Learning Unit

“IMAGE CLASSIFICATION"

“Image Classification"

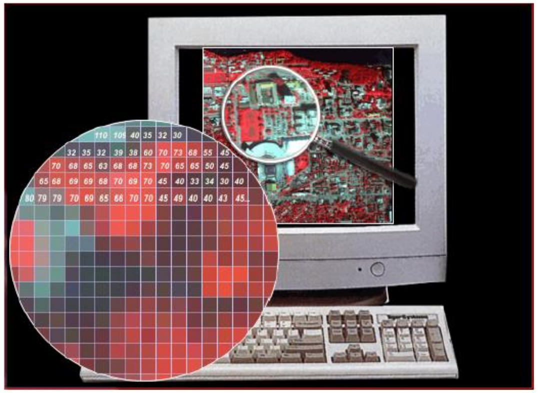
This *learning unit* will introduce the main concepts related with Digital Image Classification.

Students will be entitled to identify different types and techniques of classification, besides understanding the parameters adopted throughout the process. Relations between the resolutions of remote sensors adopted and the final scale of the mapping will be discussed and exemplified in this unit, to a better understanding. Questions about the uncertainty of the final mapping and procedures to guarantee the best accuracy will also be addressed.

From the image to the thematic map

Remote sensing images are composed by pixels and not by objects

Images are matritial representations, whose cells (or pixels) storage numerical values, entire and positive, that are associated with grey shades when the spectral bands are visualized individually; or to colors, when there is a combination of channels, like RGB.



Near-IR

Red

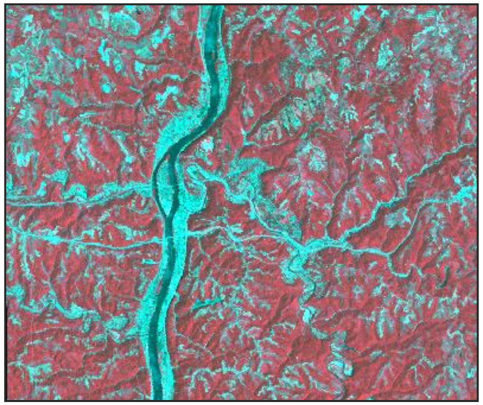
Combined (432)

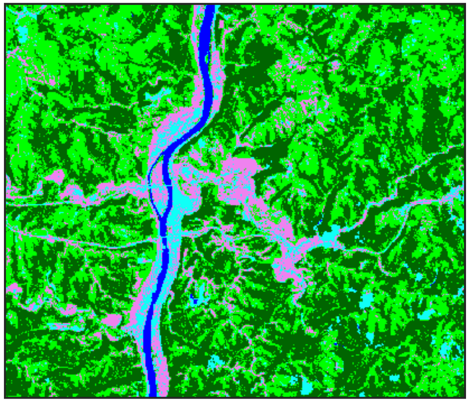
FROM THE IMAGE TO THE THEMATIC MAP

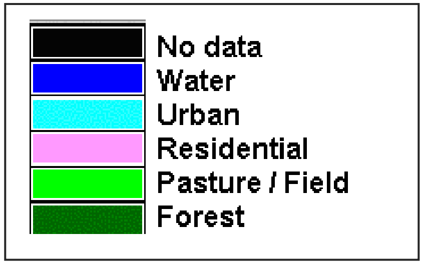
To transform images in maps is not a simple operation, and demands knowledge of the area and issue of interest, as well as of the techniques that will make possible the extraction of features and classes.

These techniques vary on complexity, and on autonomy of the interpreter, allowing the generation of products for different themes.

But it is important to stress that images are not maps! Images have no scale, but resolution. They are polysemic, while maps are monosemic. Hence, a same image can result in different types of interpretation, while a map, on the other side, is considered to be already a product of interpretation, including a legend for the recognition of the features represented on it.







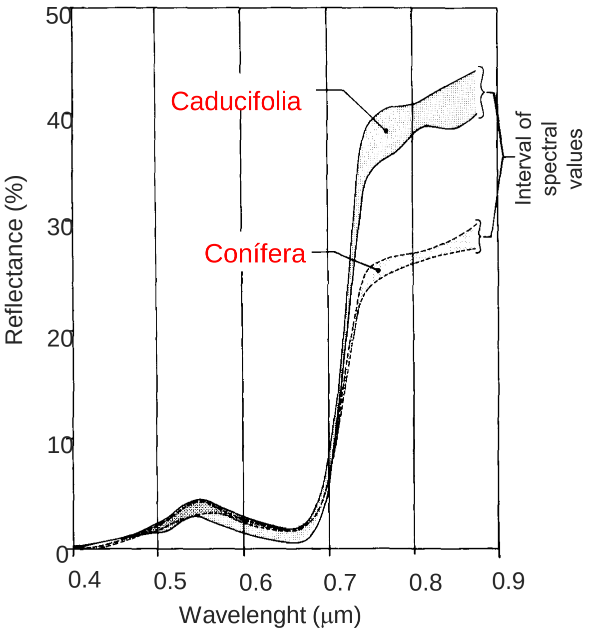
Read more in Classification.pdf

FROM THE IMAGE TO THE THEMATIC MAP

Objects of similar natures have similar spectral properties

Image classification aims to identify homogeneous patterns that characterize a given object or thematic class. Those patterns are defined by the spectral behavior of the targets in the surface, that must be similar to areas with similar characteristics.

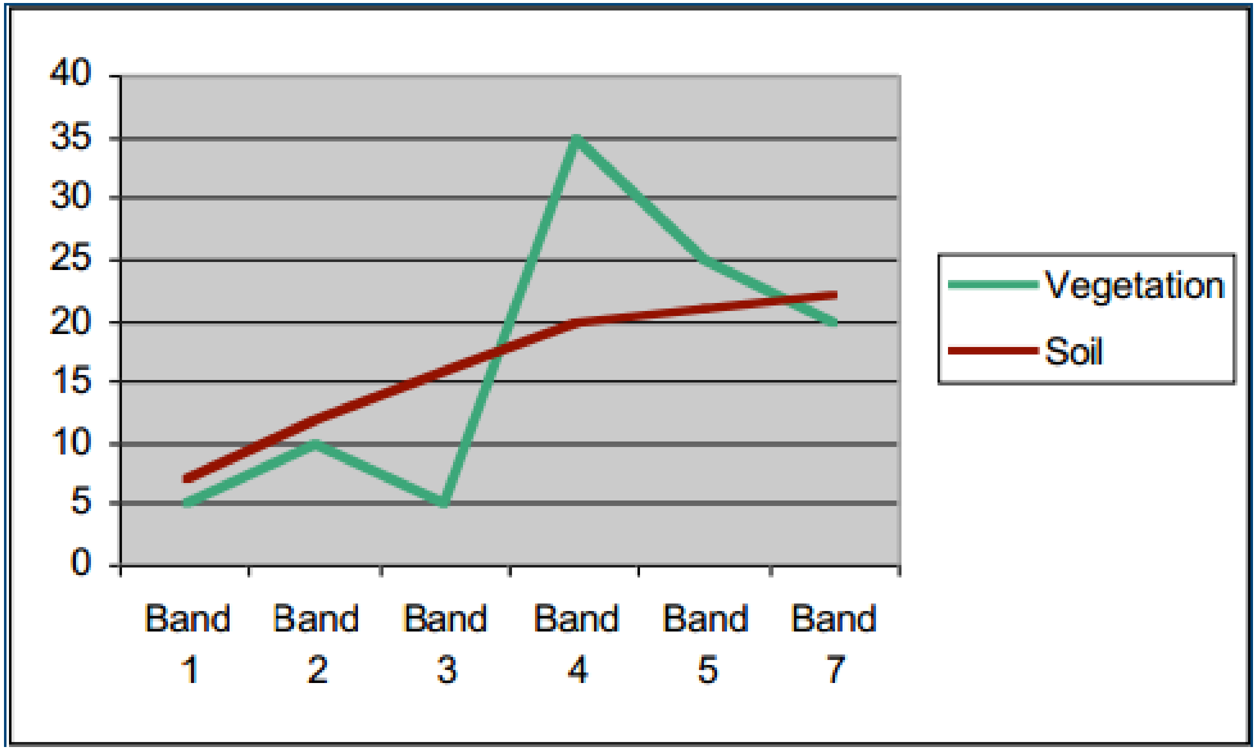
Spectral signature is the way we define the response of each object to different wavelengths. It is expected, hence, that different objects present distinctive responses. One of the main challenges of the digital classification techniques is the description and identification of the unique signatures existent in a thematic legend. This complexity includes the need to discriminate and generalize at the same time, once each point in the surface presents a singular response, although the points grouped on the same class must present similar responses. This generalized signature of a given class of objects is the biggest challenge of the whole process.



