Describing landscapes by statistics of local pattern features:

application to landscape regionalization, change, and search
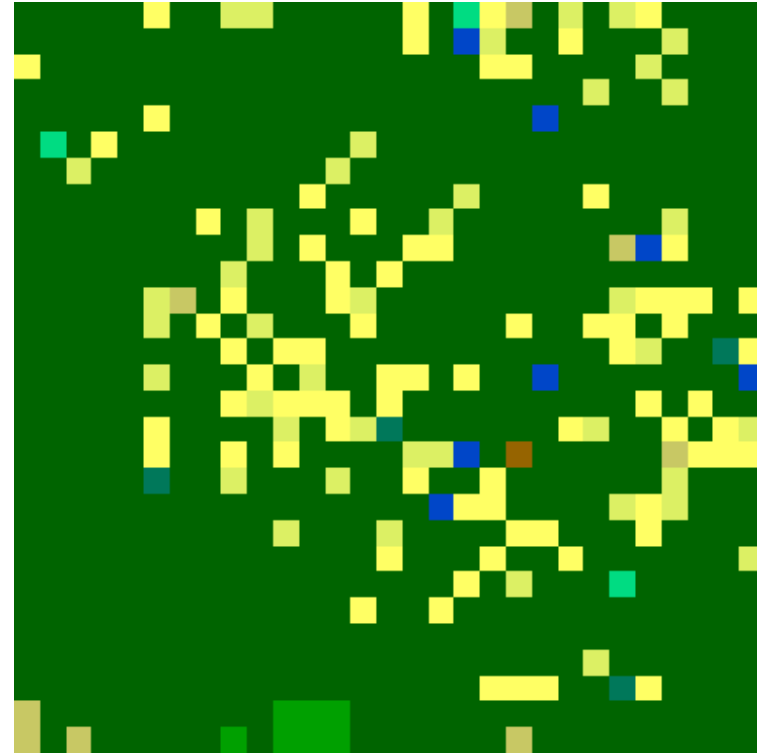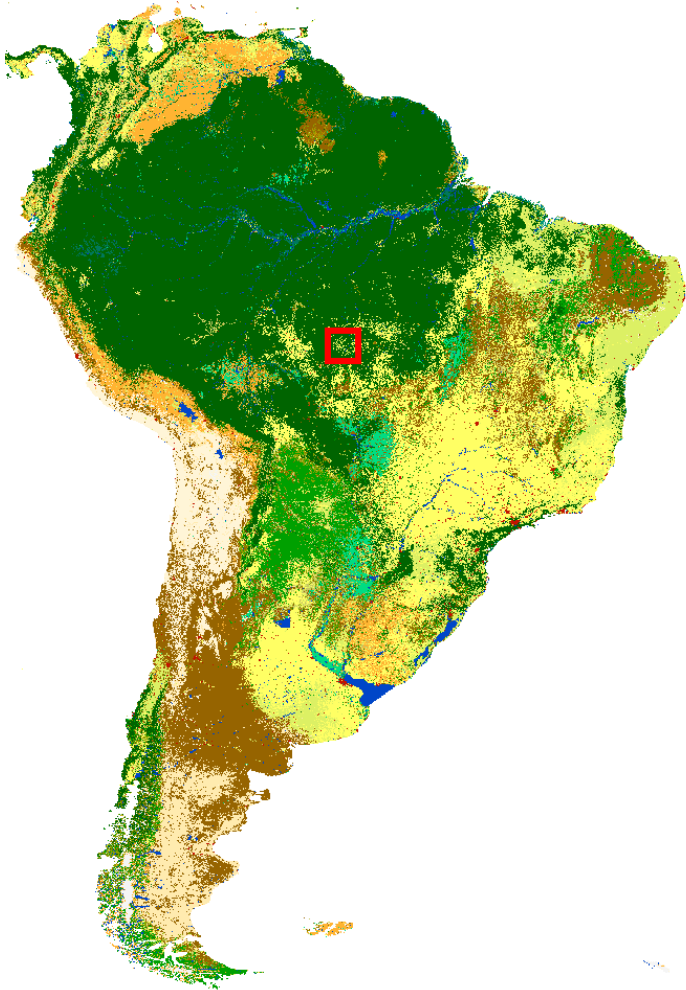
Jakub Nowosad   Tomasz Stepinski

Space Informatics Lab
http://sil.uc.edu/

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Analysis of large spatial datasets

- High resolution spatial data at local scale **do not provide information about global properties**
- To understand global character of large spatial datasets, they need to be **analyzed in their entirety**
- It is possible with **the Pattern-Based Spatial Analysis**

