GLOBAL URBAN AREAS MAPPING FROM MERIS DATA.

FIRST ANALYSIS AND PRELIMINARY RESULTS

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ABSTRACT

The Joint Research Centre is developing a prototype for global urban areas mapping at 300m resolution mainly based on ENVISAT-MERIS. Other urban areas maps (MODIS urban layer and DMSP data) will be integrated in order to increase the coherence of the final product. In this prototype phase, three heterogeneous continental regions have been selected as test sites: South and North Western Africa, North Latin America and Europe.

This paper introduces three new MERIS indices oriented to the classification of urban areas. These indices allow the discrimination of 7 classes: four build-up classes (high, medium and low urban density and bare soil), two water classes (surface water and deep water) and vegetation. These classes are not definitively defined and continue to be tuned in the framework of this prototype phase. The preliminary results on Bogota, Johannesburg, Milan and Sao Paolo are presented and discussed.

INTRODUCTION

The process of urbanisation is one of the consequences of the human development. It is related to economic growth, as well as changes in the social, political and demographic structure of nation states. Nearly half of the world's population (47%) lives in urban areas. According to UN predictions, this figure is expected to growth by average 2% per year in the next 10 years. This average value is not homogeneously distributed all over the world. Population in developing countries is expected to experiment a more rapid urbanization than in developed countries. This is the case of Africa (average 3.5%) and Asia and the Pacific (2.4%), for instance, but even at these continental levels there exist important heterogeneities (Malawi – average 6.3%). Accurate figures of these processes are a need for decision-makers in terms of social and economic service management.

These processes not only concentrate people, it also creates hot spots for energy and natural resources consumption, wastes management, for emissions of pollutants, and greenhouse gases. The impact of urbanization has direct consequences on environment around the city on scales from local to global. Therefore, an improved consistent data base describing urban areas is an ever growing need.

These data bases should not only describe the boundaries of urban areas but also should give information about their levels of urban development: high, medium or low urbanized. This information will constitute the base of a temporal monitoring.

In this paper, we propose a set of indices describing urban areas as a land cover consisting on four main classes: build-up areas, bare soils, vegetation and water. The first part of this paper introduces a brief description of the ENVISAT-MERIS data. A Principal Component Analysis (PCA) of MERIS spectral bands on urban areas shows the spectral distribution of the land cover information in the space of the PCA. From this analysis, we introduce three discrimination indices oriented to the land cover classification of urban areas.

Some preliminary results obtained from the discrimination and analyses of these new indices are presented and discussed.

METHODS

MERIS is an ESA "push broom" imaging spectrometer measuring the solar radiation reflected by the Earth with 15 spectral bands in the visible and near-infrared. This instrument allows a global coverage at 300m (9ha) resolution of the Earth in 3 days.

Although the MERIS primary mission is the measurement of sea colour in the oceans and in coastal areas, it also retrieves measurements of chlorophyll over land and therefore on vegetation (i). This also allows retrieving information at medium resolution of the land covers in urban areas greater than 27 hectares. The question here is to know the possibilities of the MERIS spectral bands to discriminate urban areas classes.

For this purpose, we realized a Principal Component Analysis (PCA) of the MERIS data in some urban areas: Bogota, Sao Paolo, Johannesburg, and Milan. We used a random sampling of pixels of these cities that were visually classified using Landsat TM images as follow (Figure 1):

a) Urban – High Density
b) Urban – Medium Density
c) Urban – Low Density
d) Urban – Parks
e) Vegetation
f) Water

Figure 2 depicts a clear spatial distribution of spectral bands and normalized values of the urban land covers of the different cities (vegetation and different urban densities – from high density to bare soil). In the space of the two firsts principal components, the total spectral variability is explained up to 69%.

In this figure, we see an "evolution" of vegetation pixels from:

a) On one side, a high amount of chlorophyll (a vegetated pixel) to a mix vegetation in urban high density; and,
b) On the other side, a high amount of chlorophyll to bare soil or low urban density.