FROM THE IMAGE TO THE THEMATIC MAP

<u>Different objects have different spectral signatures</u>

Hyperspectral sensors allow the generation of signatures with more detail than those generated by multispectral sensors.



Example from the multispectral sensor TM from Landsat 5

FROM THE IMAGE TO THE THEMATIC MAP

In summary...

The image classification process consists in the conversion of such a representation in a thematic map, whose classes are defined out of the patterns observed in the surface (color, size, shape, texture…).

Its best or worst capacity to perceive the targets depends on the resolution of the sensor capturing the images, techniques adopted, and the experience of the interpreter in the topic and area of study.

The first techniques of classification were based in the visual interpretation of remote sensing results, at first represented by aerial photographs and later by orbital images. With time, and the improvement of software and hardware, came the wish and need of progress in the automation of the procedure. Nowadays, we dispose of a variety of classification techniques that, isolated or together, seek the generation of thematic maps increasingly complex and accurate, and in shorter gaps of time.

TYPES OF DIGITAL CLASSIFICATION

Digital classification can be of two types, supervised or unsupervised.

In the first case, training areas are selected and used, representing small samples of the classes identified in the final legend. The training areas must be well representative (in number and distribution), homogeneous (to avoid border effects) and precise. Some rules, established through a specific algorithm that will allow the differentiation of each area, are summed to the samples. It is essential to have a good knowledge about the spectral behavior of the classes and the area of interest.

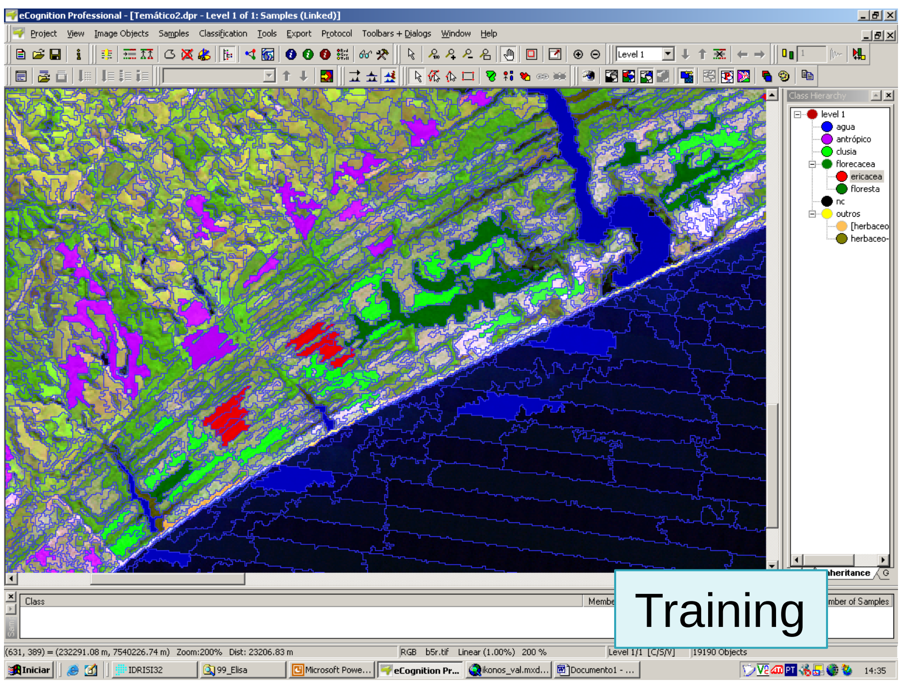
To the unsupervised techniques, this previous knowledge is not demanded. The process of classification consists, in this case, in the identification of clusters, with more or less level of detailing, expressed in the final legend. An analysis of the groupings must be made a posteriori so that a meaningful legend can be elaborated. Among other applications, these techniques can be interesting to the preliminary detection of homogeneous and similar areas, assisting, for instance, in the definition of sampling strategies in the field.

TYPES OF DIGITAL CLASSIFICATION

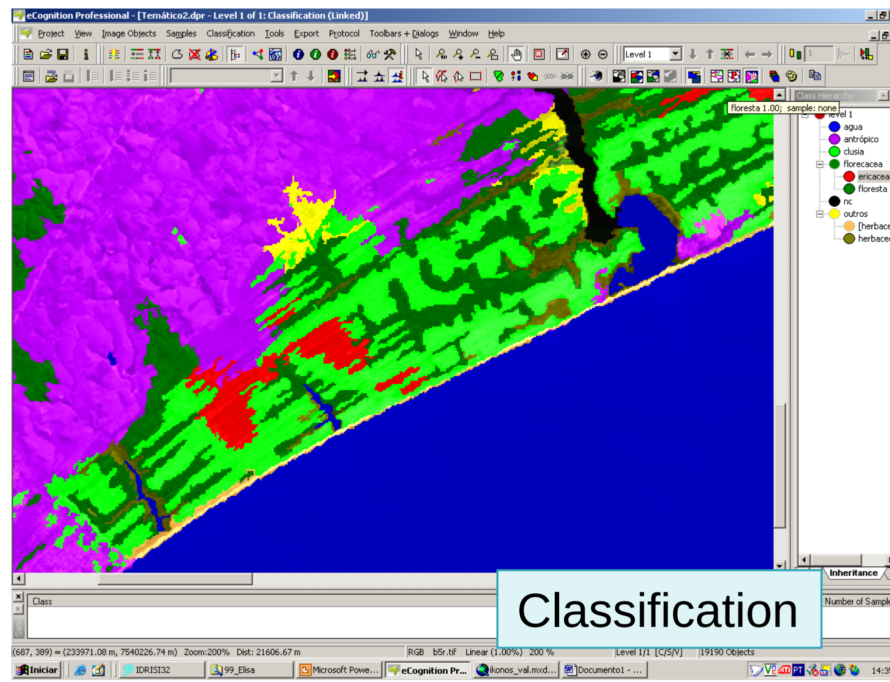
A conscious identification of samples is fundamental so that the supervised classification produces good results.

Representativeness and good distribution of samples.

- All classes must include at least one sample.
- All samples must be associated to only one class.



