LANDSAT TIME SERIES ANALYSIS – The Impact of Forest Ecosystem History on Biodiversity

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Objectives

Relationship of ecosystem history and biodiversity in temperate forests in Germany.

1. Can trends, changes in trend or disturbances be detected in Landsat time series of temperate forests from 1985 to 2015?

2. Do disturbances and changes in trend affect herbal layer plant species diversity in temperate forests?
Study area & Project background
Methods – NDVI time series

- **USGS archive (3365 images)**
- **ESA archive (747 images)**
- **Georeferenced data**
- **LEDAPS**

**Mission**
- Landsat 5, 7 (ESA)
- Landsat 4, 5 (USGS)
- Landsat 7 (USGS)
- Landsat 8 (USGS)

**Julian Date**
- NDVI
- Mean NDVI for each EP
- Maximum of mean NDVI for each growing season

**Surface reflectance**
- Extraction of surface reflectance values

**CFmask**
- Calculation of NDVI
- Exclusion of cloud pixels (NDVI < 0.002)
- Mean NDVI for each EP
Methods – NDVI time series

**USGS archive** (3365 images)

- **ESA archive** (747 images)
  - Georeferenced data
  - LEDAPS

**Mission**
- Landsat 5, 7 (ESA)
- Landsat 4, 5 (USGS)
- Landsat 7 (USGS)
- Landsat 8 (USGS)

**Surface reflectance**

**CFmask**

- **Masking**
- Extraction of surface reflectance values
- Calculation of NDVI
- Exclusion of cloud pixels (NDVI < 0.002)
- Mean NDVI for each EP
- Maximum mean NDVI for each growing season
Methods – Time series analysis

- Test for significant upward or downward trend
  - Mann-Kendall trend test (Mann 1945)
  - R-package: Kendall (Davison and Hinkley 1997, Hipel and McLeod 2005)
Methods – Time series analysis

- Detection of breaking points and their magnitude in trend
  - Breaks For Additive Seasonal and Trend (BFAST) algorithm
  - R-package: bfast (Verbesselt et al. 2010 a, b)
  - Ordinary least squares residuals based MOving SUM (MOSUM) test (Zeileis et al. 2002)
Methods – Relationship of biodiversity index and time series parameter

- **Simpson’s diversity index** (Simpson 1949)
  - Plant cover estimations of species in the herbal layer in an area of 20x20m in all forest EPs in 2015 (Fischer et al. 2015)

- **Differences in Simpson’s diversity index** between plots with and without **breaking points** (Wilcoxon-Mann-Whitney test (Bauer 1972))

- Linear relationship between **Simpson’s diversity index** and **trend parameter**

![Graph showing NDVI and time series analysis with key points and measurements such as maximum, minimum, variance, mean, slope, root mean square error, and Kendall's tau.](image)
Results – Trend

- Kendall’s tau: **positive** between 0.31 and 0.82
- **Significant** at a significance level of 0.01 (44 trends) and 0.05 (3 trends)
Results – Breaking points

Magnitude of change: 0.033
Results – Breaking points

Magnitude of change: 0.152
Results – Breaking points

Magnitude of change: -0.072
Results – Relationship of biodiversity index and time series parameter

**Significant positive** linear relationship with Simpson’s diversity index:
- RMSE (Hainich)
  - R-squared: 0.15

**Significant negative** linear relationship with Simpson’s diversity index:
- Kendall’s tau (Hainich)
- Mean NDVI (Hainich, Schwäbische Alb)
- Minimum NDVI (Hainich)
  - R-squared: 0.04 – 0.20

(Significance level at 0.05 or 0.01)

- Not statistically significant (Wilcoxon-Mann-Whitney Test)
Discussion

Time series of EPs with significant breaking points in Hainich

Time series of EPs with significant breaking points in Schorfheide
Discussion & Conclusion

1. The combined Landsat time series of the archives of USGS and ESA can be used to analyze **ecosystem history** in temperate forests in Germany from 1985 to 2015.

2. Further research on the **relationship** between **Simpson’s diversity index** and **ecosystem history** is needed.

3. **Continuous forest cover management** in our study areas causes **small-scale, low magnitude disturbances**, which do not affect the greenness over several years.

→ **Analyses of the seasonal component**
   - Algorithms allowing for discontinuous time series data e.g. Continuous Change Detection and Classification (Zhu and Woodcock 2014)
   - Fusion of Landsat and MODIS time series to obtain dense, continuous time series e.g. Spatial and Temporal Adaptive Reflectance Fusion Model (Gao et al. 2006)
Thank you for your attention

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References

• Fischer, M., Schäfer, D., Boch, S., Biodiversity Exploratories, BeXIS Dataset Vegetation Records for Forest EPs, 2008-2015, V 1.2.2, ID 20366, University of Bern.
Acknowledgment

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• **Landsat archives**
  - Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) Surface Reflectance data courtesy of the U.S. Geological Survey.
  - Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) 1992 – 1999 Data provided by European Space Agency.
Picture credits

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