Grassland management change over 25 years: A landscape analysis using remote sensing

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1. Introduction

Decline in insect biomass is an emerging issue of concern. The complexity of natural biosystems over such long periods of time make a comprehensive understanding of all the relevant factors difficult to achieve. Key drivers in this trend likely span a variety of influences at the landscape scale, including changes in habitat brought about by anthropogenic activity (e.g., urbanization, agriculture, and cultural behavior). Characterizing change in landscape over time as it relates to insect habitat can provide one piece to the larger puzzle of insect decline.

We describe applying novel remote sensing image processing methods to capture landscape-level changes in grassland management over a 25-year period near Krefeld and Wahnbachtal, Germany. Locations were specifically selected to correspond to insect trap locations in the Hallmann *et al* study[1].

2. Materials and methods

Each study area was based on a 10km radius from center locations in Krefeld and Wahnbachtal, Germany encompassing 300 km^2 (Figure 1). Polygons of land parcels from 1989 were utilized within a GIS, selecting parcels corresponding to grassland areas (e.g., parks, natural grassland, pasture, meadows, and hay fields).

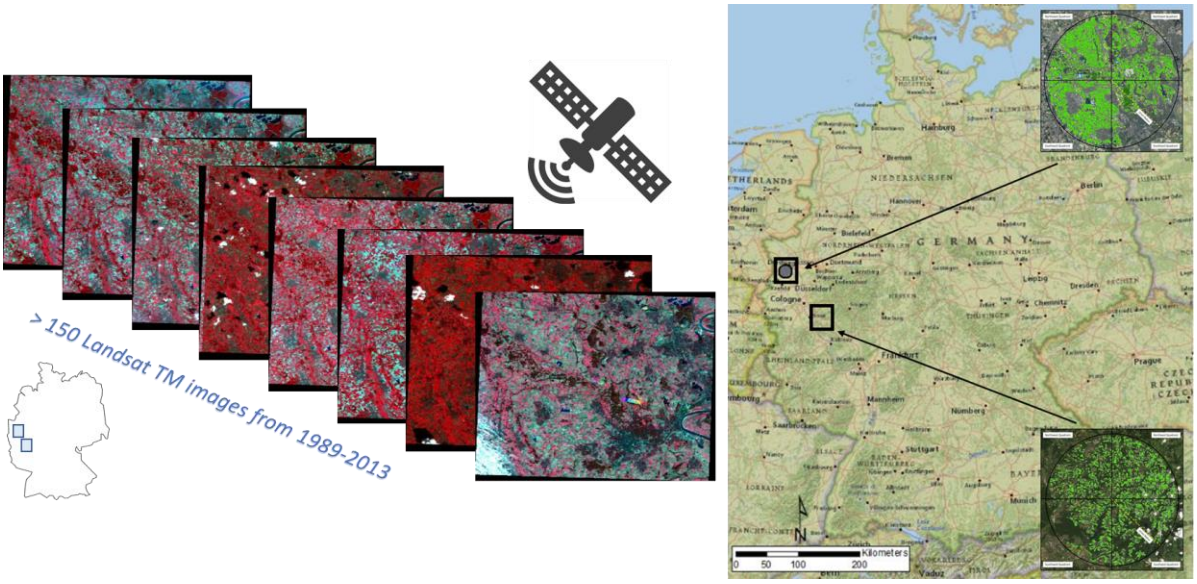

Figure 1: Location of two study areas containing grassland parcels

For each site, over 150 satellite images from 1989 to 2013 across all seasons were acquired from NOAA's Landsat program. Images within each year were normalized for atmospheric and illumination variation to focus on vegetation changes due to plant structure and vigor which was quantified using different vegetation indices based on visible and infra-red wavelengths. Similar groups of grassland fields were identified using a k-means clustering algorithm using spectral information within and across years. This produced clusters that had the greatest within-cluster similarity and between-cluster separability. The distinctness of the clusters was assessed using Tansformed Divergence and also confirmed using an independent statistical analysis (Elbow Method and Gap Statistic Method). Year to year variability due to widespread weather effects (e.g.,

drought) was removed to focus on parcel-level changes. K-means clustering was performed with three vegetation indices to assess consistency in clustering.

3. Results and discussion

In the Krefeld study area, four clusters of grassland parcels (818 parcels) were identified with separate vegetation and temporal characteristics (Figure 2, left); in Wahnbachtal five distinct clusters (1367 parcels) were separated (Figure 2, right). The assignment of grassland parcels to clusters was consistent across three vegetation indices providing increased confidence in the cluster assignment.

