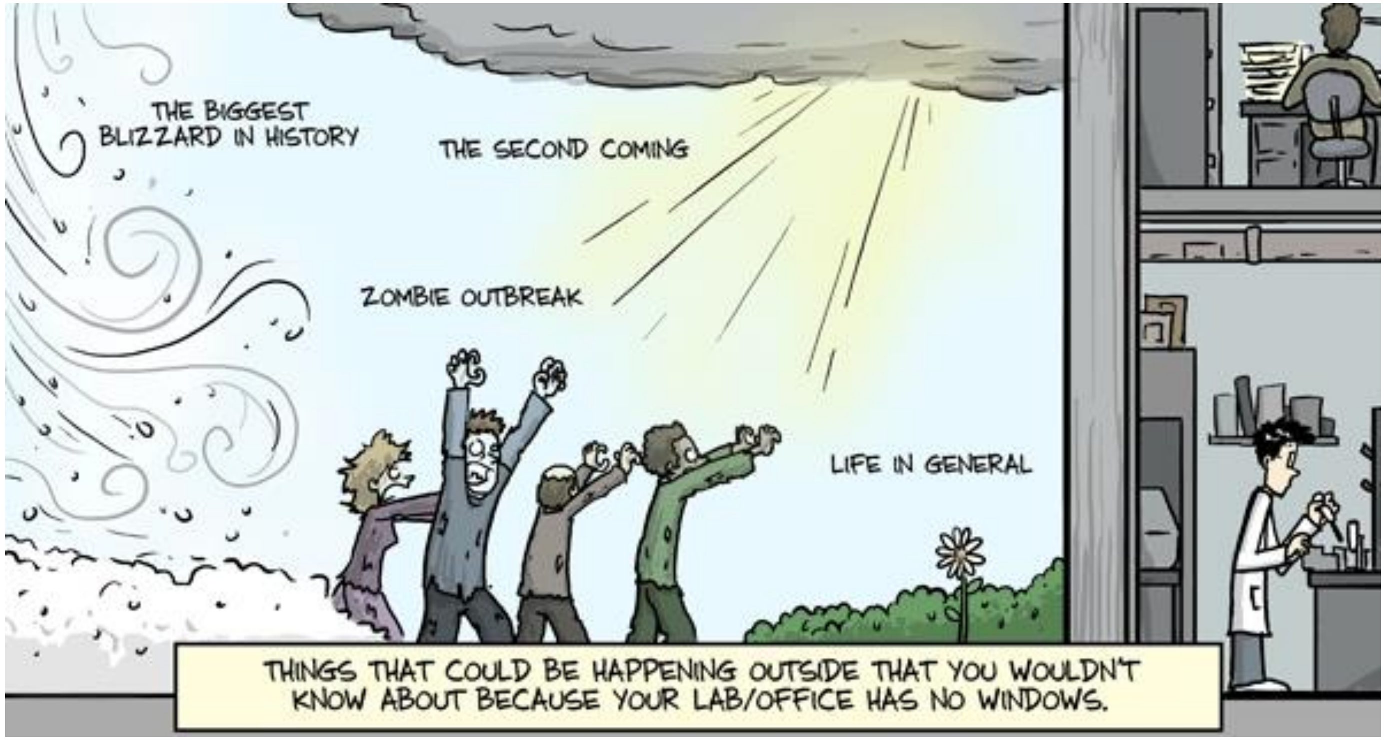
How to conduct Field Experiments

Lutz Weihermüller & Arne Kappenberg



What are field experiments?

A field experiment is a scientific study that is conducted outside of a controlled laboratory setting, in a real-world environment. It involves sacrificing control in order to achieve greater generalizability and often helps generate new hypotheses in the early stages of research. Field experiments are valuable for understanding how findings from controlled laboratory studies can be applied to real-world situations, although they present challenges such as lack of control over treatment conditions and potential confounding factors. The results of field experiments are typically interpreted in conjunction with findings from other research methods to increase confidence in their accuracy.

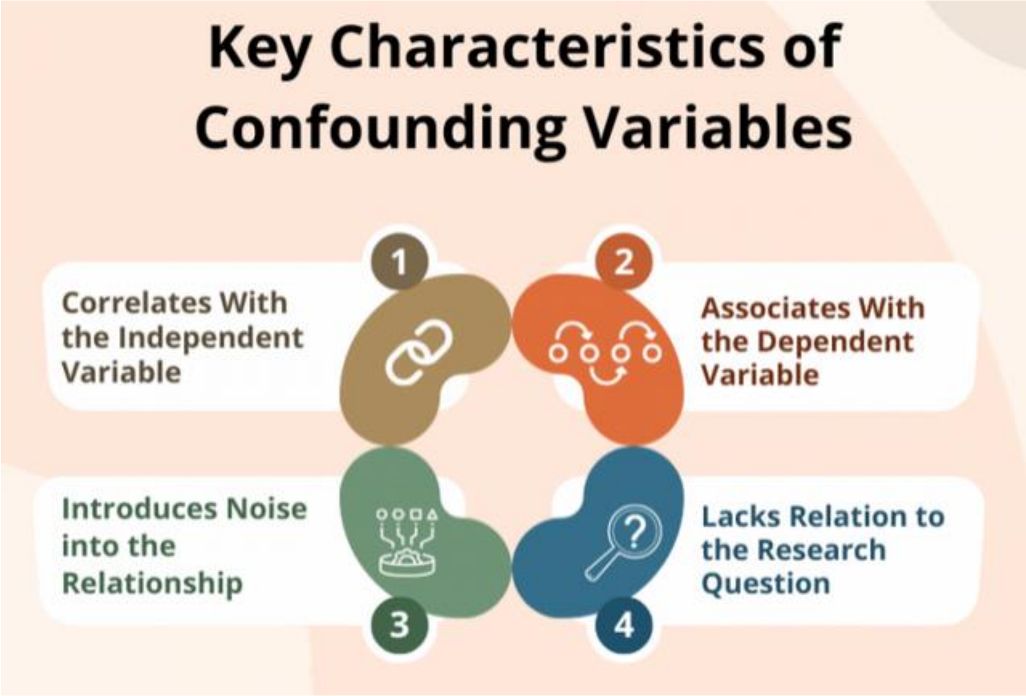
https://www.sciencedirect.com/topics/computer-science/field-experiment

That means.....

- If you cannot control the field experiments largely enough you should maybe best go back to controlled conditions (lab / greenhouse)

- You have to be aware of confounding factors and conditions

- Therefore, you should have knowledge of those and the theory



Glossary of foreign terms

- A field test consists of researching the experiment variations in field conditions.
- The experiment variation is the object of your experiment. These could be the fertilizer rate, tilling method, crop varieties, growing conditions, or something else.
- The control is what you want to compare with the experiment variations. The standard practice can be the control for experiment variations.
- Replication is the number of areas in the field that have the same experiment variations and the same soil conditions.

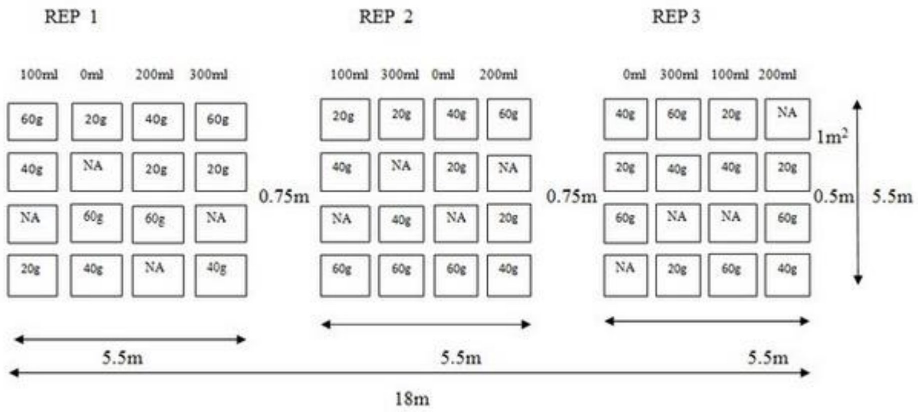
General recommendation

- Select a homogeneous field for your experiment
- Establish 3–6 replications to avoid mistakes when analyzing the result
- Do not perform new experiments on fields where other experiments have been performed in the previous growing season – there can be a legacy effect

Homogeneous fields

Homogeneity is a prerequisite for a proper analysis of the results

Field experiments are often designed using randomized blocks



Field experimental layout in a randomized complete block design (RCBD)

