Earth Observation Laboratory

PhD Program in GeoInformation

DISP - Tor Vergata University

The potential of Hyperspectral and Multi-angle CHRIS Proba images in vegetation identification and monitoring

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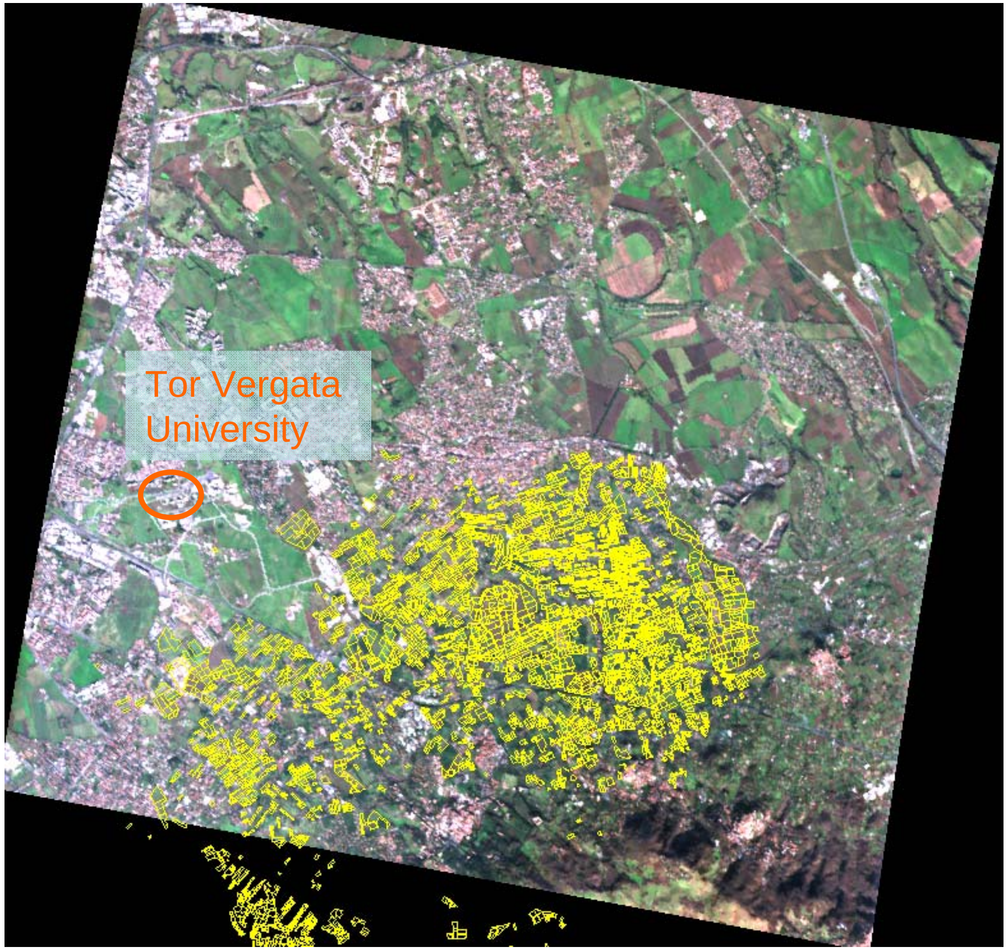
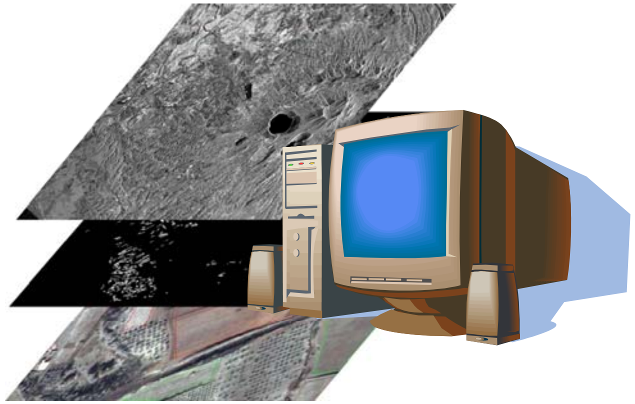
OVERVIEW

- The use of CHRIS hyperspectral images over the area of Frascati and Tor Vergata
- Pre processing: destriping and atmospheric correction
- The neural network classification for the CHRIS images
- The multiangular information as an improvement for features retrieval and classification
- The multitemporal classification for the vegetation identification and discrimination
- Conclusions and future developments

THE IMAGE DATASET OVER FRASCATI AND TOR VERGATA

Previous works and several projects about the Frascati/Tor Vergata area (e.g. Bacchus Doc, DiVino,…) provide a lot of information and data for this area like SAR products , GIS data, Landsat and high resolution images.





Proba images can integrate this kind of data allowing new analysis using the spectral bands and the new multi-angle capabilities.

In our ESA cat-1 (3075) one acquisition for month is planned over the target area of Frascati and Tor Vergata.
Seven images has been acquired

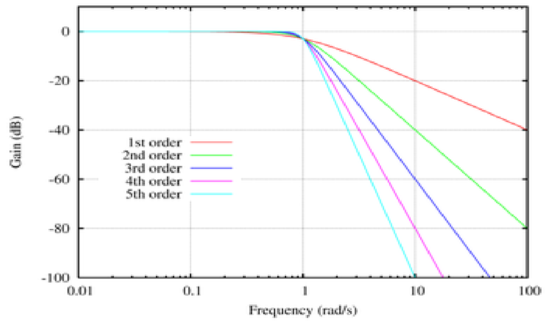
This algorithm has been proposed by M.J.Settle [Settle, 2004] and includes some important steeps:

1. For each band, calculate an average radiance for each column of data
2. Calculate the logarithm for these averages
3. Apply a low pass filter to cut the high frequency components
4. Subtract the result of step 3 from the logarithm of averages to obtain the correction factors
5. Calculate the anti-logarithm
6. Apply the correction factors to each column of the image.

THE CRUCIAL STEP!