Pattern-Based Spatial Analysis - core idea

- **Motifel** - a square-sized blocks of cells representing local pattern
- Motifel is characterized by **the co-occurrence histogram of its constituent cells** (composition and configuration)
- A distance between a pair of motifels is measured as the degree of dissimilarity (using, for example **the Jenson-Shannon divergence**) between their histograms
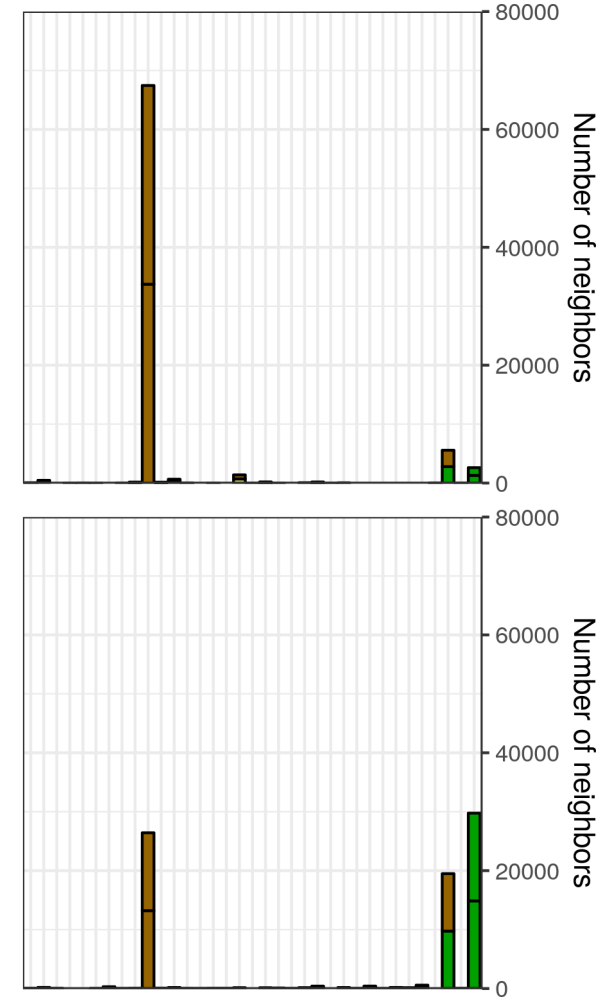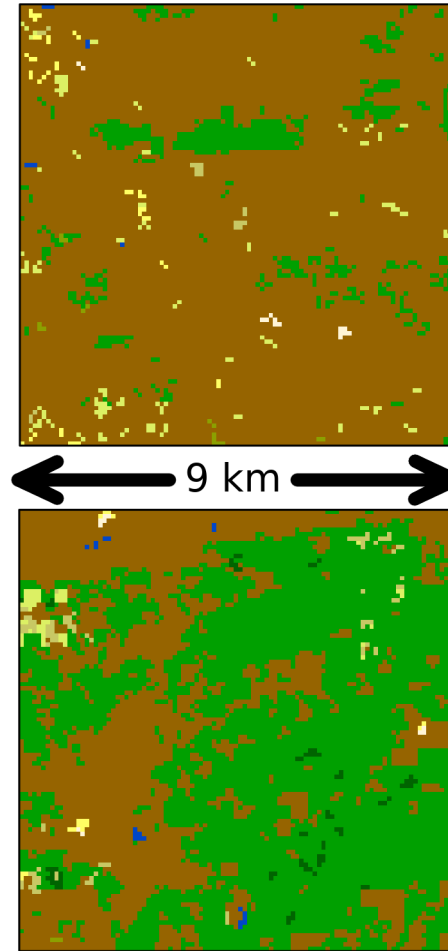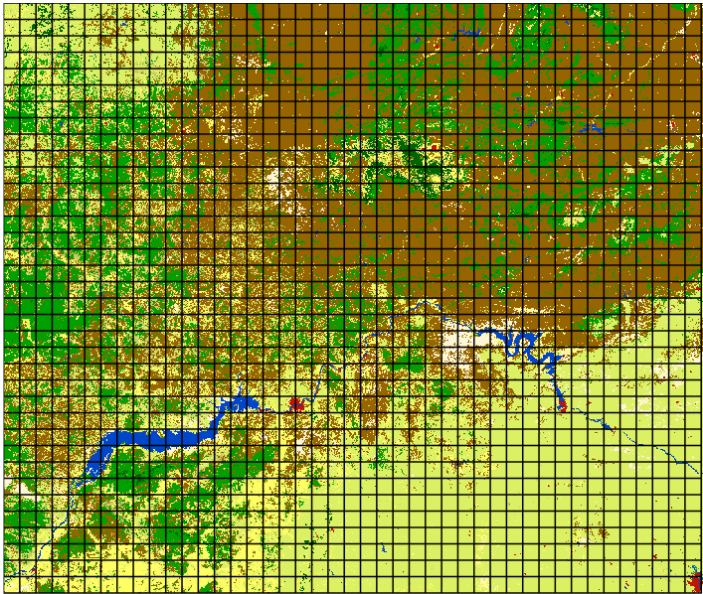
the Jenson-Shannon divergence: **0.43** (range 0-1)

Pattern-Based Spatial Analysis

The core idea it to **transform data from a large number of cells having simple content (one value) to a much smaller number of blocks with complex content**. In other words, decreasing a spatial resolution while increasing thematic resolution.

