

Detecting vegetation impact due to construction events with semantically enriched Sentinel-2 time-series

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ZGIS



PARIS
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Background

ESG (environmental, social, governance) investing:

- Lack of standardised metrics

Example: **How a construction project affects local biodiversity/vegetation.**

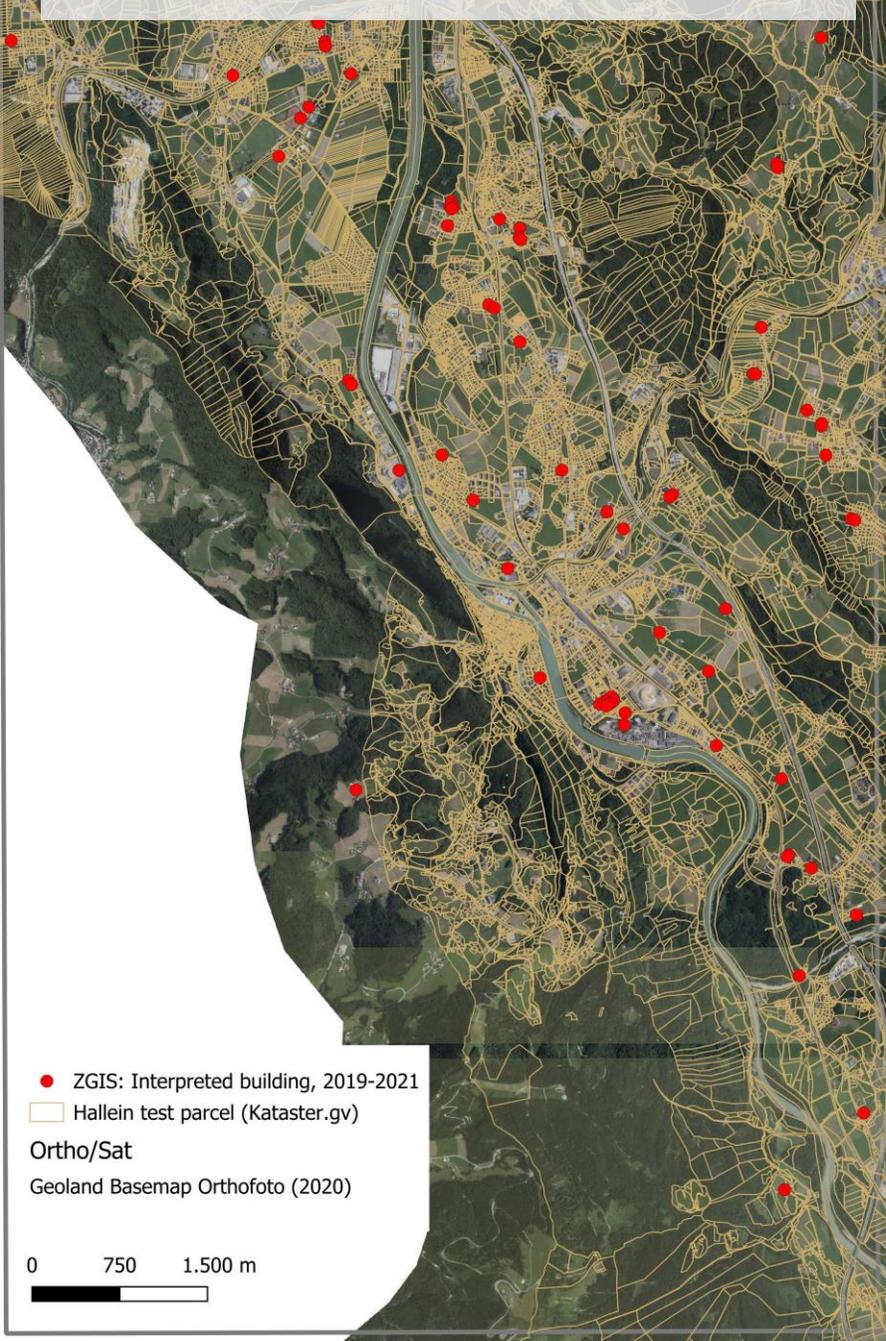
This work: Part of a SWOT analysis for Sentinel-2.

=> Nationwide monitoring?

Sen2Cube: Semantically enriched, Austria-wide Data Cube



Test area: Hallein, Austria



Reference data

Date	Imagery
27-Aug-2018	Planet, approx. 3m spatial resolution
26-Jul-2019	Pleiades, approx. 50cm spatial resolution
6-Aug-2020	Pleiades, approx. 50cm spatial resolution
Aug-2020	Geoland aerial Orthofoto, approx. 30cm spatial resolution [1]
13-Aug-2021	Planet, approx. 3m spatial resolution
Various	Google Earth – Maxar and others

- Cadastral data (bev.gv.at, 2023) [2]
- Manual interpretation, guided by GWR's Neuerrichtungen [3]

- [1] <https://www.data.gv.at/katalog/dataset/254757be-69ef-4a6c-a4c1-1432815d7522>
- [2] <https://data.bev.gv.at/geonetwork/srv/ger/catalog.search#/metadata/a513aa72-2921-4299-98ac-111cf7e54ba4>
- [3] <https://www.statistik.at/atlas/gwr-neuerrichtungen/>

2022-07-22 Sentinel-2, North Hallein, Austria



Contains modified Copernicus Sentinel Data, 2022

RGB

SIAM* Spectral Categories

Greenness index



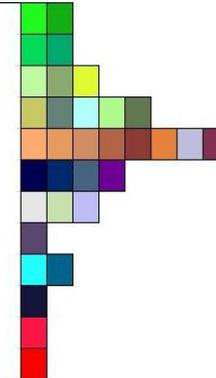
*Satellite Image Automatic Mapper

- Pixelwise
- (Spectral) knowledge-based
- Decision-tree algorithm
- Parameter-free

⇒ No training samples needed

⇒ Scalable geographically and computationally (Baraldi et al. 2010)

"High" leaf area index (LAI) vegetation types (LAI values decreasing left to right)
 "Medium" LAI vegetation types (LAI values decreasing left to right)
 Shrub or herbaceous rangeland
 Other types of vegetation (e.g., vegetation in shadow, dark vegetation, wetland)
 Bare soil or built-up
 Deep water, shallow water, turbid water or shadow
 Thick cloud and thin cloud over vegetation, or water, or bare soil
 Thick smoke plume and thin smoke plume over vegetation, or water, or bare soil
 Snow and shadow snow
 Shadow
 Flame
 Unknowns



$$= \text{Greenness}(R, NIR, MIR) \in [0, \infty)$$

$$= \max \{0, (NIR/R) + (NIR/MIR_{1.55-1.75}) - (R/MIR_{1.55-1.75})\}$$

≥ 0

(Baraldi et al. 2010)

$MIR \approx SWIR$

(Hartmann et al. 2023)