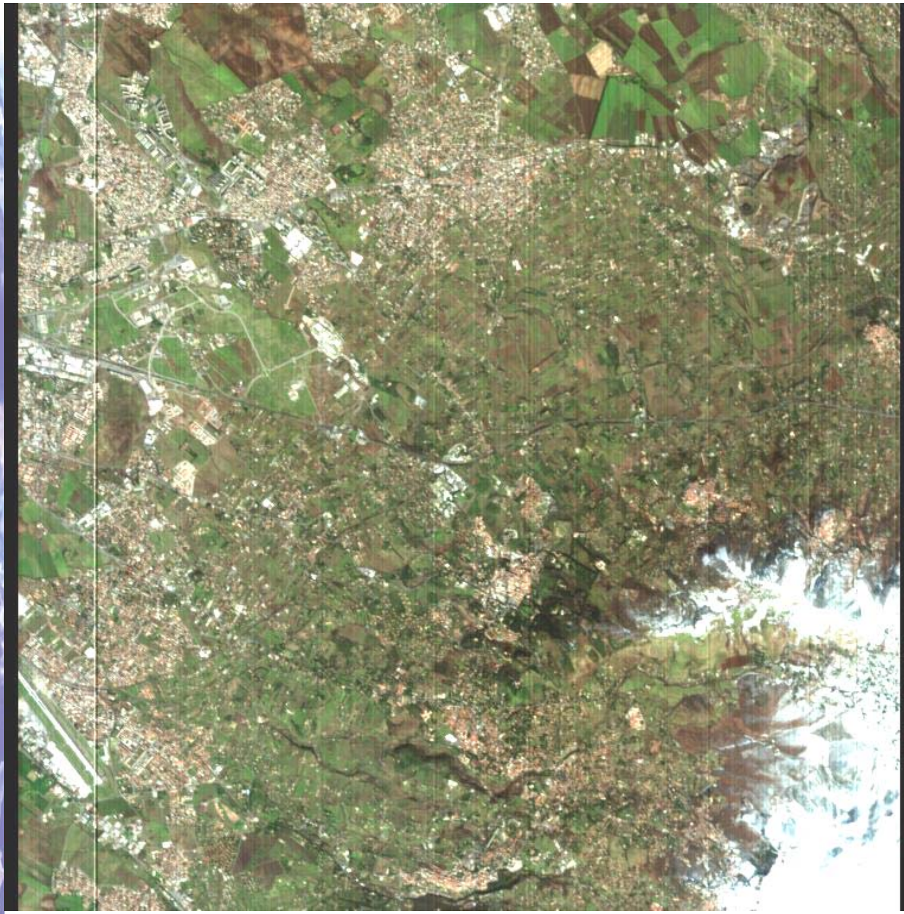
In particular we focused on the point number 3 which now consists in making a low-pass filtering in the spatial frequency domain. The low-pass filter is a Butterworth filter.

$$\frac{1}{1 + C(R/R_0)^{2n}}$$



The destriping tool has been fully developed using IDL and it can operate having as input any CHRIS/proba images in any operation mode, in full resolution (18m) and medium resolution (30), in half swath and full swath.

Frascati/Tor Vergata test site



Before destriping

After destriping

THE METHODOLOGY FOR ATMOSPHERIC CORRECTION (1/2)

The atmospheric correction has been performed by the use of the simulated atmospheric parameters obtained with the radiative trasfer model LibRadTran

PRINCIPAL STEPS

1 For the retrieval of the atmospheric parameters the radiative trasfer model has been used (irradiance, difuse and direct transimmattance, radiance and atmospheric scattering). For the needed aerosol values the the CNR Tor Vergata sensor have been considered (http://aeronet.nasa.gov)

2 A comparison with the radiances of some specific surfaces (motoway asphalt) has been done to extract the recalibration coefficient. For this purpose the average values of sime kinds of sphalt available at the JPL library has been used.

THE METHODOLOGY FOR ATMOSPHERIC CORRECTION (2/2)

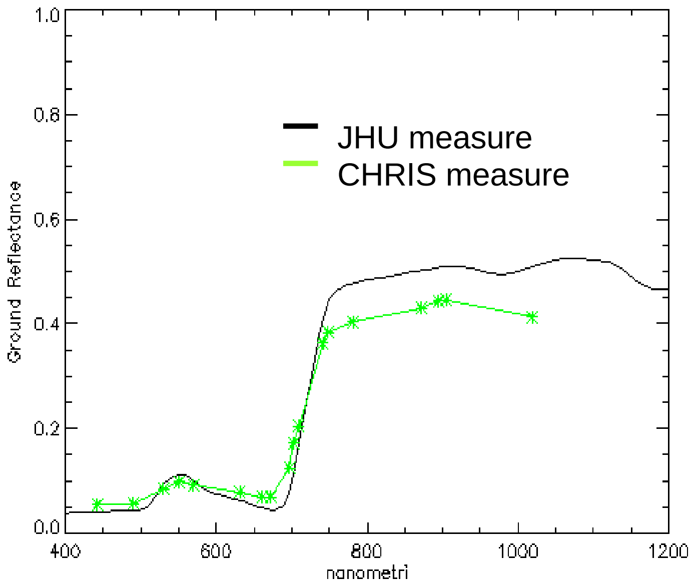
3 The adjacency effect is corrected by the use of weighted mean in a large window applied to all image pixels.

$$\rho^{(2)}(x,y) = \rho^{(1)}(x,y) + q\{\rho^{(1)} - \bar{\rho}(x,y)\}$$

$$\bar{\rho} = \frac{1}{N^2}\sum_{i,j=1}^{N} \rho^{(1)}_{i,j}$$

4 The CHRIS image has been corrected and a recalibration step has been applayed

$$\rho(\lambda,\theta) = \frac{\pi(L_{TOA}(\lambda,\theta) - L_{path}(\lambda,\theta))}{E_0(\lambda,\zeta)T(\lambda,\theta)}$$

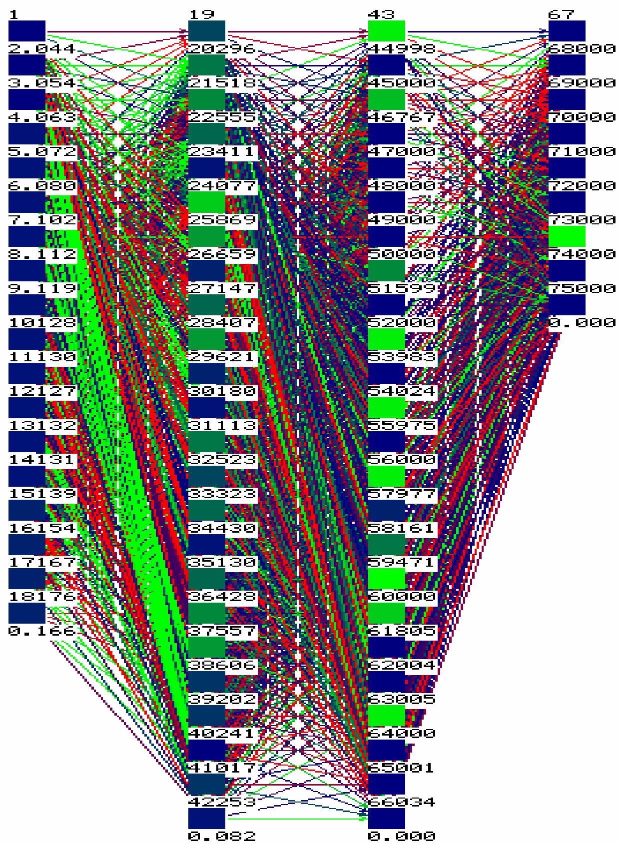


A comparison with a measured reflectance for a grass surface has been done (http://speclib.jpl.nasa.gov).

The measure is made by Johns Hopkins University and the grass was illuminated from directly above and the reflectance angle is 60 degree.

