MULTITEMPORAL LANDSCAPE PATTERN ANALYSIS: A QUANTITATIVE APPROACH TO SUPPORT SUSTAINABLE LAND MANAGEMENT

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ABSTRACT:

Remotely sensed images are an essential component for the analysis of landscape trends. In this contribution we introduce the analysis of a large study area in the Bassin Minier Nord-Pas-de-Calais (France) were we reconstructed a Corine Land Cover map for the year 1954 on the basis of historical aerial orthophotos. On such a basis we were able to analyse land use/land cover changes and their relative impact on landscape pattern. Whereas the main driver revealed being the urban sprawl in areas dominated in 1954 by agriculture, the study shown how quantitative approach in landscape pattern analysis can provide possible innovative tools to support patrimonial landscape mapping and the identification of possible future projects for territorial development

1. INTRODUCTION

Ecosystem services (ES) represent the goods and services derived from the functions of ecosystems utilized by humanity (Costanza et al. 1997). Human wellbeing is tightly connected to the provision of these services. Ecosystem services represent an high relevant issue that should be included in multi-level land policies and planning activities (Frank et al., 2015, Kangas et al. 2018).
Policy makers are increasingly recognizing the potential of ecosystem service mapping in strategic planning (Vorstius and Spray 2015).
The ecosystem services are operationalized through a selected set of indicators. The purpose of the indicators is to support management of the ecosystems and communicate the condition of ecosystems themselves. Indicators can be estimated under a quantitative approach with different approaches. See for example the pan-European project related to Mapping Ecosystem Services (Maes et al., 2012).
The territorialist approach to land management is an integrated and multi-scale way oriented to take into consideration several thematic elements in defining large interconnected bioregions. In this kind of planning approach the ways for designing territories is aimed to achieve several targets: interconnecting different local territorial systems by networking urban areas and taking into consideration morphological and social elements; recovery and enhancing the relationships between urban systems and natural/rural surroundings areas heading towards a balanced ecosystem; recreating circular matter and goods balances in water basins; regenerating ecological networks at landscape scale level.
This approach was applied and unfolded in a large study site of the Bassin Minier Nord-Pas-de-Calais (France) in the area of Lens, where the Università degli Studi di Firenze and the Ecole Nationale Supérieure d'Architecture et de Paysage de Lille are cooperating for both scientific and didactical purposes. The current area condition was shaped after three centuries of coal extraction from 18th century to 20th century and is now object of several restoration and valorization policies and projects.

In the contribution we present some examples of the use of multitemporal landscape pattern analysis based on diachronic land cover maps acquired from remotely sensed technologies. We produced quantitative analyses which demonstrated the potential benefits that may arise by the use of multitemporal aerial imagery and historical maps for producing a detailed reconstruction of the historical evolution of urban areas. Remotely sensed-based landscape maps may be used for the analysis of different components of the landscape (for example for the analysis of ecological networks) which are the basis for the estimation of the temporal changes in ecosystem service provisioning. Results may be used for supporting the reconstruction of the patrimonial landscape values and the identification of possible future projects for territorial development.

2. METHODS

Following the European Mapping Ecosystem Services approach developed by a large international research group coordinated by the Joint Research Centre of the European Commission, the first step for the spatial assessment of ecosystem services is to create a multitemporal land-use / land-cover map (Maes et al., 2012).
The study area is defined as the administrative region of Bassin Minier Nord-Pas-de-Calais for a total of 1812 km^2. Around the area we created a buffer zone of 10 km in order to take into consideration land use/land cover changes occurred on the border of the investigated area. The total area included within the French border reaches a total of 4563 km^2 (Figure 1).