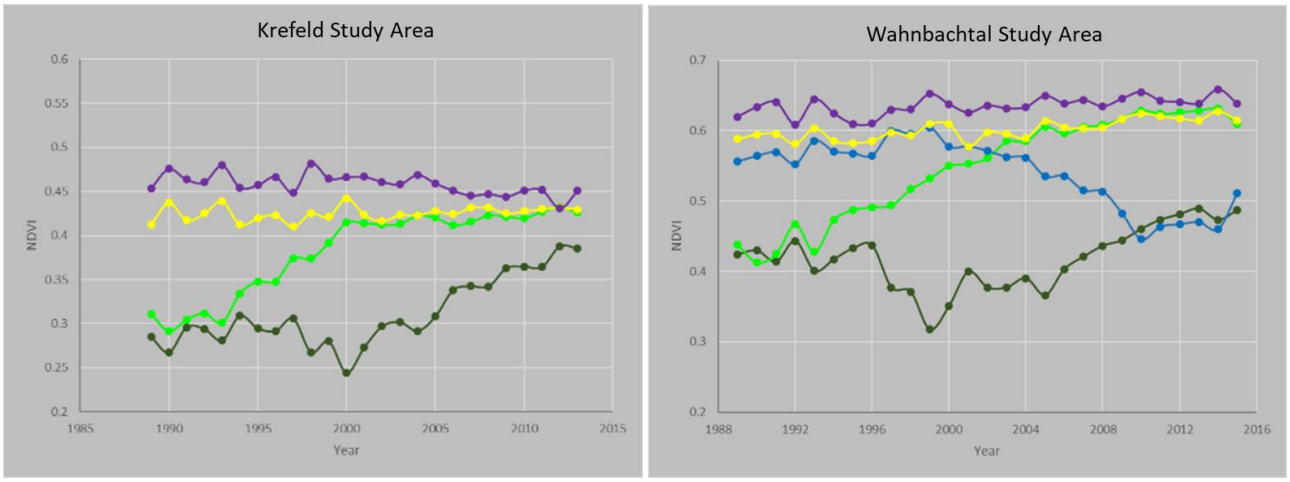

Figure 2: Vegetation biomass for distinct clusters of grassland parcels over 25 years

In Krefeld, three distinct patterns emerge in grassland biomass (as quantified by the NDVI vegetation index). Two clusters of grassland parcels remain fairly constant over 25 years, representing 67% of the grassland area studied. Parcels in the light green cluster (17% of grassland area) start to increase in biomass in the mid-1990's, reaching the levels of the consistent clusters around year 2000. The dark green cluster (16%) remains fairly constant until the early 2000's and then increases to almost the level of the other clusters by 2013.

Similar patterns can be observed in Wahnbachtal with the light green cluster (8.3% of grassland area) exhibiting increasing biomass starting in the early 1990's and matching the high biomass clusters around 2004. Further analysis of this cluster using three sub-clusters (Figure 3) reveals additional temporal patterns indicating that each of the three sub-clusters increases in biomass at different time periods. Analysis (not shown) also demonstrated that variability within each cluster decreased over time.

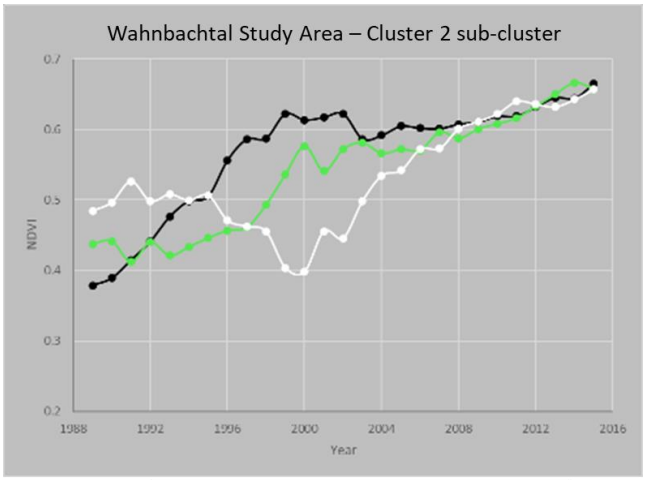

Figure 3: Sub-clustering of Wahnbachtal Cluster 2

4. Conclusions

Periods of distinct increase in vegetation biomass (defined by vegetation indices) may indicate changes in grassland management practices over that time to include more intensive management activities (e.g., fertilization, more frequent cutting, silage production). Other groups showed relative consistency over time. In addition, the decrease over time of variability in parcel biomass within clusters indicates less diversity of grassland habitats and likely reduction in insect biodiversity. Further investigation of results is ongoing.

5. Reference

[1] Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, et al. (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLOS ONE 12 (10): e0185809. https://doi.org/10.1371/journal.pone.0185809