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Combination of Sentinel-2 change detection and forest site factors

Patterns of forest degradation in Thuringia

Birgitta Putzenlechner, Georg-August-University Göttingen, Cartography, GIS and remote sensing
Philipp Koal, Forestry Research and Competence Center, ThüringenForst, Gotha

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

Kartographie - GIS - Fernerkundung

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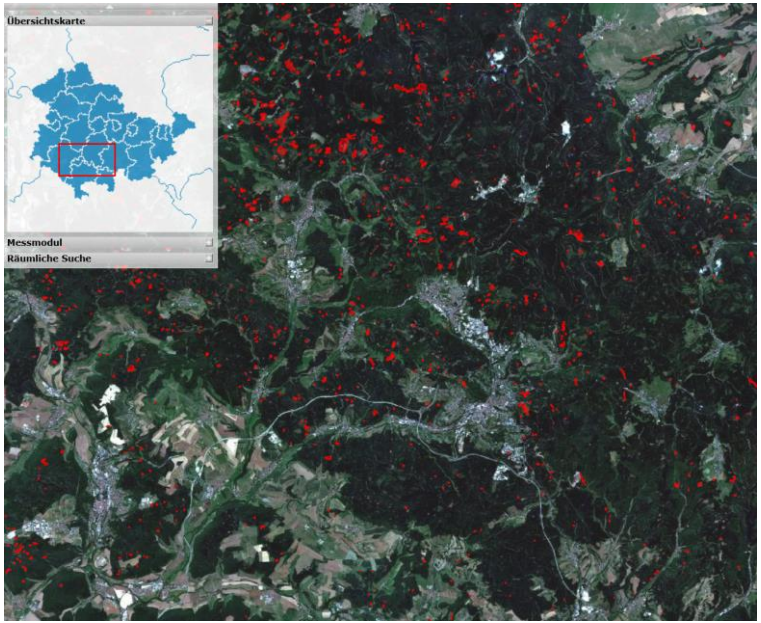
Forest degradation

- Prolonged drought of recent years (2018-2020) and the additional weakening caused by pests and storm events

→ large areas of calamity in spruce stands, degradation in deciduous forests across Germany

- Thuringian forests also heavily affected
- Remote sensing data, e.g. Sentinel-2, is increasingly used for operational monitoring the status and dynamics of forests
- Mapping of forest site factors and huge amounts of 'old data' available in Thuringia – more than 90% of the forest area is mapped!

Photo: I. Profft, FFK Gotha



http://www.geoproxy.geoportal-th.de/geoclient/control with Sentinel-2 mosaic 2020 and calamity layer

Forest site factor mapping

Spatial data

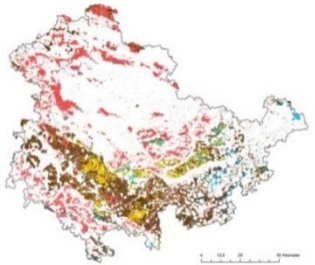
Forestry site maps (*Lokalbodenformen*)	1 : 10.000
Soil-geological maps (*Substratgruppen*)	1 : 100.000
DEM 10 (slope, aspect)	

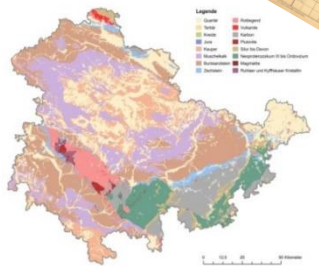
Point data

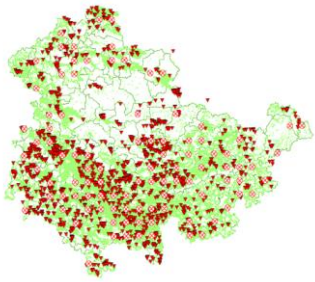
Soil measurement stations (*BZE-Punkte*)	108
Soil profiles (with laboratory data)	1827

