CUSTOM-MADE HR REMOTE SENSING PRODUCT FOR THE EUROPEAN BIODIVERSITY RESEARCH INFRASTRUCTURE (LIFEWATCH)

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ABSTRACT

The European Infrastructure for Biodiversity and Ecosystem Research (Lifewatch) aims at providing data and analytical tools focused on pressing scientific issues related to biodiversity. Our contribution to this initiative is to describe the biotopes in Europe (EU-38 countries) on a yearly basis. A geographic database has therefore been designed after identifying the specific needs of the biodiversity and macroecology communities.
The methodology is organized around the concept of spatial regions, which are landscape units with similar properties. Spatial regions are delineated by the segmentation of filtered images and characterized using a set of remote sensing data and GIS derived indices. Preliminary results with Rapideye images are promising and we are looking forward to the Sentinel-2 mission.

1. INTRODUCTION

Lifewatch is a European Research Infrastructure Consortium in development. Its aim is to provide access to a variety of data, analytical and modelling tools as served by a variety of collaborating initiatives. In this framework, the Lifewatch Wallonia-Brussels(WB) project aims at providing geographical data tailored to the specific needs of the biodiversity and macro-ecology communities.

The requirements of the biodiversity science community are broad. Methods must be developed to fulfill it and they must be repeatable [1,2]. The requirements can be divided in two types of products:
The first one is change detection. Science communities need to understand how biotopes respond in changing world [3]. The monitoring of biotopes at the European scale is one of the major challenges to assess biodiversity [1,4]. Such monitoring will help to create a coherent framework of protected areas, restore fragmented biotopes and find where to invest conservation funding [5].
The second is a database which describes biotopes. This product will be also an excellent tool for different kind of researches: to assess ecosystems services, to understand drivers of species distributions and species richness, etc. [5,6]

This paper focuses on the delineation and characterization of the biotopes. The ideal product should match the thematic precision of field survey by an expert (e.g. EUNIS legend), cover all European countries at the 1/10000 scale and be yearly updated. Of course, the thematic precision is not achievable with remote sensing only. Furthermore, there are little consensual low level classes at the European scale. A static classification would therefore not be suitable because the habitats are usually defined based on the variable needs of the animal species. However, the main strength of remote sensing in this context is the repeatability of the measurements to provide reliable quantitative information about the land cover. Our hypothesis is that remote sensing is able to delineate reliable spatial regions as a consistent proxy for the biotopes. All but one interviewed scientists preferred this type of representation compared with the pixel-based classification.

The main challenge of our project was thus to derive meaningful spatial region in a consistent way, based on image segmentation algorithm. The resulting spatial regions are then characterized based on state-of-the-art low level image classification and additional features derived from GIS and statistical analyses.

2. DATA AND STUDY AREA

For this proof of concept, a set of 100 Rapideye images covering Belgium has been selected. The majority of the images, kindly provided by the GMES Space Component Data Access, were acquired in early spring 2011 (with little or no leaves on deciduous trees). Form a biogeographical point of view, Belgium is crossed by two regions: the Atlantic and the Continental regions. Additional images from Spain, Romania and Finland have also been used for testing in other biogeographical region (Mediterranean and boreal).

A large number of ancillary data has also been used for the characterisation of the spatial regions. This includes existing maps with land use information (such as CORINE Land cover and protected areas), products derived from remote sensing data (NDVI and clouds from SPOT-VGT, burnt area and snow from MODIS) and major abiotic factors such as the SRTM digital elevation model or the WorldClim database.

3. METHOD

The method is composed of two parts: the delineation of the spatial region and their characterisation. For the delineation, the challenge was to remain consistent in heterogeneous areas. For the characterisation, the complexity of the biotopes is reflected by the object-oriented model being used.

3.1. Spatial region delineation

The image segmentation is performed using the commercial software e-Cognition. This software uses an optimized region growing algorithm that aims at minimizing the internal variance of the image-object and allows for additional constraints on the shape of these image-objects.

The minimization of the differences inside image-objects is an issue when the area to be segmented is heterogeneous. This issue is of paramount importance in large parts of Mediterranean and boreal biogeographical regions where the vegetation is often sparse. The delineation of these sparsely vegetated spatial regions is made difficult, even for trained photo-interpreters, due to the lack of objective delineation rules. While the segmentation process is difficult to control, a filter helps to harmonize the response to a given landscape structure with a set of static rules.

Morphological mathematics provides useful tools to analyze the structure of an image. The two main operations are opening and closing, based on erosion and dilatation filters. Those filters look for a specific template in the image and change the value of the central pixel when the template is found.