Parcel k.6133293

2018-08-10, Google Earth/Maxar

2019-07-26, Pleiades

2020-08-06, Pleiades

Area: 0.24ha

47.7014°N,13.0755°E

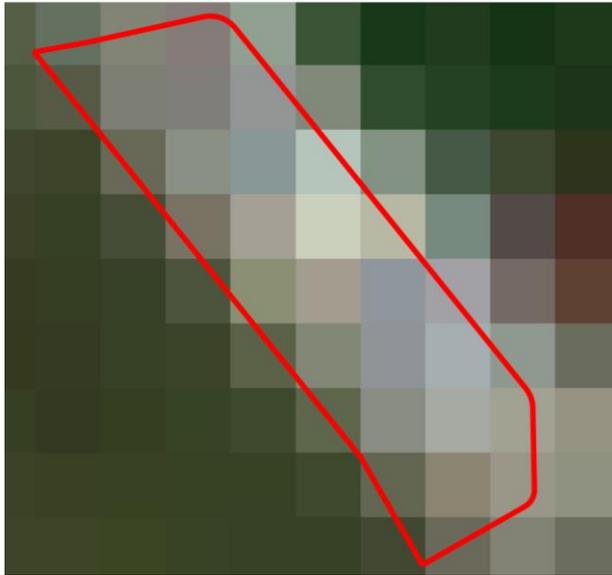
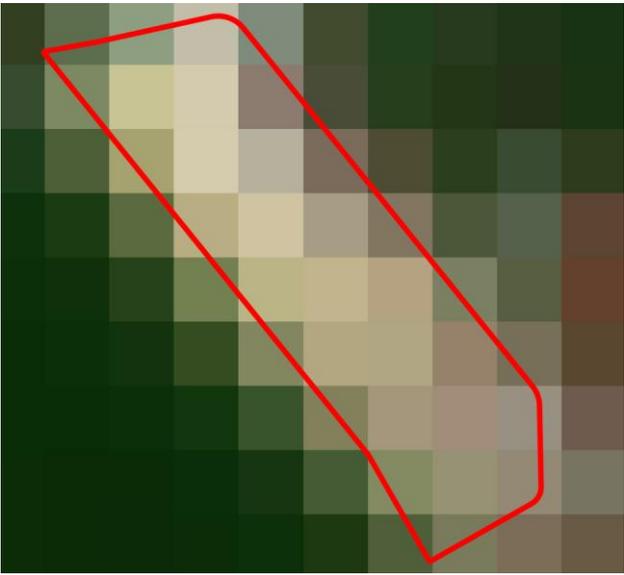


2018-08-12, S2 RGB

2019-07-23, S2 RGB

2020-08-06, S2 RGB

Sentinel-2: 25 pixels



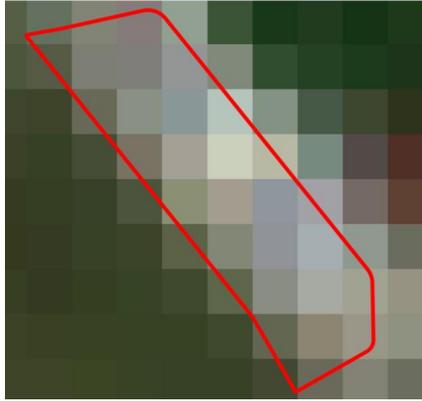
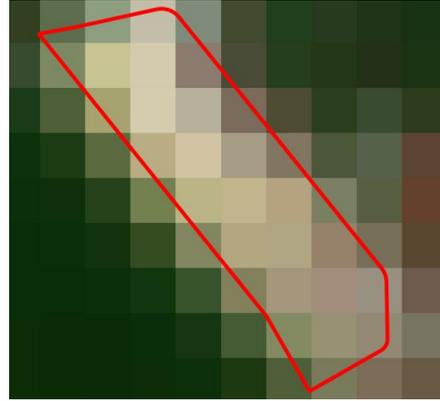
Parcel k.6133293

2018-08-12

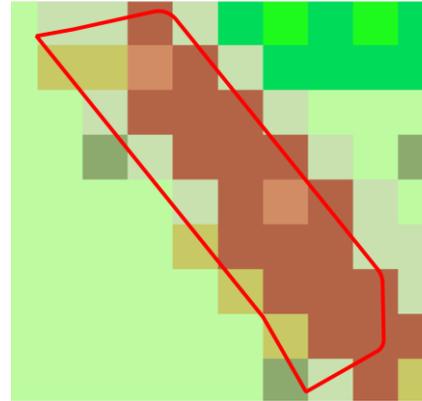
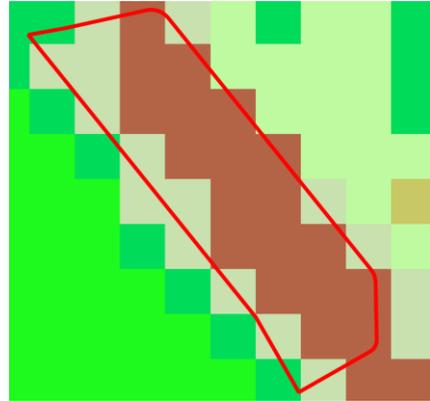
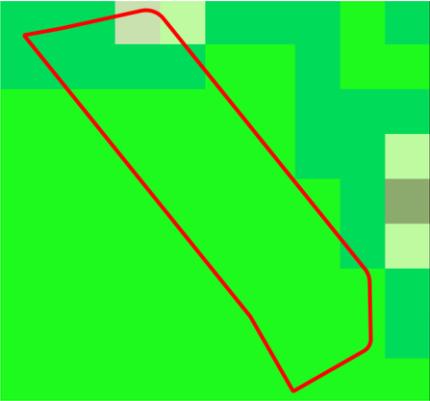
2019-07-23

2020-08-06

RGB

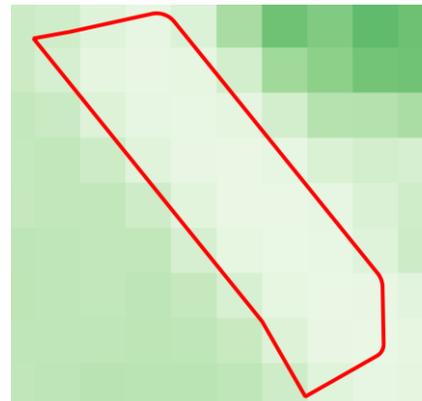
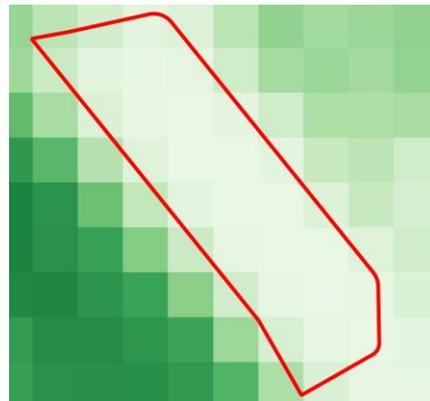
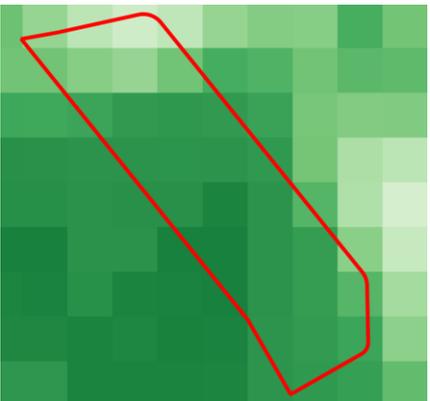


SIAM Spectral cats.