Many **numerical signatures** (e.g. Cartesian product, co-occurrence histogram, landscape indices vector) could represent the complex content. It is also possible to measure distances between complex contents using **dissimilarity measures** (e.g. JSD, Euclidean distance).
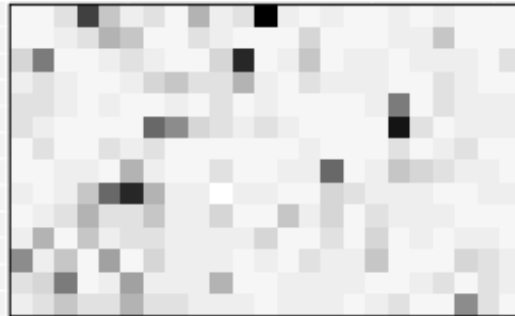
This approach enables a group of analysis to be performed on the grid of complex cells (local patterns):

- **Search** - search for areas similar to a query
- **Change detection** - comparison of local patterns between two maps
- **Segmentation** - division of a map into regions of cohesive patterns
- **Clustering** - grouping patterns that are similar to each other
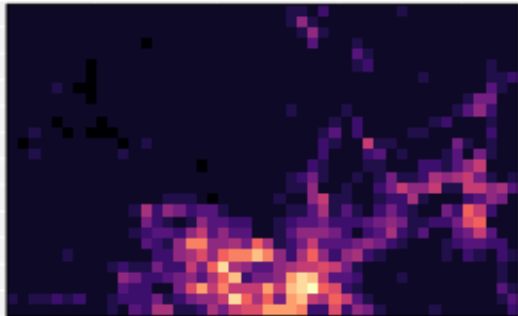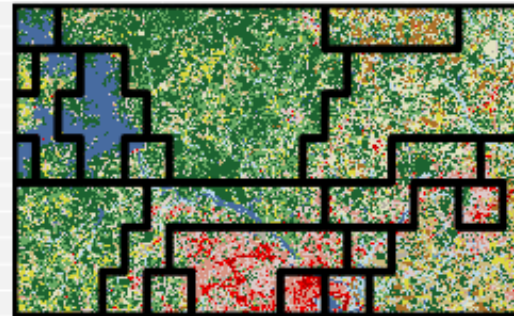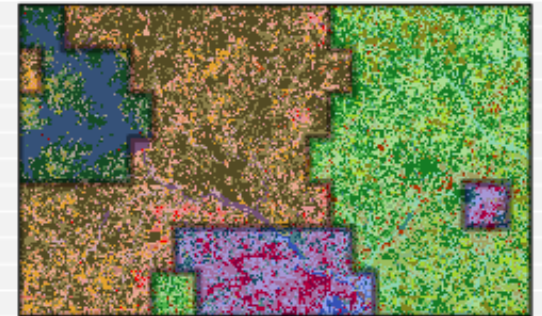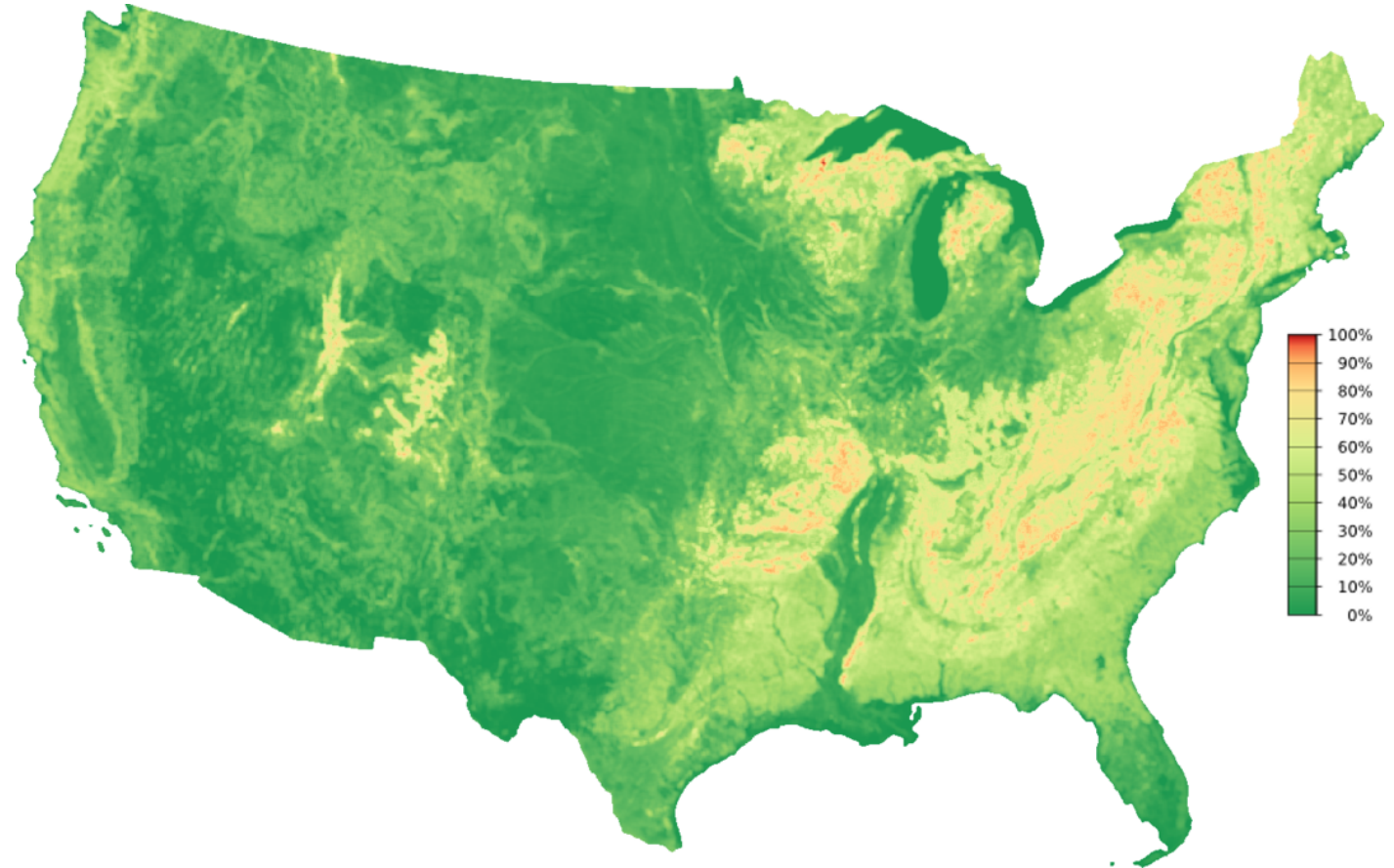
Search - Where can we find a similar local pattern?

