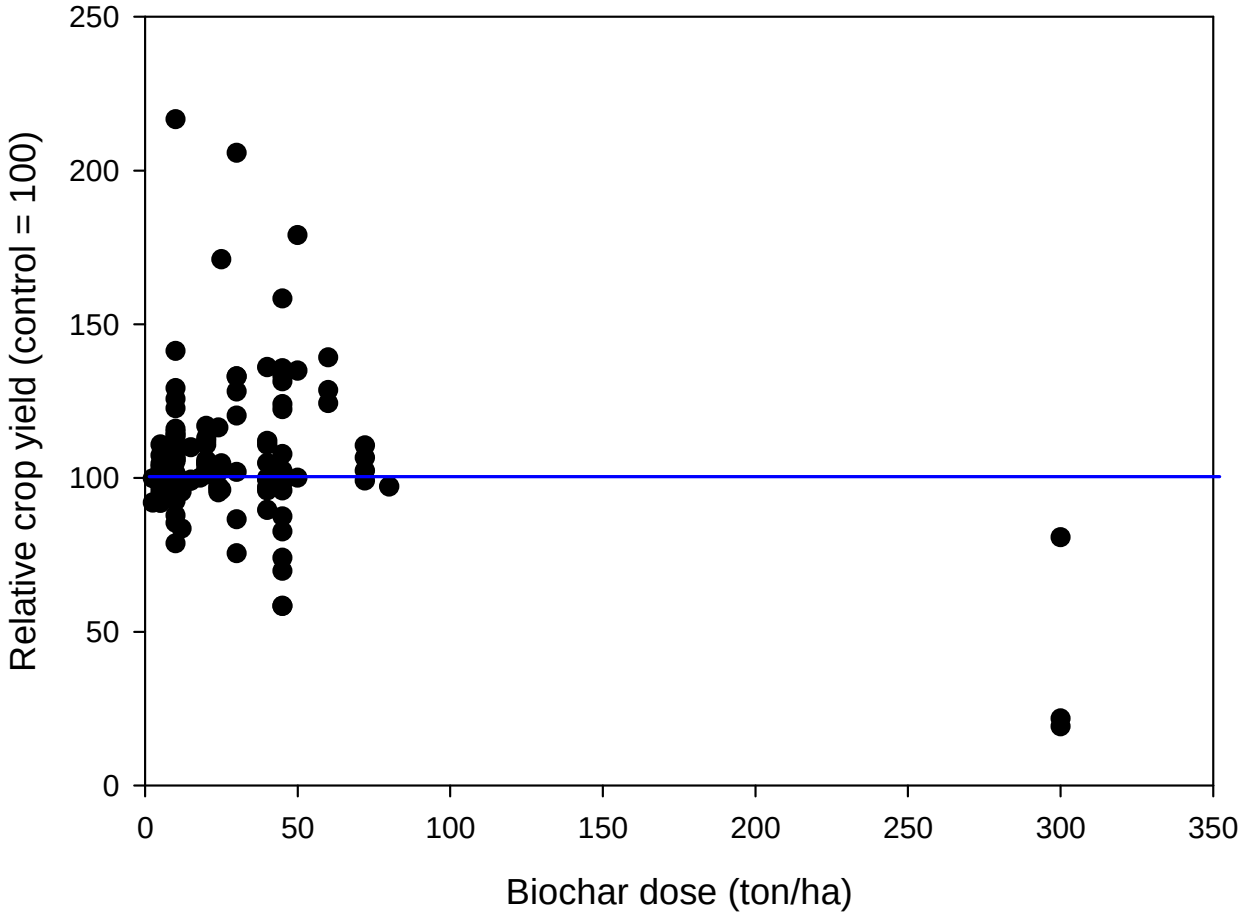
ILVO Instituut voor Landbouw- en Visserijonderzoek