Training



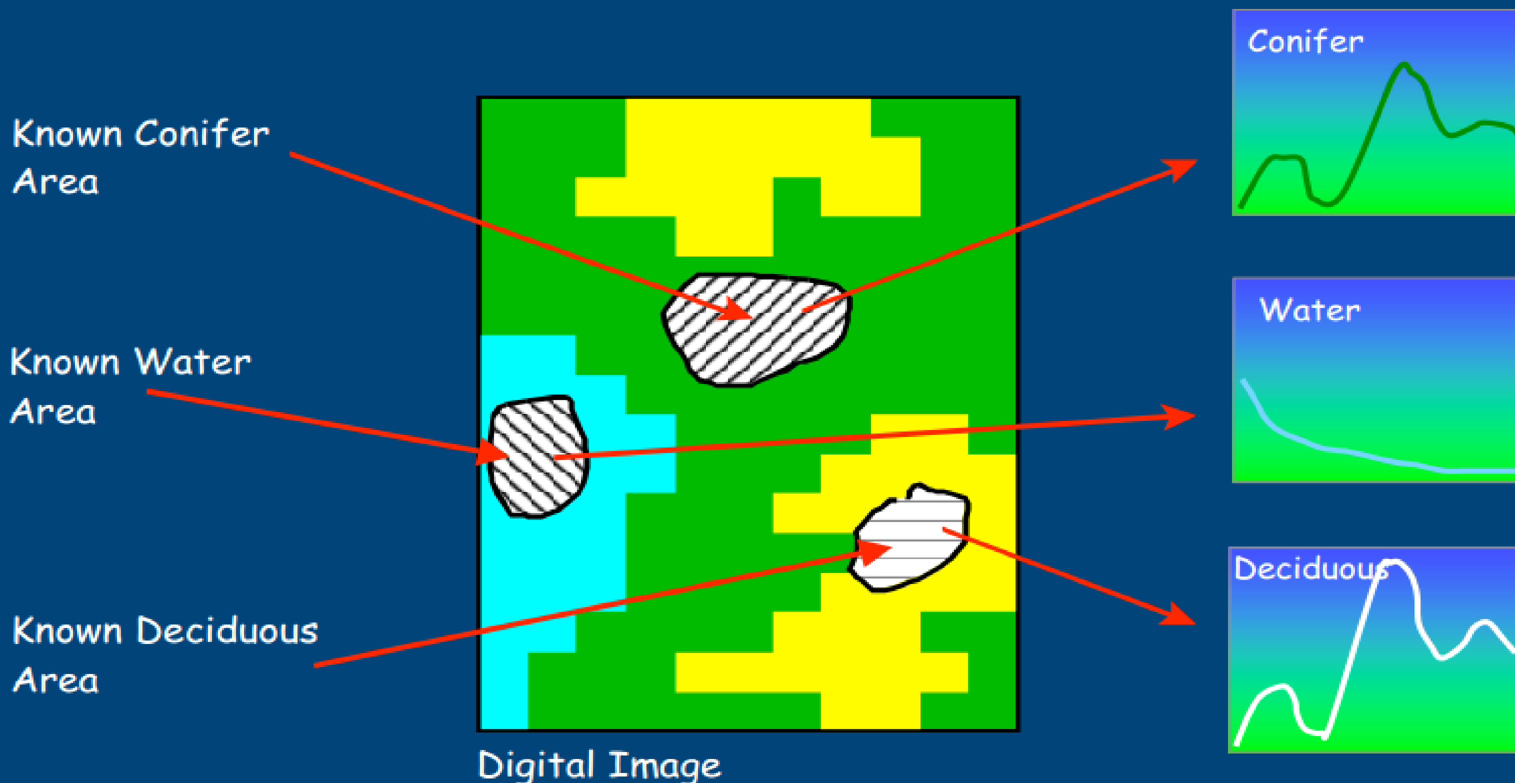
Classification

Supervised Classification

Supervised classification requires the analyst to select training areas where he/she knows what is on the ground and then digitize a polygon within that area...

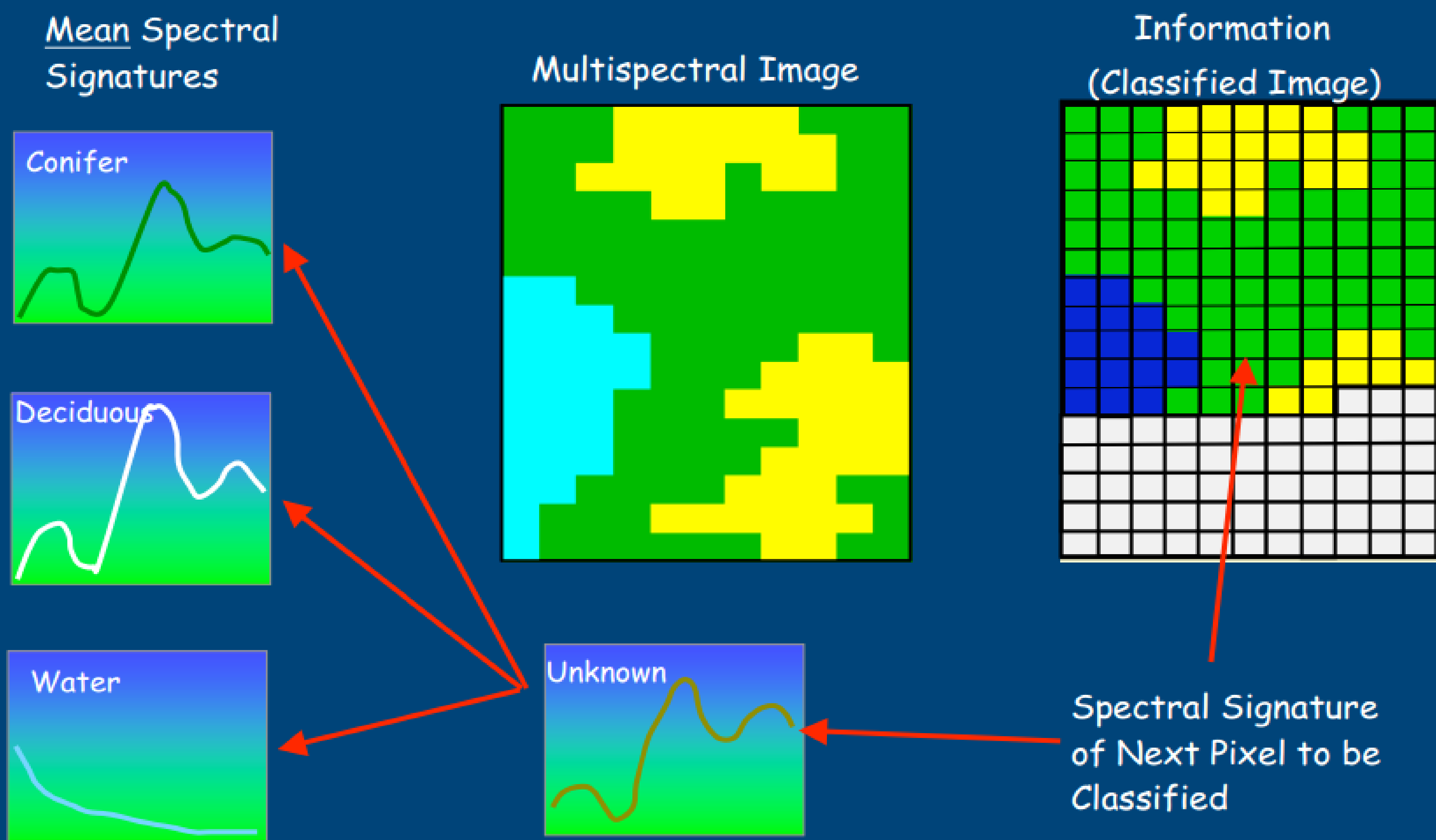
The computer then creates...