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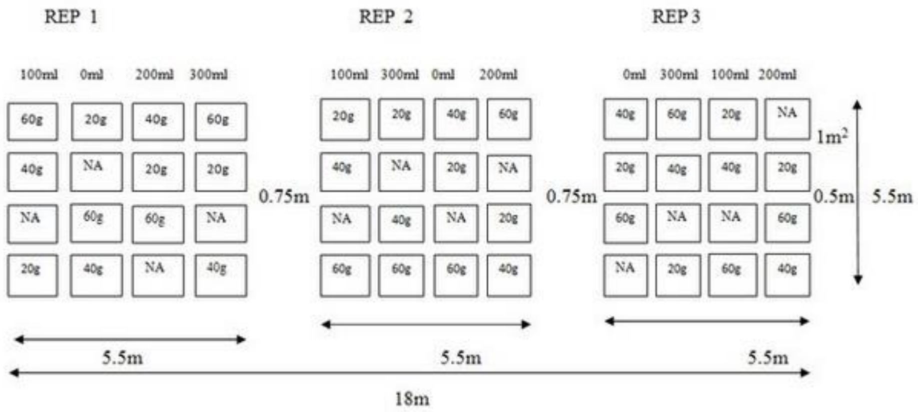

Field experimental layout in a randomized complete block design (RCBD)

But those designs can be problematic if the field shows non-random heterogeneity

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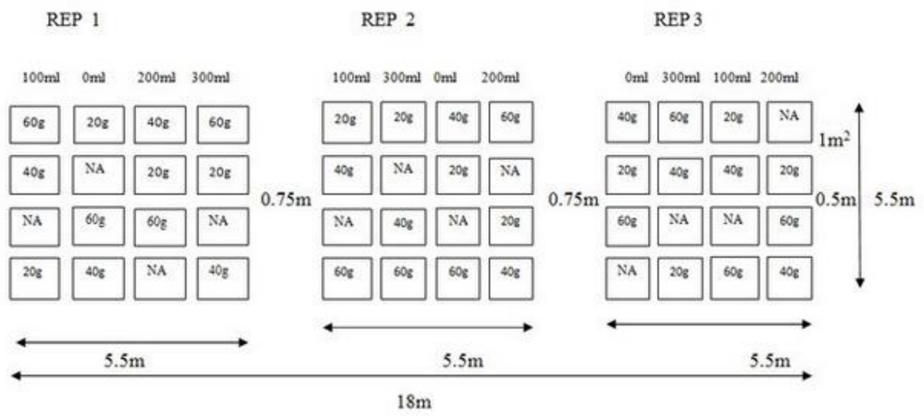


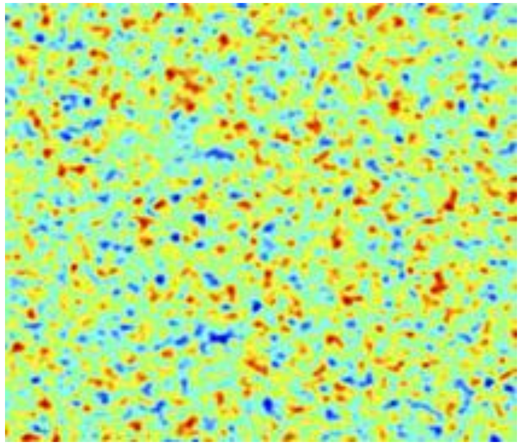
Field experimental layout in a randomized complete block design (RCBD)

But those designs can be problematic if the field shows non-random heterogeneity

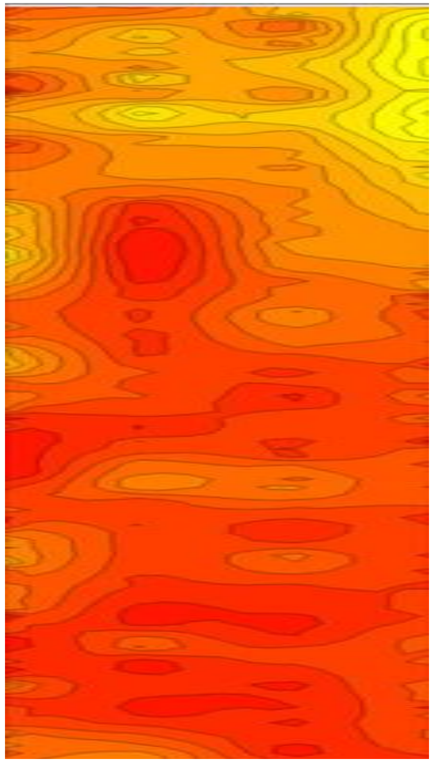
Example is a field experiment of a large agrochemical company which has lead to detailed field characterization due to unexplained variability

Random versus structural heterogeneity

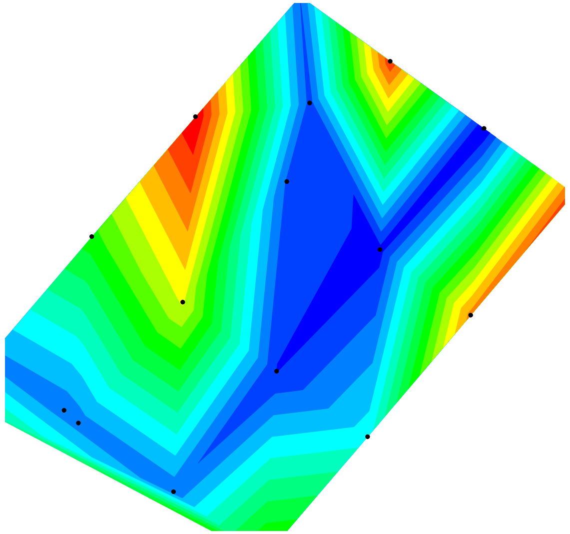
Fully random



Deterministic trend



Structured



Capturing Heterogeneity in Upland cropping systems

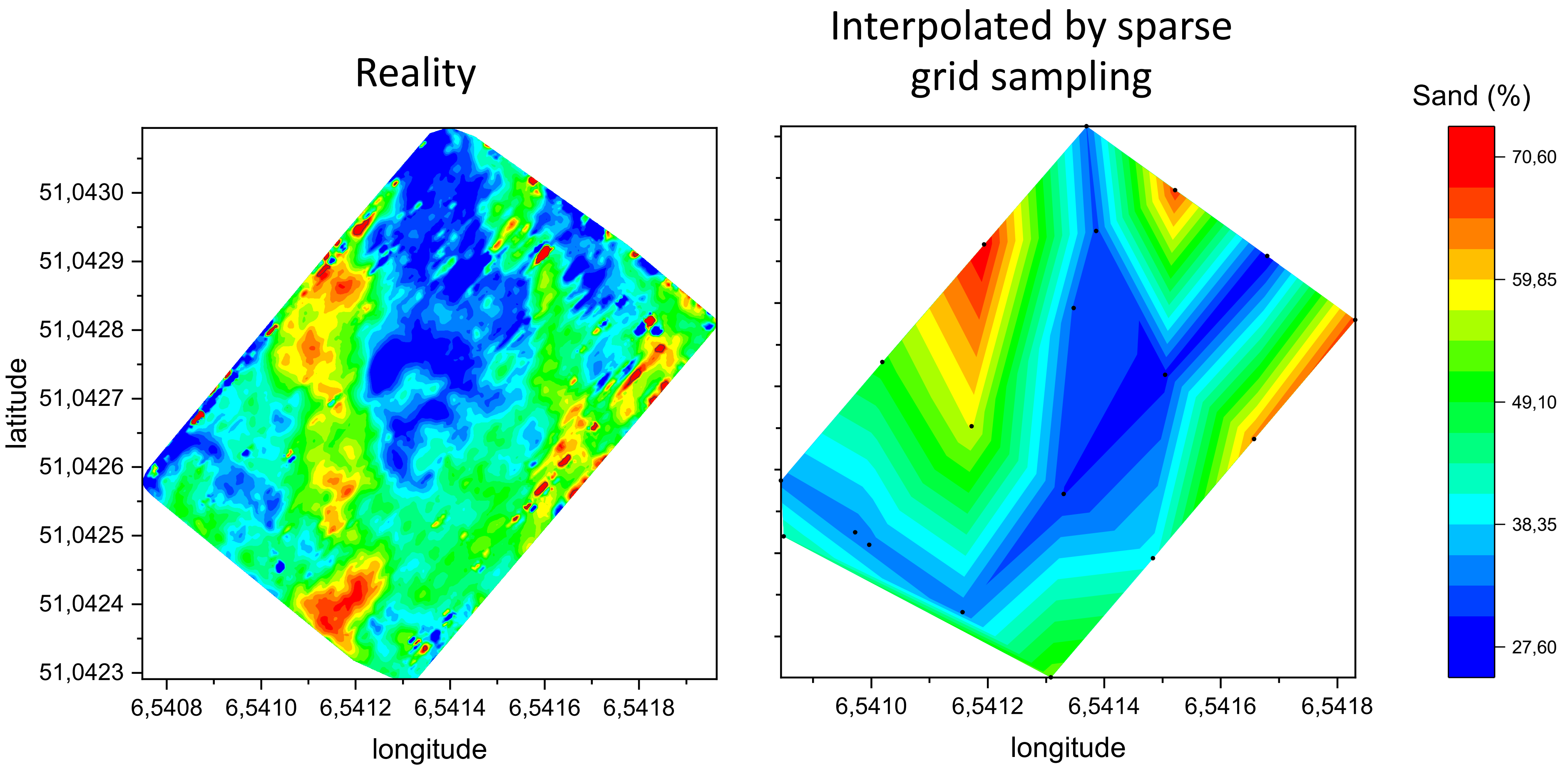
The spatial variability of soils due to natural features