AN ARTIFICIAL BRAIN FOR THE CHRIS IMAGES: THE NEURAL NETWORK CLASSIFICATION

" …The design of a neural network is motivated by analogy with the brain, which is a living proof that fault tolerant parallel processing is not only physically possible but also fast and powerful…" (S.Haykin)



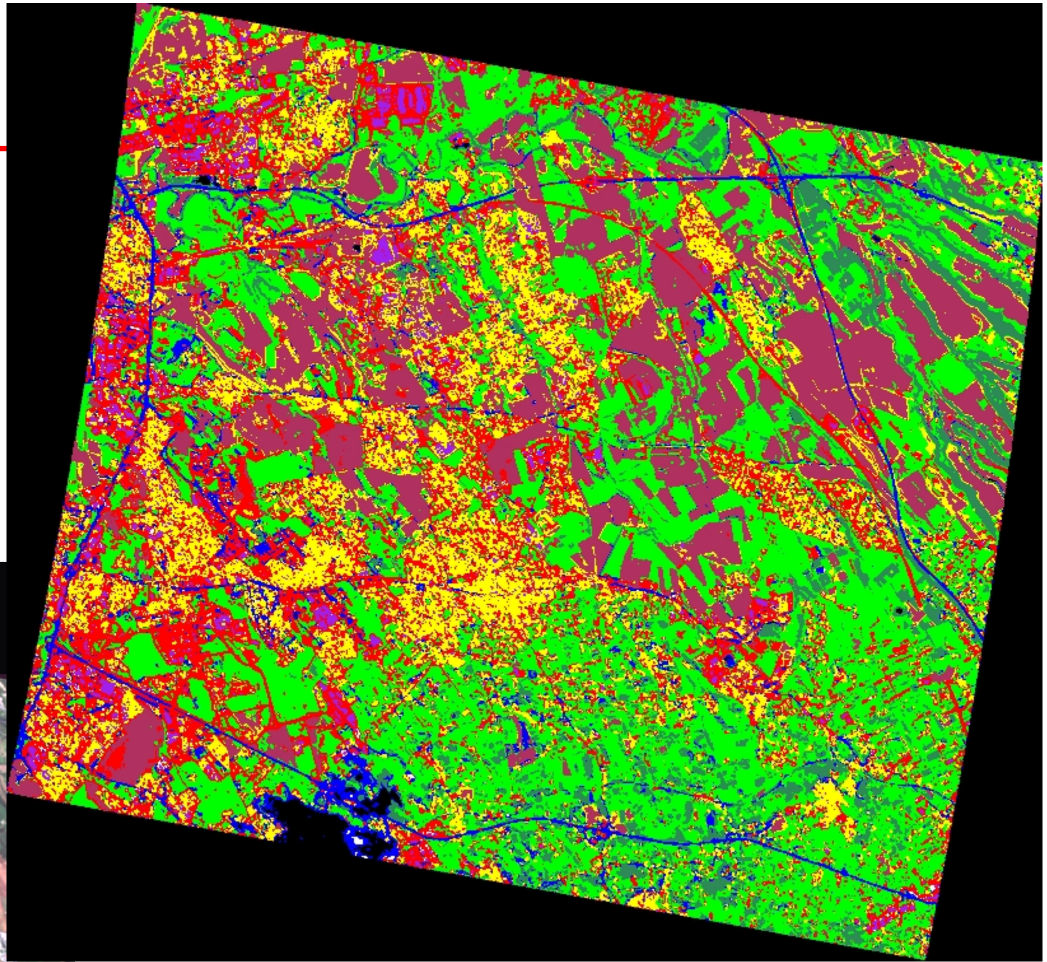
18 – 24 – 24 – 9
topology

PRINCIPAL BENEFITS

- Generalization: the NN could provide good outputs taking inputs not encountered in the training phase
- Input-Output Mapping: capability to modify the synaptic weights by the use of a set of labeled task examples
- Multidomain handling: capability to manage at the same time different kinds of inputs (spectral, multitemporal, multiangle)

We have trained a neural classificator which can map the CHRIS hyperspectral pixels into nine classes of land cover

Highway asphalt
Road asphalt
Residential
Bare soil-arable land
Unclassified
Clouds (withe)
Commercial-Industrial
Vegetated areas
Forest



Classification related to the acquisition of 09-10-2006. The classification has been done taking the corrected and rectified image

ACCURACY RESULTS

(ABOUT 900 VALIDATION POINTS)

TRUE CLASS

ESTIMATED

	Highway Asphalt	Road Asphalt	Urban Residential	Industrial Commercial	Unclassified	Bare Soil	Vegetated	Forest
Highway Asphalt	93,10	0,00	0,00	0,00	0,00	1,07	0,81	0,00
Road Asphalt	3,45	95,15	1,06	5,26	0,00	0,53	3,25	0,00
Urban Residential	1,72	0,00	86,24	0,66	0,00	0,53	0,00	0,74
Industrial Commercial	0,00	0,00	2,65	92,11	0,00	0,00	0,00	0,00
Unclassfied	0,00	3,88	0,00	1,97	100,00	0,00	0,00	0,00
Bare Soil	0,86	0,00	9,52	0,00	0,00	97,86	0,00	2,94
Vegetated	0,00	0,97	0,53	0,00	0,00	0,00	92,68	2,94
Forest	0,86	0,00	0,00	0,00	0,00	0,00	3,25	93,38

Overall Accuracy = 93%
Kappa Coefficient = 0.91

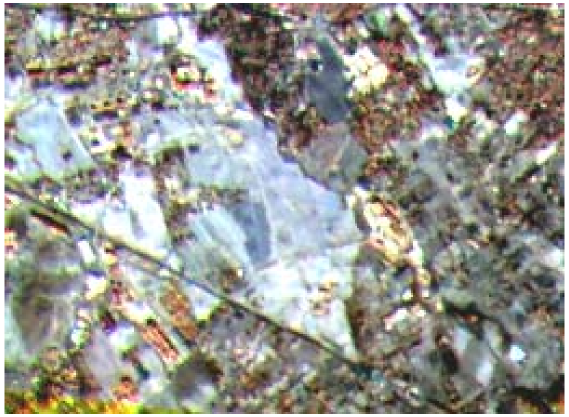
The use of multiangular information to improve the classification results

THE MULTI-ANGLE BAND COMPOSITIONS

Multi-angle band composition over the campus of Tor Vergata University (band 10, 703 nm)