Mean Spectral Signatures



Kahlid Soofi, ConocoPhillips, Satellite Remote Sensing Lecture, 2005

Supervised Classification



Kahlid Soofi, ConocoPhillips, Satellite Remote Sensing Lecture, 2005

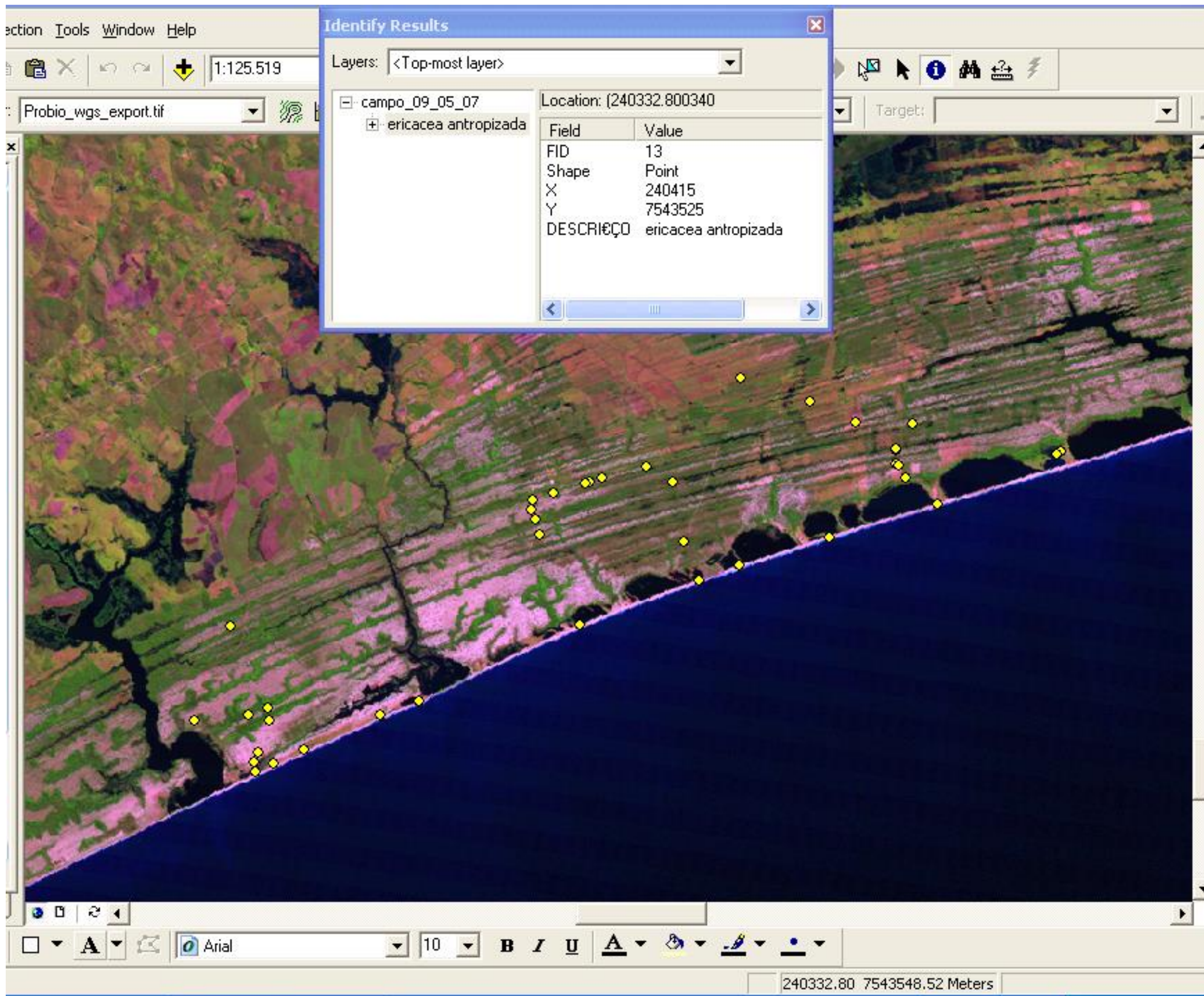
TYPES OF DIGITAL CLASSIFICATION

Fieldwork

The execution of fieldwork is very interesting in the training phase, especially when there is no certainty in the selection of samples.

This first fieldwork is called Recognition.

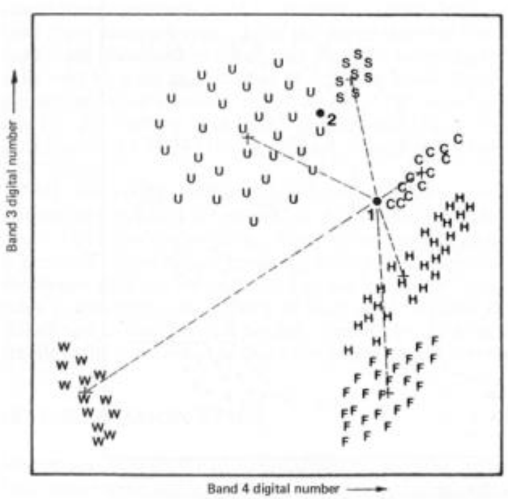
The use of GNSS equipment to georeference the samples in the field is essential.



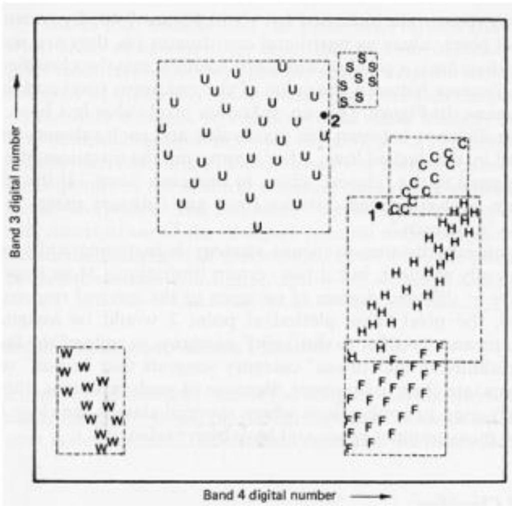
TYPES OF DIGITAL CLASSIFICATION

The digital classification can also be of the pixel-to-pixel type or by regions.

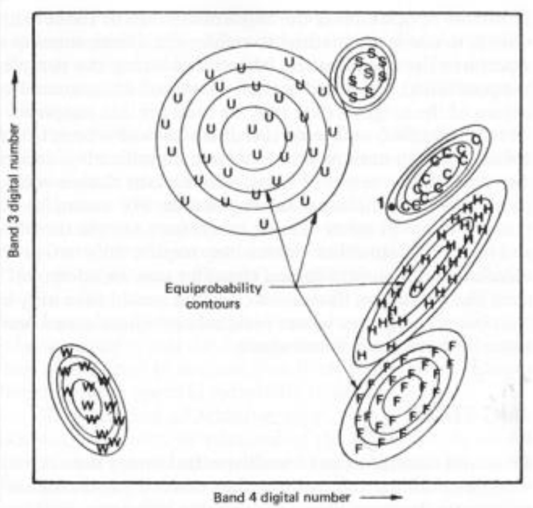
The pixel-based classifications do not recognize its neighborhood context, and therefore are more vulnerable to the existence of noise. So, it is necessary to apply filters to standardize the themes (to help in the elimination of the “dapple” effect of the generated thematic map, also called Monet effect). The pixel-to-pixel classifiers were the first to be available in software. As examples of the techniques we have: parallelepiped, minimum-distance and maximum-likelihood methods.



Minimum distance



Parallelepiped

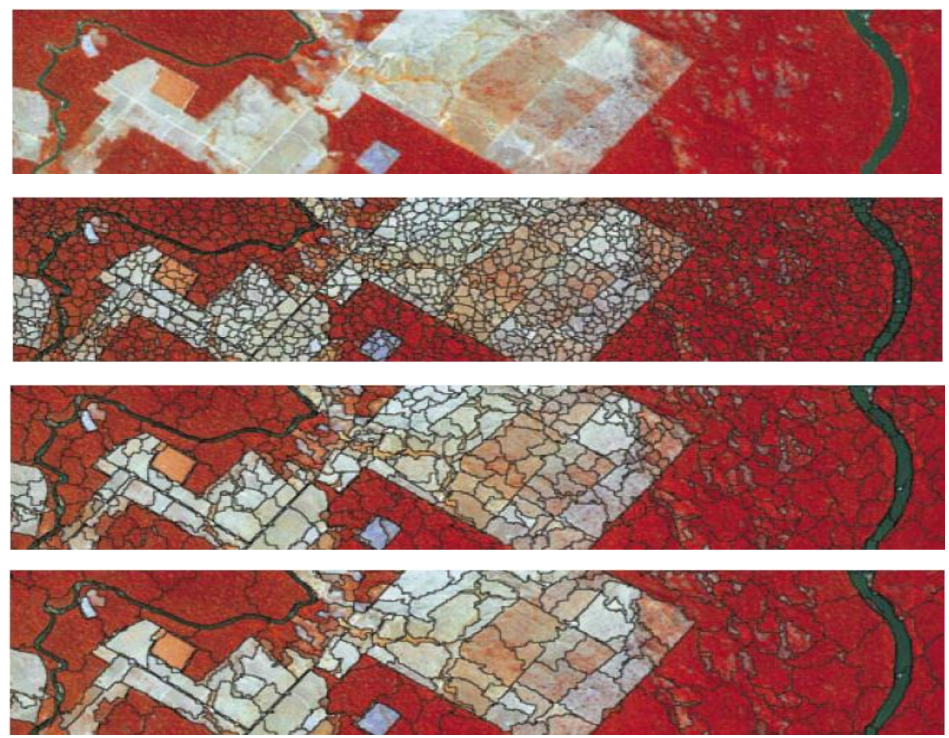


Maximum likelihood

TYPES OF DIGITAL CLASSIFICATION

To the classifiers based in homogeneous regions, it's necessary to run a process preliminary to the classification itself, called segmentation. In this case, the segments generated replace the pixels as mapping units, and will be the targets of the classification process.