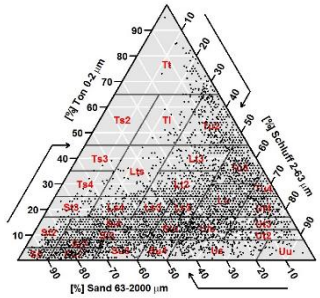
Analog data

Soil type catalog	30 +
Recording sheets	1000 +

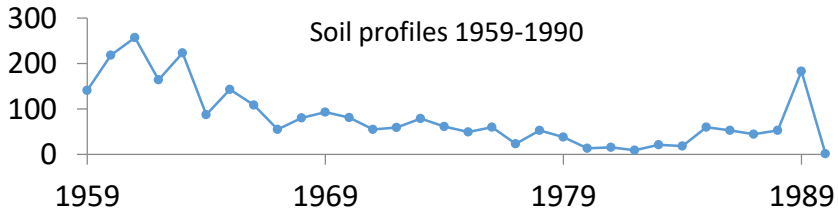








>5800 horizons with texture data

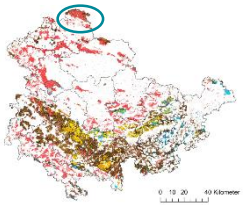


Questions

- Is there a spatial coincidence between certain forest site factors and calamity / loss of vitality detectable from space?
- Are there specific site factors that have an increased risk for degradation?

→ **Combine change detection based on Sentinel-2 derived vegetation indices with forest site factors**

- **aspect**
- **slope**
- **nFK (available water capacity)**
- **soil substrate**

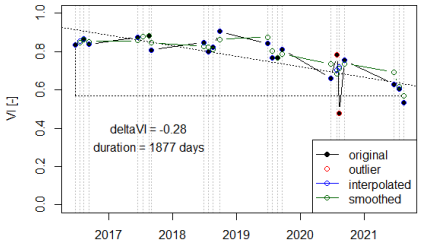


Workflow

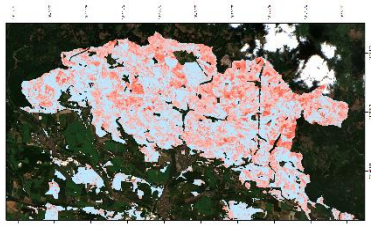
Sentinel-2 data
- years 2016-2021
- summer (Jun-mid Sep)
- atmospherically corrected (Level2A), cloud-masked

Multitemporal vegetation indices
- NDVI
- NDWI (Gao 1996)
- NDREI (Gitelson & Merzlyak 1994)

Succession-optimized index differencing routine
→ maximum period of (negative) trend per pixel



Composite difference image
per vegetation index



Forest site factors
- slope
- aspect
- nFK-levels
- soil substrate

Forest attributes

Intersection and statistical analysis

Succession-optimized image differencing

- Outlier detection and removal (adapted from Löw & Koukal)
- Linear interpolation and moving average smoothing
- Identification of maximum period with negative trend
- Composite difference image with ΔVI