RGB

FZA: -36, 0, 36



FZA: 0, 36, 55

MULTIBAND COMPOSITION OVER THE PANTANO/VERMICINO FIELDS

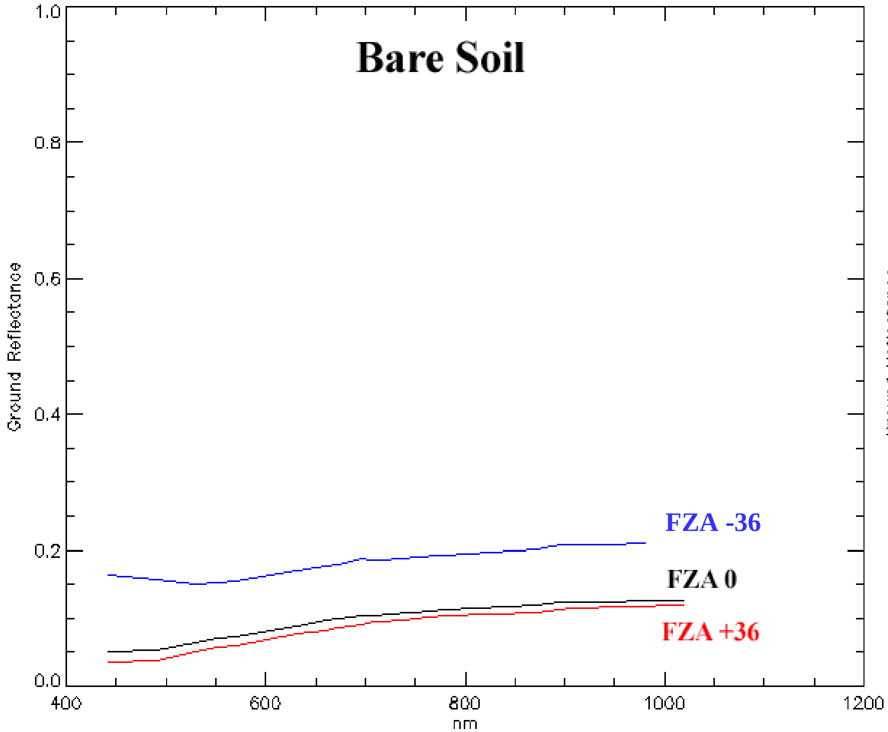
True Color

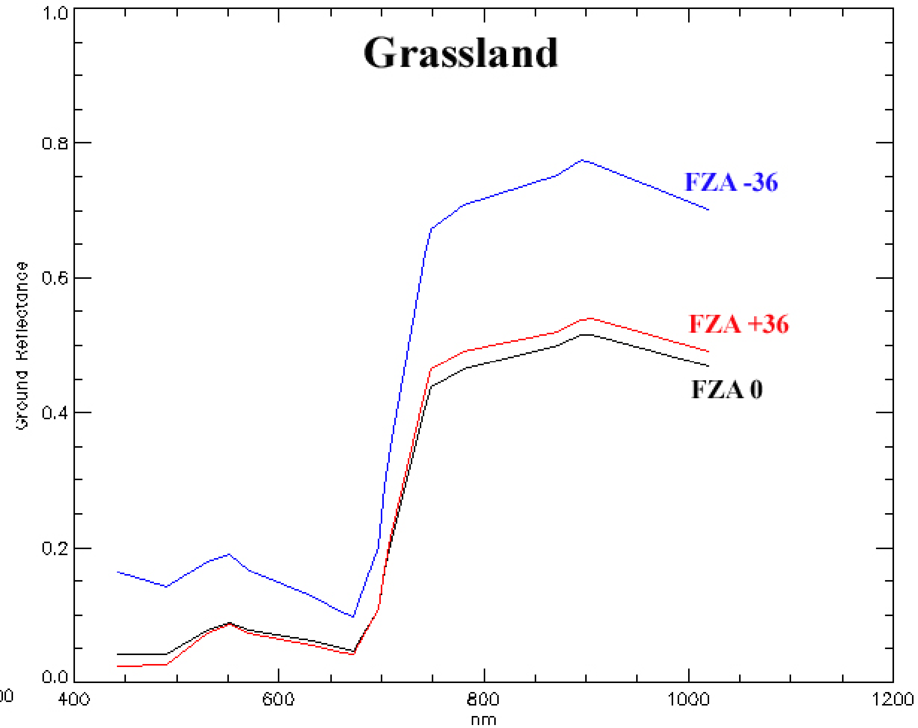
Band 8 multiangle composition

The band 8 composition evidences a radiance difference which could be due to a different structure or cultivation

The high resolution image confirms that the large triangular field is really composed by two different filelds

The analysis has shown how different surfaces have different angular and spectral sensitivity