- **Query** - diverse landscape in the north Wisconsin (1.5 x 1.5 km)
- Mosaic of a mixed forest, evergreen forest, shrubs, woody wetlands, and water

Dataset: NLCD 2011. Red color indicates larger similarity. Online application available at http://sil.uc.edu/webapps/landex_usa/.

Change detection - Where the local pattern has changed? What was the scale of the change?

magnitude of change 0.45 (changed)

magnitude of change 0.007 (unchanged)

magnitude of change 0.34 (changed)

CCI-LC 9-categories legend

Agriculture | Wetland | Sparse vegetation
Forest | Settlement | Bare area
Grassland | Shrubland | Water
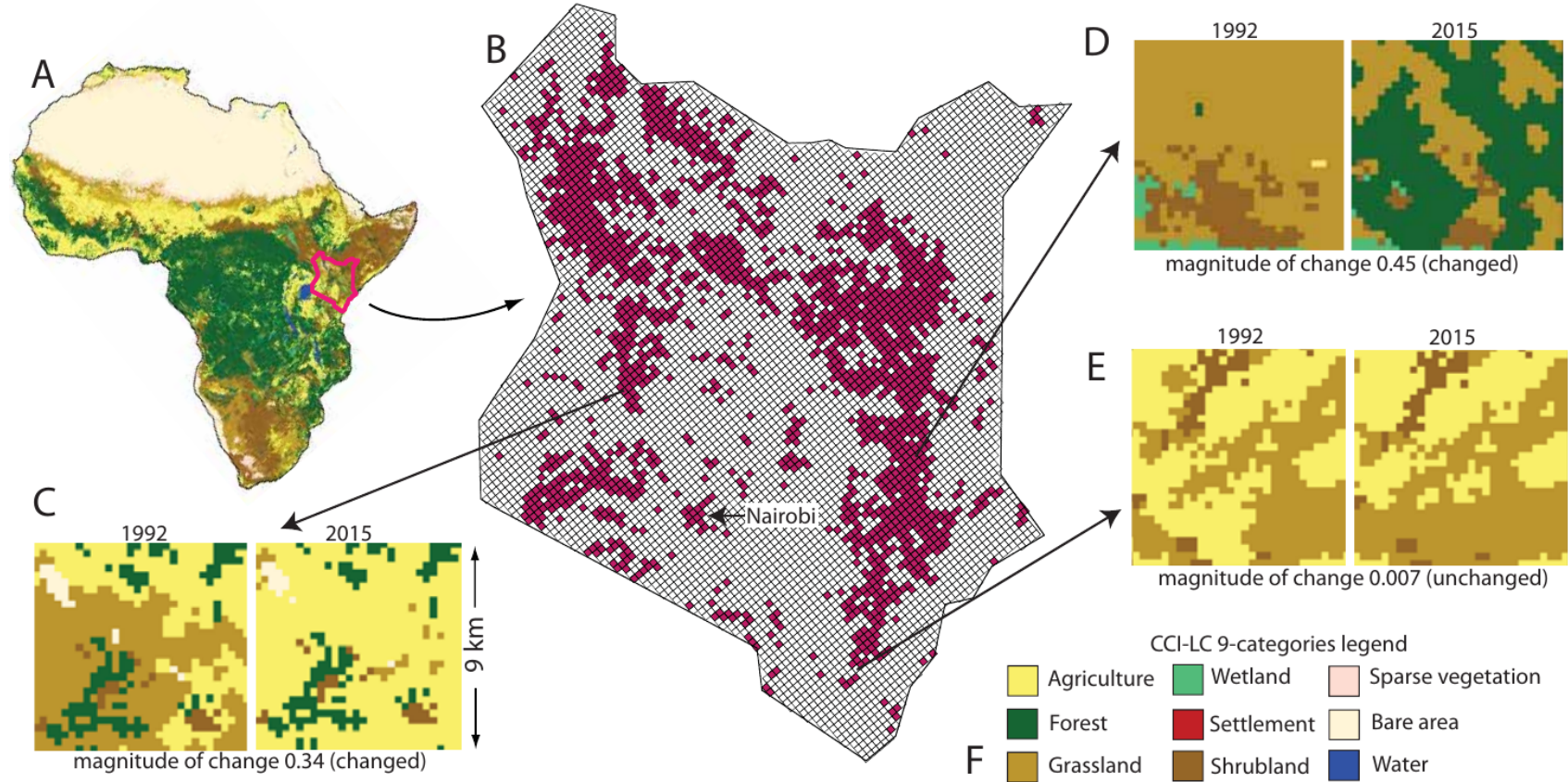
Dataset: CCI LC 1992 and 2015. Land cover pattern's changes between 1992 and 2015. Calculations for entire world, Kenya is shown for details