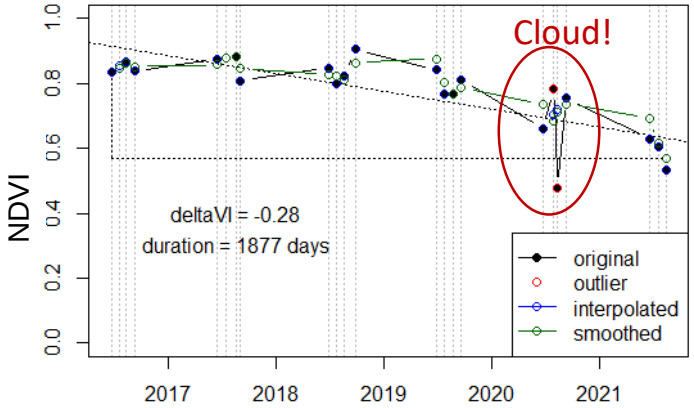
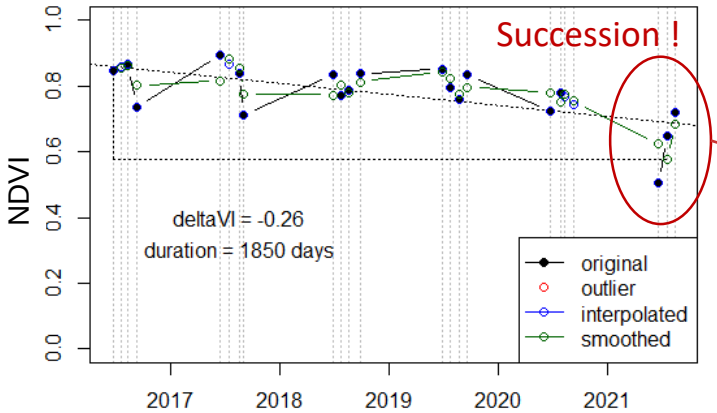
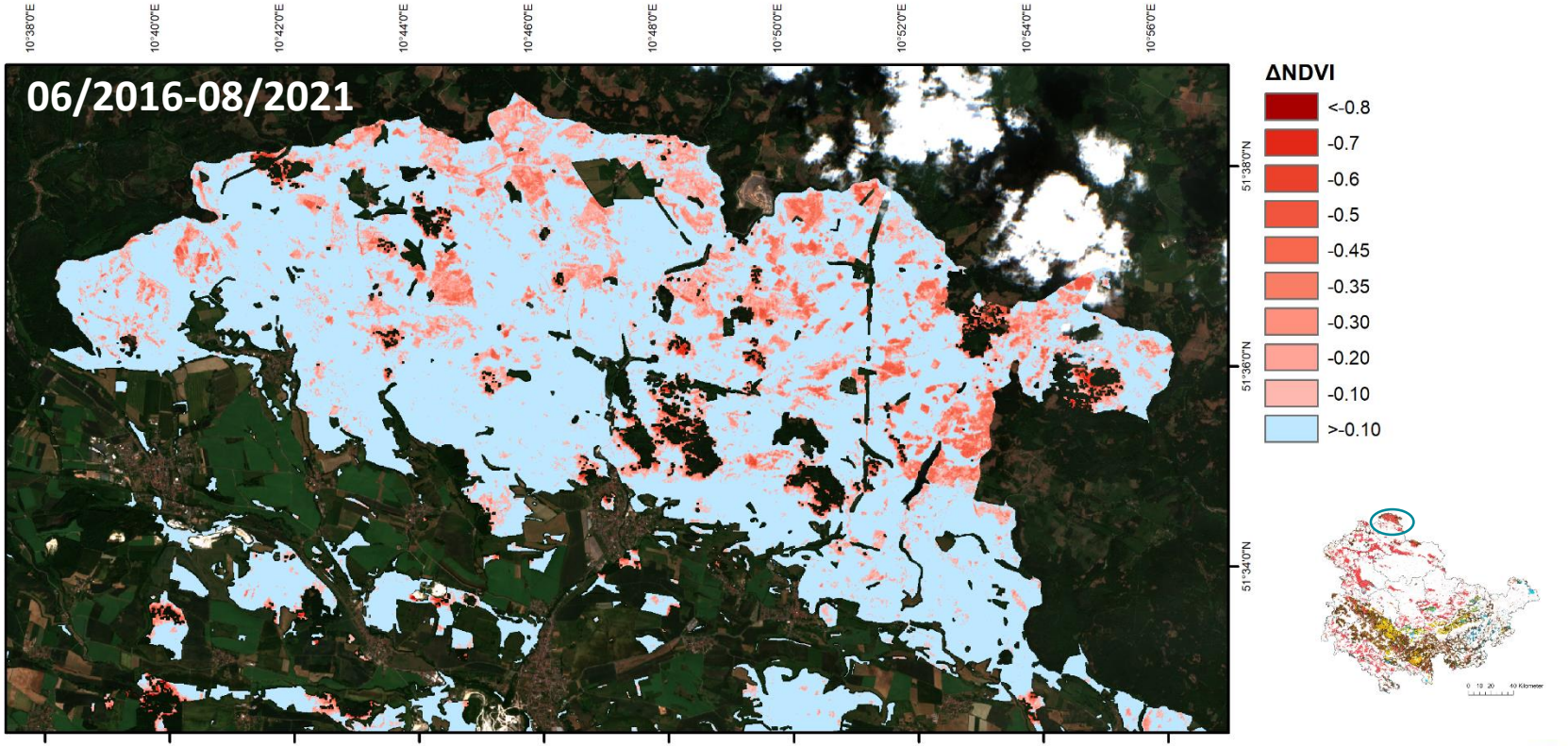