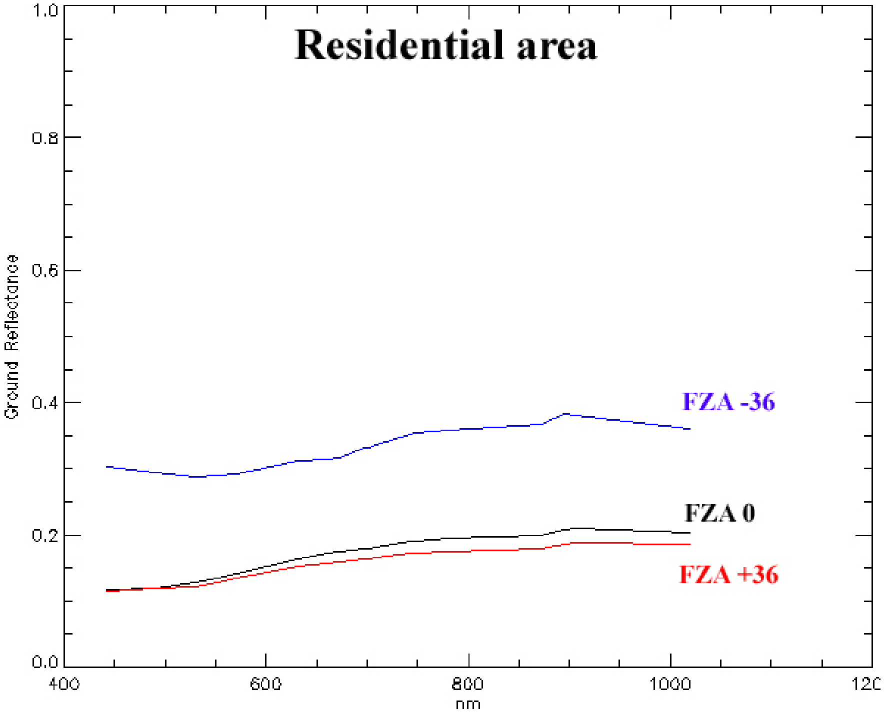


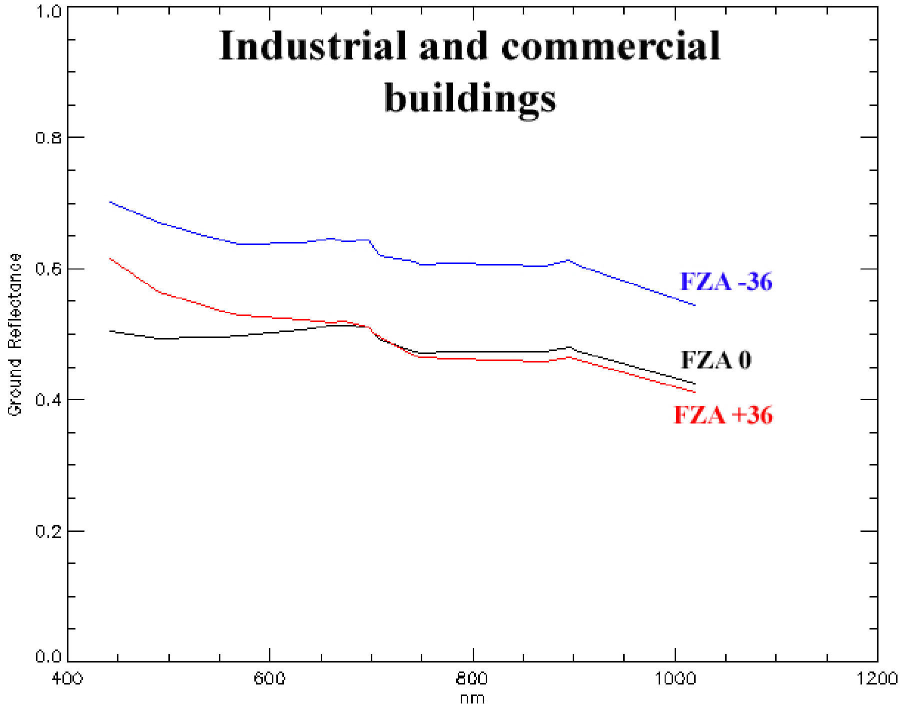


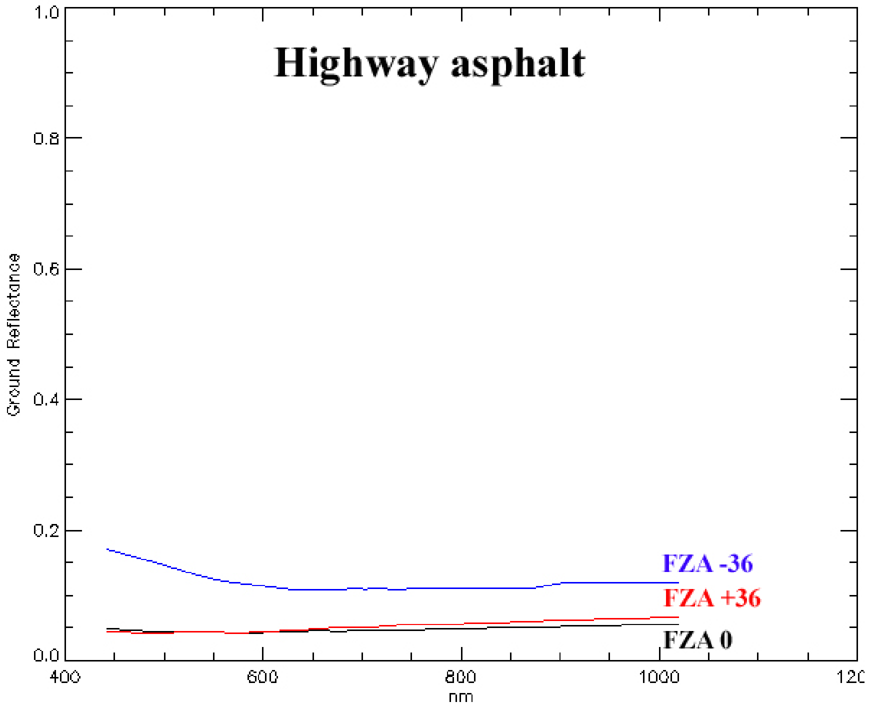
The angular analysis is related to the acquisition of the 28-02-2006. In this case an high reflectance dynamic for the +36 image has been observed, probably due to the geometric configuration of the sun and the satellite

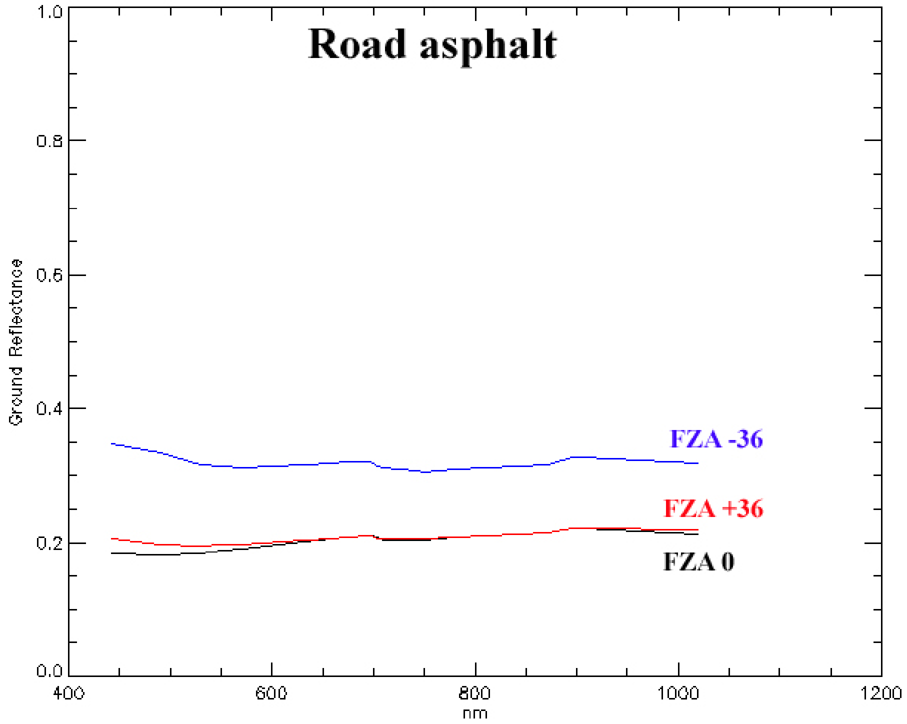
MULTI-SPECTRAL/ANGULAR ANALYSIS (ii)

For the big buildings, which are characterized by a vertical and geometrical structure, it is possible to observe a strong angular dipendence for the reflectance respect to the asphalted surfaces, like roads and parking areas.