Build-up pixels evolve from "Urban – High density" to "Urban – Low density/Bare soil".

From the PCA, MERIS spectral bands can be distributed in three main groups:

a) MERIS B01, B02, B03 and B04. The inter-correlation values between these spectral bands are greater than 0.98. These are aligned along the second component of the PCA.
b) MERIS B05, B06, B07, B08 and B09. The inter-correlation values between these spectral bands are greater then 0.96. These are aligned along the bisector second and first PCA components.
c) MERIS B10, B11, B12, B13, B14 and B15. The inter-correlation values between these spectral bands are greater than 0.99. These are close to the first PCA component.

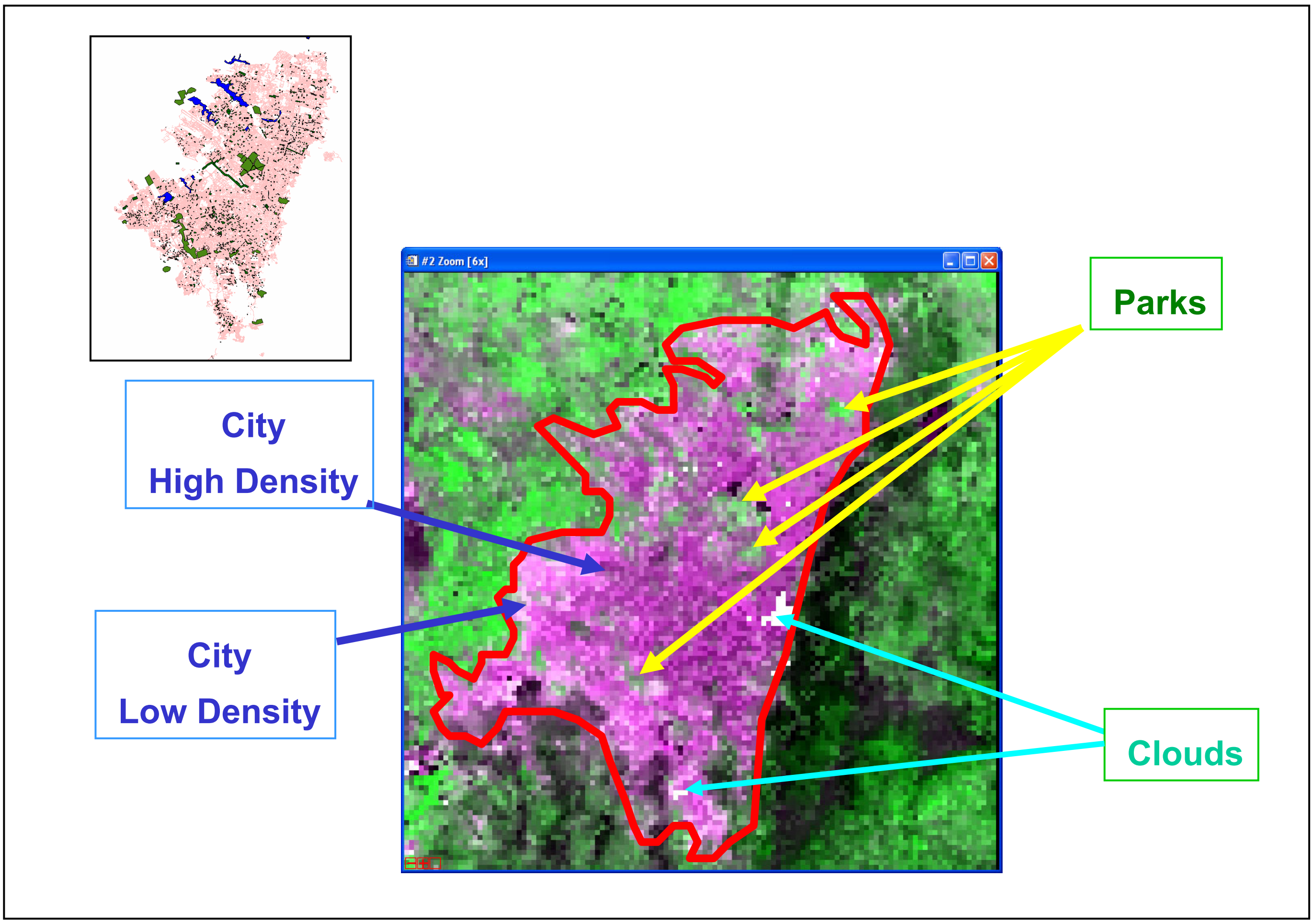

Figure 1: MERIS image of Bogota city (B08-Red, B15-Green, B09-Blue) and land cover at high resolution (1m resolution).

The indices are computed by maximizing the range of the spectral variability between the different urban classes including water bodies (ii). The indices come from a linear combination of the three major spectral band groups identified by the PCA analysis. The indices deduced from this analysis and maximizing the above criteria are:

a) Index 1 – used for the discrimination of water bodies: $I_1 = \frac{B15 - B8}{2xB11}$

b) Index 2 – used for the discrimination of vegetation: $I_2 = \frac{B7 - B12}{B7}$

c) Index 3 – used for the discrimination of urban classes: $I_1 = \frac{B3 - B9}{2xB9}$

Figure 3 shows a colour composition (RGB) of the three indices over the Bogota city. This figure illustrates the potential of discrimination of the new MERIS indices proposed.

The MERIS indices have been computed from and for urban data and, in this way, they should only be applied to urban areas. DMSP (iii) and MODIS urban layer data (iv) will be used as a mask for this purpose.