Photo: I. Profft, FFK Gotha



“Traditional” vs. succession-optimized image difference imaging



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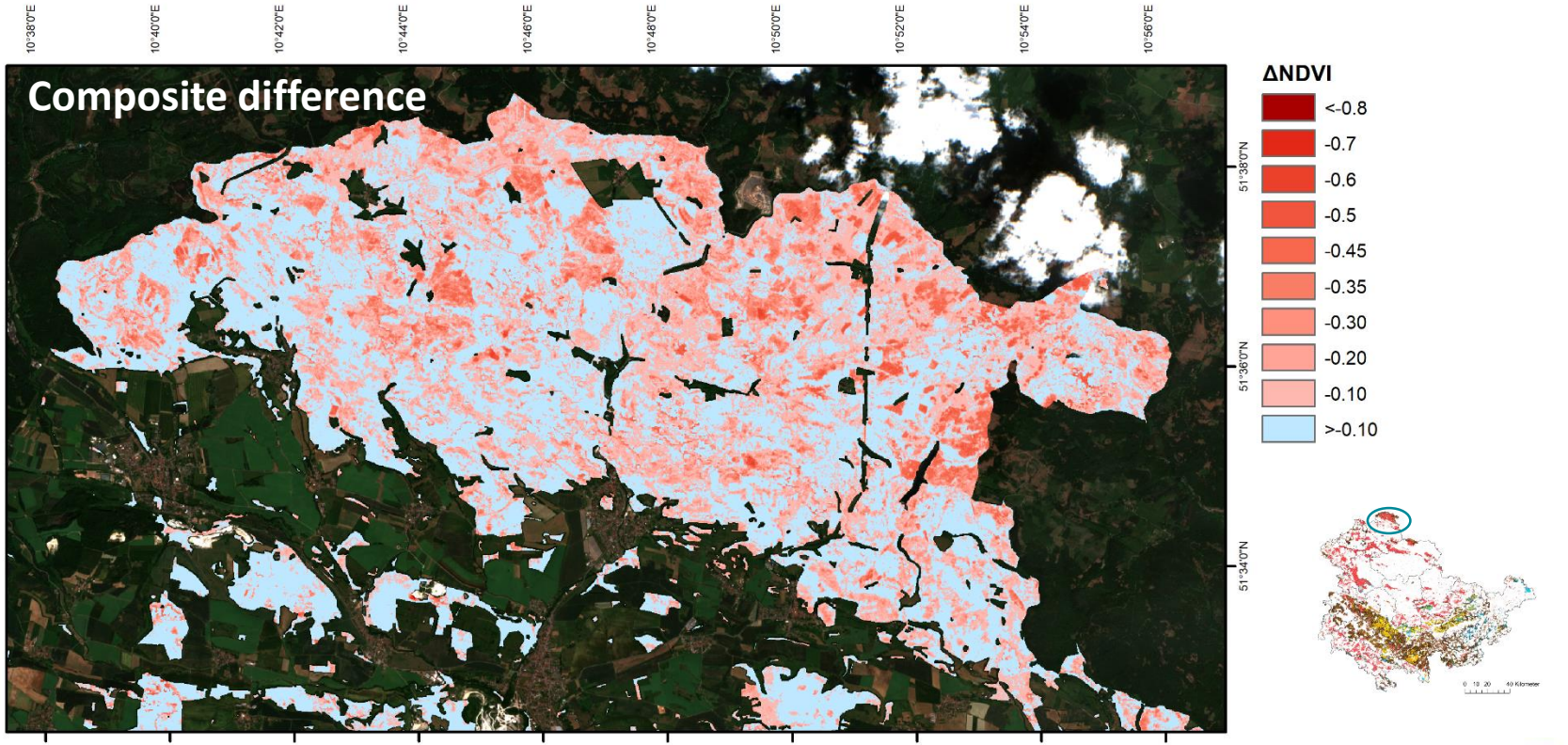
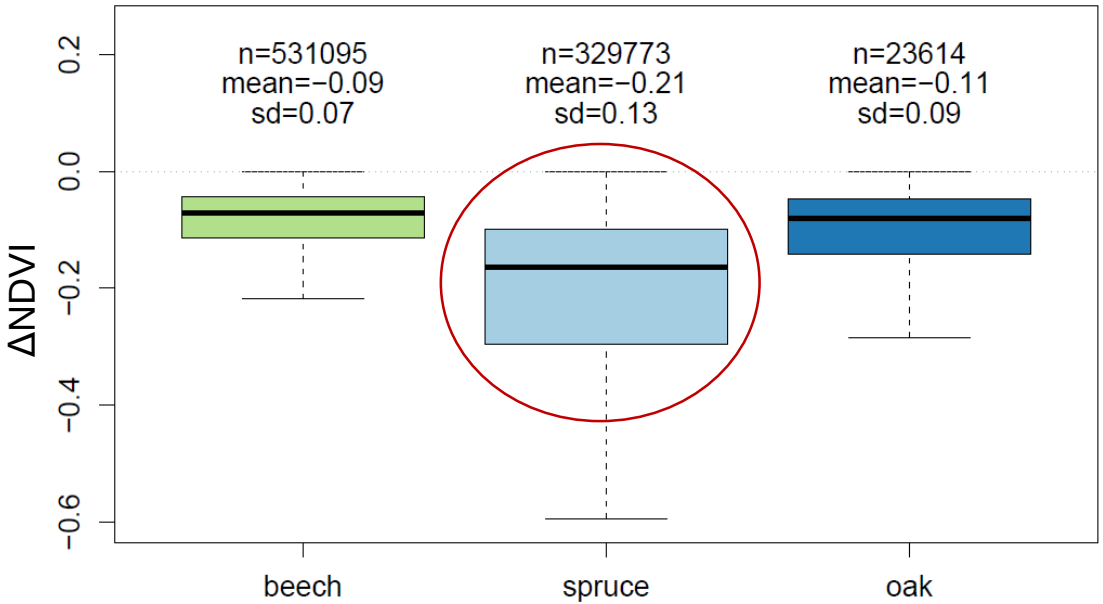
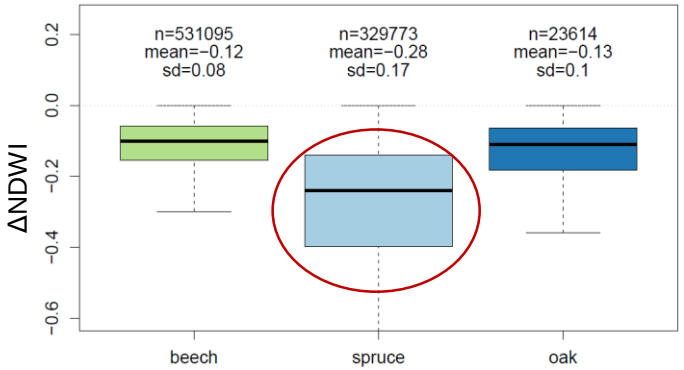
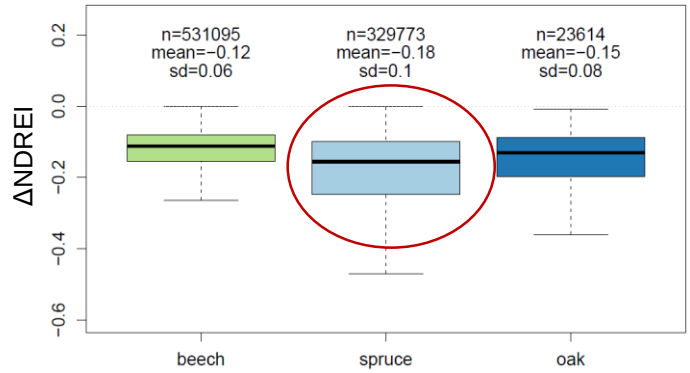