A field next to the Research Center @ Jülich, Germany

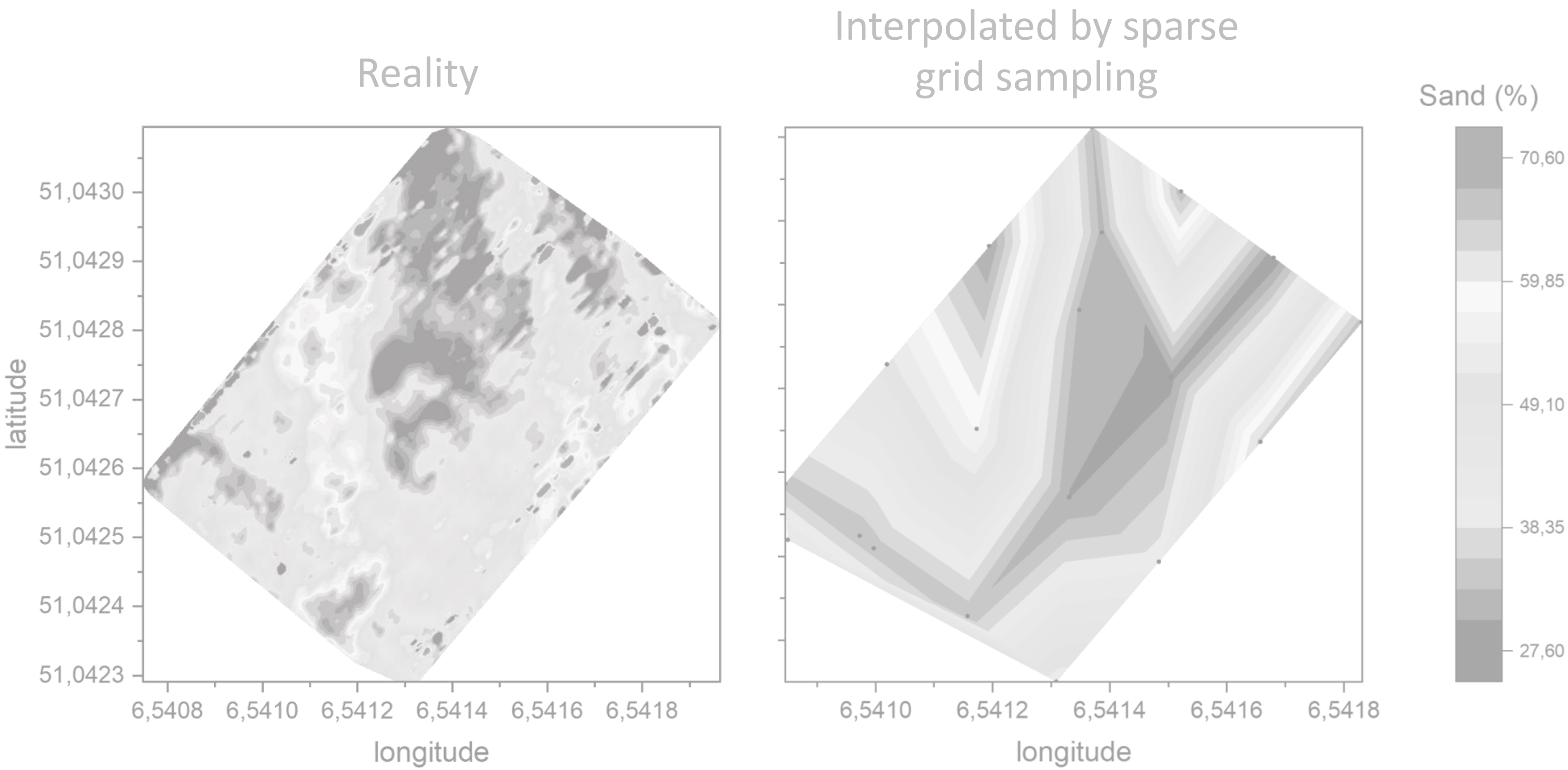
Capturing Heterogeneity in Upland cropping systems

or in Vietnam also due to the construction of the uplands

Grid sampling



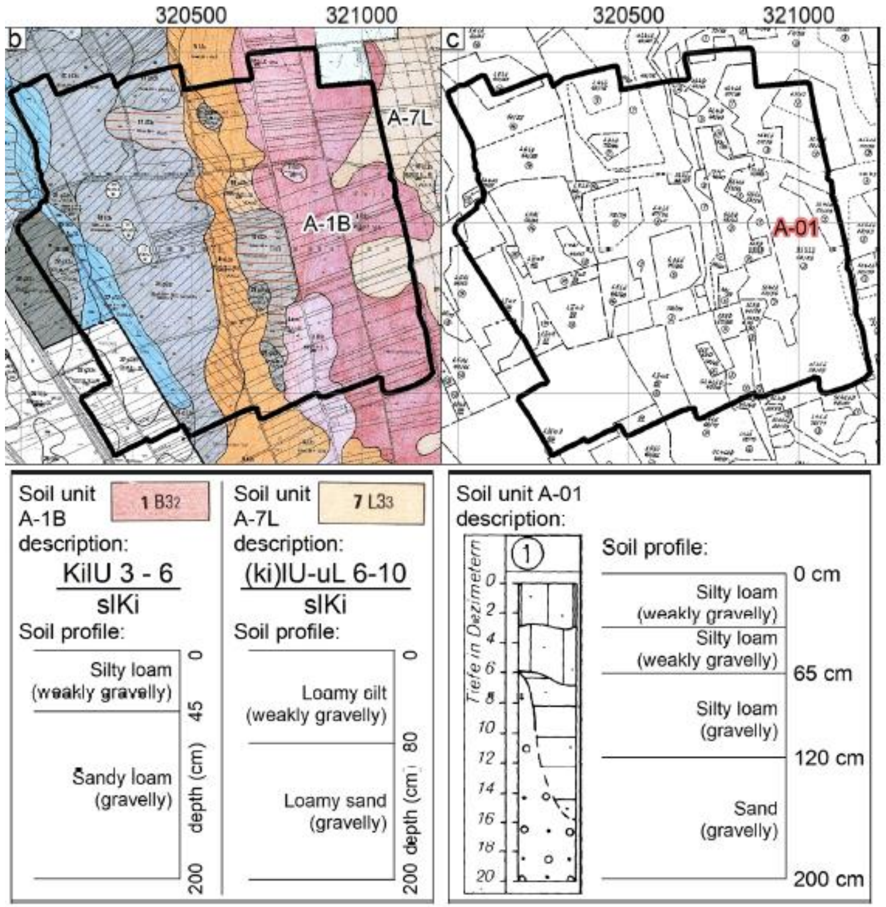
Grid sampling



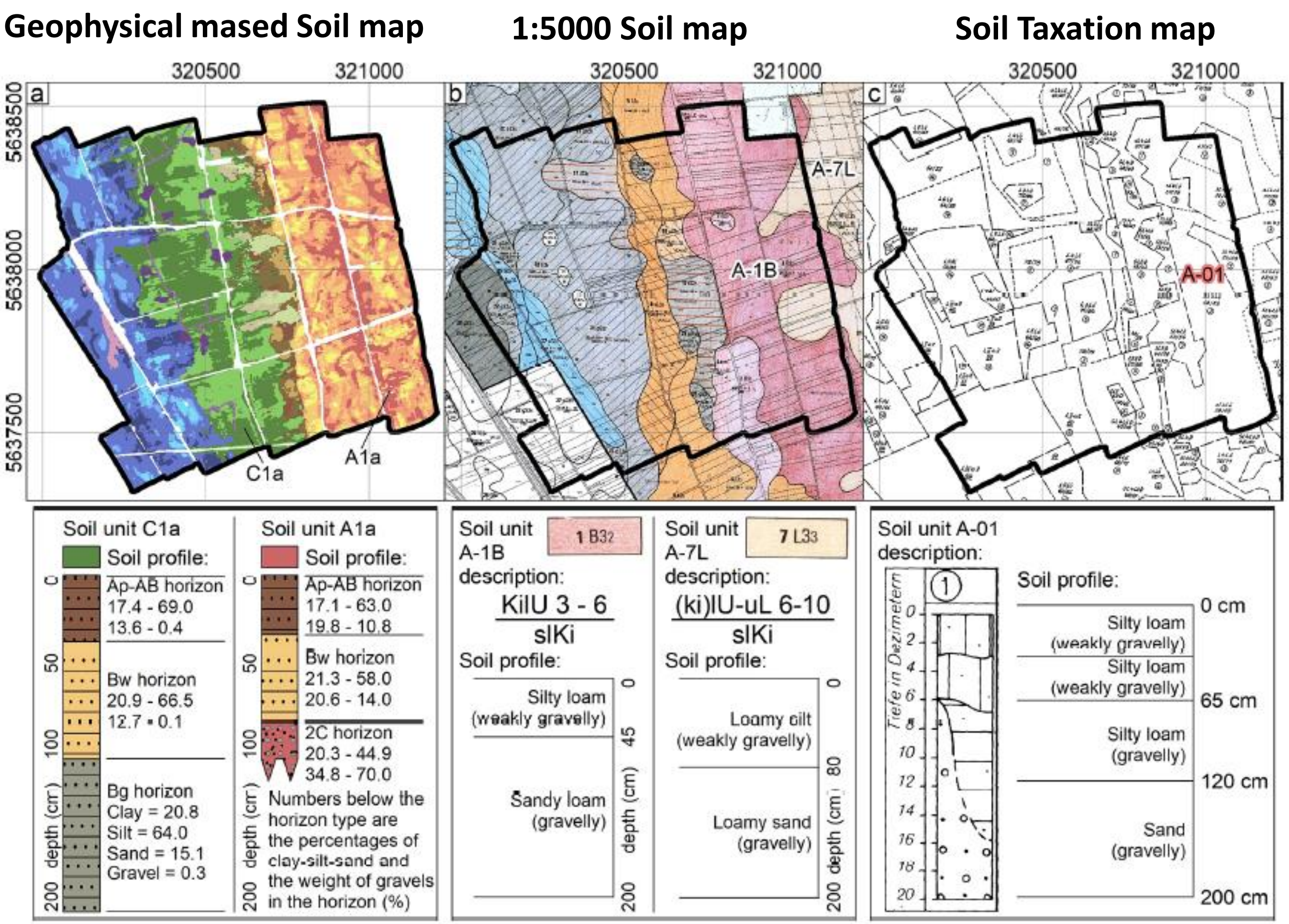
Sparse grid sampling might lead to a loss of spatial information, especially of features with lower extend as grid size