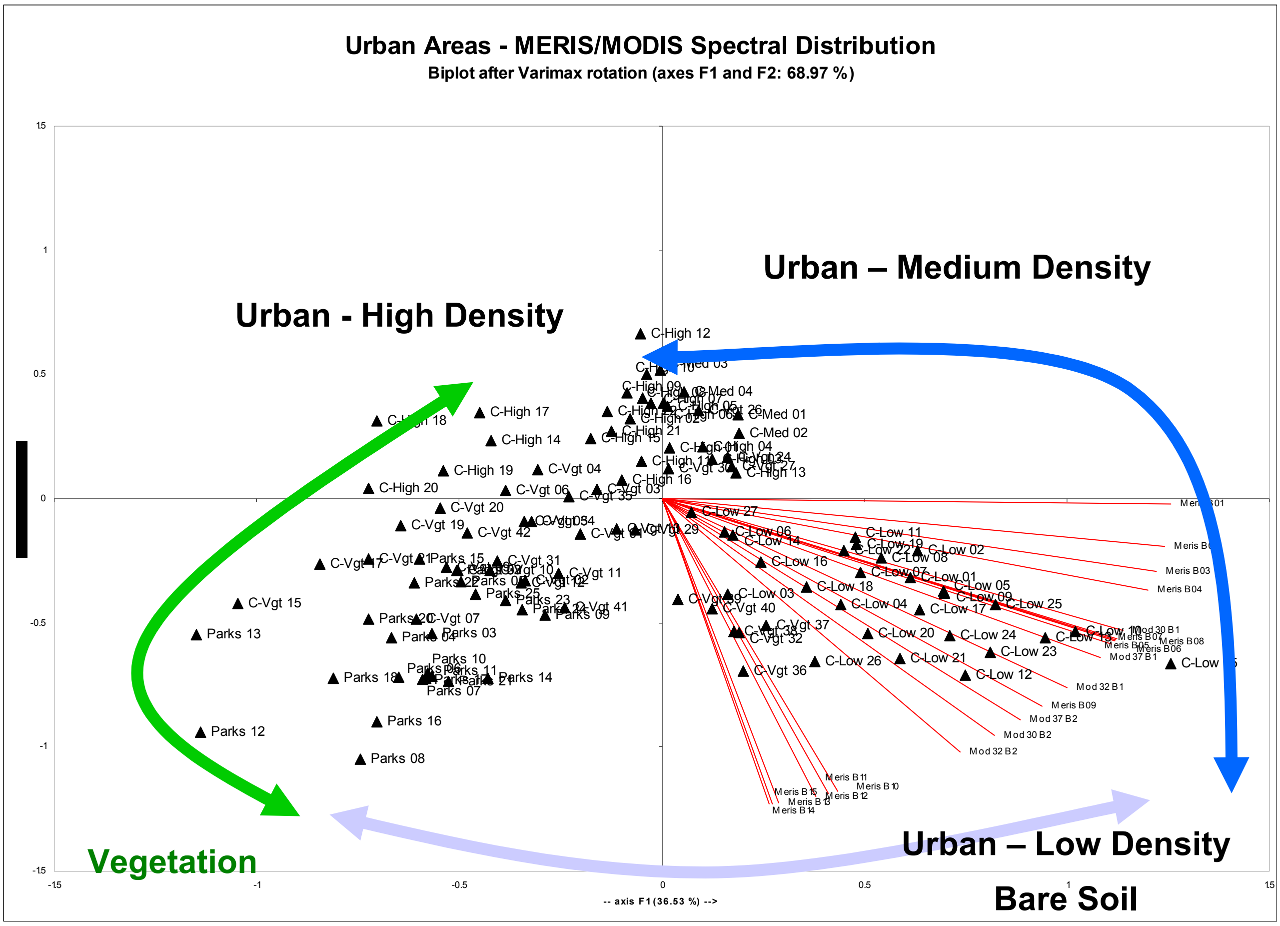

Figure 2: Principal Component Analysis of the urban area pixels of Bogota, Sao Paolo, Johannesburg, Dakar and Milan.

A set of thresholds were applied to the MERIS indices. At the stage of this test phase, these thresholds are being still tuned, but the classifications shown encouraging results (see Figures 4 – 5).

The main urban class identified by the indices is generic but has values evolving in a wide range allowing a segmentation in sub-classes from low to high density. In the same way, we have also the water class that could be segmented from surface water to deep water. An explicit definition of these subclasses and definitive thresholds for each MERIS index are part of the next step of this project.

The urban legend is available in figure 4.