Vitaly loss per dominant trees species

- Highest losses for spruces due to recent bark beetle outbreaks, but deciduous species also degrading
- Minor differences between vegetation indices





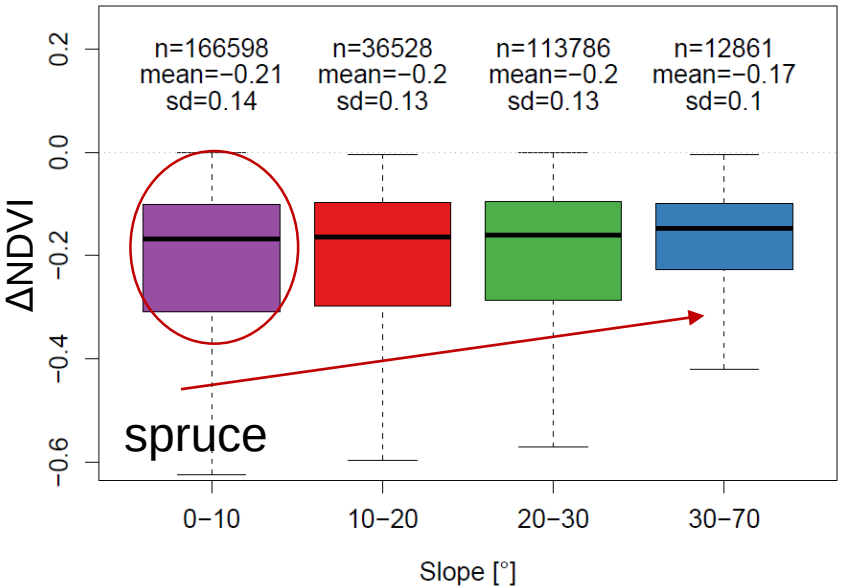


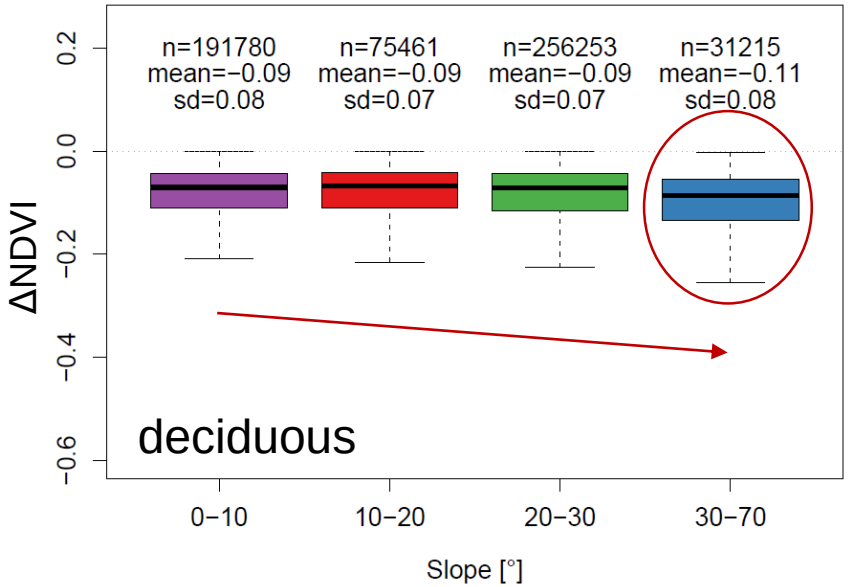
Influence of terrain slope

- Spruce with high vitality losses on flat areas, whereas beech more prone to vitality loss on sloped terrain

→ Beech and oak with deeper root system less prone to drought on flat terrain; spruce not well adapted on flat areas with deeper soils (?)