- Average Vegetation with High NIR
- Strong Vegetation with High NIR
- Shrub Rangeland with High NIR
- Shrub Rangeland with Low NIR
- Thin Cloud over Vegetation
- Strong Bare soil or Built-up
- Average Bare soil or Built-up
- Weak Rangeland

Greenness Index



Parcel *GreenScore*

Median Greenness Index * Percentage of parcel that is green

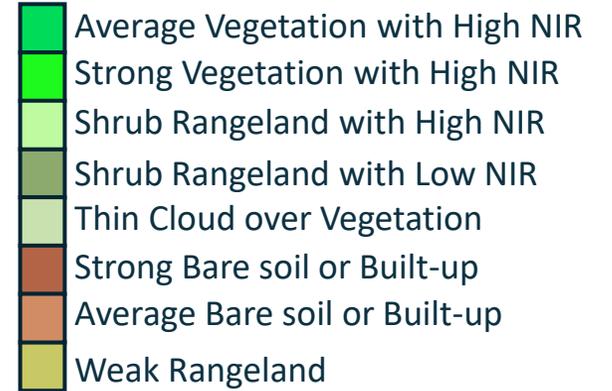
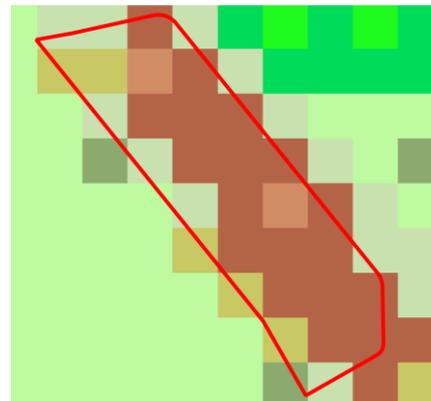
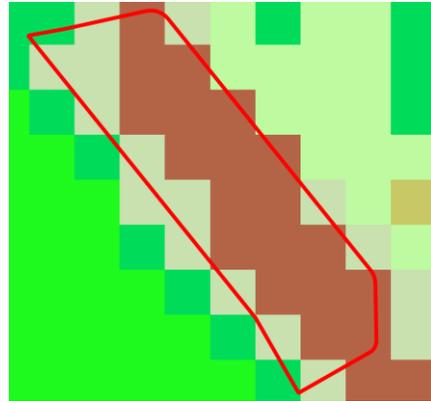
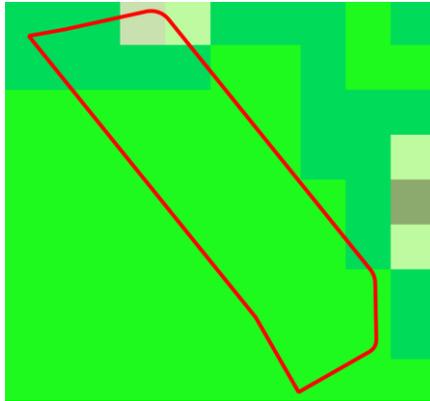
Parcel k.6133293

2018-08-12

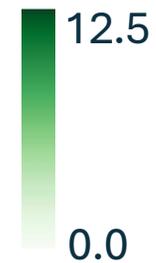
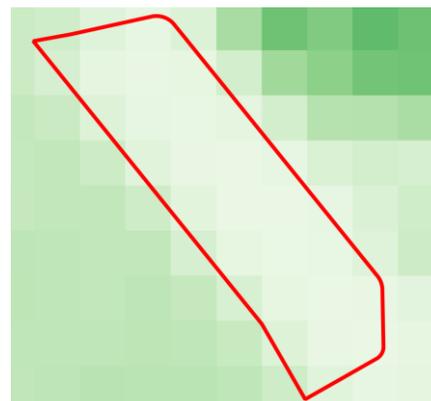
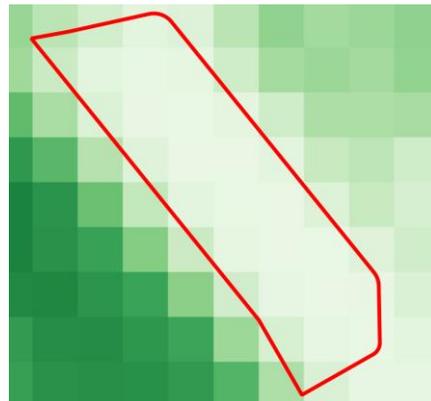
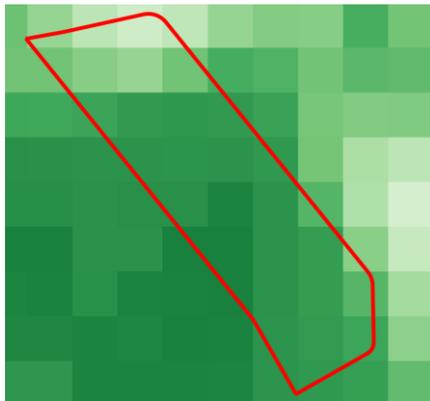
2019-07-23

2020-08-06

Spectral cats.