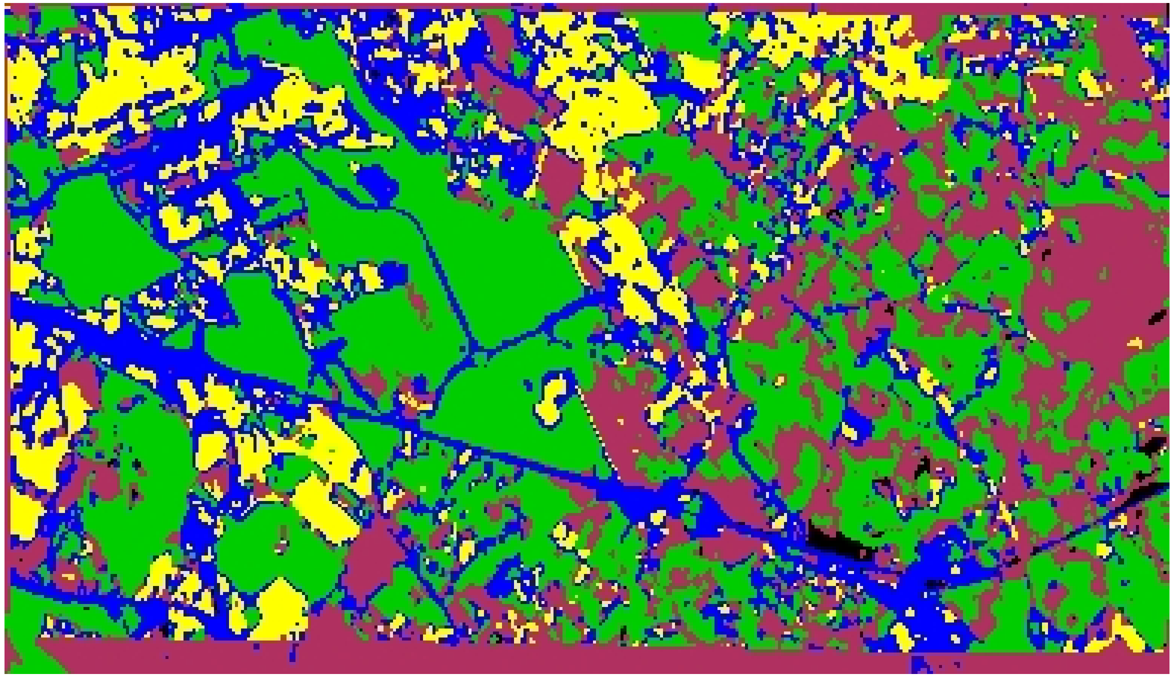






The multiangular information has been used to improve the classification process, especially to discriminate better the urban features, the flat man-made surface and the bare soils.

THE NEURAL NETWORK CLASSIFICATION



Asphalt
Urban
Bare soil
Unclassified
Clouds (white)
Vegetation

Net topology:
54-56-56-6

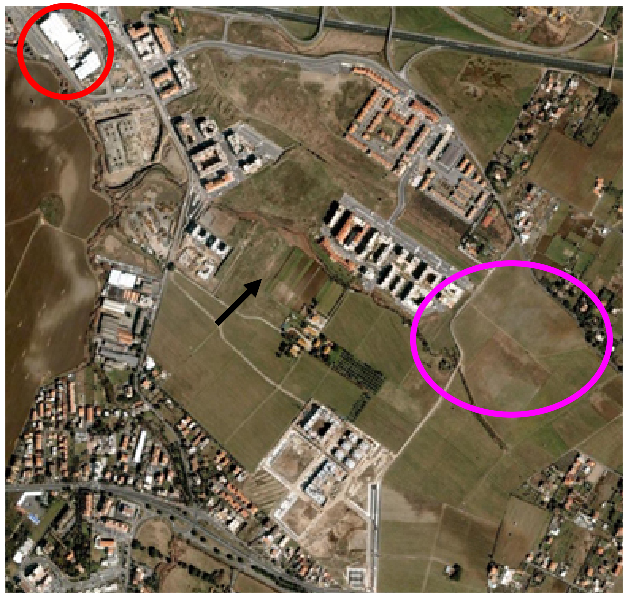
TRUE CLASS (columns) / **ESTIMATED** (rows)

	Asphalt	Urban	Vegetation	Bare soil
Asphalt	97,26	2,3	0	0
Urban	2,74	92,72	0	1,45
Vegetation	0	0	93,33	3,19
Bare soil	0	4,98	6,67	95,36

Overall Accuracy = 94%
Kappa Coefficient = 0.91

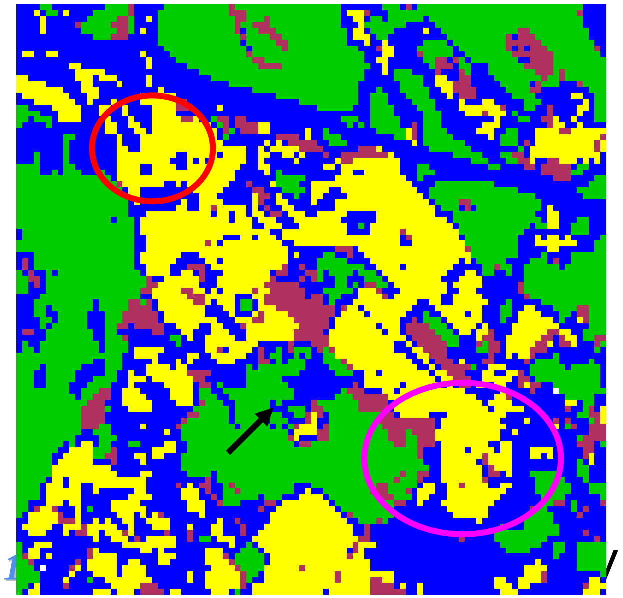
<u>More than 1000 validation points</u>

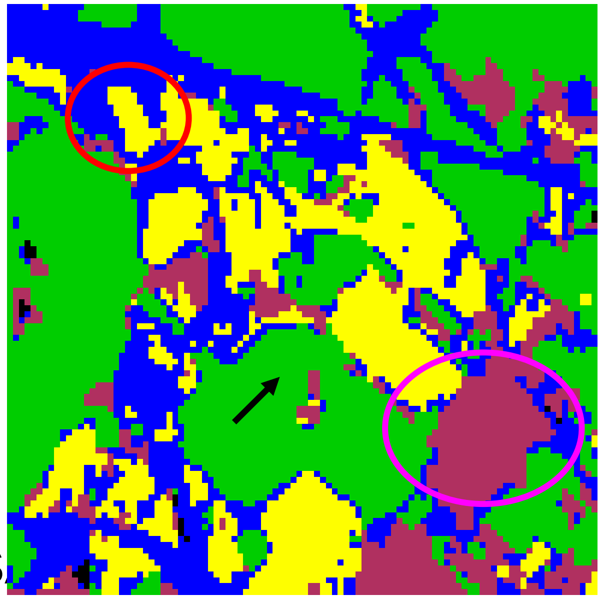
THE MULTIANGULAR IMPROVEMENTS



SINGLE

MULTI





Some surfaces, initially not well discriminated, now have been correctly classified.
The shapes of the big structures have been better identified in the multiangular acquisition than in the single one

Asphalt
Urban
Bare soil
Unclassified
Clouds (white)
Vegetation

The multitemporal capabilities of the CHRIS images for the classification

We have made a layer stack using two CHRIS images over the same area, acquired on the same year (2006). The area has been observed in different seasons with a time gap of seven months. Untill now, it is only the possible combination that we can do using our dataset.

The images have been rectified by the use of the VHR Quickbird image and merged having as result a new multispectral and multitemporal image (36 bands)

THE MULTITEMPORAL ANALYSIS

Using only one image it may be difficult to discriminate among different kinds of vegetated areas, especially using only one image.
In some cases also a trained photo-interpreter could encounter difficulties in classifyng particular vegetated surfaces, even if they have a regular geometric shape.

