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

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1. Introduction

Investing with Environmental, Social, and Governance (ESG) principles in mind can be difficult, given a lack of standardised metrics and methods to calculate them. One such example is the impact of construction projects on the environment of the surrounding area, potentially leading to habitat destruction and consequential loss of biodiversity. We propose using a proxy for this derived from earth observation data (EO) – the vegetated greenness of a cadastral parcel – and monitoring its change over the course of associated construction events. We assessed the capabilities of open and free Copernicus Sentinel-2 data for measuring this, using the Austrian semantically enriched EO data cube platform, Sen2Cube (https://sen2cube.at), and some classical signal processing techniques. A pilot study was conducted in the area of Hallein, Austria.

2. Methodology

The semantic enrichment of the Sen2Cube platform consists of pixel-level spectral indices, similar to the normalized difference vegetation index (NDVI), and *spectral categories*, based on spectral signatures, assigned using a decision tree algorithm (Sudmanns et al., 2021). Spectral categories were used to model the vegetated, non-vegetated, and obscured (by cloud or snow) parts of a parcel. A median greenness spectral index (of Baraldi et al., 2010) was calculated for the vegetated pixels, and multiplied by the proportion that these make up of the total parcel area. We term this, *GreenScore* (1).

$$GreenScore = greenness_{median} \times \frac{area_v}{area_t}, \qquad (1)$$

where $area_v$ = vegetated area of parcel
$area_t$ = total area of parcel

We aimed to calculate approximate stable levels of vegetation pre- and post-construction for comparison, but seasonal (phenology) and atmospheric variances, e.g., haze, led to *GreenScore* time-series based on Sentinel-2 observations that were often erratic (see, e.g., Figure *1*). To this end we evaluated several low-pass filtering techniques, resulting in a digital forward-backward 5^{th}-order Butterworth filter design, which compensates for annual seasonal effects, short-term atmospheric variances, and is somewhat resilient to observation irregularity caused by cloud/snow.

The timeline of a construction project is a crucial piece of information for assessing pre- and post-event greenness levels; unfortunately, there is limited available data for this. As such, we devised an approach for estimating construction event start times, based on the gradient of the smoothed *GreenScore* signal: Construction activities such as ground clearing, and the appearance of building materials, machinery and temporary structures lead to a rapid, significant drop in a parcel's *GreenScore* (as demonstrated in Figure *1*); when the gradient drops below a threshold for a specified amount of time, an event is flagged.

The smoothed *GreenScore* is measured at a point before the event start, and after, accounting for lag introduced by the filtering process and duration of construction (which we assume to be fixed at approx. 1 year). We term the difference of these, *GreenImpact* (2).

$$GreenImpact = SGS_{after} - SGS_{before}, \qquad (2)$$

where SGS_{after} = smoothed *GreenScore* 1 year after event start
SGS_{before} = smoothed *GreenScore* 1 year before event start

The Hallein test area covered approx. 47.62°N to 47.73°N, 13.03°E to 13.13°E. Five high resolution optical imagery sources were available, spanning August 2018 to August 2021. From these, construction events were identified, via manual interpretation. This information was then used to validate our approach, with a series of spot checks. At present, only a qualitative analysis has been performed, regarding the loss of vegetation.

3. Results and discussion

For the test parcels where construction events were identified, the calculated *GreenImpact* correlates a with the loss of vegetation, as demonstrated in Figure 2. We were able to identify significant drops in vegetation associated with construction events in parcel areas covered by as few as four Sentinel-2 pixels, but with high uncertainty due to mixed pixels.

The approach has several limitations. For one, we modelled construction events as having a fixed 1 year duration, when calculating *GreenImpact*. This was based on exploratory analysis, but we later identified some projects lasting several years for which we couldn't accurately assess the impact. Also, as an indicator for biodiversity impact, *GreenImpact* alone is not enough – the problem is much more complex, and ideally species information, morphology and other environmental factors would be incorporated into a broader indicator.

Overall, we found that despite the low spatial resolution of Sentinel-2 pixels relative to the size of a typical parcel, the 5-day revisit time was able to compensate for this in many cases.

4. Illustrations

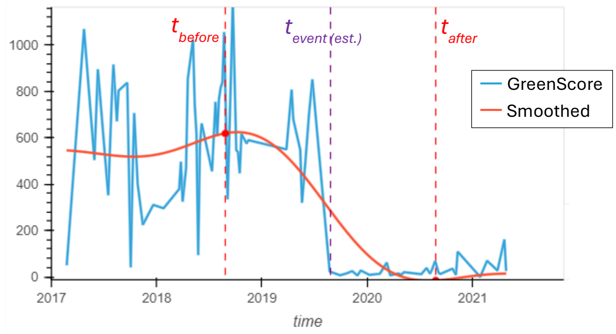

Figure 1. *GreenScore* profile for a Hallein sample parcel of 0.24ha., corresponding smoothed signal, and estimated event timings used as input for the *GreenImpact* calculation.

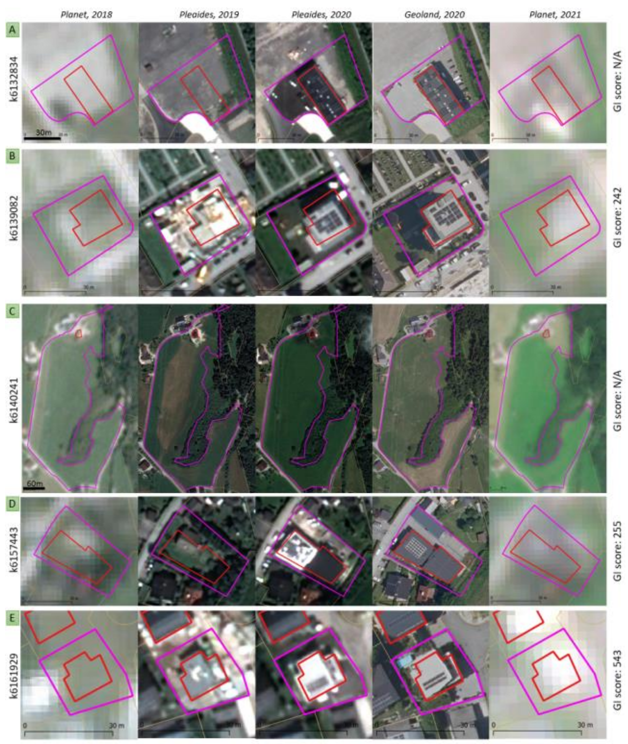

Figure 2. A selection of spot-checked construction events in the Hallein test area, and their calculated *GreenImpact* scores. N/A indicates too low to be detected. Red polygons are constructed building footprints, and purple polygons are the associated subject parcels. Reference imagery © Planet Labs, 2018-2021; CNES 2019-2020; geoland.at 2020.

5. Acknowledgements

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