Segmentation - Delineate areas of homogeneous local patterns.

- The grid of motifels is segmented to **optimize homogeneity** of a pattern within segments
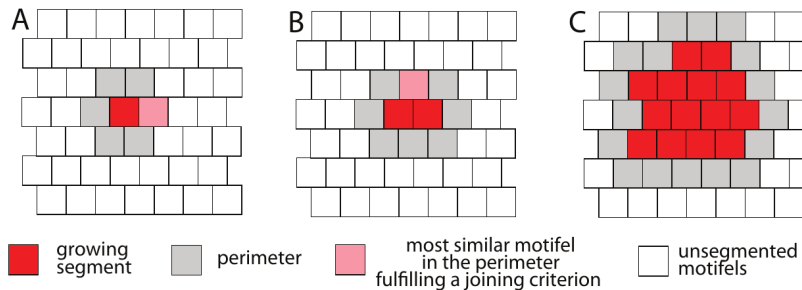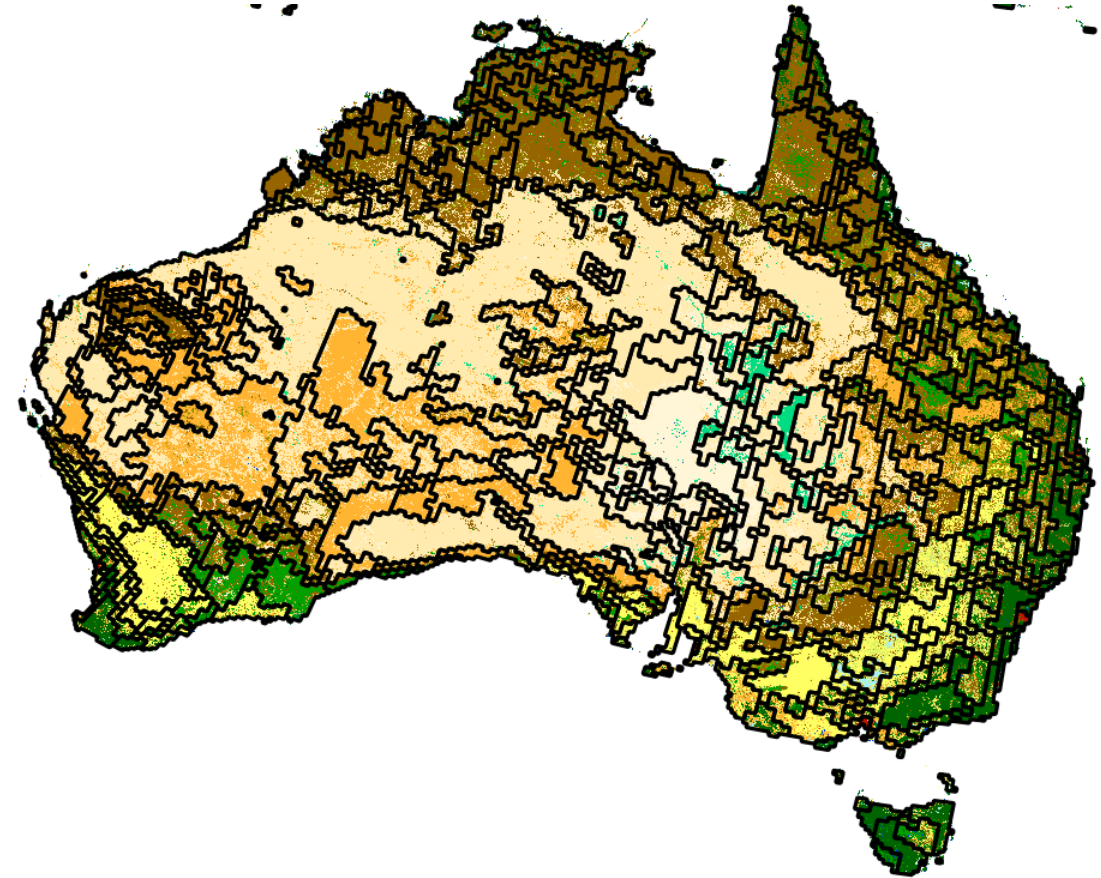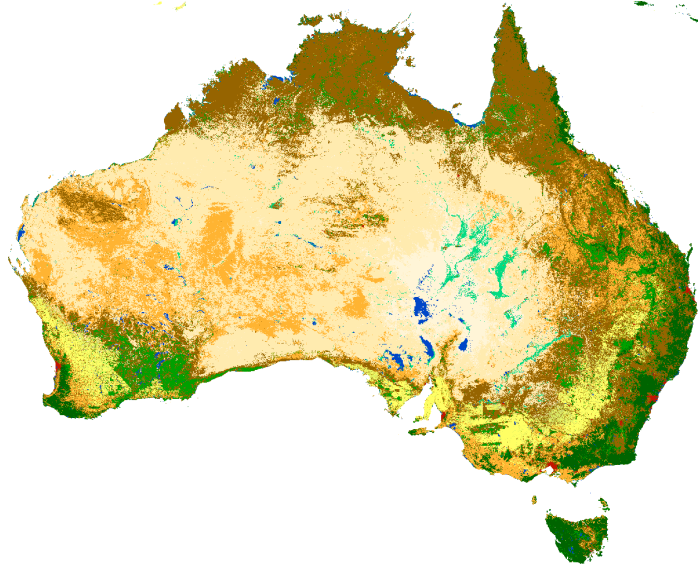
Dataset: CCI LC 2015. Segments of land cover classes in Australia.