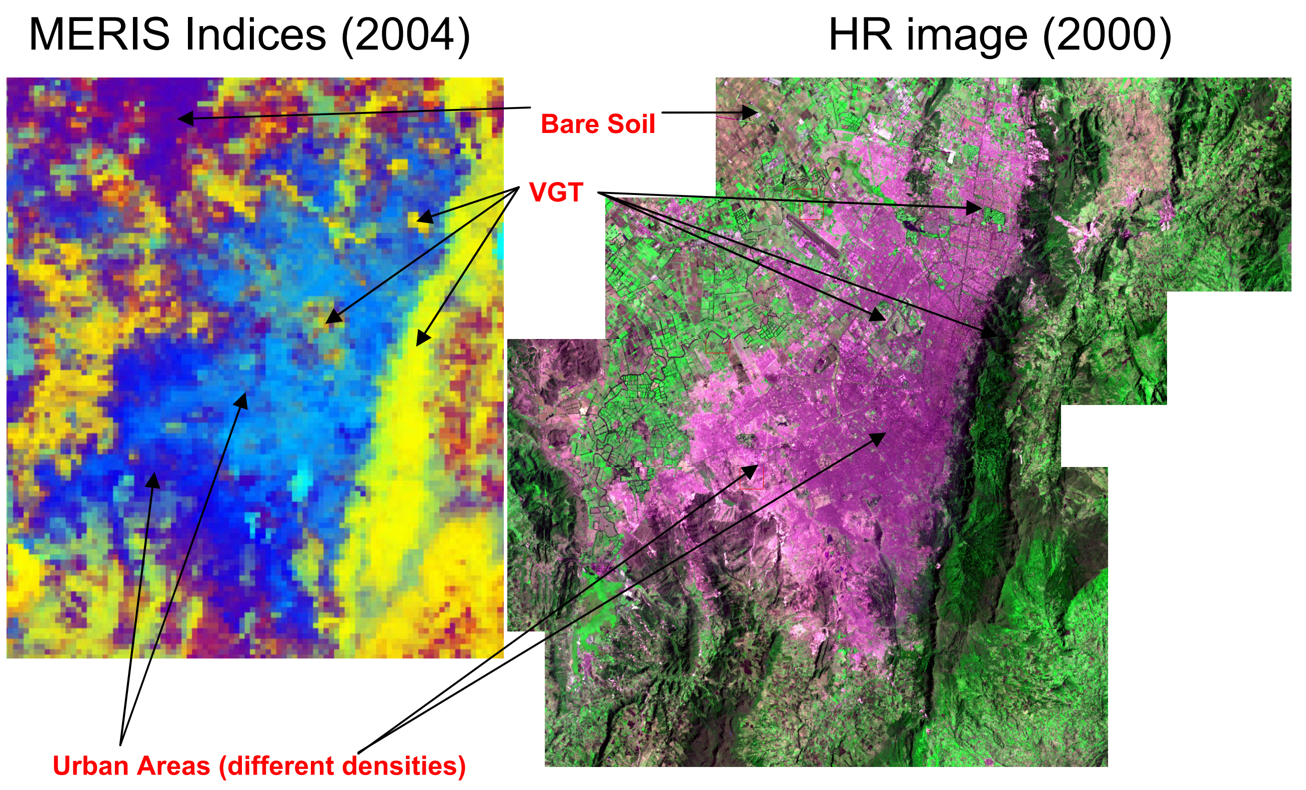

Figure 3: MERIS Indices image (300m resolution) compared with IKONOS high resolution mosaic (1m resolution).

RESULTS

This paragraph introduces our preliminary results and, at this stage of the prototyping phase, an accuracy assessment has not been done yet, but only a visual evaluation. This visual interpretation has been established on the base of the main urban classes as presented above.

Figures 4 – 5 show the results of the classification of the different MERIS data. The results of these classifications have been evaluated using Landsat TM images of the urban areas and a high resolution image (IKONOS) in the case of Bogota city.