The Interreg IVB North Sea Region Programme

European Union The European Regional Development Fund

BIOCHAR

# 3. European biochar field experiments

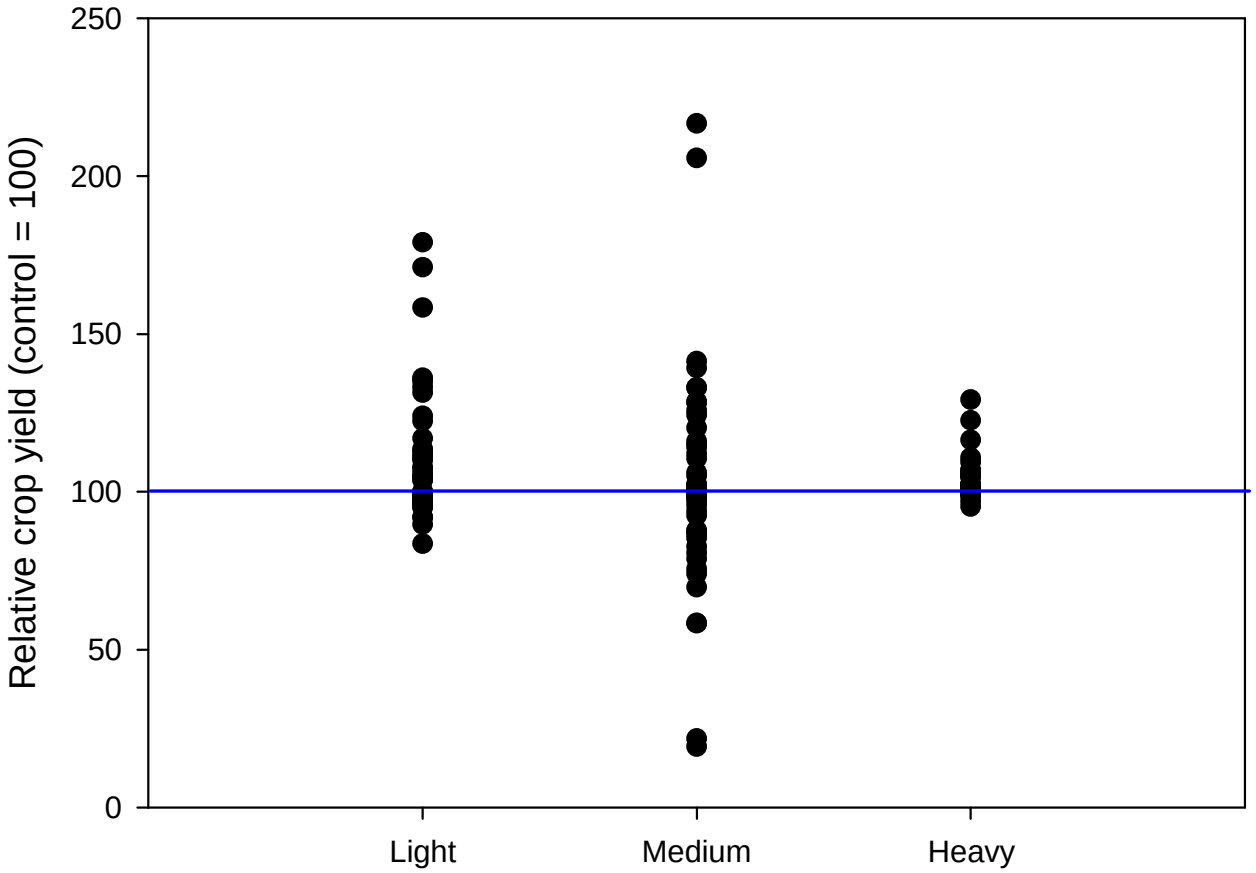



Biochar dose

- 2.5-300 ton/ha
- Positive effect from 10 ton/ha
- High dose: risks for yield reduction

# 3. European biochar field experiments

On what soil types to use biochar?