QuickBird (0,6m of spatial resolution)

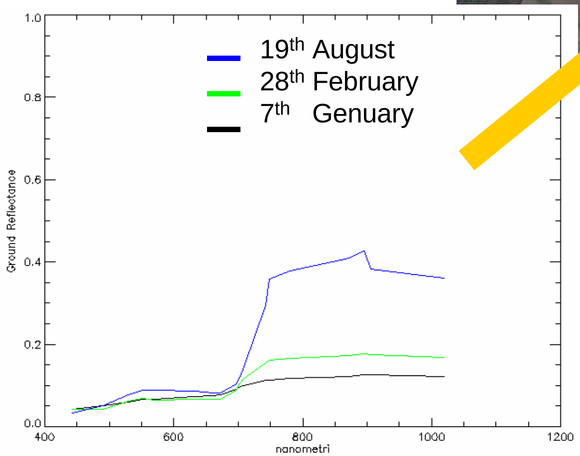
Cultivated or uncoltivated?

One of the possible solutions is to collect and analyze different acquisitions over the same areas and merge this multitemporal information with the spectral properties of the surface under test

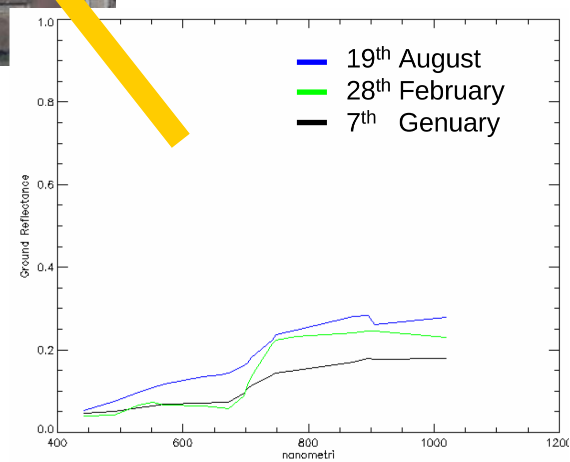
REFLECTANCE ANALYSIS OVER SOME CULTIVATED FIELDS

How we have demostrated in the last PROBA workshop, the reflectance is tightly correlated to the cultivation growth according to the seasonal cycle of development

Maize



Uncoltivated

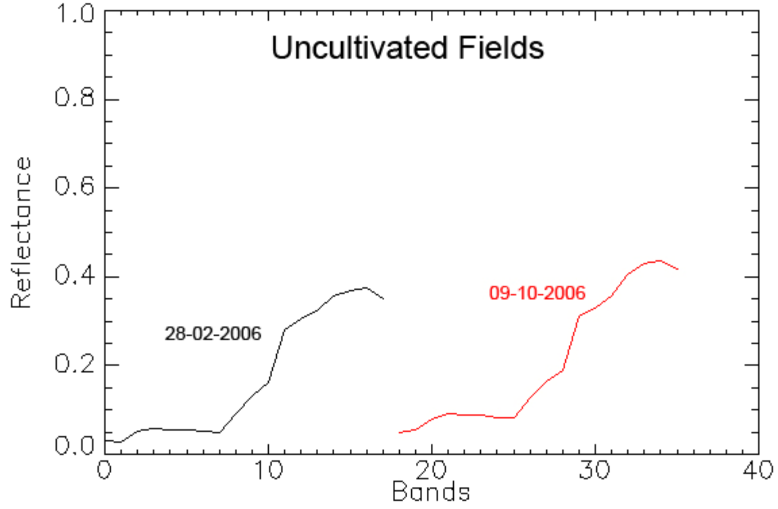


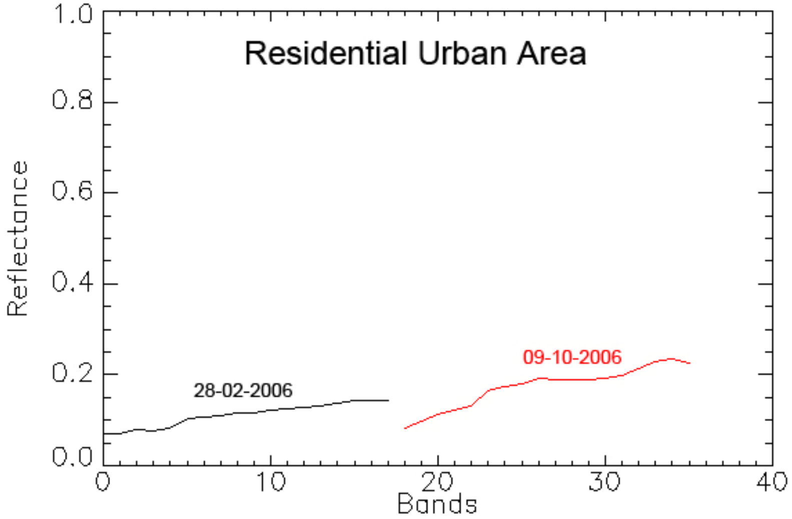
It is possible to use the multitemporal reflectance to evaluate and classify different typologies of vegetated surfaces

THE CLASSIFICATION USING THE NEURAL NET APPROACH

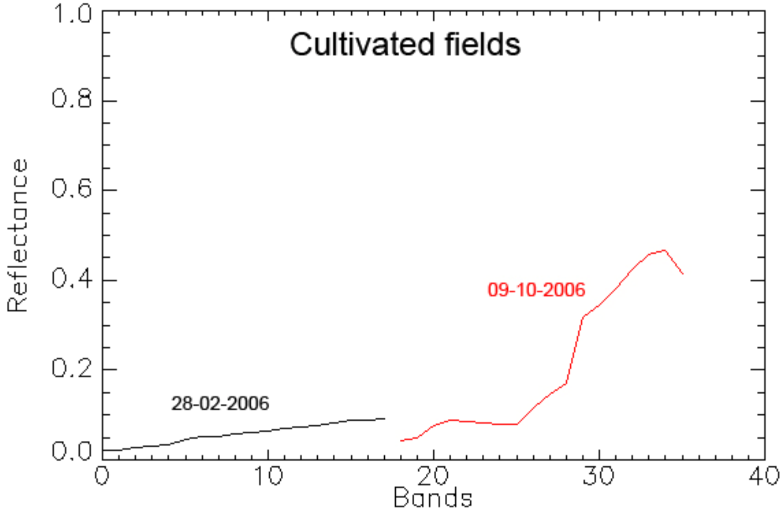
We have trained a neural net classificator which performs the decision taking account the spectral properties of the surfaces and also the multitemporal information