Morphological filters are primarily designed for single band images. In our case, the input image is a multispectral image, so that the morphological filters needed to be adapted. There are three main features that characterize the filter. First, a NDVI threshold allows selecting the pixels that are averaged in the neighborhood. The filter is thus able to either expand or shrink the vegetation values in order to fill small gaps in the landscape. Second, the neighborhood radius is adjusted to the closest vegetation values in order maintain sharp edges between two different vegetation types (e.g. between deciduous and coniferous forests). Third, the final filter is composed of the two opposite filters in order to keep a high fidelity to the boundary location.

Depending on the order of the two opposite filters, two types of results are obtained. When the first step is an erosion of the vegetation, heterogeneous areas are homogenized by removing vegetation pixels; on the other hand, starting with the dilation of the vegetation fills the gaps in heterogeneous regions.

The red and the NIR bands of the opened and closed images are then stacked with the original image as input for the image segmentation. Using the hierarchical possibility of the multiresolution segmentation algorithm, two image-object level are created. The first level is based on the non-filtered images to derive small image-objects of 10 to 20 pixels that will be used for the classification; the second level is based on the filtered images and aims delineating the biotopes. Contrary to the first level, a shape constraint is used to derive the image-objects of the second level.

3.2. Biotope characterisation

The characterisation of the biotopes is based on several ancillary data. Instead of building a crisp land cover legend, the proportion of elementary descriptors of the land cover is computed for each spatial region. This pure land cover description is completed using abiotic factors, land use information and temporal indices.

The land cover description is based on the classification of the first image-object level into elementary land cover classes as based on objective criteria as long as possible. For instance, the distinction between tree and non tree is left at the last level. Another aspect of this legend is that it is a pure land cover legend in the sense that the land use information is not included at this level (e.g. no distinction between orchard trees and forest trees, or between pasture and natural grassland).

The low level classification is performed using a SVM classification algorithm with radial basis functions as kernel. The SVM is trained for two different phenological states (with and without leaves on the deciduous trees) that are visually identified at this stage. The percentage of each land cover class is then computed by spatial aggregation at the second level.

Information related to the land use is provided independently using a majority labelling based of CLC data. This is further enriched by the Natura 2000 dataset and the World Database of Protected Areas.

In order to complete the description, several temporal metrics are extracted from existing time series and additional information is derived from the SRTM DEM. The description of those datasets is beyond the scope of this paper.

4. RESULTS

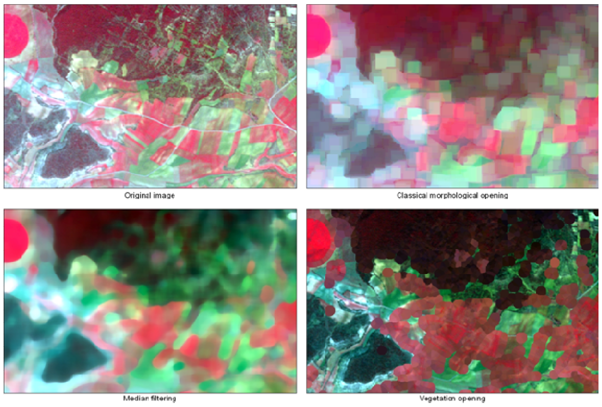

Figure 1. Comparison of blurring filters (Spain). Original image on top left, classical morphological opening on top right, median filter on bottom left and the proposed filter on bottom right.

Figure 1 shows the results of different filters together with the new vegetation erosion filter. It can be seen that the proposed filter clearly fills the gaps in the open forest on the top of the image. On the other hand, most boundaries remain sharp so that the landscape is visually simplified. At this stage, the location of the boundaries is however inexact because a buffer has been applied on the vegetation.

Figure 2 then highlights the results of the two stage processes of opening and closing the vegetation. In this case, the urban area and the heterogeneous forests are modified while the remaining of the image is similar to the original. The location of the boundaries between distinct spatial regions is now exact despite a few small artefacts around the corners. On this example, the urban area is modified in a way that will help to distinguish the dense area from the area including gardens.

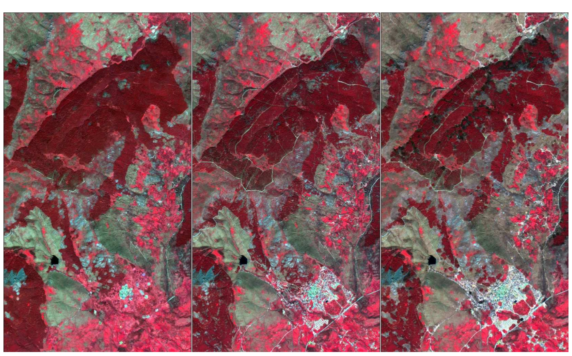

Figure 2. Opening(left) and closing (right) of the vegetation compared with the original image.

