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Extracting Urban Areas on Simulated Proba-V Data Using ANFIS

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Abstract. Urban sprawl is gaining interest because its intensity has been strong during the recent years as well as because it greatly affects natural ecosystems. This paper is focusing on developing a method to monitor urban sprawl using medium resolution optical data. The image source is simulated Proba-V data at a spatial resolution of 300 meters. Proba-V is designed as a continuity mission to the SPOT VEGETATION series, to be launched on 2012. The simulation involves a change in spatial as well as in radiometric resolution and will be based on MODIS data. Overall, the objective is to investigate whether it is possible to monitor urban sprawl using medium resolution data and an automated method (supervised classification) instead of having to rely upon CORINE that requires considerable more effort as it is a product of manual photo interpretation.

Keywords. Proba-V, urban sprawl, ANFIS.

1. Introduction

Urban areas cover a small fraction, less than 3%, of the earths' surface [1]. Yet their importance is probably higher than any other land cover type. One reason is that a great part of human activities are concentrated there. More than 50% of the global population is now concentrated in urban areas, a percentage that rises up to 80% for industrialized countries. What makes urban areas even more significant is the rapid pace of urbanization. Urban dwellers have increased fivefold during the past decade and developing countries will approach the urbanization level of industrialized countries in the following decades [2]. A further reason why urbanization currently draws a lot of attention is its association with climate change. Cities are hot spots of green-house emissions with increasing ecological footprints. At the same time urban expansion permanently occupies land that used to be suitable for other uses (agricultural production, recreation etc), irreversibly undermining the remaining land reservoir.

It is mainly for these reasons that monitoring of urban areas and their expansion is critical. In most countries the only economically viable means of monitoring is earth observation. Monitoring can also be based on land cover datasets that are being produced by several international organizations. However, even the most detailed datasets, such as the CORINE land cover produced for Europe [3], are not updated as frequently as would be optimal. Inevitably, they also contain errors as they are products of manual photo interpretation.

In the Hellenic Republic, urban sprawl has been particular intense during the past decade especially in the capital, Athens, but also elsewhere. To a large degree this was driven by the newly built infrastructure related to organizing the 2004 Olympic Games. It was also driven by economic prosperity as well as political decisions to expand Athens, towards the new airport (east). Nevertheless, since 2008 the construction sector is facing an almost complete stand-still due to the economic crisis. The Athens expansion is shown in Figure 1 based on data from the European Environmental Agency (EEA). Currently EEA provides the only consistent dataset for the country.

However the EEA datasets are not based on the same standards. Notably the 2009 data (Urban Atlas) is suitable for 1/10.000 scale whereas the 1990 and 2000 datasets (CORINE) are suitable for 1/100.000.

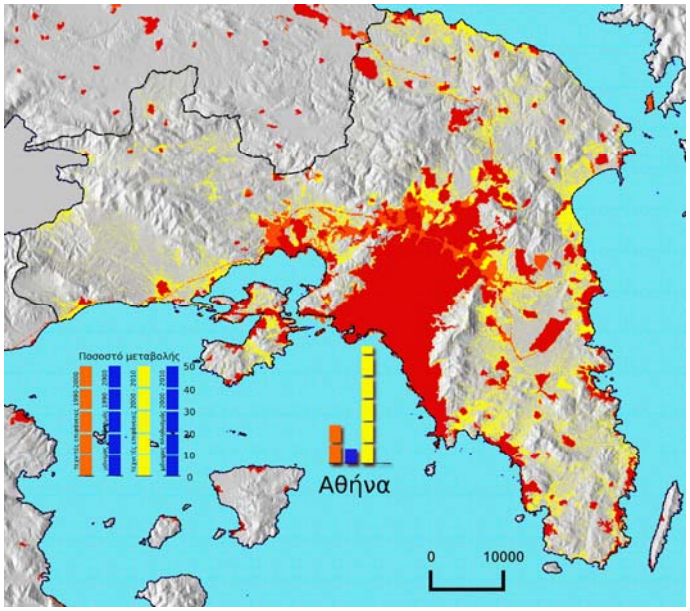

Figure 1: Urban sprawl in Athens. Urban sprawl during 1990-2000 (orange) and during 2000-2010 (yellow) is shown. The blue bars refer to population growth (%) for the corresponding decades.

To summarize the situation in the country, recent expansion of cities has been enormous. The exact amount of expansion is hard to quantify however due to lack of data. The only available datasets are those from the EEA and only for years 1990, 2000 and 2009. The Hellenic Republic is the only European country that does not have a CORINE dataset for the year 2006. The EEA dataset for 2010 is not directly comparable as it only covers main urban areas (population over 100.000) and the mapping standards are different. In effect, this means that it is hard to say whether changes evident amongst EEA data for 2000 and 2010 are actual changes on the ground or artifacts due to differences in mapping specifications. Obviously this lack of knowledge regarding the expansion of cities is strongly related to inefficiency evaluating and perhaps mitigating, planning policies. The lack of reliable time series data regarding urban areas is a negative driver in constructing robust models of future expansion. This leads to weak predictions of areas receiving greater pressure for urbanization. In turn, this means that planning is currently based on rough estimates instead of hard evidence. Notwithstanding, it is very important in both economical and social terms to quantify current urbanization as well as to predict future expansion. In economical terms expansion is associated with land values, increased transportation cost, increased (and sometime infeasible) costs for new infrastructures. In social terms expansion is associated with pollution. This is air pollution due to the increased use of private car for transportation but also land and water pollution due to the lack of efficient infrastructure (sewerage systems, wastewater treatment etc).

