An Ontological Indicator System Based on MODIS Images to Detect Changes in Habitats Functioning in Sierra Nevada (Spain) Natura 2000 Site

Francisco J. BONET-GARCÍA[1], Ramón PÉREZ-PÉREZ[1],
Antonio J. PÉREZ-LUQUE[1] and Pedro J. MAGAÑA-REDONDO[2]

[1]Laboratorio de ecología, CEAMA, Granada/Spain · fjbonet@ugr.es
[2]Fluvial Dynamics and Hydrology Resarch Group, CEAMA, Granada/Spain

This contribution was double-blind reviewed as extended abstract.

Abstract

We have created an indicator system whose main aim is to assess significant changes in the habitats existing in Sierra Nevada Natura 2000 site. This system is able to automatically download, process and analyse raw data from two MODIS products (snow cover and vegetation indexes). Besides, the system calculates automatically several indicators useful to assess different ecological functions of Sierra Nevada habitats: phenology, seasonality of biomass production, duration of snow cover, etc. We also calculate trends in those indicators. These indicators are aggregated into composite indexes that allow the identification of habitats suffering significant changes in both their ecological functions and physical context. Finally we created an ontology that adds semantic meaning to the whole dataset. This allows the formulation of complex questions regarding the changes observed in habitats.

1 Introduction and Objectives

Gathering data thanks to monitoring programs is the first step towards the design of protocols to face up global change. We need to create tools able to translate raw data into useful knowledge that helps managers to face up global change. This challenge is especially important in Natura 2000 network. This work shows the design and implementation of an indicator system whose main aim is to assess significant changes in the habitat functioning of habitats existing in Sierra Nevada Natura 2000 site.

2 Design and Implementation of the Indicator System and Ontology

2.1 Conceptual framework

The conceptual framework that governs the design of our indicator system is based on the need of processing a big amount of data. The following scheme shows the different steps that will be described in the next paragraphs.

Jekel, T., Car, A., Strobl, J. & Griesebner, G. (Eds.) (2013): GI_Forum 2013. Creating the GISociety.

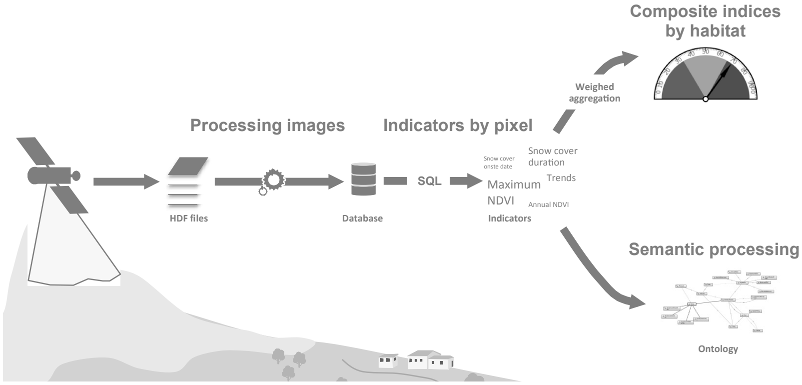

Fig. 1: Conceptual framework showing the steps needed to create the indicator system

2.2 Target spatial entities

We used a detailed vegetation map (1:10,000) to show the spatial distribution of habitats in Sierra Nevada. We also used the MODIS grids: a) Vegetation indexes have a resolution of 250 m and b) snow cover has a resolution of 500 m. We have clipped the MODIS grid with the distribution maps of the Natura 2000 habitats. Then we calculated indicators for each single isolated polygon containing a given habitat type.

2.3 Input data

MODIS sensor captures data in 36 spectral bands. These bands allow the creation of relevant geophysical information. Our system is able to process and analyse automatically the following MODIS products:

- Snow cover: MODIS provides information about snow cover extent and fractional snow cover (percentage of snow per pixel). The product called MOD10A2 has a periodicity of 8 day and a spatial resolution of 500 m.
- Vegetation indices (MOD13Q1) NDVI and EVI are also provided by MODIS. The spatial resolution of this product is 250 m. The temporal resolution is 16 days.

2.4 Data processing

We stored all the previous information in a relational database in order to run complex queries and calculate indicators. NASA provides MODIS images using HDF. Once the HDF files are downloaded from NASA's servers, they are automatically processed using a scientific workflow.

2.5 Calculating indicators

The next step is to calculate indicators using SQL statements. We implemented several indicators regarding snow cover and vegetation indexes.

Vegetation indexes

NDVI and EVI seasonal measurements are valid tools to quantify productivity and biomass seasonality and others phenological measurements:

- Annual mean (NDVI-I) which can be used to estimate fAPA and thus net primary production;
- annual relative range (RREL); difference between maximum and minimum NDVI divided by annual mean. This variable provides an indicator of the seasonality of the photosynthetic activity;
- Maximum and minimum NDVI values (MAX and MIN);
- Months of the maximum and minimum values of NDVI (MMAX and MMIN), which provide an additional description of vegetation phenology, indicating the intra-annual distribution of the periods with maximum and minimum photosynthetic activity.