Map based information

1:5000 Soil map **Soil Taxation map**

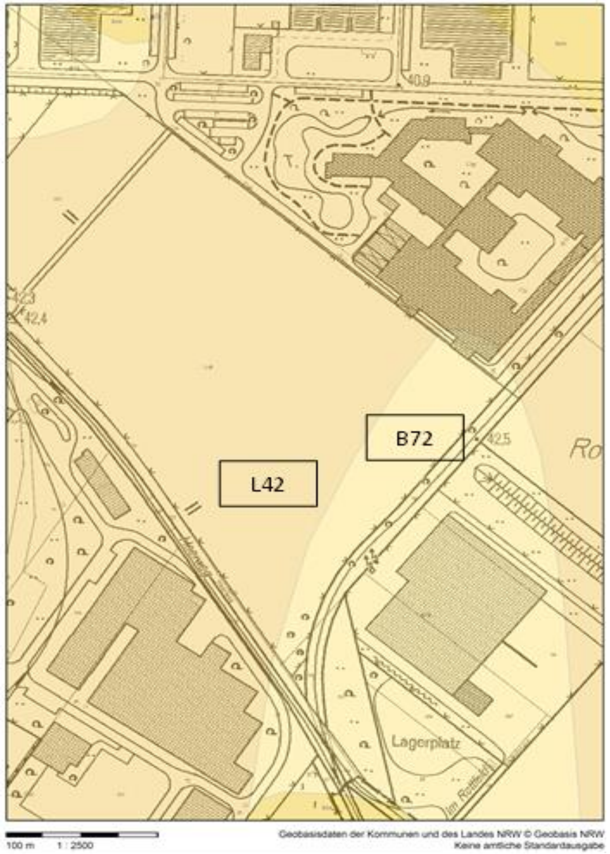


Map based information



Satellite based information

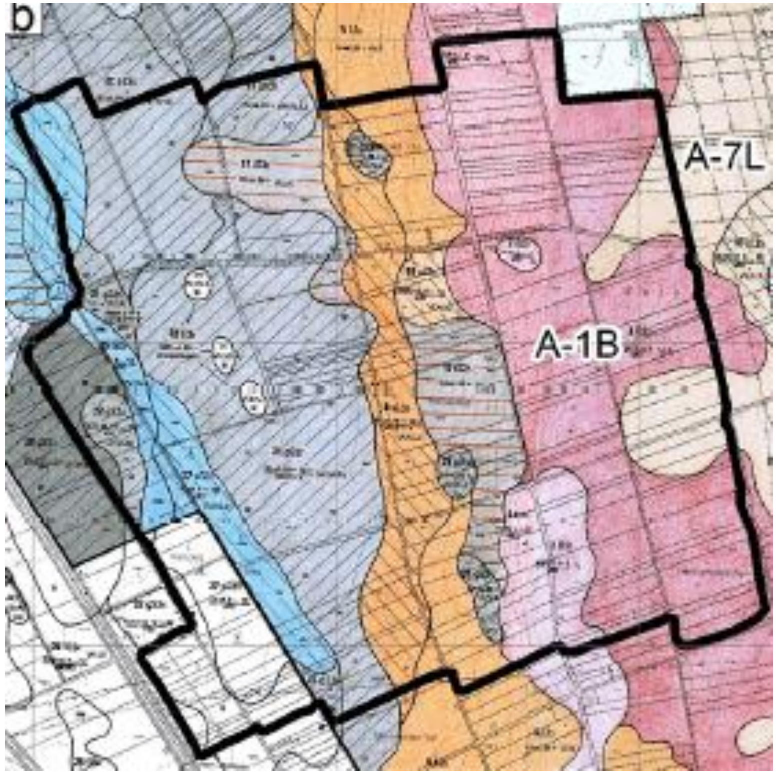
Soil map (1:500000)



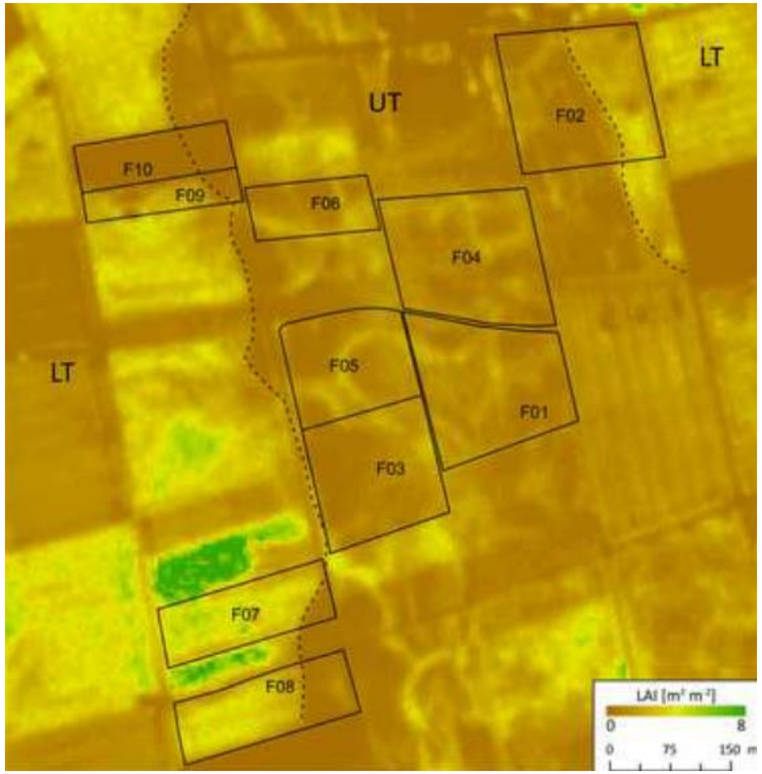
Google Earth image

Satellite based information

Soil map (1:5000)