Greenness Index



GreenScore

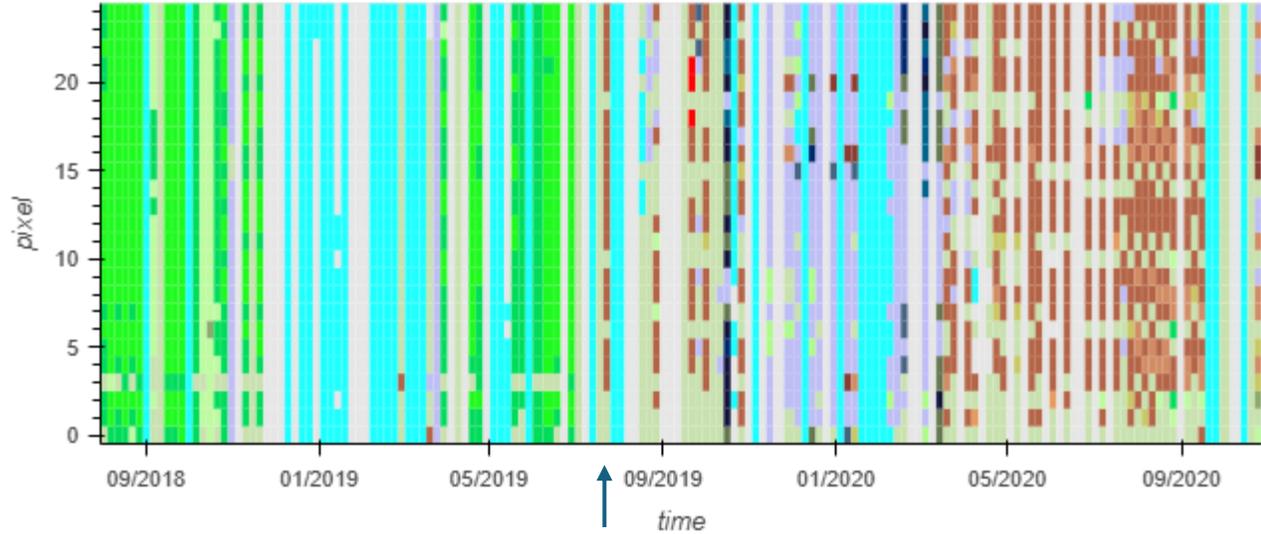
$8.0 * 96 = 768$

$1.0 * 0 = 0.0$

$1.0 * 12 = 12.0$

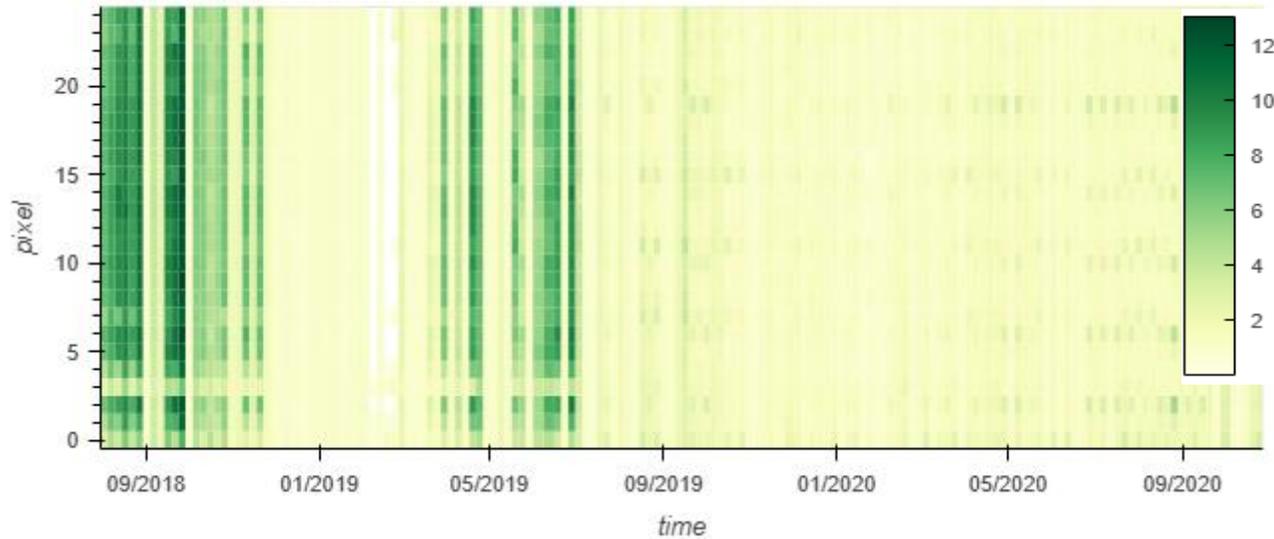
Parcel k.6133293, 2D -> 1D

Categories



Construction started

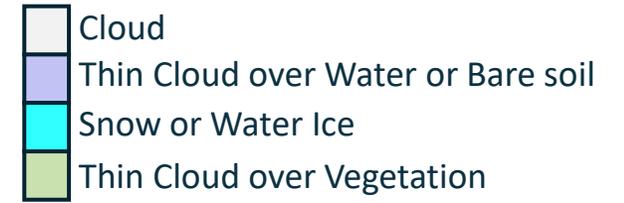
Greenness



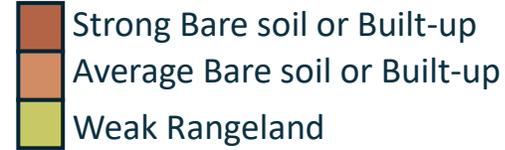
Vegetation



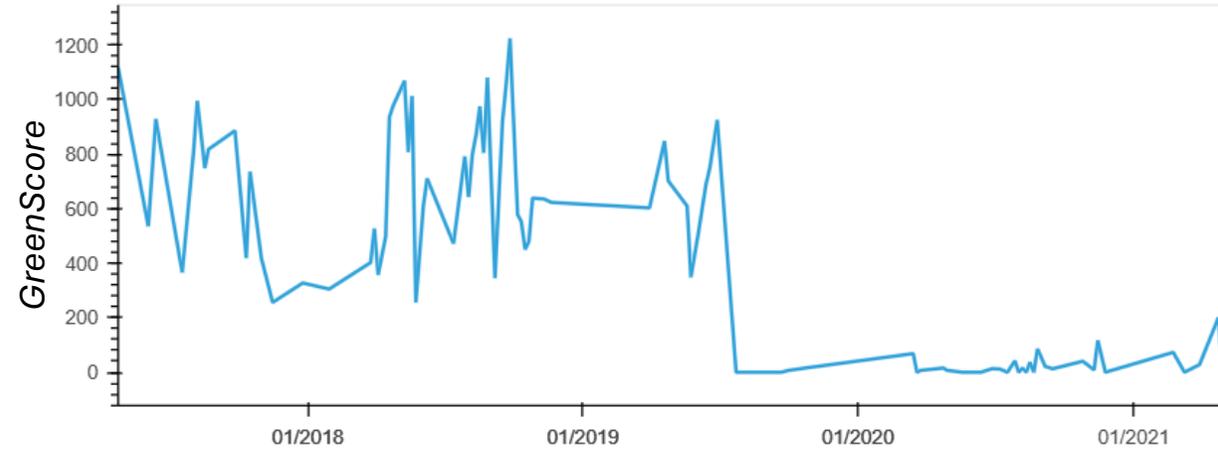