Clustering - grouping motifels or segments into sets of similar objects
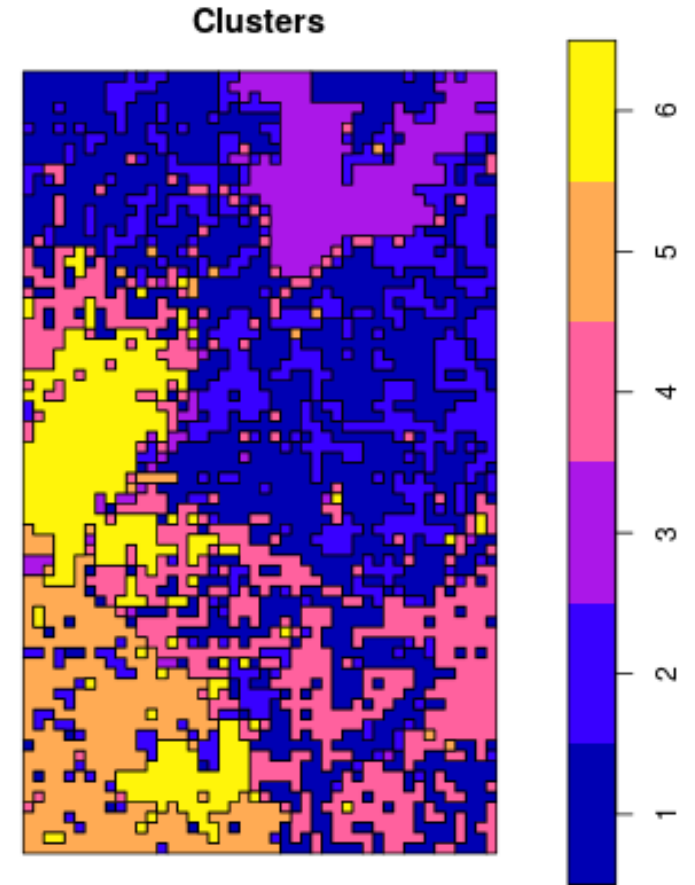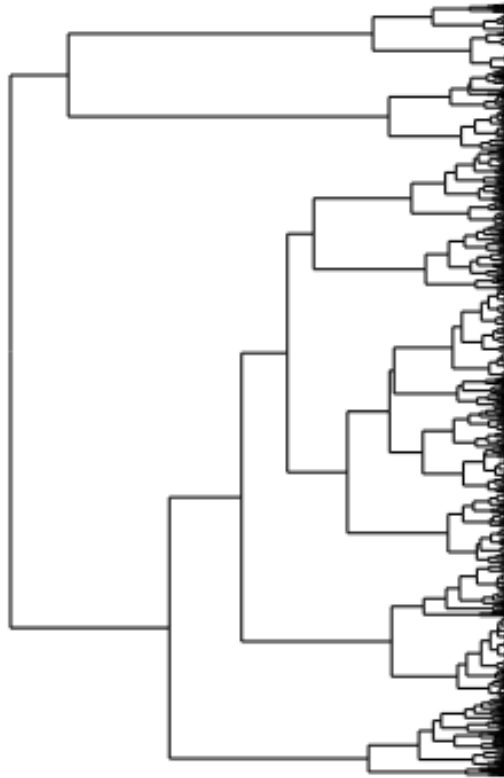
Dataset: NLCD 2011. Example of land cover classes clustering into land cover pattern types.