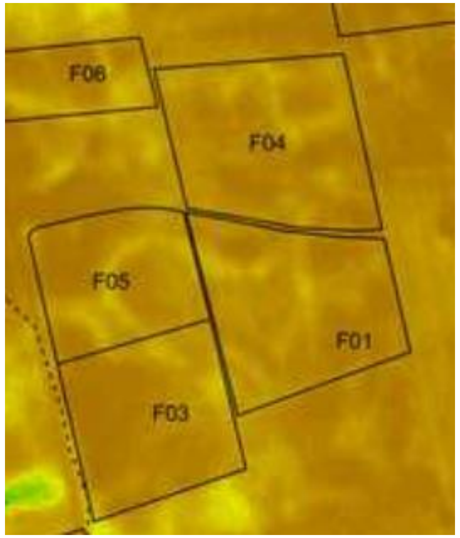


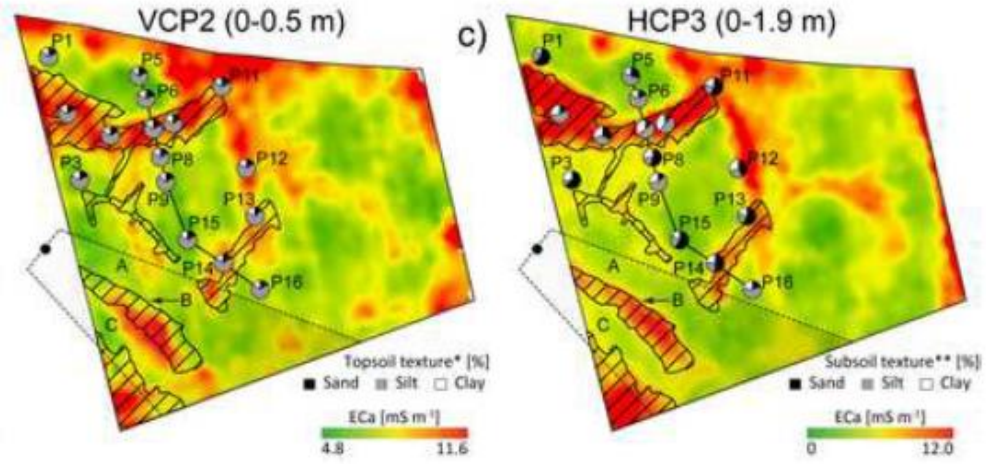
Rapid Eye Image derived LAI

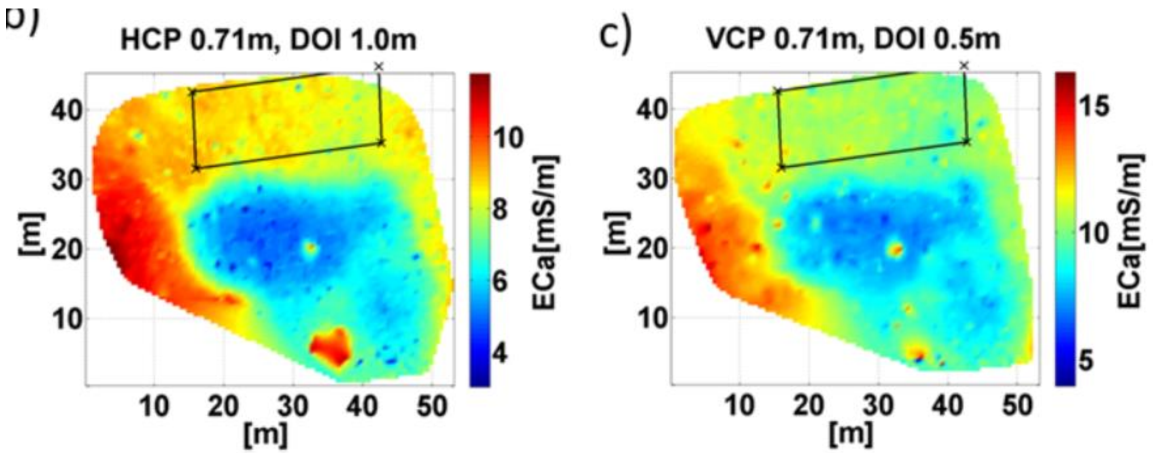


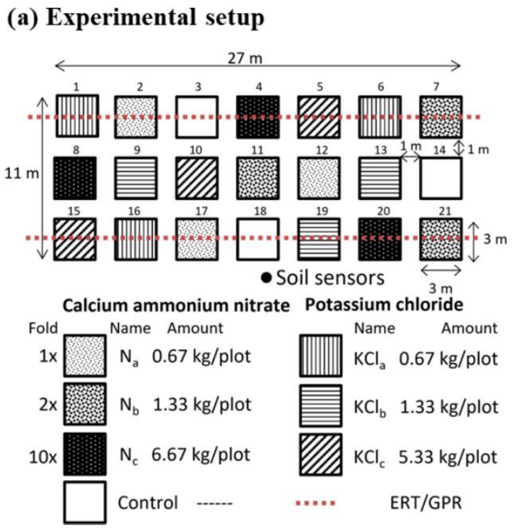
Drone based information

Geophysical based information

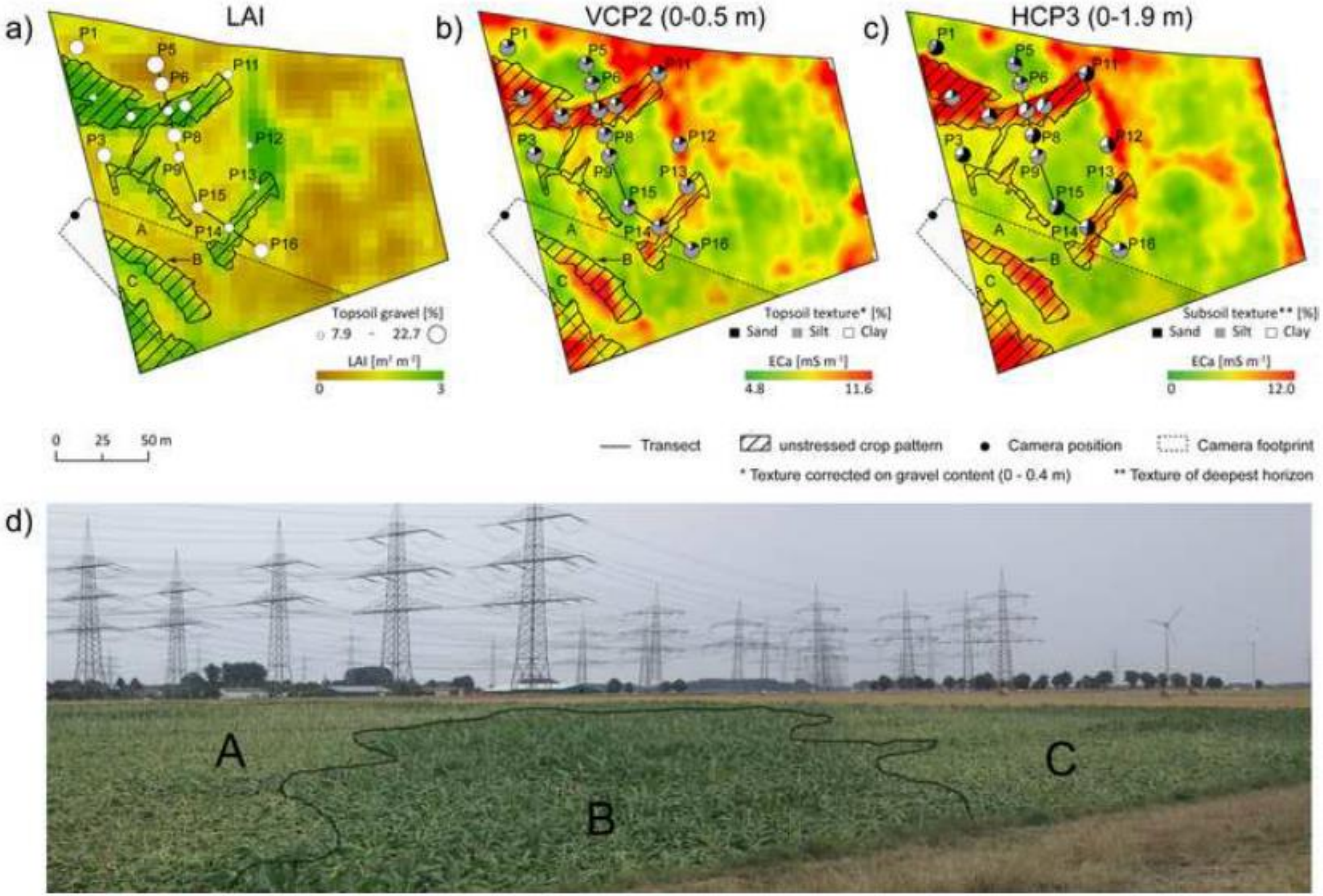








Visual based Information



Capturing Heterogeneity in paddy rice systems

The spatial variability of soils are less easy to detect in paddy rice systems

As the soil water status play not an important role and as the fertilization status is normally quite homogeneous

Nevertheless, some heterogeneity can be detected

as can be sometimes seen in the growth pattern

Photo from An Giang province

https://www.globalwaterforum.org/2023/09/19/rice-irrigation-policy-and-the-need-for-improved-water-management-in-vietnam/

Recommendations

- **Stay away from field boarders**
- **Stay away from impacting vegetation / structures** (e.g. trees close to your field, water ways)
- **Sample the field precisely and focus especially on soil properties /states which might impact the target variable**

Setting up the field trials

- Requirements from statistical analysis?

  Strip versus block design

- What and how often to measure?