Cloud/snow/ice filtering

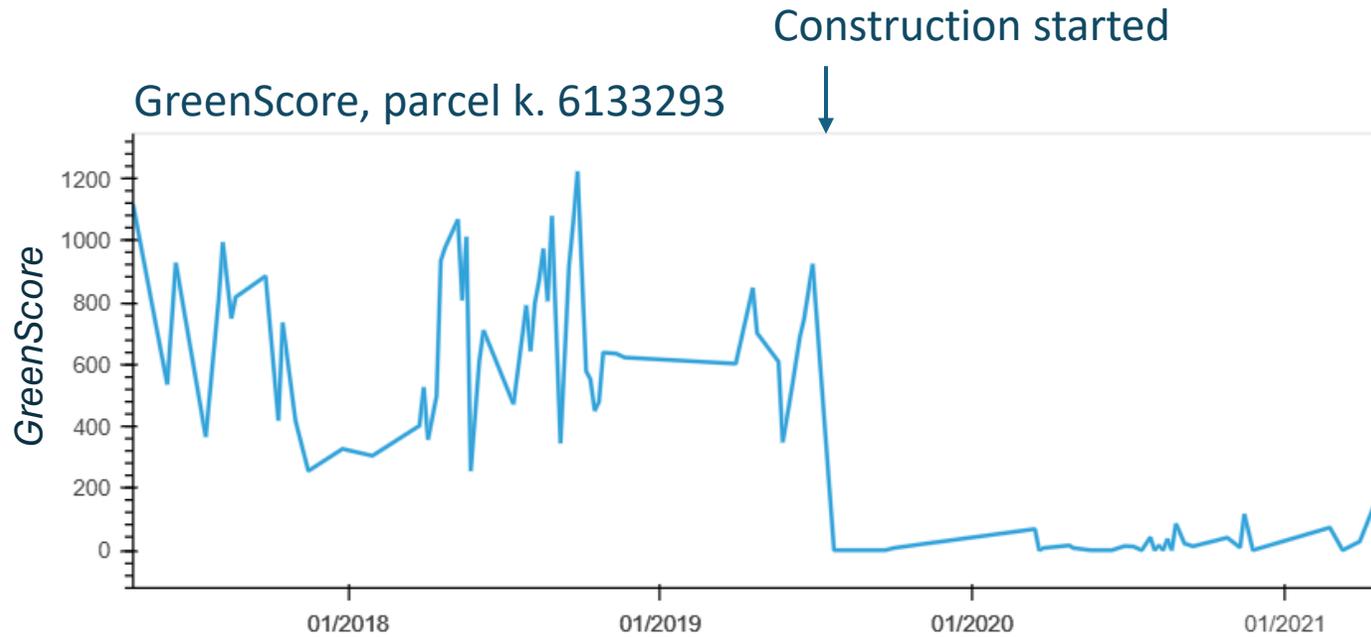


Not vegetation



GreenScore





Q: How to get stable before and after values?

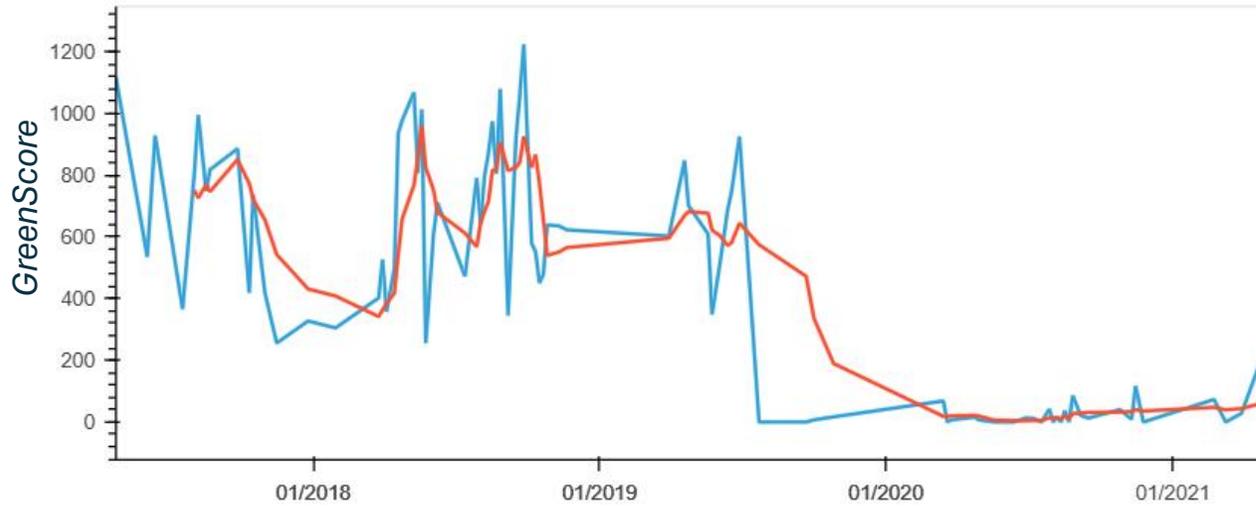
A: Some kind of smoothing filter

Goals:

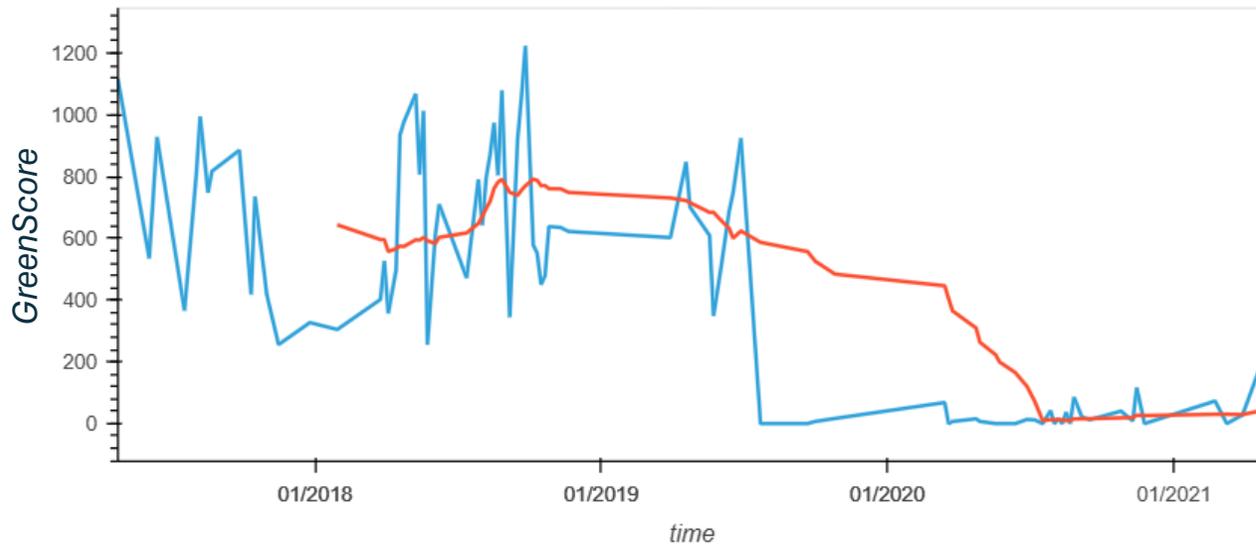
- Highlight long-term changes.
- Suppress short-term variances.
- Suppress seasonal effects.

Moving average?