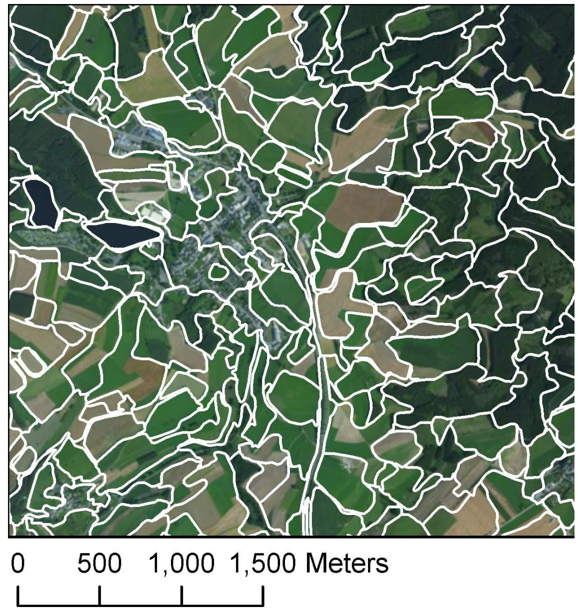

Figure 3. Example of segmentation results (Belgium) overlaid on an aerial photography.

The segmentation results are visually good (figure 3) excepting the linear elements that are not well captured. The filtered bands smoothed heterogeneous areas so that the resulting image-objects have a similar size. Furthermore, important boundaries such as forest/non forest or water/non water are well preserved. As previously mentioned, the delineation of the urban area could be discussed, but the advantage of the method is its repeatability.

The classification results for the smaller image-objects are shown on figure 4. The classification accuracy for the training stage was above 90% on average, but an independent validation still needs to be performed to estimate the true overall accuracy.

The visual comparison with the CLC map (figure 4) shows that the first results are encouraging. Apart from the difference in planimetric precision, the two datasets are indeed very similar. The main difference comes from the conceptual gap between the two datasets. Indeed, only pure land cover classes are observed at this level, so that the mixed forest class (in brown on the CLC map) does not exist in our dataset. For the aggregation at the spatial region level, the percentage of each type of tree will indeed be computed.

Figure 4. Comparison between the object-based classification and Corine Land Cover for a subset in Belgium. The central image is an orthophotography.

In order to further characterise the spatial regions, a set of ancillary data has been computed. Figure 5 shows an example of time series analysis that has been used for the enrichment. Five major variables had been identified (snow, flood, fire, sunshine, vegetation) and all have been processed but the flood. The snow is particularly important for the life cycle of various species, from butterflies to big mammals. Flood and fires may induce disturbance of the biotopes, which are sometimes necessary for its rejuvenation. Sunshine creates microclimatic conditions and may affect the migration of birds. Eventually, vegetation is a major aspect of the ecosytems as it is also closely related to the life cycles.

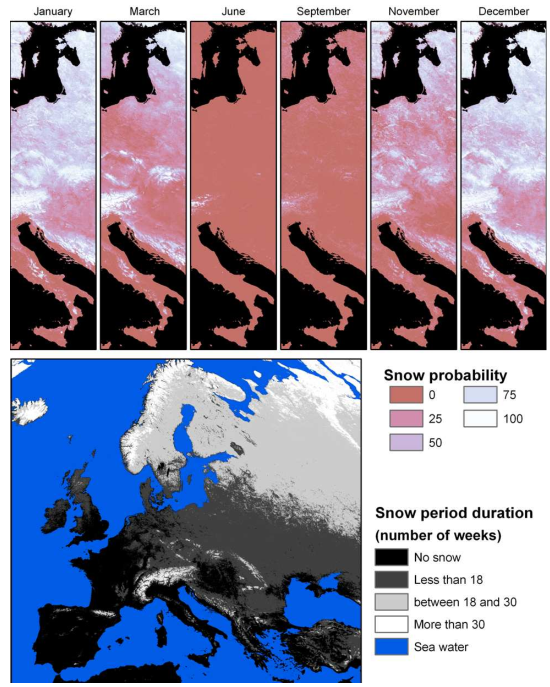

Figure 5. Example of products used for the temporal characterisation of the spatial regions.

5. CONCLUSION

The preliminary results of the Lifewatch WB project show that remote sensing is capable of providing valuable information for the research community in biodiversity. Even if the thematic precision required by the biodiversity scientist could not be achieved, the quantitative variables and the large coverage of remote sensing data provide a good complementarity with filed inventories. Sentinel-2 data could probably be used in a near future for the monitoring of biotopes in Europe.

6. AKNOWLEDGEMENT

This project is funded by the Fédération Wallonie Bruxelles in the frame of the Lifewatch European Research Infrastructure Consortium. The authors would like to thank GSCDA for the RapidEye images and the OTB team for their useful image processing library. T. De Maet, A. Verhegghen, D. Jacques, E. Van Bogaert and C. Lamarche also contributed with useful comments. Last but not least, we would like to thank all the 29 biodiversity scientists who responded to our survey.

7. REFERENCES

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