The influence of spatial resolution of Normalized Difference Vegetation Index (NDVI) data on greenness exposure misclassification

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Background

Research analyzing associations between urban vegetation and health commonly use NDVI to assess exposure to overall vegetation or greenness. We analyze how spatial resolution of data impacts greenness exposure assessment in relation to buffer size and decisions on variable construction.

Data & Methods

Greenness datasets
2016 Summertime NDVI (July 15th–August 15th) derived from 4 remote sensing data products: National Agricultural Imagery Program (NAIP). Sentinel-2, Landsat 8 OLI-TIRS, and MODIS 16-day data product.

Figure 1. NDVI data at different spatial resolutions

Exposure assessment
- Greenness exposure was estimated for 31,280 children (5-18 years old) living in the Greater Boston Area, Massachusetts, USA in 2016.

- Exposure estimates derived for each NDVI product using:
  - 4 buffer sizes: 50m, 250m, 500m, and 1000m radii.
  - 4 categorical exposure variables: 2, 3, 4, and 5 quartile cutoffs.

Statistical analysis
- Inter-rater reliability assessment framework to quantify differences in exposure estimates.
- Continuous estimates: Agreement and consistency intraclass correlation coefficients (ICC, 2-way mixed models).
- Categorical estimates: Agreement across all NDVI datasets evaluated using Light’s kappa, a multivariate metric of accuracy.
- Misclassification analysis: Pairwise assessment of change in quartile positions relative to NAIP data.

Results

Figure 2 shows the distribution of greenness exposure estimates from the four NDVI datasets by buffer size.
- Estimates from NAIP (highest resolution) were lower than Sentinel-2, Landsat 8, and MODIS (coarser resolution) data, respectively.
- 50% of NAIP estimates were ≤0, while 100% of estimates from MODIS, Landsat 8 and Sentinel-2 estimates were >0.

Figure 2. Distribution of NDVI estimates by buffer size

Table 1 shows ICC of agreement and consistency between continuous NDVI exposure estimates by buffer size.
- Agreement was poor (<0.5), while consistency ranged from fair (0.5-0.7) to excellent (>0.9).
- Both agreement and consistency increased with buffer size, indicating estimates were more alike at larger buffer sizes.

Table 1. Intra-class correlation coefficients (ICC): agreement and consistency

<table>
<thead>
<tr>
<th>Buffer Size</th>
<th>ICC (2-way)</th>
<th>95% CI</th>
<th>ICC (2-way)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.233**</td>
<td>0.020 - 0.445</td>
<td>0.796*</td>
<td>0.658 - 0.882</td>
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</table>

** Significant at p<0.05. * Significant at p<0.1.

Figure 3 shows Light’s kappa values for all NDVI data products across buffer sizes, indicating agreement between categories of exposure. Agreement was higher with larger buffer size and less number of quartile classes (Fig. 3).
- Agreement ranged between 0.41 (50m buffer, 5 classes) to 0.88 (1000m buffer, 2 classes).

Figure 3. Agreement in categorical NDVI estimates across buffer sizes

Figure 4 shows changes in quantile positions of greenness exposure derived from Sentinel-2, Landsat 8, and MODIS data in relation to the high resolution NAIP data. Plots are organized by buffer size in rows and number of classes of categorical variables in columns.
- MODIS showed the greater proportion of participants that changed at least one position in their exposure category, ranging between 13% (1000m buffer, 2 classes) and 61% (50m buffer, 5 classes).

Figure 4. Change in quantile position relative to NAIP (1m) data by buffer size

Conclusions

- Greenness exposure estimates are not invariant to spatial resolution, data treatment, aggregation area, and categorical structure of variables.
- Higher resolution NDVI data yielded lower greenness estimates, suggesting greater ability to differentiate non-vegetated surfaces in predominantly urban areas.
- Exposure misclassification increases with coarser spatial resolution and greater number of classes in categorical variable, while decreases with greater buffer size.
- Differences between categorical exposure estimates are most sensitive at smaller buffers and greater number of classes.
- The use of 250m MODIS data in urban settings led to the greatest exposure misclassification when used to assess greenness in close proximity of participants’ residences.
- We recommend the use of high resolution NDVI for estimating greenness exposure at smaller buffer sizes to capture small scale heterogeneity in land cover.
- Researchers should consider NDVI spatial resolution in relation to buffer size and variable structure to reduce exposure misclassification in epidemiological studies.

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