Strip design

A simple design along strips treated differently

Biochar amount effect Petershagen 2009 by Bruno Glaser Uni Halle

Strip design

A simple design along strips treated differently

Biochar amount effect Petershagen 2009 by Bruno Glaser Uni Halle

Strip design

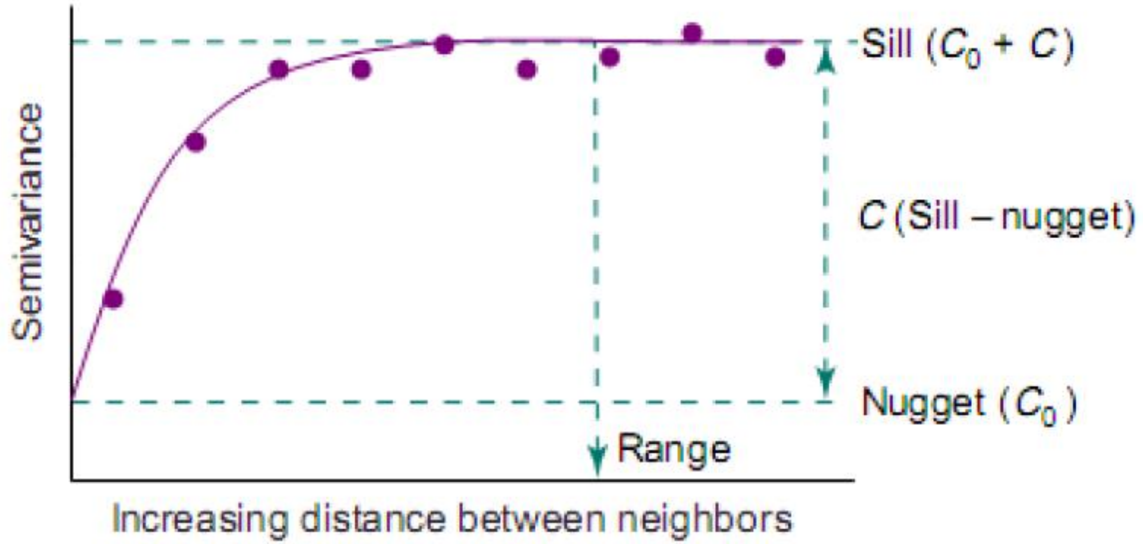
A simple design along strips treated differently

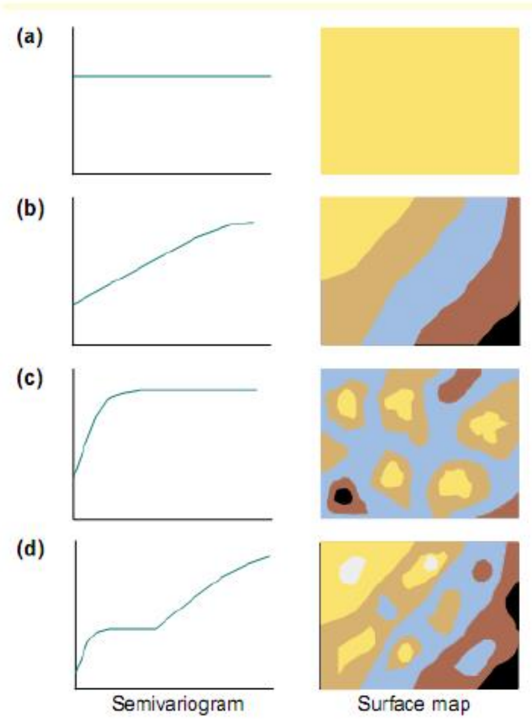
Often not accepted in publications as the individual plots in the strips are no true replicates

Strip design

How to prove that there is no trend within the field?

Prove by (Semi)-Variograms



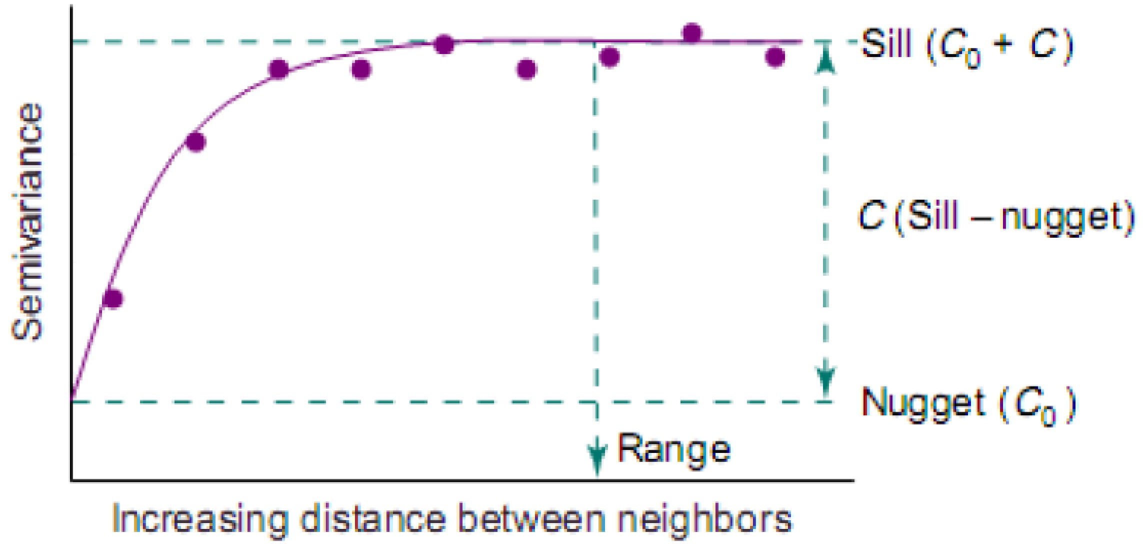


Therefore, the field has to be sampled prior the experiment and the confounding factors impacting the target have to me measured **(e.g., soil texture or nutrient status if the target is yield)**

Strip design

How to interpret the variogram?

The semi variogram indicates the difference in values between points with respect to distance between points.
If the semivariance is small, the difference between the attribute at these points is also small.



Nugget = attributed to measurement errors or spatial sources of variation at distances smaller than the sampling interval

Strip design

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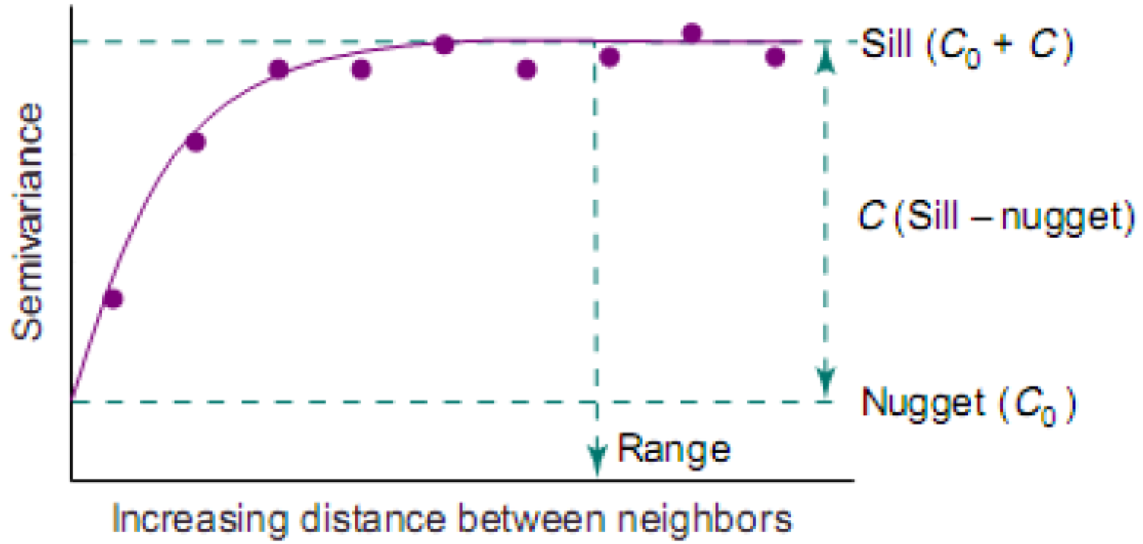

Sill = attributed to distance, where the maximum dissimilarity between pairs of point occur

Strip design

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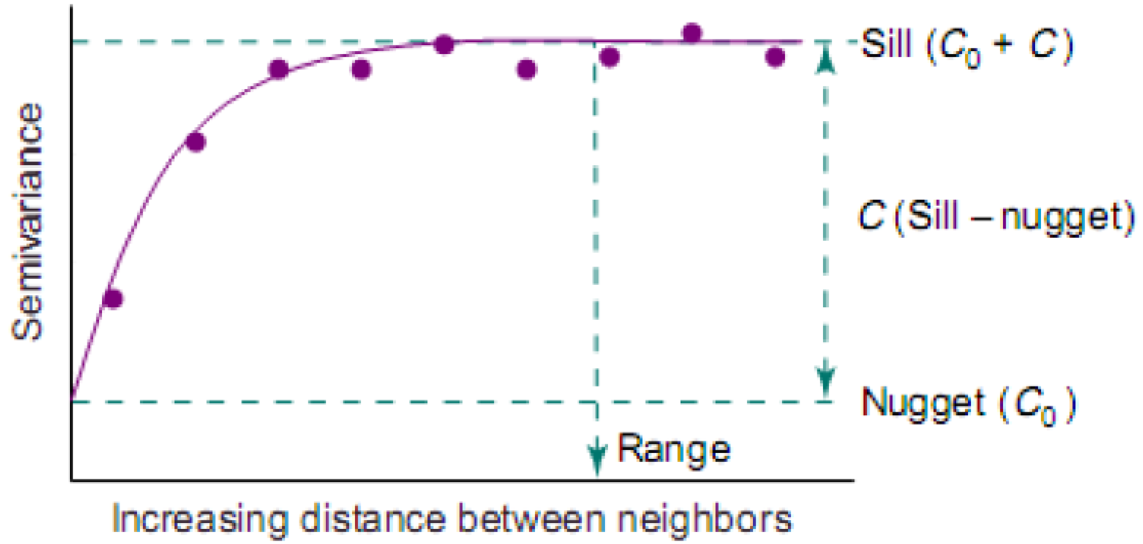