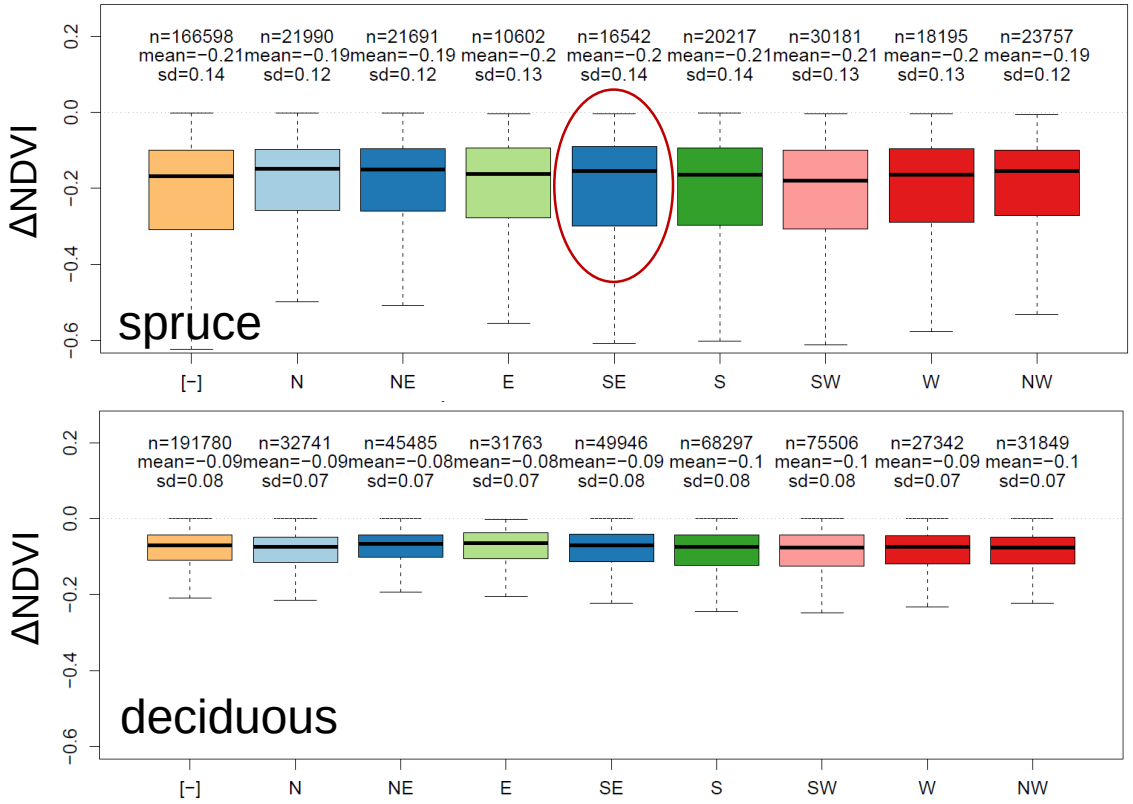
- Agreement among different VIs





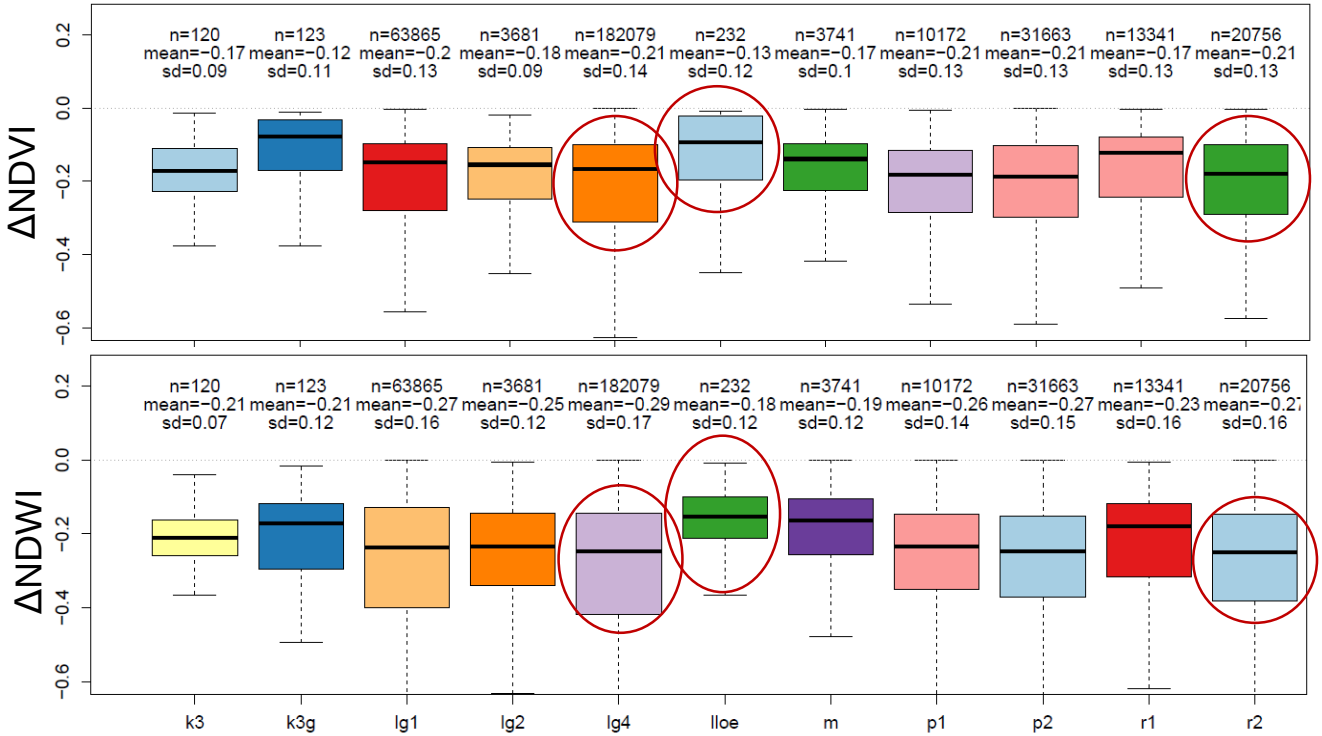
Influence of terrain aspect

- Southern slopes slightly more affected, especially spruce
- Deciduous forest with similar patterns as spruces forest but less pronounced
- Agreement among different VIs



Influence of soil substrate (spruce forest)

- Significant differences between most soil substrate classes
- Spruces on class “lloe” = “slope clay, loess-like” least affected
- Contrarily, spruces on skeletal soils (“lg4”,”r2”) heavily affected
- Difference of NDWI more sensitive → better response to water deficiency