GreenScore, parcel k. 6133293



- GreenScore (orig.)
- Moving average, window size = 5

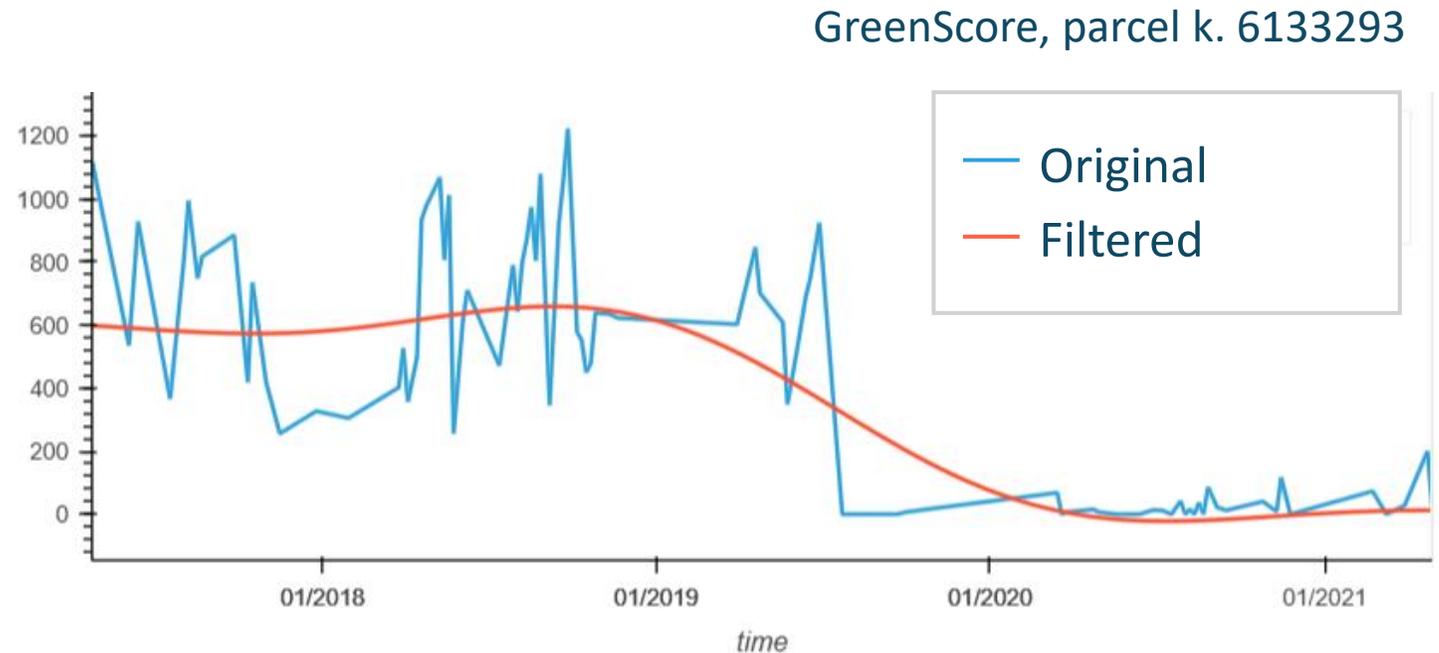
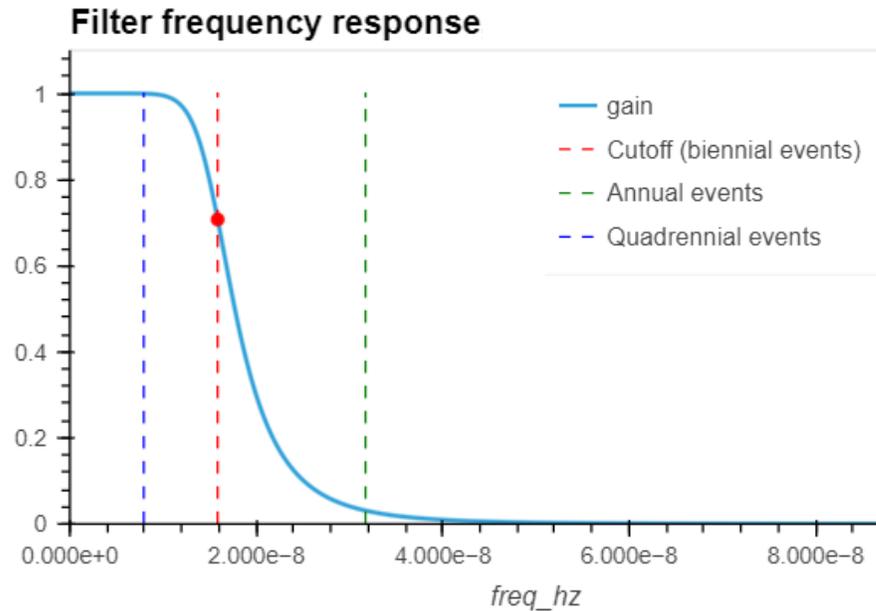


- GreenScore (orig.)
- Moving average, window size = 15

Still jumpy; longer lag; running out of data

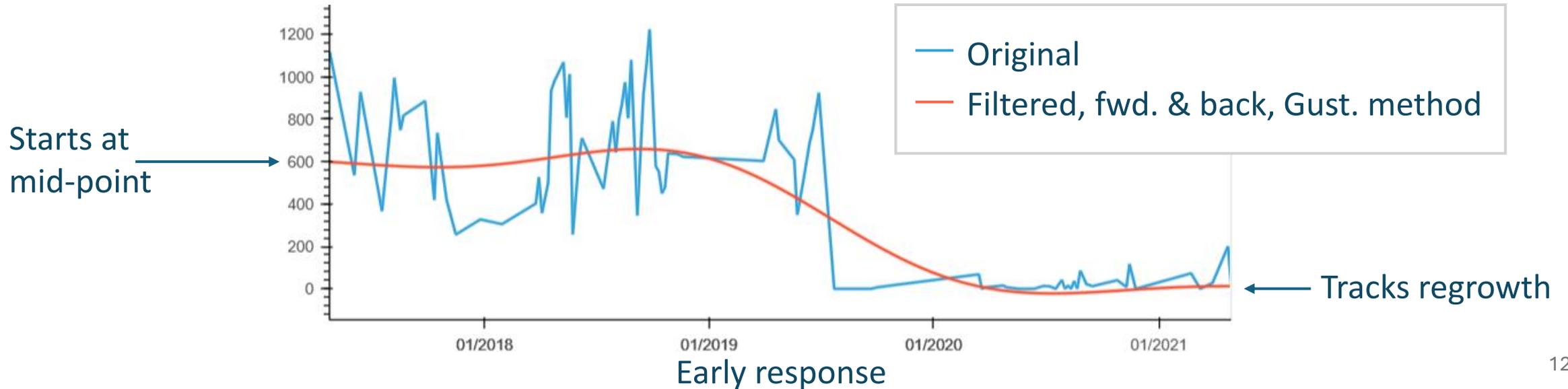
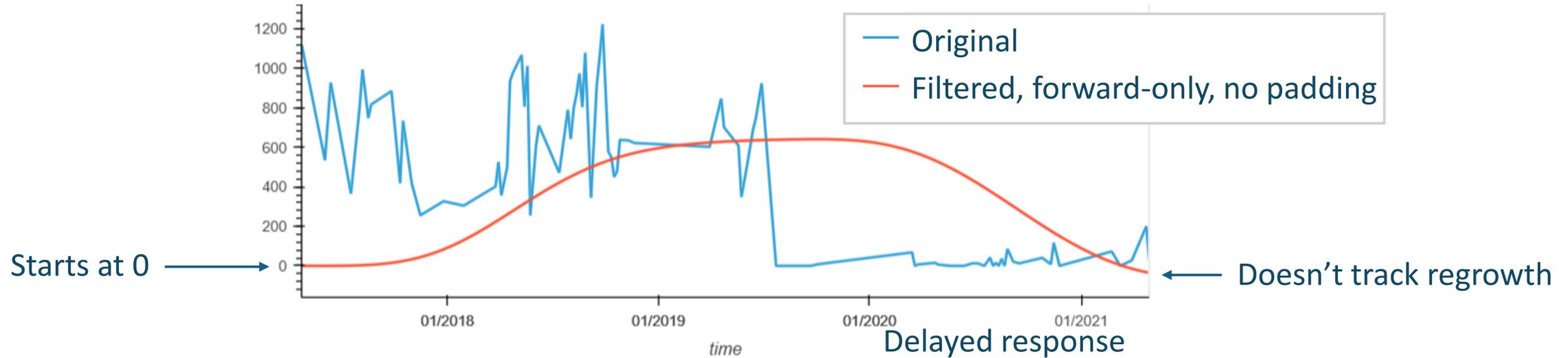
Butterworth filter