UNCHANGED

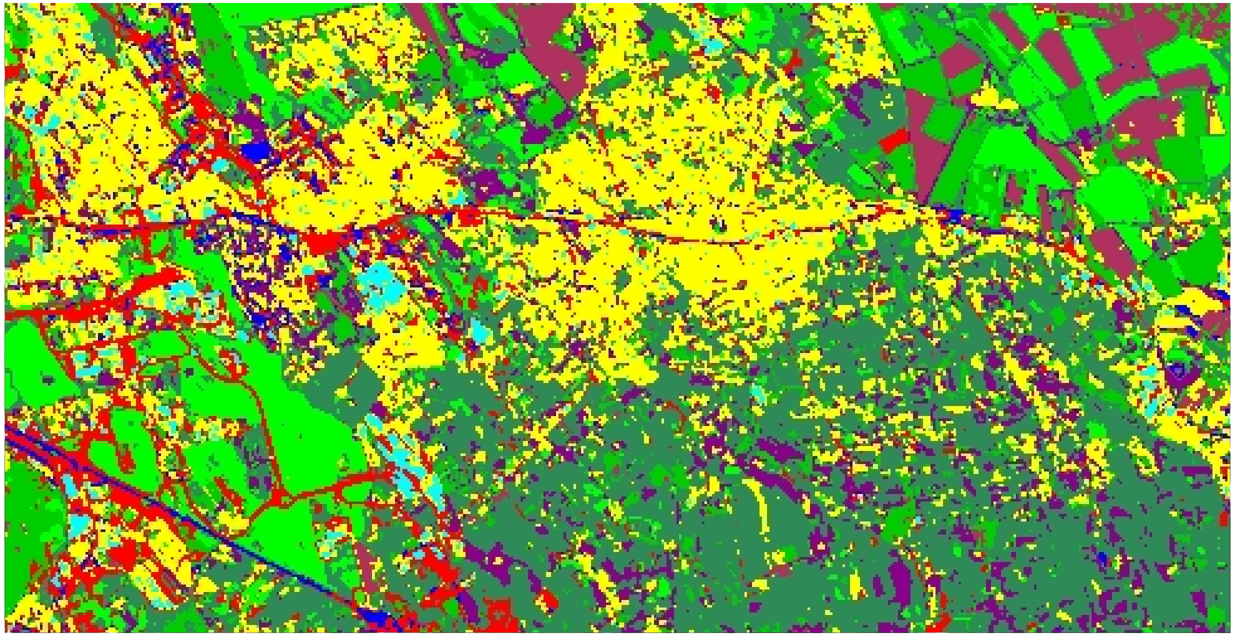




CHANGED

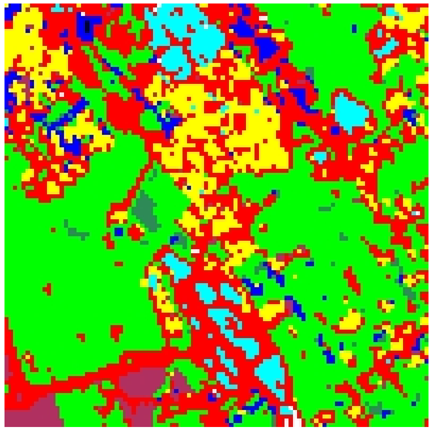


THE RESULTS: THE CLASSIFIED IMAGE

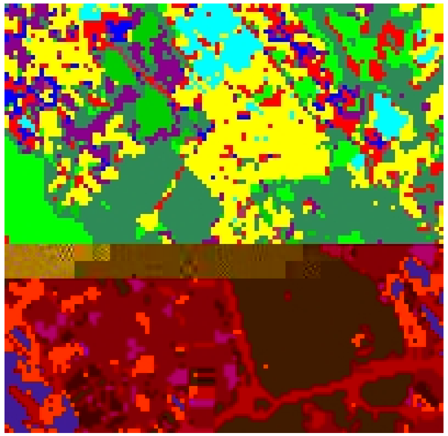


Motorway asphalt
Road Asphalt
Urban residential
Urban industrial
Uncoltivated
Coltivated fields
Vineyards
Olive tree
Bare Arable soil

Single image



Multitemporal image



THE RESULTS: QUANTITATIVE ASSESSMENT

(ABOUT 6000 VALIDATION POINTS)

Overall Accuracy = 91%
Kappa Coefficient = 0.89

GROUND TRUTH

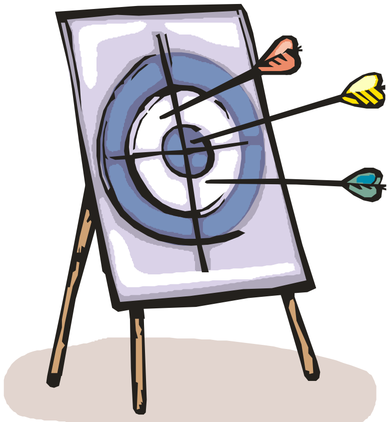
ESTIMATED

	Motorway Asphalt	Road Asphalt	Urban Residential	Industrial Commercial	Uncoltivated	Coltivated	Vineyard	Olive tree	Bare Arable
Motorway Asphalt	100	1,30	0,42	0,0	0,0	0,0	0,0	0,0	0,0
Road Asphalt	0,0	88,31	0,63	3,21	4,77	0,53	3,08	0,0	0,0
Urban Residential	0,0	6,49	96,41	3,93	0,0	0,11	2,21	0,0	0,0
Industrial Commercial	0,0	3,90	2,53	92,86	0,0	0,0	0,0	0,0	0,0
Uncoltivated	0,0	0,0	0,0	0,0	90,55	3,7	4,97	0,0	0,0
Coltivated	0,0	0,0	0,0	0,0	0,0	94,07	5,05	6,74	2,57
Vineyard	0,0	0,0	0,0	0,0	4,68	0,11	84,62	1,55	0,38
Olive tree	0,0	0,0	0,0	0,0	0,0	0,11	0,0	91,71	0,0
Bare Arable	0,0	0,0	0,0	0,0	0,0	1,38	0,08	0,0	96,95

CONCLUSIONS AND FUTURE IMPROVEMENTS(i)

WHAT WE HAVE DONE…

- Tools for destriping and for atmospheric correction have been developed.
- The NN approach to the classification problem appears a good solution to manage an heterogeneous domain of inputs (angular, multitemporal, spectral)
- The multiangular images could give reasonable improvements especially for the urban features discimination.
- The multitemporal observations could be used as inputs for the classification, allowing a complete monitoring and identification of several vegetated surfaces.



…BUT HAVING PARTICULAR CARE IN SOME STEPS…

- The atmospheric correction phase is very important, especially for the retrieval of the aerosol parameters in some geometric configurations
- The spatial rectification becomes a critical step for the processing
- Some parameters, initially related to the satellite mission such as the temporal sampling for the acquisition, the swath and the geometric configuration for the observatin, play a critical role under the applicative point of view

CONCLUSIONS AND FUTURE IMPROVEMENTS (ii)

…THE WAY TOWARDS THE FINISH LINE CONTINUES…

- New classified images could be produced and validated, eventually trying to force the classification at more than nine classes
- The optimization of the neural network continues (optimization of the number of hidden units, generalization, pruning,…)
- New multiangular images could be used for the classification
- The potential of multitemporal classification could be investigated considering new sets of acquisitions, eventually well distributed during the seasons (at least one image every two months, we hope for the 2007…)
- The possibility of an integration of the multitemporal products with the angular information could be investigated.

THANKS FOR THE ATTENTION