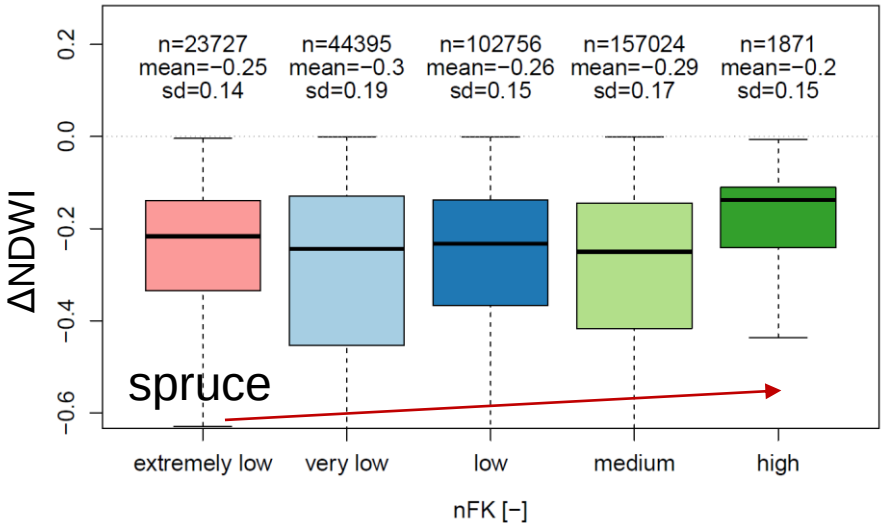


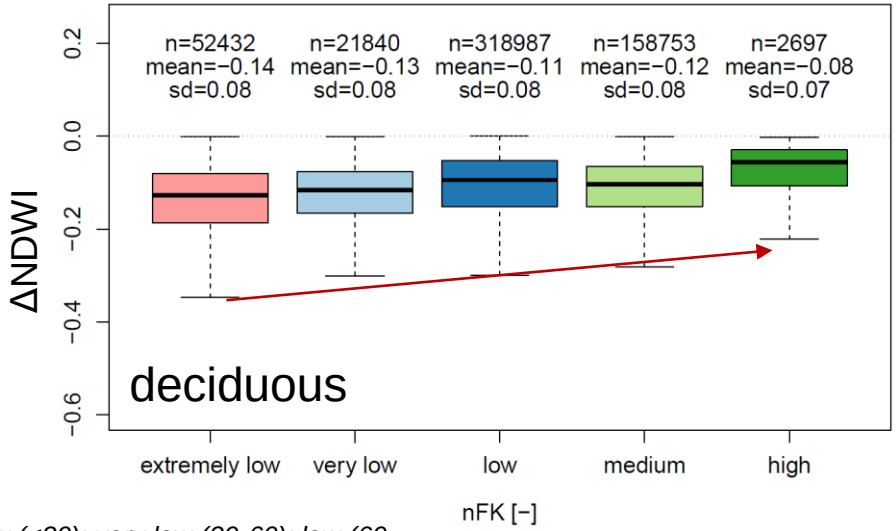
**abbreviations according to the legend of the soil geological overview map of Thuringia 1:100,000*

Influence of available water capacity (nFK)

- Agreement among different VIs: generally highest water availability with lowest vitality loss
- Deciduous trees clear trend from low to high, spruce more diverse

→ different underlying agents; quasi-randomized calamity with high bark beetle populations in spruce





**nFK-levels according to forest site factor mapping (2016) in mm: extremely low (<30); very low (30-60); low (60-90); 4= medium (90-120); high (120-180)*

Conclusions & Outlook

Lessons learnt:

- Image differencing approaches in forests should account for succession to avoid false positive change signal
- Strong explanatory potential of forest site factors for remote sensing observed vitality losses
  - Terrain factors (aspect, slope) with minor influences
  - Soil substrate and nFK with high influence on vitality loss
  - Choice of VI generally less important due to strong change signal, but site and species-specific

Next steps:

- In-depth analysis of the spatio-temporal dynamics - which spatial setting (soil, terrain) was affected first? Tipping points?
- Investigate potential of Sentinel-2 derived ECVs such as LAI and FAPAR as these variables can be better validated in the field (compared to VI values)

→ Remotely sensed change signal should be intersected with existing forest geoinformation to develop vulnerability maps according to stand properties

Thank you!

Contact:
Dr. B. Putzenlechner
Georg-August-Universität Göttingen
Institut für Geographie/ Kartographie, GIS und Fernerkundung
birgitta.putzenlechner@uni-goettingen.de

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