- 5th order Butterworth low-pass.
- Cutoff: $\sim 2 \cdot 10^{-8}$ Hz (two-yearly). (v. important because of limited data)
- Forward & backward passes (*SciPy's* `filtfilt`).
- Initial conditions set using Gustafsson's method (1996).
- Requires regular sampling period



Forward-only, without Gustafsson's Method

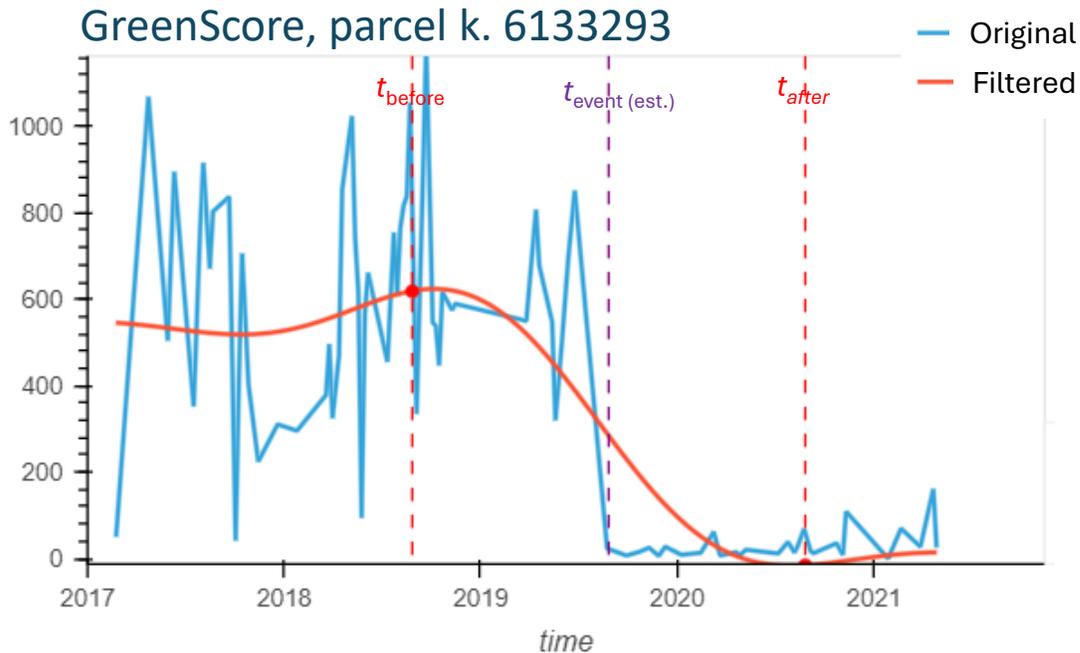
GreenScore, parcel k. 6133293



GreenImpact

- Measure smoothed GreenScore signal 'before' and 'after' estimated construction start*, take the difference.

*Approx. one year either side. Signal is still subject to lag: intrinsic properties of signal processing + natural phenomena



Green score 365 days before: 618.5,
Green score 365 days after: -15.6.

GreenImpact: 634.1

Note:

- For particularly impactful events, the smoothed GreenScore can go negative, temporarily.

(Based on earlier version with less strict cloud filter.)

Construction event estimate

Principle:

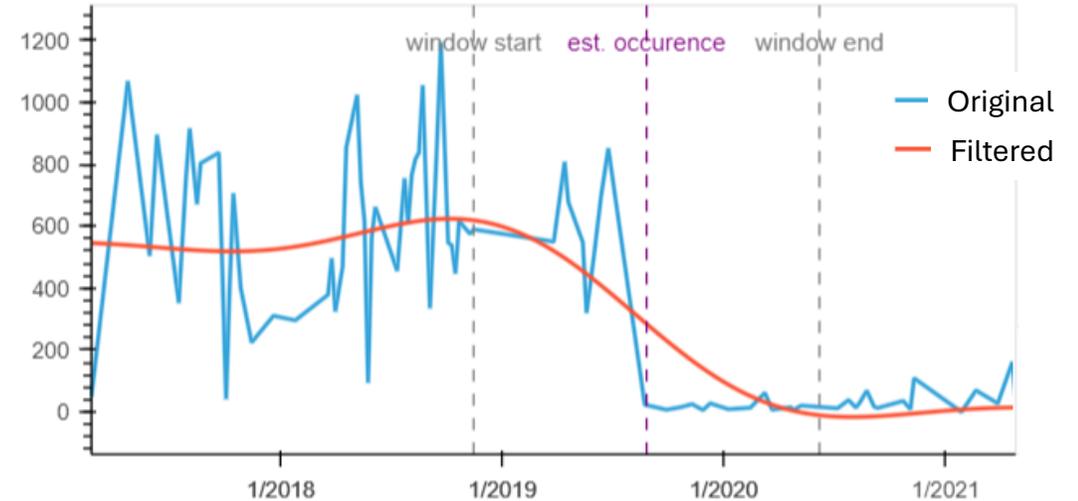
- Detect significant declines of GreenScore.