GeoPAT 2.0

- **GeoPAT 2.0** is an open source software available for download at http://sil.uc.edu/cms/index.php?id=geopat2.
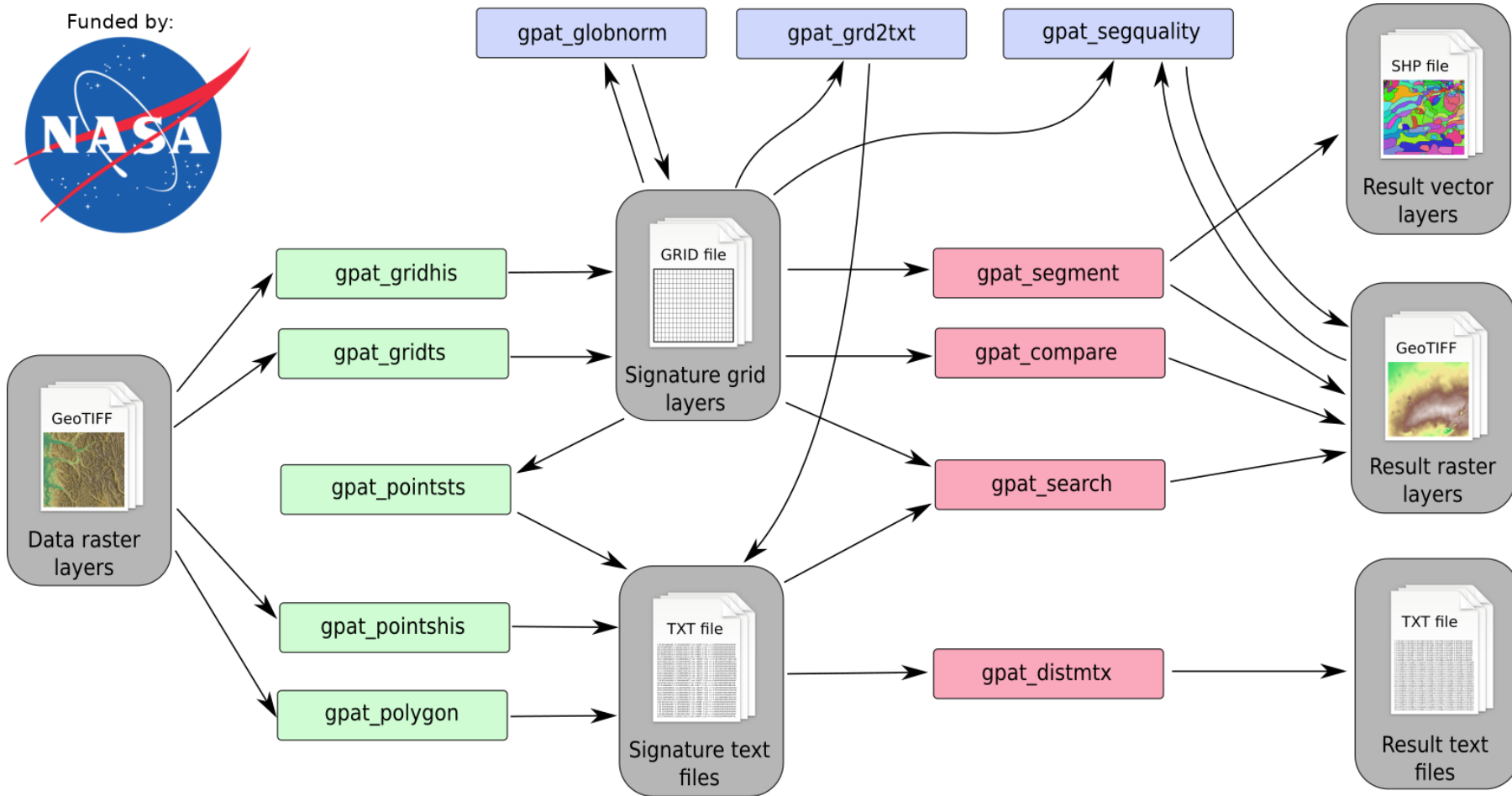
Outline of the GeoPAT 2.0 architecture