2. Methods

The Proba-V sensor is planed as a successor of the SPOT VEGETATION instruments. It will start operation in 2012. It will scan the surface of the earth with four spectral bands, in specific blue (0.44-0.48 μ), red (0.62-0.698 μ), near infrared (NIR, 0.79-0.90 μ), and short wave infrared (SWIR, 1.56-1.65 μ). Data products will be made available at a resolution of 1000 m (VNIR and SWIR), 600 m (SWIR) and 300 m (VNIR). The operational altitude is planned to be approximately 820 km

providing a near daily (90% daily coverage of equatorial zones) and near global cover. The orbit is sun-synchronous with acquisition time 10:30 – 11:30 AM.

First of all, a standard maximum likelihood classification was performed to classify data into the land-cover classes of CORINE's level 1 (urban, agricultural, forest, water). Then ANFIS was used as a more advanced technique. ANFIS [4] is a five-layer neural network [5], [6] architecture that contains both adaptive (having parameters) and fixed nodes (not having parameters). The original version of ANFIS is limited to producing two output classes [7]. The two classes here is urban vs. non-urban.

3. Results

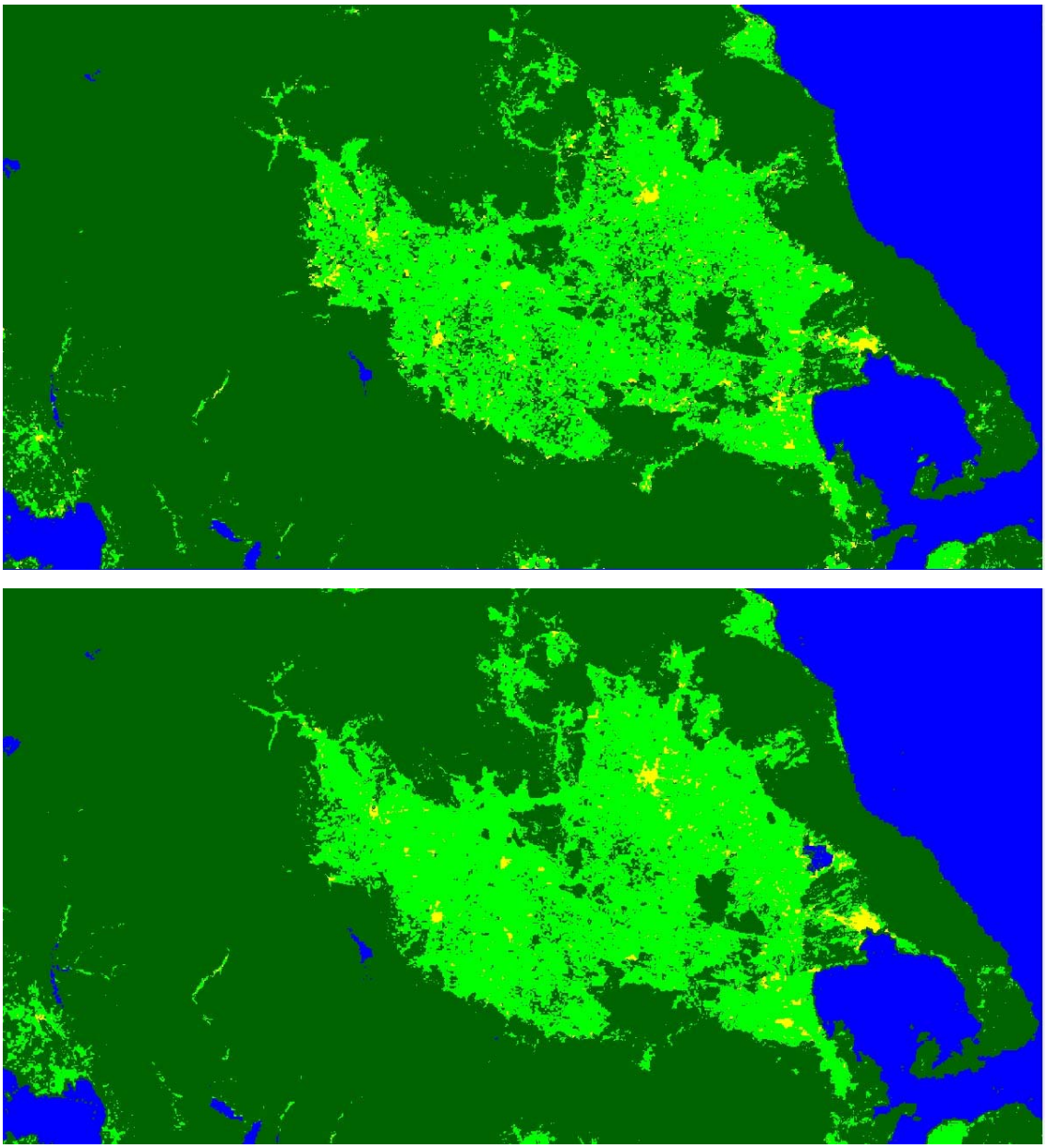

Figure 2: Results of a standard maximum likelihood classification for the study area. Year 2000 is shown at the top and year 2010 below. Yellow areas are urban. Light green agricultural. Dark green forest. Some indication of urban expansion is evident.

The maximum likelihood classification for the year 2010 yielded an overall accuracy of 82.63% (k coefficient 0.7). In comparison, ANFIS classification using as inputs spectral (R, NIR and SWIR) as well as topographic information (slope) yielded a maximum accuracy of 91.57 (k coefficient 0.84).

4. Conclusions

Overall it has been shown that monitoring urban sprawl by means of earth observation is possible. Standard methods such as maximum likelihood yielded satisfactory results that can be improved using more advanced methods such as neuro-fuzzy classifiers. Proba-V data, especially its higher resolution (300m) has been found useful in urban sprawl studies.

Acknowledgements

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