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Remote Sensing for Monitoring Biodiversity in Urban Environment

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Abstract

Monitoring the evolution of biodiversity in urban environment is a challenging topic that requires deep investigation with multidisciplinary approaches. Several factors, such as invasive plants, can dramatically reduce biodiversity in urban ecosystems. As a result, the composition of plant communities changes, and the habitat becomes less suitable for native species. Remote sensing technologies, including aerial and satellite imagery, can play a crucial role in mapping and analyzing urban green spaces. In this paper we present a multidisciplinary approach devoted to map the green spaces and monitor the expansion of invasive species in urban ecosystems. The case study is focused on *Ailanthus altissima*, a tree species that is considered invasive in Europe. The strategy is based on the joint use of very high resolution multispectral (MS) images acquired *una tantum* and Synthetic Aperture Radar (SAR) data acquired continuously. The information acquired on ground is used to add the semantic information to the images processed through spectral analysis and land cover classification. This approach enables to evaluate the connectivity of green patches, assess the impact of urban infrastructure on habitats, and propose strategies for habitat restoration or conservation.

1. Introduction

Urbanization has transformed landscapes globally, bringing deep changes in ecosystems and biodiversity. As cities continue to expand, the need for effective monitoring and management of urban biodiversity becomes increasingly critical. As an example, invasive plants are non-native species that, when introduced into a new area, compete with and often displace native vegetation. This phenomenon impacts biodiversity and the overall health of urban ecosystems and can have significant ecological, economic, and social consequences.

Invasive species can have rapid growth rates and high reproductive capacities, are able to adapt to various environmental conditions, and this allows their quick diffusion in cities, affecting the overall functioning of urban ecosystems.

To address the adverse effects of invasive plants and the preservation of biodiversity in cities, management strategies are crucial. These may include early detection and rapid response programs. However, the management and control of biodiversity in urban areas requires significant costs.

The use of remote sensing instruments that provide a synoptic view of wide urban areas with relatively high spatial resolution can provide a useful tool to mitigate these problems [1], [2]. Indeed, high-resolution imagery acquired through remote sensing aids in assessing the size, distribution, and health of green spaces.

This paper investigates the role of remote sensing in monitoring urban biodiversity, providing an overview of the most suitable instruments, identifying potential applications and open challenges.

In Section 2 we present an analysis of the available images and data acquired in ground. Section 3 explores the methodological approach and present preliminary examples of the potentialities of remote sensing data for biodiversity monitoring. Section 4 is devoted to the final conclusions

2. Materials

A. Remote Sensing data

Remote sensing from aerial and satellite platforms offer a plethora of data acquired with continuity covering almost the entire surface of the Earth. Choosing between the huge array of data poses the first challenge for a biodiversity monitoring activity. Particularly important in this context is the choice of the suitable spatial resolution and the development of techniques able to identify changes in the scene. In the last decades, a number of spaceborne missions carrying MS (WorldView, Landsat, GeoEye, QuickBird, Ikonos) and SAR (Cosmo Skymed, TerraSAR-X, Sentinel-1) sensors for Earth Observation applications has been planned and launched, providing a continuous monitoring of the Earth's surface with an unprecedented spatial resolution and revisit time (up to few hours). We will focus on very high resolution (up to few tens of centimeters) Multispectral (MS) data and series of 3 m resolution SAR images. A proper combination of MS and SAR data must be chosen considering the trade-off between costs and resolution. A possible approach is to acquire, at least once per year, a very high resolution MS image for assessing the land cover and to calibrate open source medium resolution (3m) SAR data to monitor the temporal evolution in the year of vegetated areas

B. Integration with in situ data acquisition

The use of remote sensing in real-world scenarios requires a multidisciplinary approach for integrating satellite data with ground-based measurement campaigns. Even if time-consuming and expensive, field activities are crucial to provide accurate information to complement remote sensing data, helping a comprehensive understanding of urban ecosystems. Citizen science initiatives can be also adopted to integrate information and to calibrate remotely acquired data [3]. This synergy enhances the accuracy and reliability of the assessments.

3. Methodological Approach

A Mapping of Species Distribution

The first step to be performed is the identification of the existing species in urban areas via land cover mapping. The integration of remote sensing technologies with measurement campaigns facilitates the identification of species distribution within urban environments. Analysis of data on vegetation indices and land cover assists in inferring the presence and abundance of different species. This information proves invaluable in identifying biodiversity hotspots, and evaluating the success of conservation efforts. The proper combination of bands must be studied to separate different species. As an example, in Figure 1 two compositions of different bands of a WorldView-2 high resolution (1.6 m) is presented acquired in the Capodimonte park in the city of Napoli, Italy. As shown in Figure 1b, the use of the Near Infrared (NIR) bands, sensitive to the chlorophyl abundance, along with the red edge band can help to distinguish species that appears inseparable in the visible region. The false color image in Figure 1b increases the classification performance of a standard classification with respect to the real color image 1a, where the vegetation cover appears more homogeneous.