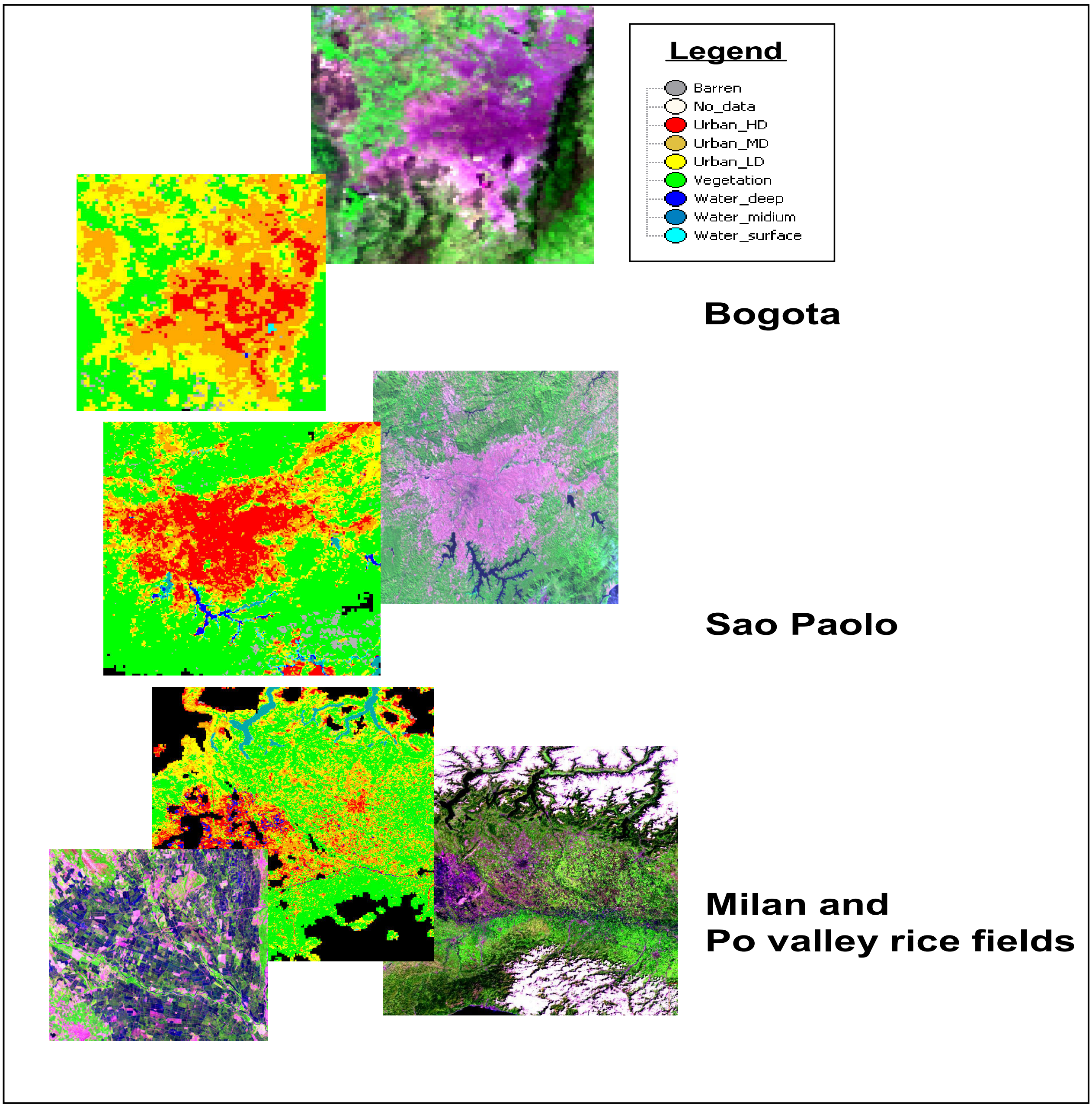

Figure 4: Classification results: Bogota, Sao Paolo and Milan-Po Valley.