For its generation we must set some parameters that will be responsible for the accuracy in the final detailing, both in terms of internal homogeneity of the segments as in terms of the minimum mapped area. Those parameters vary with the resolution of the sensors.



TYPES OF DIGITAL CLASSIFICATION

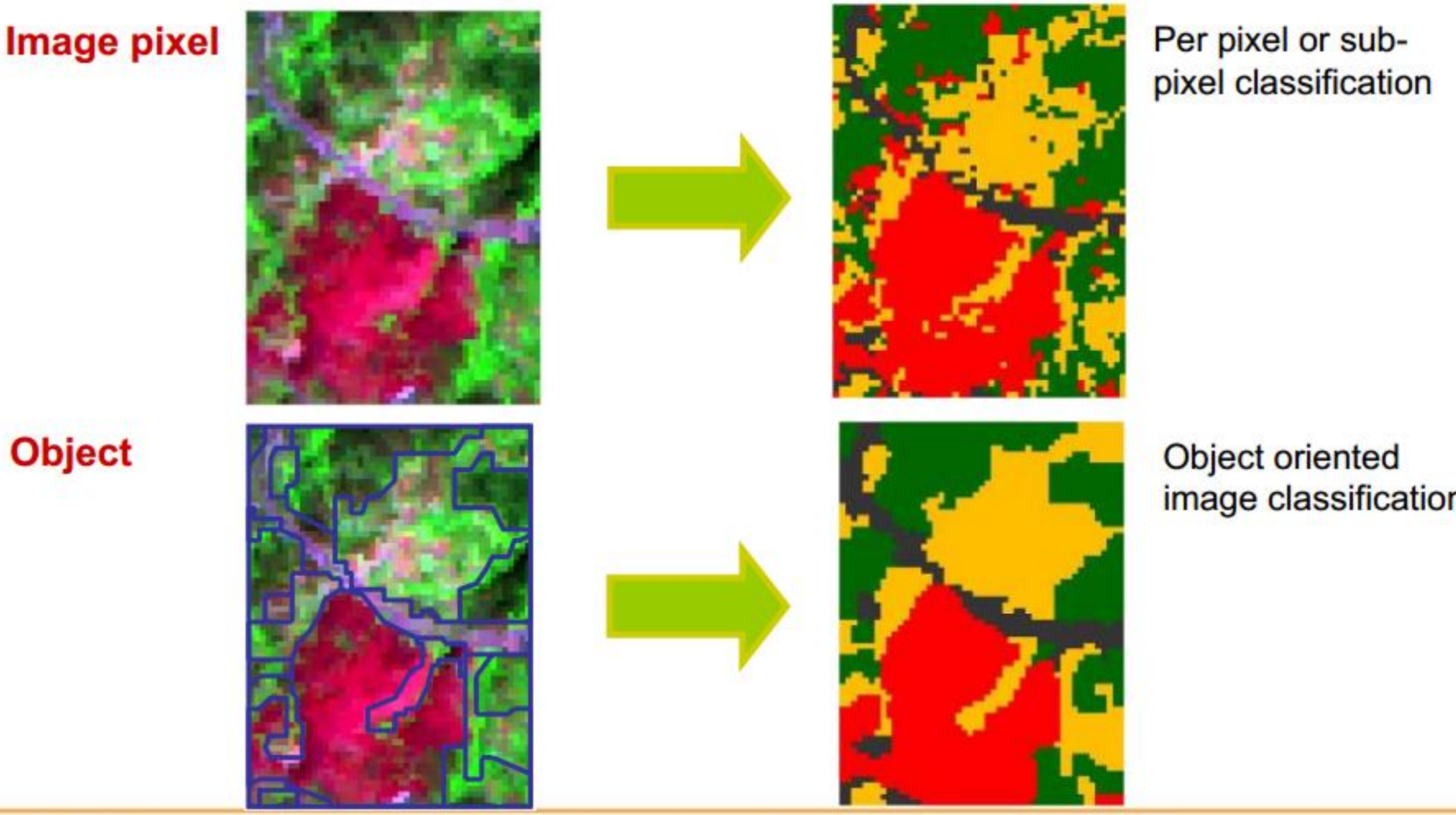


IMAGE SEGMENTATION

In segmentation, the image is divided in regions that must correspond to the areas of interest to the application.

What we understand by regions is a set of uninterrupted “pixels”, that spread bidirectionally and show uniformity. The division in portions consists basically in a process of regions’ growth, as well as borders’ and drainage basins’ detection.

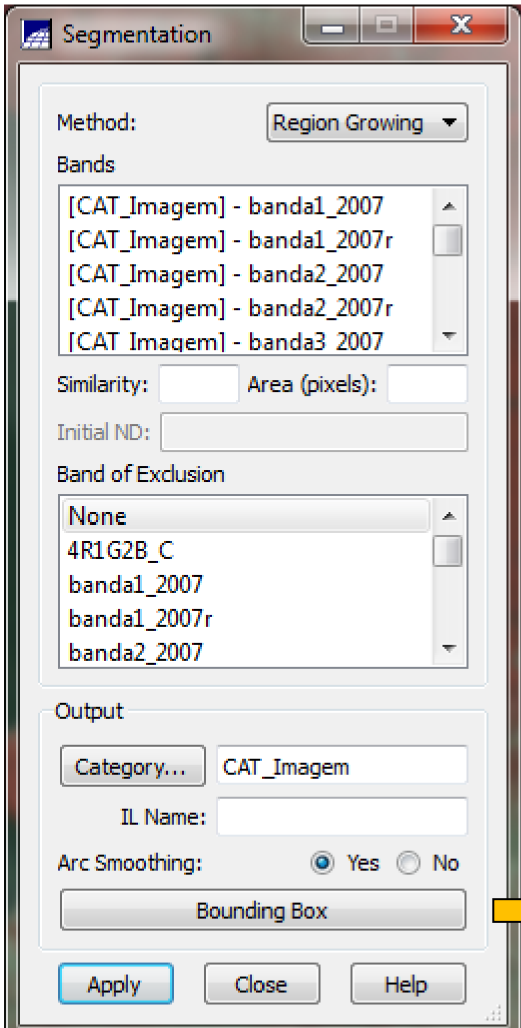
In the Spring software, the definition of the segmentation’s detailing level depends on two parameters:

- Similarity (based in the Euclidian distance between the mean values of the grey levels in each region; so, two regions are considered different if the distance between their means is superior to the chosen Similarity levels).
- Minimum Area (regions with an area smaller than the chosen minimum will be absorbed by the most resembling adjacent areas. This area is measured in pixels).