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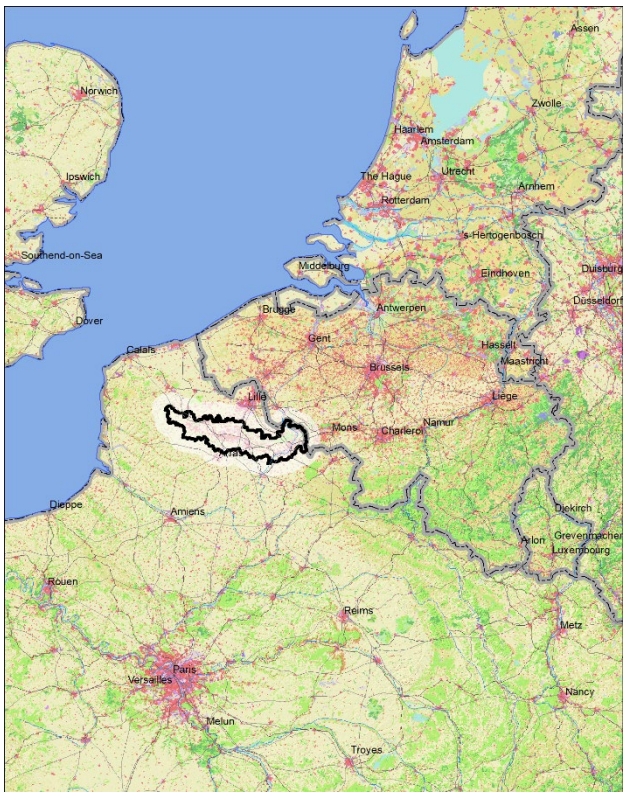

Figure 1. location of the study area and its buffer zone on the basis of Corine Land Cover 2012.

Following the procedure originally proposed by Chirici et al. (2006), we used the oldest Corine Land Cover (CLC) map (year 1990) available for the whole Europe from the European Environmental Agency and jointly the historical photos BD ORTHO® HISTORIQUE available from the Institute National de l'Information Geographique et Forestiére (http://professionnels.ign.fr/bdorthohisto) to create an historic new version of the CLC map denominated CLC1955.
In doing that the students of Università degli Studi di Firenze used the same mapping rules and definitions officially adopted for the CLC project.
The CLC1955 was then crosstabulated with an overlay approach in a GIS environment with the official CLC2012 map in order to analyses spatial dynamics. Change analysis were carried out with a pixel resolution of 20 m.

In the last decades remote sensing technologies from multiple platforms (satellite, aerial, UAV) and from different passive (optical) or active (radar and LiDAR) technologies have augmented their penetration in earth observation applications. This is due to the increased numbers of data sources available, to the fact that this data are nowadays most commonly distributed open-access on line, and that the technologies for their use in producing high added-value information have become more easy to use and powerful.
Designing territories in land management following the territorialist approach requires the elaboration of a vast amount of spatial information that in most of the cases can be derived from multiple earth observation tools. Remote sensing technologies, under this point of view, can contribute in overpassing thematic and rigid visions enabling a more integrated and cross-disciplinary approach.

3. RESULTS

On the basis of the analyses carried out we were able to calculate for each pixel in the study area the transition vector between the land use in 1954 to the new land use in 2018. It turned out how the study area is strongly dominated by anthropogenic land uses (agriculture and urban) (Figure 2).

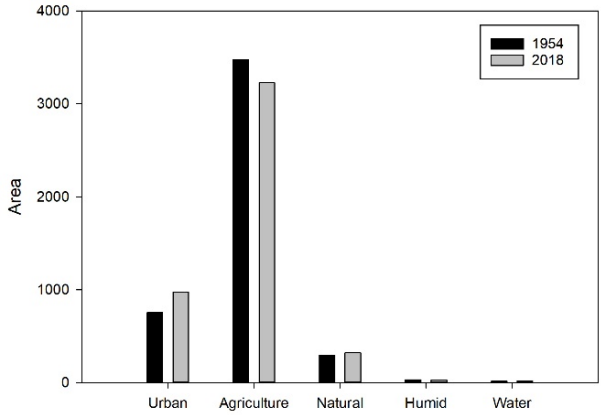

Figure 2. first level CLC classes spatial consistency at the two investigated period in the study area.

Accordingly we present below the analyses for the most important transition classes.
In the analyzed period the 7.7% (351 km^2) of the landscape changed in terms of first level CLC class.
The vast majority of this change (75% of changed areas) is determined by the urban sprawl. Mainly it happened for a transition from agriculture (72%) and just for the 2.7% from natural areas and some 0.5% from humid areas and water bodies Figure 3).