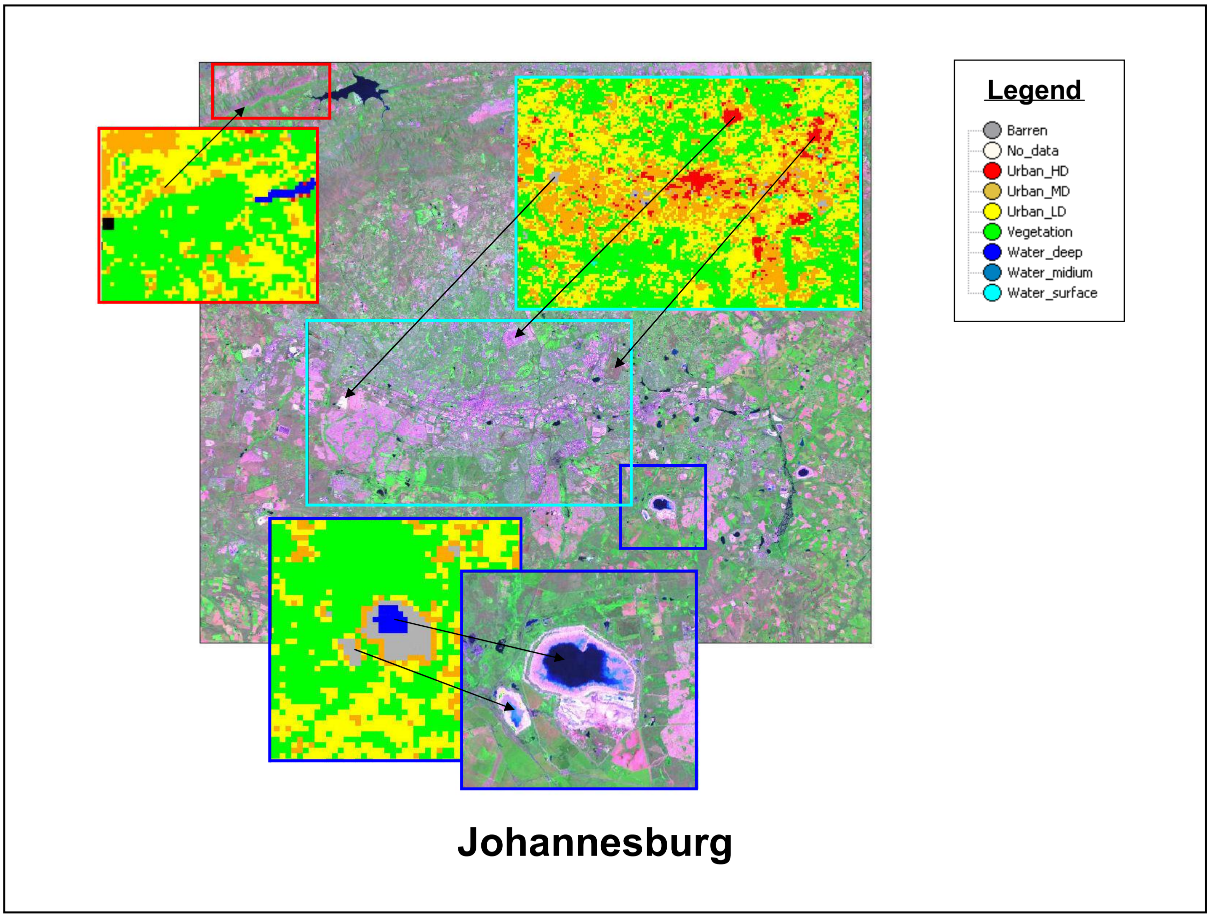

Figure 5: Johannesburg – Classification of MERIS image.

Our preliminary evaluation shows a good agreement between the results and the high resolution image classification but some issues remain:

1) Cloud, snow and ice data. Cloud, snow and ice data introduce a miss-classification of these data as Urban class. A pre-classification of the MERIS data should avoid or reduce this problem.
2) Cloud shadow data. Shadows introduce a miss-classification of the data as Urban High density class. As for the precedent case, a pre-classification of the MERIS image should avoid or reduce this problem.
3) Surface water data. Surface water without chlorophyll has a spectral response close to Urban general classes that cannot be discriminated by the MERIS spectral bands. Ancillary and/or external data are being considered to reduce or avoid this problem.
4) Some soil types with very low vegetation content. This type of land-cover data has a spectral response close to urban medium and low density class that cannot be discriminated by the MERIS spectral bands. Multi-temporal classification and/or ancillary or external data are being considered to reduce or avoid this problem.

CONCLUSIONS

In conclusion, this paper has proposed three new MERIS indices for classification of urban areas deduced from a PCA analysis. Preliminary tests show the potentiality of these three indices to set up four main classes of urban land cover type (urban, water bodies, vegetation and bare soil).

Next steps in this prototype phase will consider the following issues identified up to now:

1) the resolution of misclassification problems using other ancillary data (frequency of night lights DMSP data, ASAR radar data, land-cover maps are being considered as potential solutions) and with pre-classification methods.
2) Explicit definition of urban classes and their associated range of MERIS index values.
3) A formal definition of the urban area is a need for establishing the boundaries of the cities. An international workshop will be organised by the JRC in the coming months for this purpose.

These results represent a added value for medium-low resolution urban maps which up to now are only binary (urban-no urban class). A new regional-continental urban map with these classes is a need for the climate-global change communities.

ACKNOWLEDGEMENTS

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