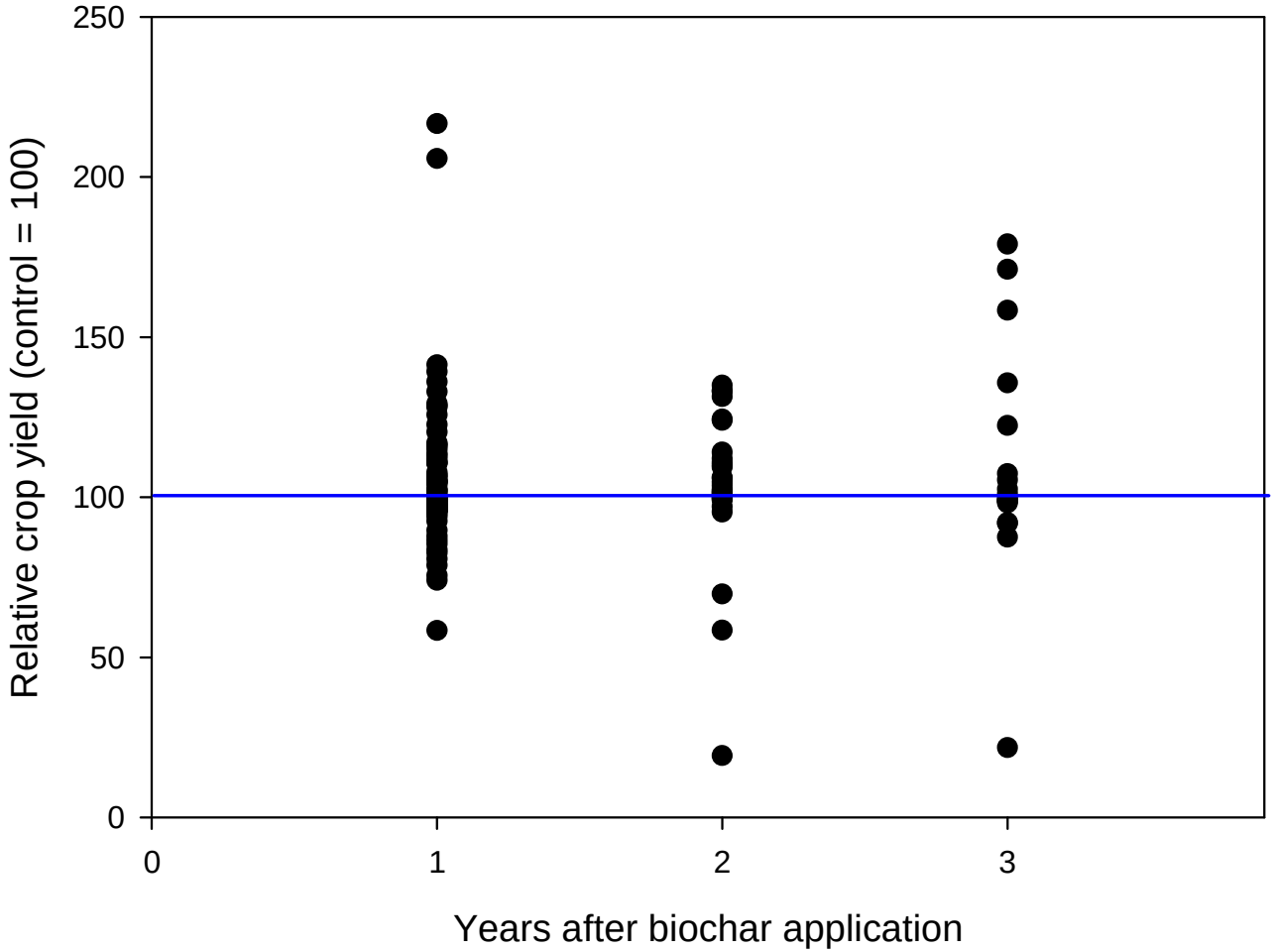



Soil texture range

- From sand to (clay) loam
- 2/3 <50% sand

# 3. European biochar field experiments

Does the biochar effect change over time?



# 4. Conclusions pure biochar additions

- Pure biochar additions in open fields mostly do not lead to crop yield effects in Europe
- Positive effects can be achieved from 10 ton/ha
- Risks at higher biochar doses (biochar dependent)
- C sequestration strategy
- Research needs
  - Longer term effects on soil and crop
  - Non-wood based biochars
  - Biochars from alternative technologies (e.g., gasification)
  - Degraded land
  - Alternative uses: e.g., combined biochar-organic material amendment, growing media

# Field trials with biochar in the North Sea Region

Greet Ruysschaert
Victoria Nelissen

End Conference of the Interreg IVB North Sea Region project 'Biochar: climate saving soils'
Groningen, the Netherlands, 10th December 2013