Snow cover indicators

NDSI has proven to be a robust indicator of snow cover using MODIS images. Both MOD10A1 and MOD10A2 products are providing information of snow cover. We have used MOD10A2 for this work. This raw information is processed to obtain the following indicators (WANG & XIE 2009):

- Snow cover duration (SCD): It summarizes the total effect of snow cover;
- Snow cover onset dates (SCOD): It refers to the starting date of a snow covered period;
- Snow cover melting dates (SCMD): This indicator refers to the ending date of a snow cover period;
- Snow cover melting cycles (SCMC): This index shows the number of melting cycles that suffers each pixel per hydrological year.

All these indicators are calculated yearly for each MODIS pixel covering Sierra Nevada Natura 2000 site. Then we calculated the trend in the time series for each indicator. We used the R "Kendall" package to do this task. Finally, we obtain the difference between the real value and the predicted one according the calculated trend. This deviation will be used to obtain two composite indicators.

2.6 Calculating composite indicators

Thanks to the previously described indicators, we can create composite indices (DOBBIE & DAIL 2013; OECD 2008) to identify significant changes in the habitat functioning. We calculate one composite indicator for vegetation indices and another one for snow cover. The first one has to be with the general functioning of the habitat (production, phenology, etc.) and shows changes in this functioning. The snow cover composite indicator shows deviations in snow patterns.

2.7 Retrieving knowledge by semantic processing

Semantic processing allows spatio-temporal aggregation of huge amount of data. We can dynamically answer different complex questions: Where are the habitats with a significant change in snow and/or vegetation trends? Is there any habitat with a positive trend in vegetation indexes in spring? The resulting ontology (Fig. 2) includes complex domains as time and spatial dimensions. Once we calculated all the indicators, we structured them according to the ontology. By using an ontology reasoning engine, we will discover new relationships between the modelled variables.

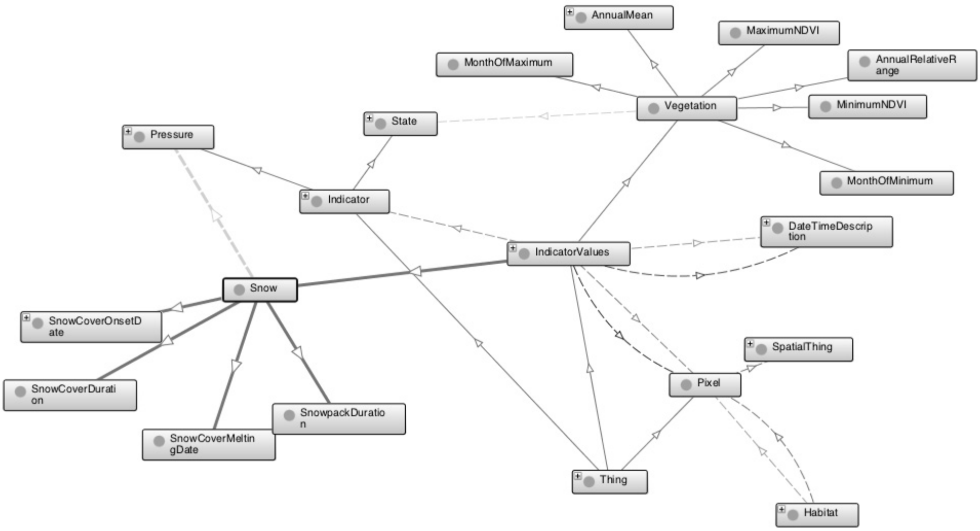

Fig. 2: Schematic representation of the created ontology; boxes represent different concepts described in the ontology; solid arrows show direct relationship among concepts and dashed arrows mean indirect relationships

3 Conclusions

We are presenting a preliminary work that will provide information about the above-described indicators and the semantic processing. Some remaining tasks are to connect the described ontology with the database containing the MODIS indicators. All this information will be available through a web portal called “Linaria”. This portal (http://linaria.obsnev.es, free registration required) currently shows information about snow cover indicators and vegetation indexes.

References

DOBBIE, M. J. & DAIL, D. (2013), Robustness and sensitivity of weighting and aggregation in constructing composite indices. Ecological Indicators, 29, 270-277. doi:10.1016/j.ecolind.2012.12.025.

NARDO, M., SAISANA, M., SALTELLI, A., TARANTOLA, S., HOFFMAN, A. & GIOVANNINI, E. (2005), Handbook on Constructing Composite Indicators: Methodology and User Guide. OECD Statistics Working Papers. OECD Publishing. Paris, France.

WANG, X. & XIE, H. (2009), New methods for studying the spatiotemporal variation of snow cover based on combination products of MODIS Terra and Aqua. Journal of Hydrology, 371 (1-4), 192-200. doi:10.1016/j.jhydrol.2009.03.028.