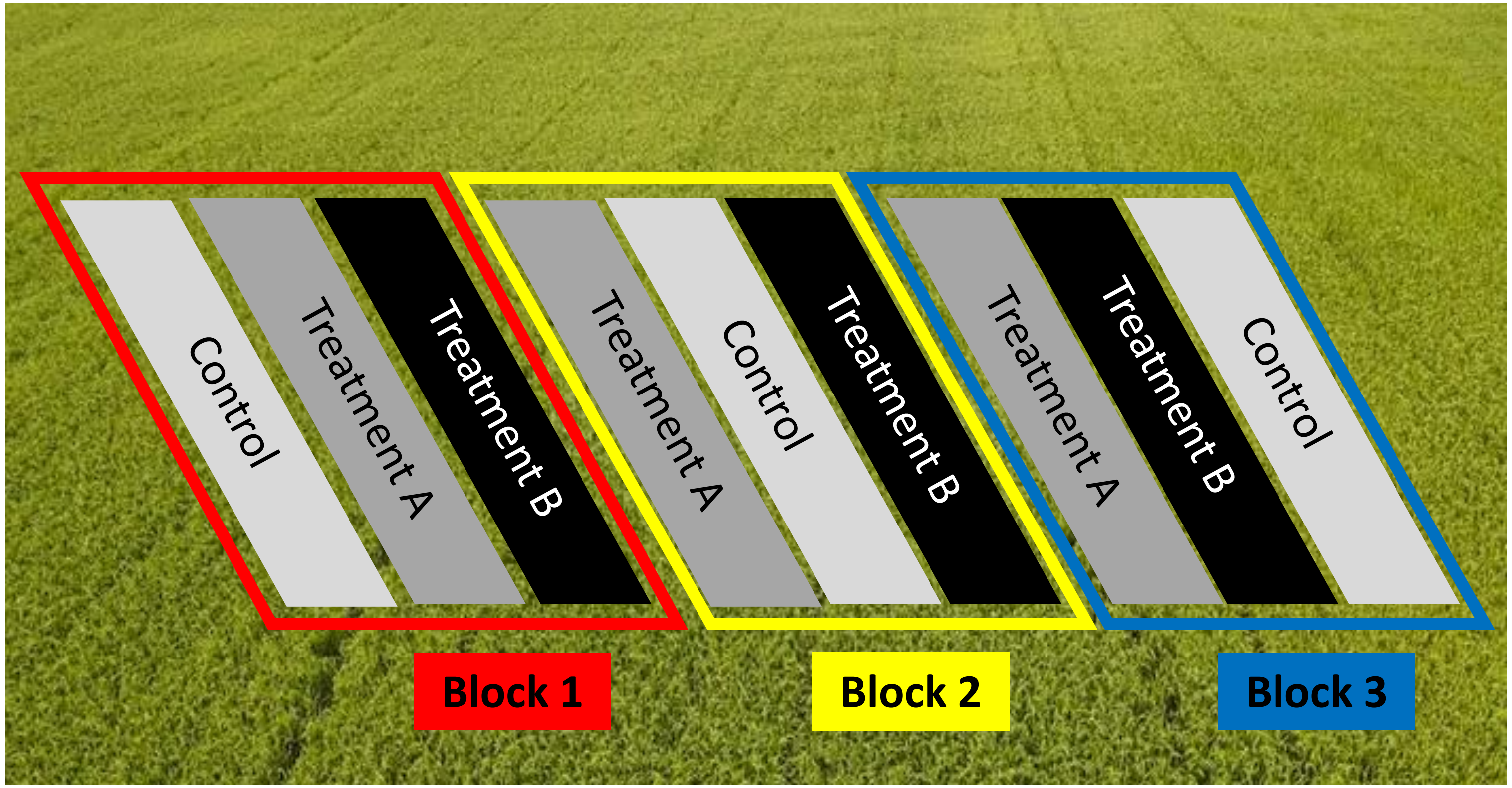
Sill = attributed to distance, where the maximum dissimilarity between pairs of point occur

Meaning that the data can be seen as independent if the size of the strips (or the semivariogram of the field with the strips) do not show a sill

Randomized block design

Here, the strips are within blocks and statistically independent

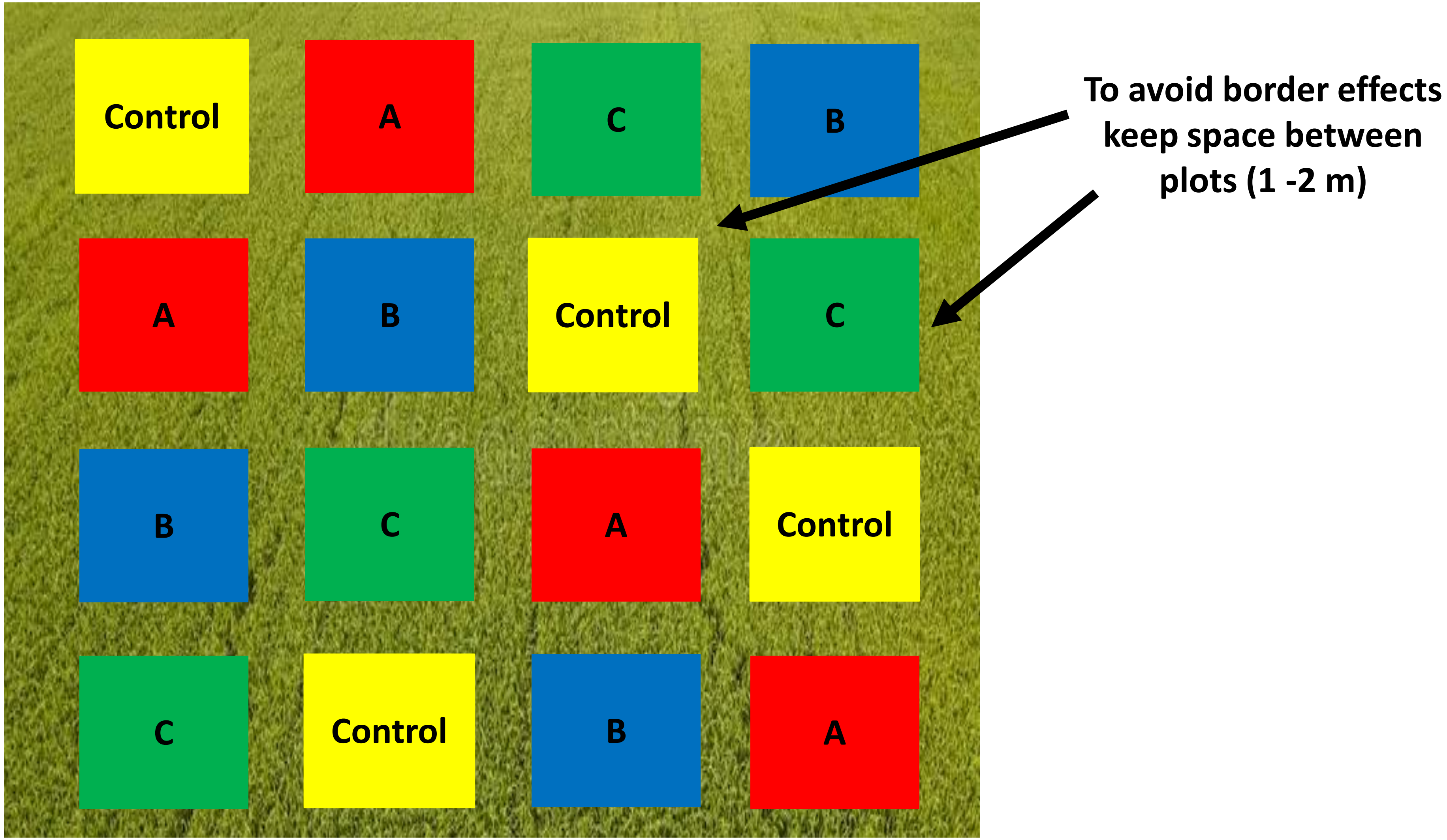
(if there is no deterministic trend from left to right)