a) b)

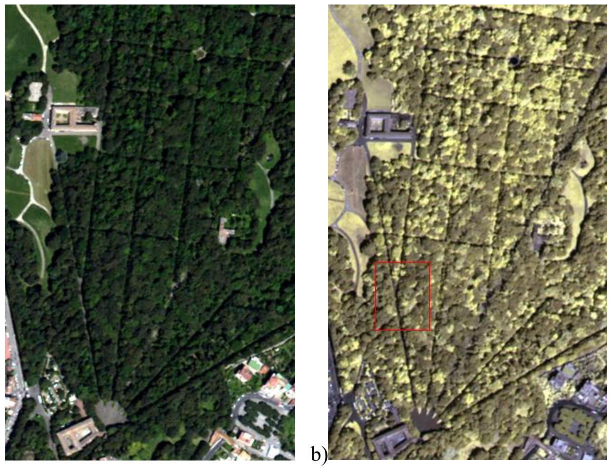

Figure 1. a) Real (bands 4-3-2) and b) false (bands 8-7-6) color images of the Capodimonte green area in Napoli, Italy.

B. Detection of Changes Over Time

The opportunity to get temporal series of remote sensing images at no cost enables the monitoring of changes in urban vegetation over time. Change detection algorithms can be performed on short and long temporal scale. On short term, they can be adopted to distinguish between trees with different coverage during the year.

As an example, the deciduous tree species *Ailanthus altissima*, a sample of which is presented in Figure 2, loses its foliage in winter. This phenomenon can be exploited to separate its electromagnetic response from the response of other evergreen tree species typical of the Mediterranean region as, for instance, the holm oak (*Quesrcus ilex*) the olive (*Olea europaea*), the alaternus (*Rhamnus alaternus*) and all the conifers.

Long-term satellite data archives provide a historical perspective, facilitating the detection of trends and patterns in vegetation cover, land use, and biodiversity. This temporal insight is crucial for identifying the impacts of urban development, climate change, or conservation initiatives on biodiversity dynamics [4], [5].

An example of the exploitation of a series of SAR data is presented alone (see Figure 3a) and in a color composition built to make emerge areas with high backscattering. Such a composition allows to identify, in Figure 3b, the green spot that represent a volumetric scattering response that was not appreciable in the single image.

Figure 2. Example of Ailanthus individuals during the summer (left) and winter (right) season.

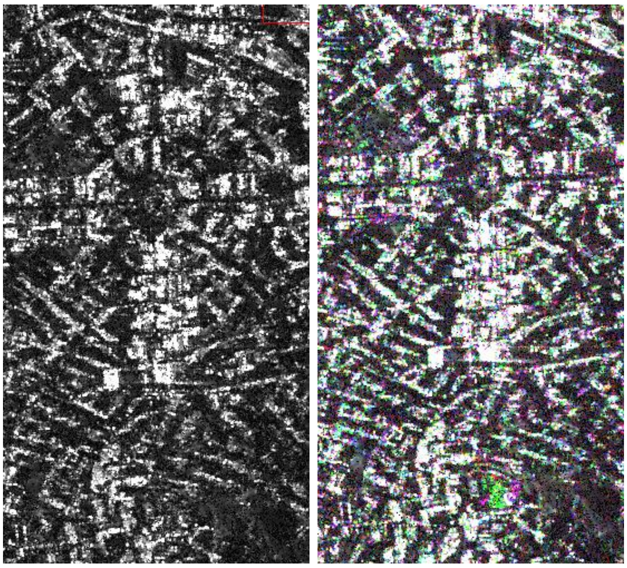

Figure 3. A Cosmo Skymed stripmap image acquired on May 2020 is depicted a) in grey scale, and b) as the green band of a false color composite.

C. Challenges and Limitations

Despite the numerous potentialities offered by remote sensing instruments, several challenges and limitations still must be faced for their use in real-world scenarios. The resolution of satellite imagery is the main limit to the detection of small-scale biodiversity features, and the interpretation of spectral data may require still massive ground validation. Additionally, factors such as cloud cover for MS data, and the costs to acquire very high resolution imagery may pose challenges in acquiring reliable and consistent data.

4. Conclusions

Remote sensing technologies offer powerful tools for monitoring and managing urban biodiversity. By mapping green spaces, assessing habitat fragmentation, monitoring species distribution, detecting changes over time, and addressing challenges through integration with ground-based campaigns, remote sensing contributes significantly to our understanding of urban ecosystems. As technology continues to advance, harnessing the power of remote sensing becomes increasingly crucial in promoting sustainable urban development that harmonizes with the preservation of biodiversity. The collaboration between technological innovation, community engagement, and informed policymaking holds the key to ensuring the coexistence of urban development and biodiversity conservation.

The joint use of very high resolution MS data purchased at least once per year, together with series of 3 m resolution free SAR data and the information provided by *in situ* measurement campaigns turns out to be a valuable combination to support biodiversity monitoring.

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