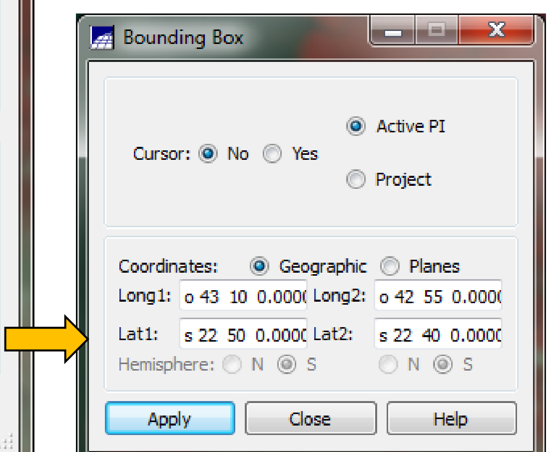
IMAGE SEGMENTATION

To perform a segmentation we must define the layers that will be used as reference, the parameters of similarity and minimum area, and a surrounding rectangle, in case we wish to apply the process to a sub-area of the project.

We must also inform the name of the new layer that will be generated. Detailed segmentations are slower.



Caution: the smaller the values to similarity and minimum area, more detail will be obtained at segmentation.



The similarity and minimum area parameters are dependent on the radiometric and spatial resolutions of the sensors, respectively.

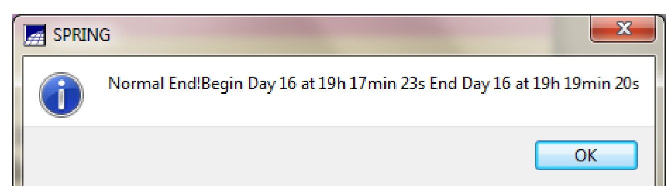
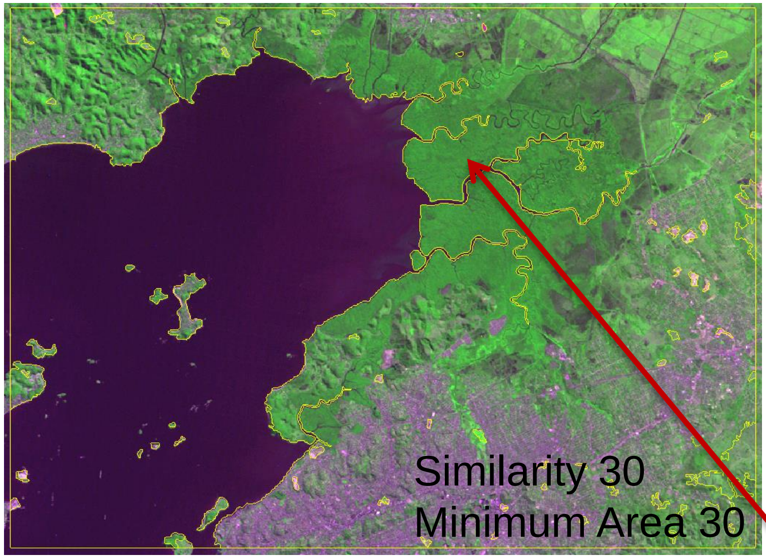
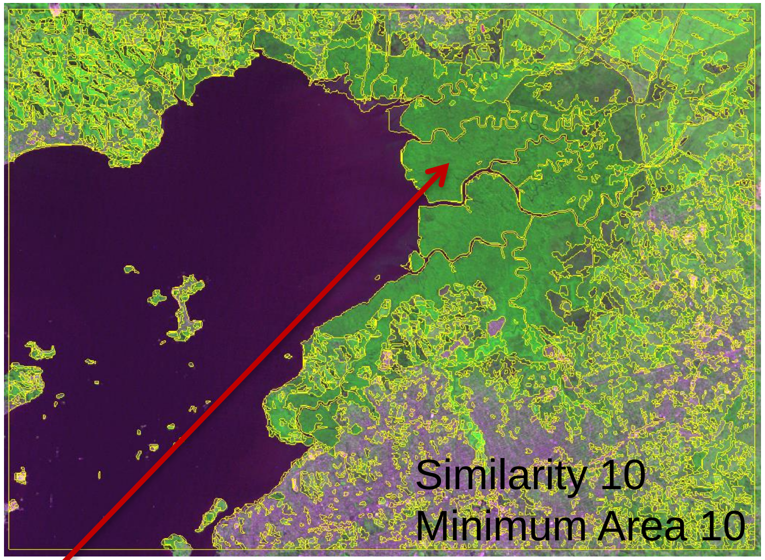
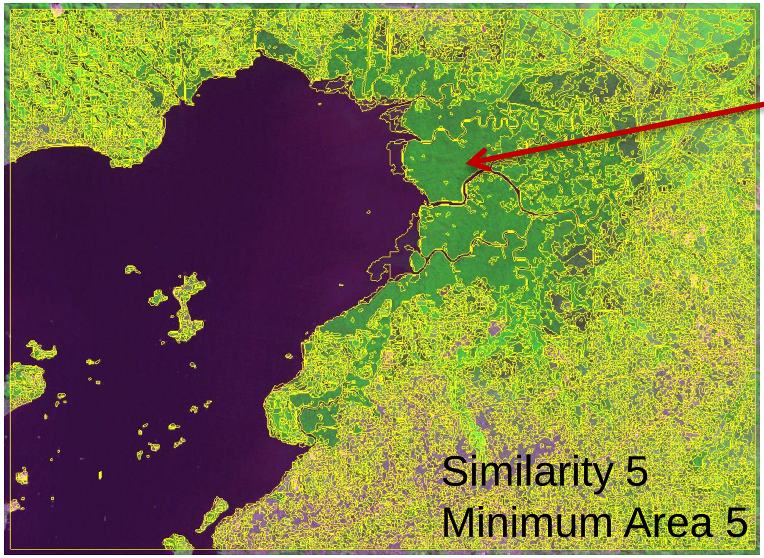


IMAGE SEGMENTATION (EXAMPLES)







Observe that in the mangrove area there's not much detailing in the segmentation, in spite of the variance in the similarity and minimum area parameters.

This is explained by the fact that these areas are very homogeneous.

NEW APPROACHES ON CLASSIFICATION

Technological advancement has allowed, among other things, the increase of the digital processing of images, allowing the execution of more complex processes. With this, emerge some techniques that aim at increasing the level of automation in the classification, using the knowledge of the interpreter through the modeling of descriptive elements that are considered in the visual process of identification.

This can be exemplified with the Neural Networks, Decision Trees, and Object-Oriented classification (GEOBIA) techniques.

Object-images

The object delimitation is conceptually more complex than a simple image segmentation, once it is only in this way that other types of classification rules, shared with the visual interpretation process, can be indeed adopted. It’s the case of object shape, that usually consist in the most significant element to the description of a given class such as, for instance, the difference between a river and a lagoon.