Easy to setup and to analyse

Latin square design

Each line and each row contains only one treatment



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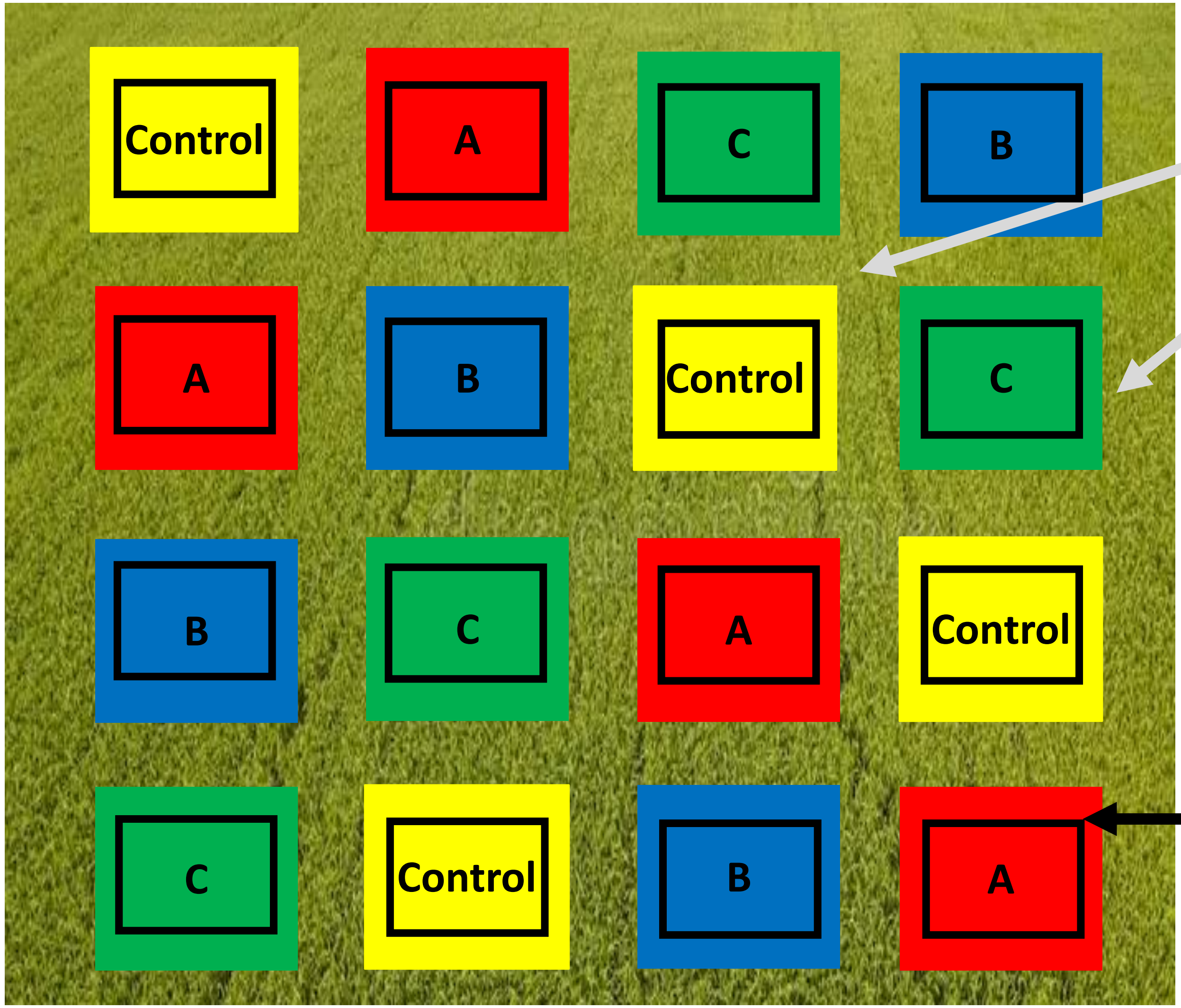
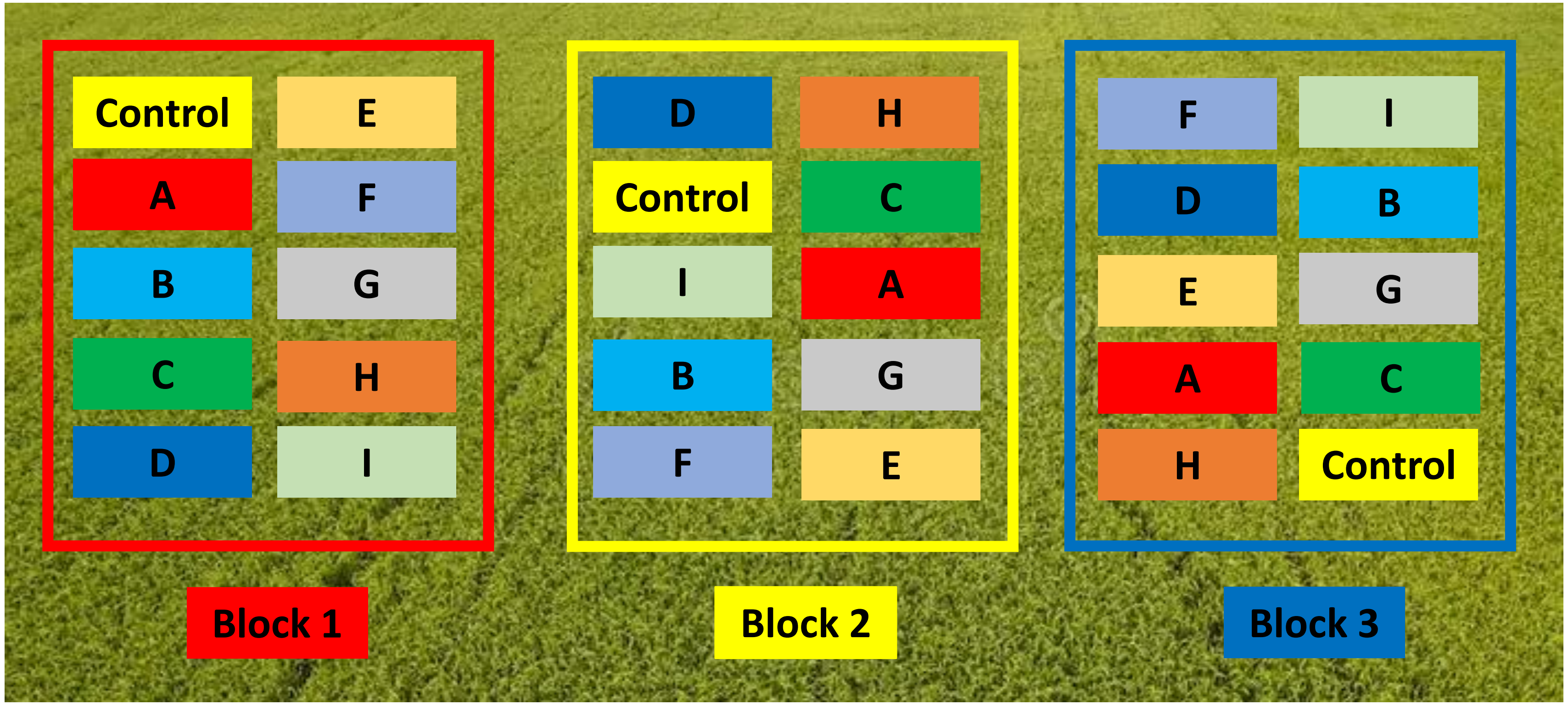


To avoid border effects keep space between plots (1 -2 m)

To avoid border effects within plots sample only inner parts

Latin rectangle

Each block is randomized



How many replicates should I have?

- *n* = 3 is commonly proposed (to calculate a mean and standard deviation) – **so minimum**
- *n* = 3 does not allow to calculate boxplots (here *n* = 5 is required)
- if *n* = 3 and something goes wrong in one treatment experiment failed

- In general, more is better and statistics get more robust

➢ But more replicates require more work !

Take more samples as you need

- Integrate potential partners to bundle resources
  ask around who might be also interested in the experiment and if they would like to participate.
  sometimes little bit more work will lead to more output

- Ask experts who will help you to identify what sampling is needed (you might have overlooked something)

- Take more samples (in time, in space and quantity) as you might need later on (backup samples) and store them correctly

Document all procedures as detailed as possible

- **Make yourself a plan of sampling and experimental details before setting up the experiment**
  (and discuss this in a larger group as you might overlook something)

- **Agree on an intuitive labelling of samples**

- **Use simple lab numbers**
  (but do not forget to have a translation to original sampling labels)

You have learned this in the training today from 10:30 - 12:30 on Data accessibility and archiving

Check data

- **Check your data whenever you get them**
  (do not wait until all data have been gathered as problems need to be early identified)

- **Discuss those data with experts as soon as possible**
  (will also help to identify any mistakes or errors)

- **Save data (raw and analysed data) in readable format and document them for next generation**

You have learned this in the training today from 10:30 - 12:30 on Data accessibility and archiving