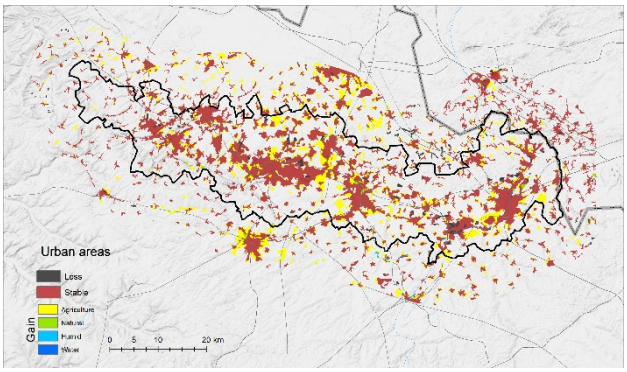

Figure 3. development of urban areas in the period 1954-2018.

New urban areas in the period 1954-2018 increased mainly as evolution from existing urban areas in 1954. The average distance of new urban areas was in fact 345 m from existing urban areas at 1954 (with a maximum of 2474 m (Figure 4).

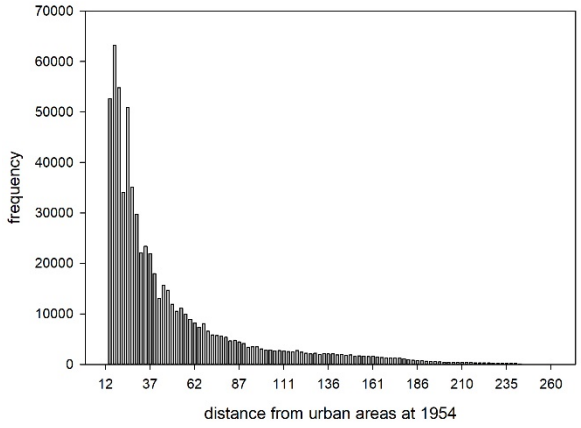

Figure 4: new urban areas created in the period 1954 – 2018 as a distance from existing urban areas in 1954. Frequency in number of pixels, distance in meters.

The increased urban area determined a reduction of more than 10% in the fragmentation of urban areas, the number of continuous urban patches moved from 580 patches in 1954 to 520 patches in 2018. With an average dimension of 1.3 km^2 in 1954 and 1.9 in 2018. The areas with the largest change in patch dimension are those in Lens and Valenciennes. Followed by Douai, which is very close to be connected with Lens, Arras and the western polycentric areas of Auchel / Bethune / Lillers / Bruay-La-Buissière (Figure 5).

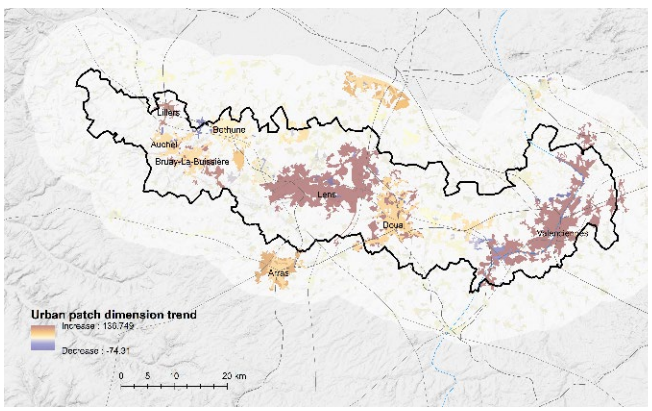

Figure 5: changes in the dimension of continuous urban areas in the period 1954-2018.

The second most important landscape change in the study area (12.2% of all changes) is the increased coverage of areas with natural and semi-natural vegetation. Mainly evolved from the abandonment of agriculture. Since the total increased area of these environments was limited to only 0.1 km^2 the impact on the connectivity of the ecological network was very limited.

4. CONCLUSIONS

In this contribution we applied a method for the analyses of landscape trend in a large study site of the Bassin Minier Nord-Pas-de-Calais (France). On the basis of the reconstruction of the land use land cover at the year 1954 and of of historical orthophotos.

The area resulted mainly dominated by a transition from agriculture areas to urban areas. Changes originated mainly from existing urban areas and determined a consistent change in the spatial pattern of landscape patches. With an augmented area of continuous urban and impervious areas.

We demonstrated that the information that can be obtained from the analysis of historical remotely sensed images can be useful to produce information that may support a multi-temporal and dynamic approach to landscape planning. A method that contributes to enhance the inherited map overlay approach in supporting the reconstruction of the enduring structures of territories and of the related patrimonial landscape values. That aiming to the identification of the key issues to underpin possible future projects for territorial place focused development.

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