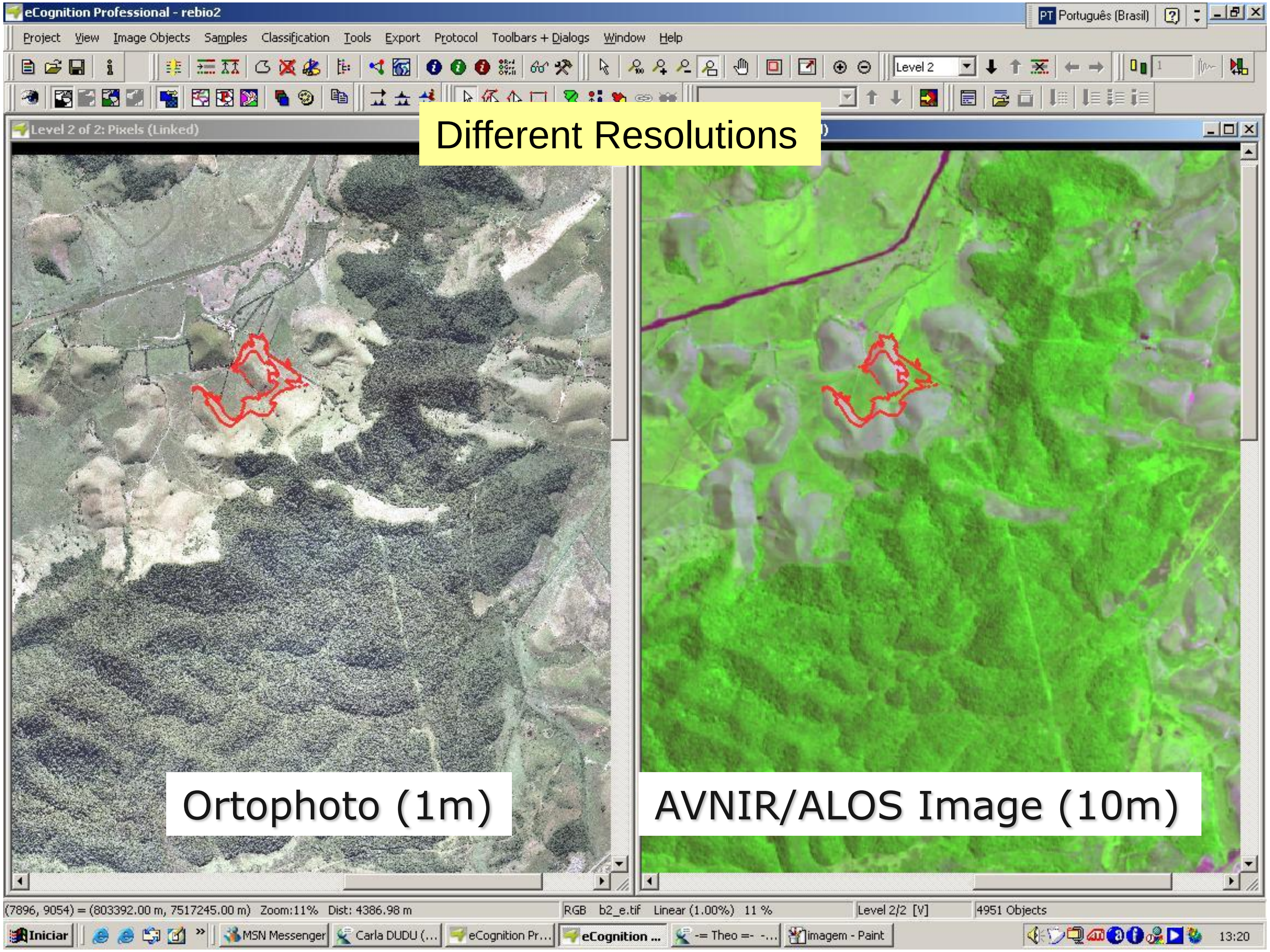
OBJECT-ORIENTED CLASSIFICATION

The object-oriented classification (GEOBIA) allows us to use different types of descriptors/rules to characterize the interest classes, avoiding the classical and exclusive use of spectral descriptors (bands).

In this approach, it becomes possible to include other kinds of descriptors, such as shape, texture, neighborhood relations and thematic correlation. Other important advantage is the possibility to define individualized classification models for each class, that can also be found in different segmentation levels, all hierarchized. It is still possible to combine sensors of different resolutions without the need of resampling or having a preliminary match. The method can be quickly characterized for allowing:

- spatial relation through the connectivity between segments.
- hierarchical relation between legend items.
- hierarchical relation with super-objects (more generalization) or sub-objects (more detail).

OBJECT-ORIENTED CLASSIFICATION



OBJECT-ORIENTED CLASSIFICATION

Once it aims at simulating the visual interpretation process, the previous knowledge of the theme and area of study is considered to be very important. The possibility to define individualized classification models to each class, in one hand, is very interesting, because it widens the analyst's power; in the other hand, it enlarges his/hers responsibility. Unfortunately, current knowledge on the characterization of classes is still small.

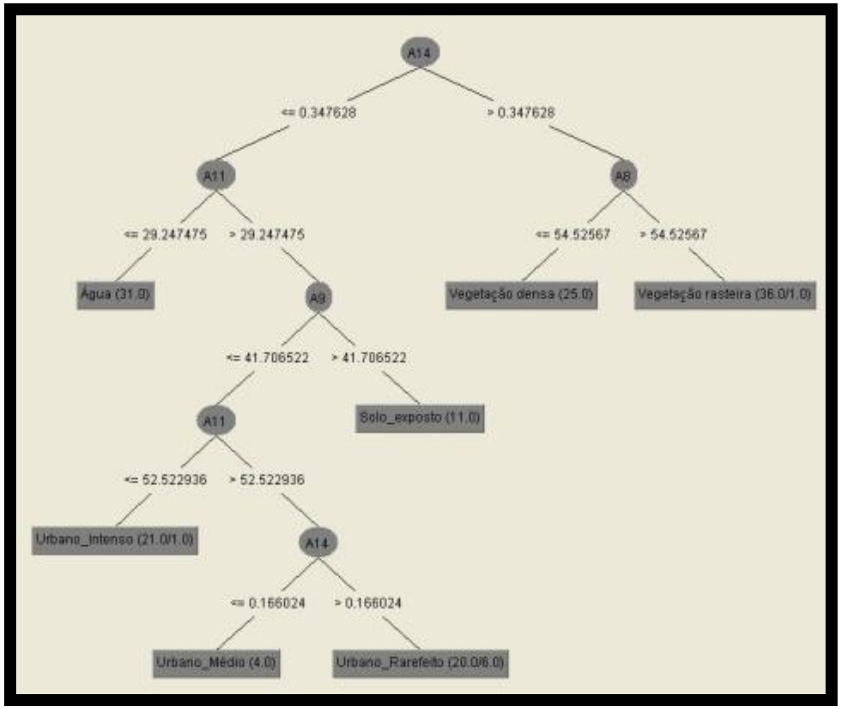
Recently, efforts started to be made in favor of the improvement of the formal and descriptive knowledge of those classes, in a way that the automation of the classification can present more accurate results.

A new line of work is also glimpsed with the adoption of data miners, such as the New Zealander free software WEKA (learn more in http://www.cs.waikato.ac.nz/ml/weka/). This resource assists the choice of descriptors and thresholds between classes from a wide set of initial data, acting also as a tool to enlarge the desirable knowledge to the modeling of the classification, considered to be of high complexity.

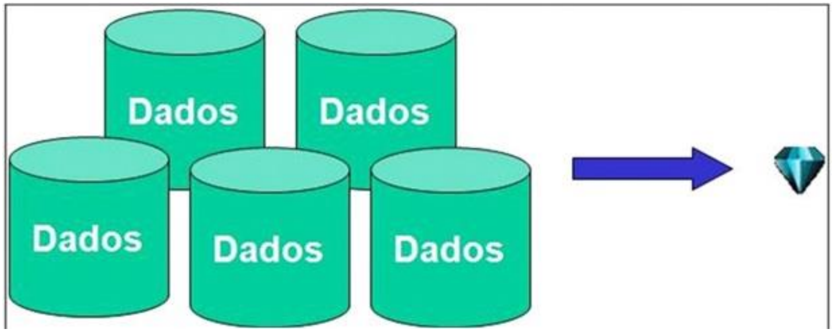
OBJECT-ORIENTED CLASSIFICATION

Data Mining is, therefore, the process made through intelligent methods that has as its objective the extraction of knowledge in large databases.

The model resultant of the mining can be represented in several ways, between them, the decision trees, represented by a flowchart with a tree structure, and that are easily converted in classification rules.