Potential applications
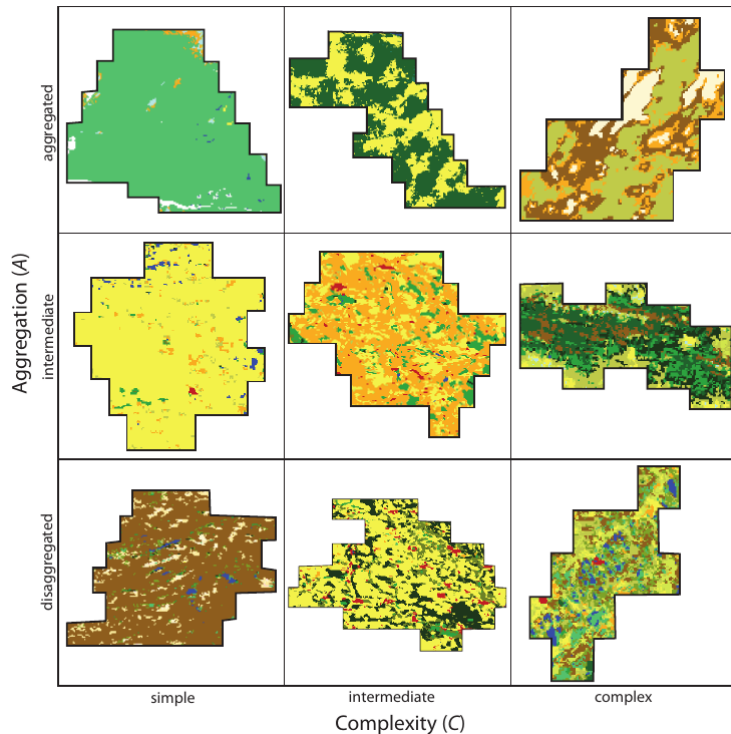
Example: **Global land cover patterns** were segmented into **homogeneous areas** and their patterns were analysed with **landscape metrics**. The results showed dependence of land cover spatial configuration on two parameters, **complexity (C)** and **aggregation (A)**.

- **Global environmental changes** -- analysis of changes in patterns of different environmental features, such as land cover
- **Global ecology** - delineation of ecoregions -- regionalization of land into homogeneous units of similar ecological and physiographic features (land cover, landform, soils, climate)
- **Forestry** - regionalization of forest patterns -- results could be used for conservation, planning and management
- **Agriculture** - identification of spatial patterns of cropland usage
- **Landscape ecology** - inventory of landscape patterns and analysis of landscape spatial configuration

Summary

- Pattern-based spatial analysis uses **blocks of pixels (motifels)** to represent local pattern
- This way **a large number of small simple cells are transformed into smaller number of large complex cells**
- This approach allows for **searching, detecting changes, segmentation, and clustering** of local patterns
- Main ideas behind the pattern-based spatial analysis are implemented in **GeoPAT 2.0**
- **The GeoPAT 2.0 software** and its **user's manual** are available through the Space Informatics Lab website at http://sil.uc.edu
- GeoPAT **does not require supercomputer or cloud computing** because core calculations are performed on a grid orders of magnitude smaller than a grid of original data
- GeoPAT also allows for **temporal analysis** of large spatial datasets (see the manual)

Global map of land cover pattern types based on the CCI-LC data using a segmentation-classification technique

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- **Nowosad, J., Stepinski, T.F.**, 2017. *Worldwide inventory of landscapes through segmentation of global land cover dataset*. GeoComputation 2017, Leeds, UK, September 4-7, 2017.
- **Niesterowicz, J., Stepinski, T. and Jasiewicz, J.**, 2016, January. *Unsupervised Delineation of Urban Structure Types Using High Resolution RGB Imagery*. In International Conference on GIScience Short Paper Proceedings (Vol. 1, No. 1).
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- **Jasiewicz, J., Netzel, P. and Stepinski, T.F.**, 2014, July. *Retrieval of pattern-based information from giga-cells categorical rasters—Concept and new software*. In Geoscience and Remote Sensing Symposium (IGARSS), 2014 IEEE International (pp. 1785-1788). IEEE.
- http://sil.uc.edu/webapps/landex_usa/ - finding locations having patterns of land cover similar to a user-selected sample
- http://sil.uc.edu/webapps/terraex_pl/ - finding locations having landscapes (patterns of landform elements) similar to a user-selected sample

Thank you

Me:

Twitter: jakub_nowosad

Email: nowosad.jakub@gmail.com

Resources:

https://nowosad.github.io

http://sil.uc.edu

Slides: http://bit.ly/geopat2