Implementation:

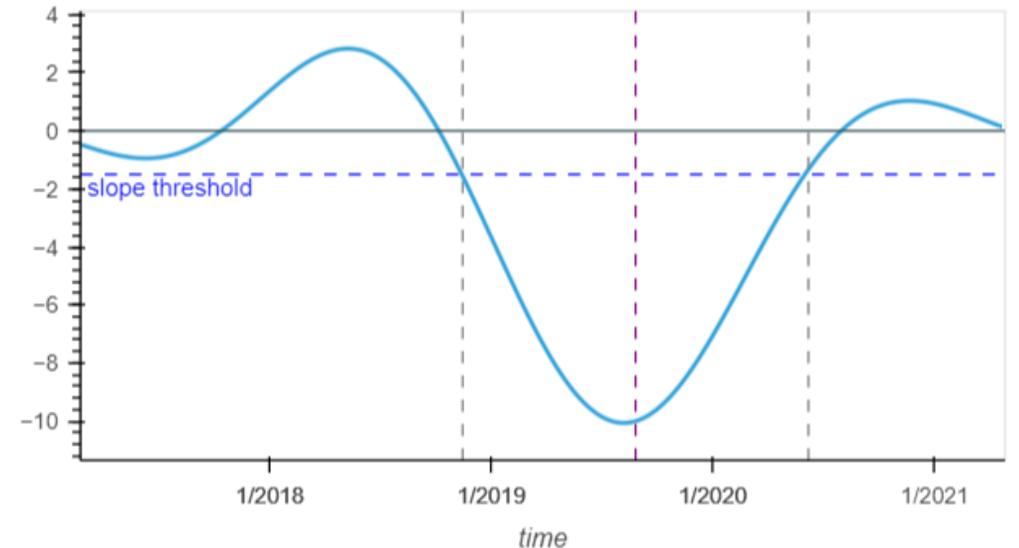
- Take the gradient of the filtered signal.
- When it's below a threshold for a certain amount of time, an event window is indicated.
- Estimate the actual event start by taking the midpoint of the window (this attempts to correct for time offsets due to filtering).

No veg. decrease => no event detected.

GreenScore, parcel k. 6133293



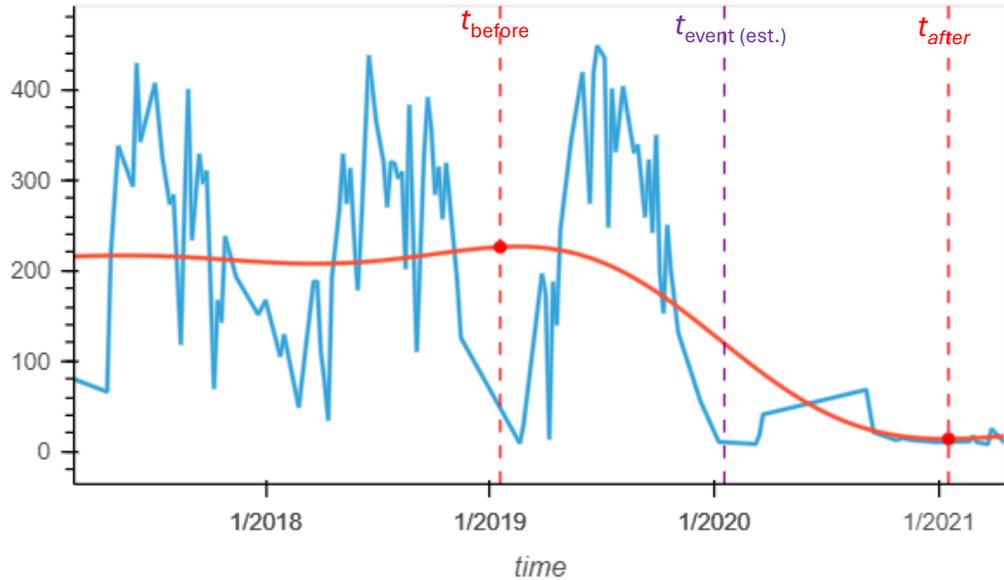
GreenScore Gradient



Further examples (1)

k.6170334, area: 0.2ha
47.6872°N,13.0935°E

GreenScore, k.6170334



Green score 365 days before: 226,
Green score 365 days after: 13.99.

GreenImpact: 212

Pleiades 2019-07-26



Pleiades 2020-08-06



— Original
— Filtered

Notes:

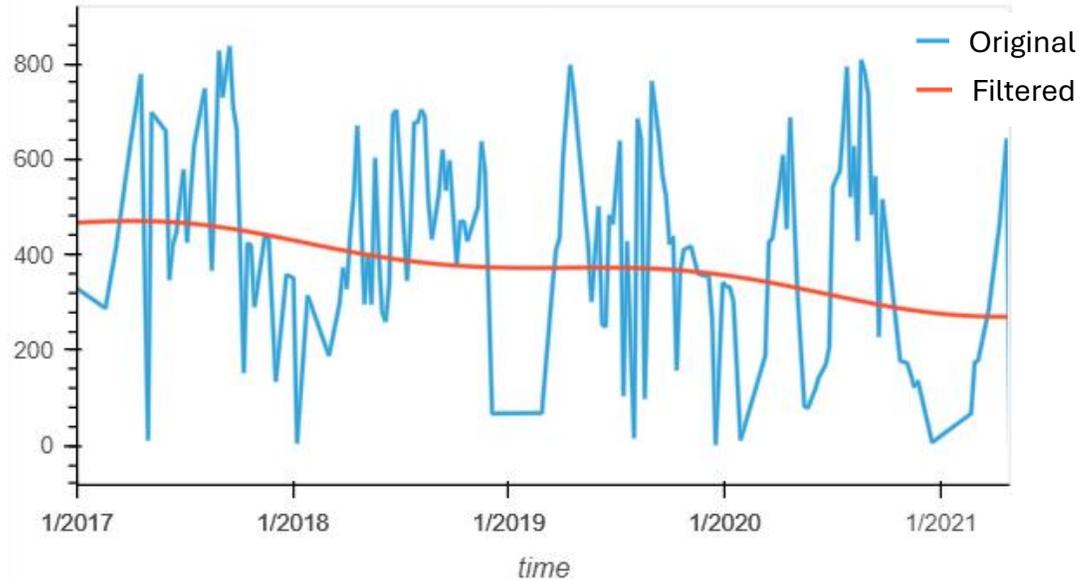
- The Pleiades images show clear development work in the time between them; our detected, estimated event start also falls between these dates.
- Seasonal effects are highly apparent in the unfiltered signal.

Further examples (2)

k.6133797, area: 5.25ha

47.6841°N,13.1123°E

GreenScore, k.6133797



No events detected.

Pleiades 2019-07-26



Pleiades 2020-08-06



Notes:

- This is a typical agricultural parcel, with no known development. While there is a downward trend in GreenScore, it is not rapid enough to trigger the event detector.

Limitations and discussion points

- Parcel size & pixel grid alignment. Doesn't work well for small parcels, e.g., in Vienna.
- Need approximately 1 year of data both sides of an event for reliable impact assessment.
- Tricky to calibrate and validate (precise green area, quality & timing needed).
- Evergreen vs deciduous bias (evergreen have higher average greenness).
- Not a metric for biomass (only LAI).
- Biodiversity more complicated than LAI alone.
- Once construction begins, we assume sudden changes to the surface (over 1-2 months), rather than gradual changes.
- Parameter-free, Sentinel-2-based => applicable ~worldwide?
- Useful for measuring impact of, e.g., forest disturbance?

Acknowledgements

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References

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