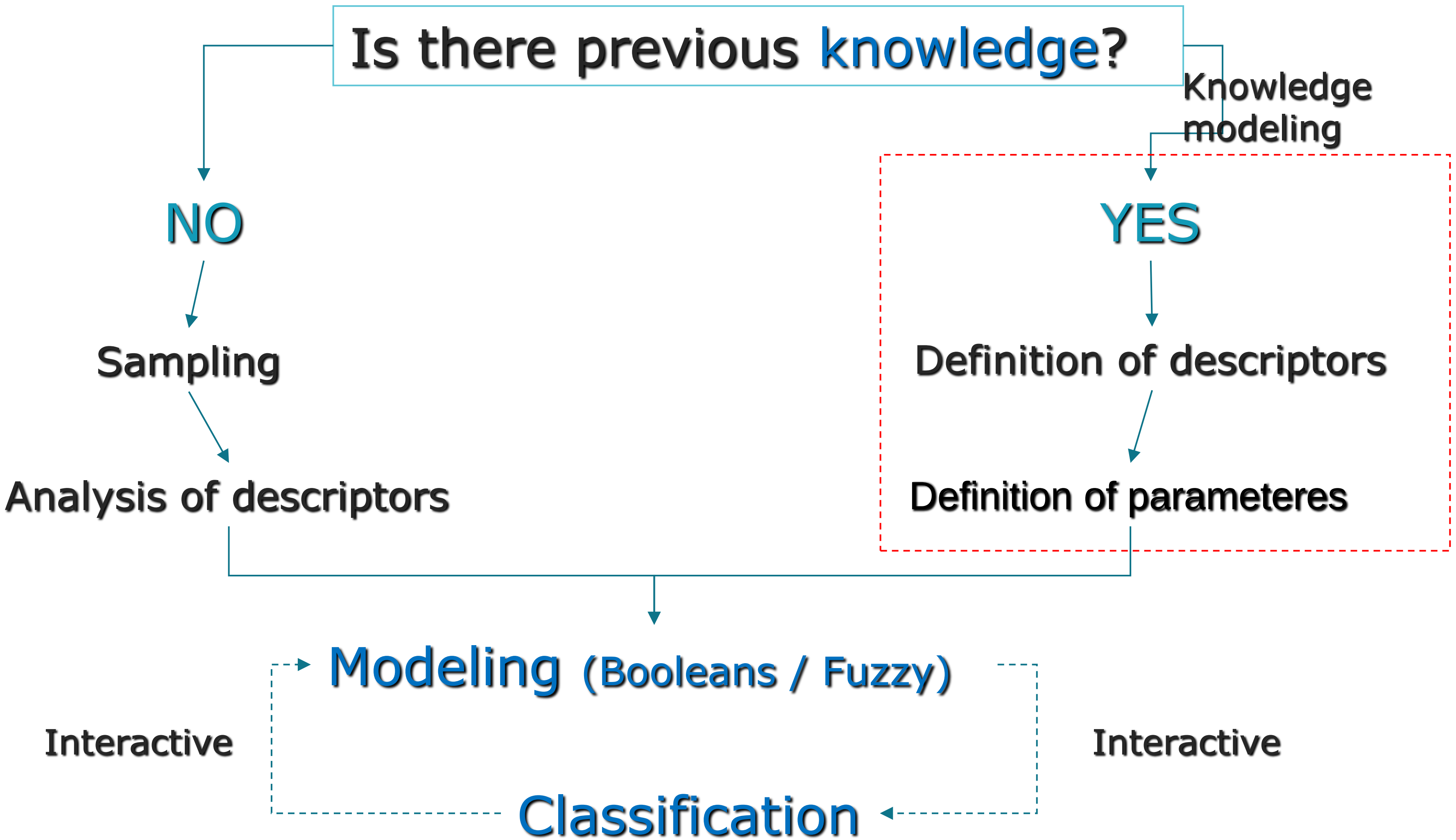
Example of a decision tree



Read further in WekaTutorial.pdf

OBJECT-ORIENTED CLASSIFICATION

In summary...



SPECTRAL MIXTURE

Mixture problems happen in Remote Sensing images because of the sensors' spatial resolution, that, in general, allow a scene element (corresponding to an image pixel) to include more than one type of terrain cover. When a sensor observes the scene, the detected radiance is the integration, denominated **mixture**, of all objects, denominated **mixture components**, inside the scene element.

The number of mixed pixels in an image varies mainly with:

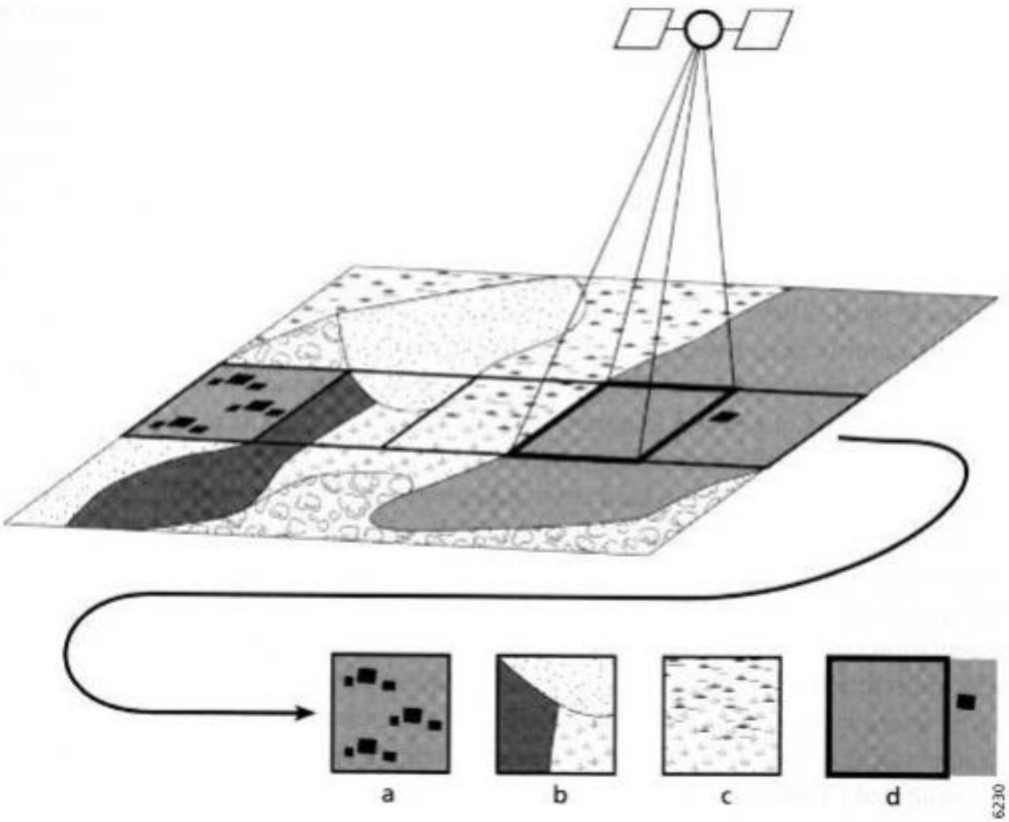
- Landscape fragmentation
- Sensor's spatial resolution

MERIS FR

IKONOS

Read further in D2L4-Caetano.pdf

SPECTRAL MIXTURE



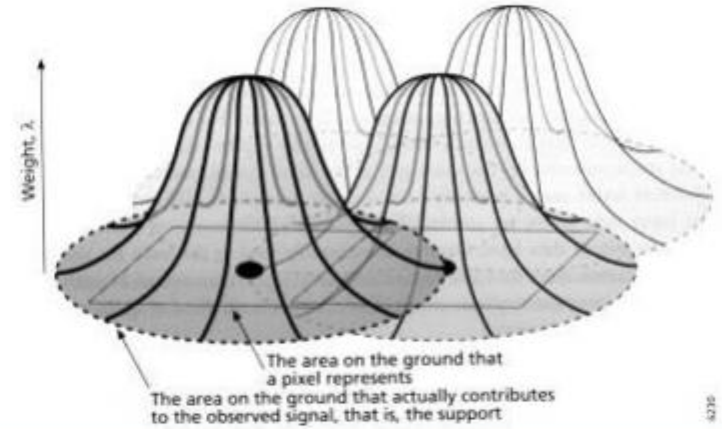
The mixed pixel problem!!!

A – presence of small, sub-pixel targets

B – presence of boundaries of discrete land cover classes

C – gradual transition between land cover classes (continuum)

D – contribution of areas outside the area represented by a pixel



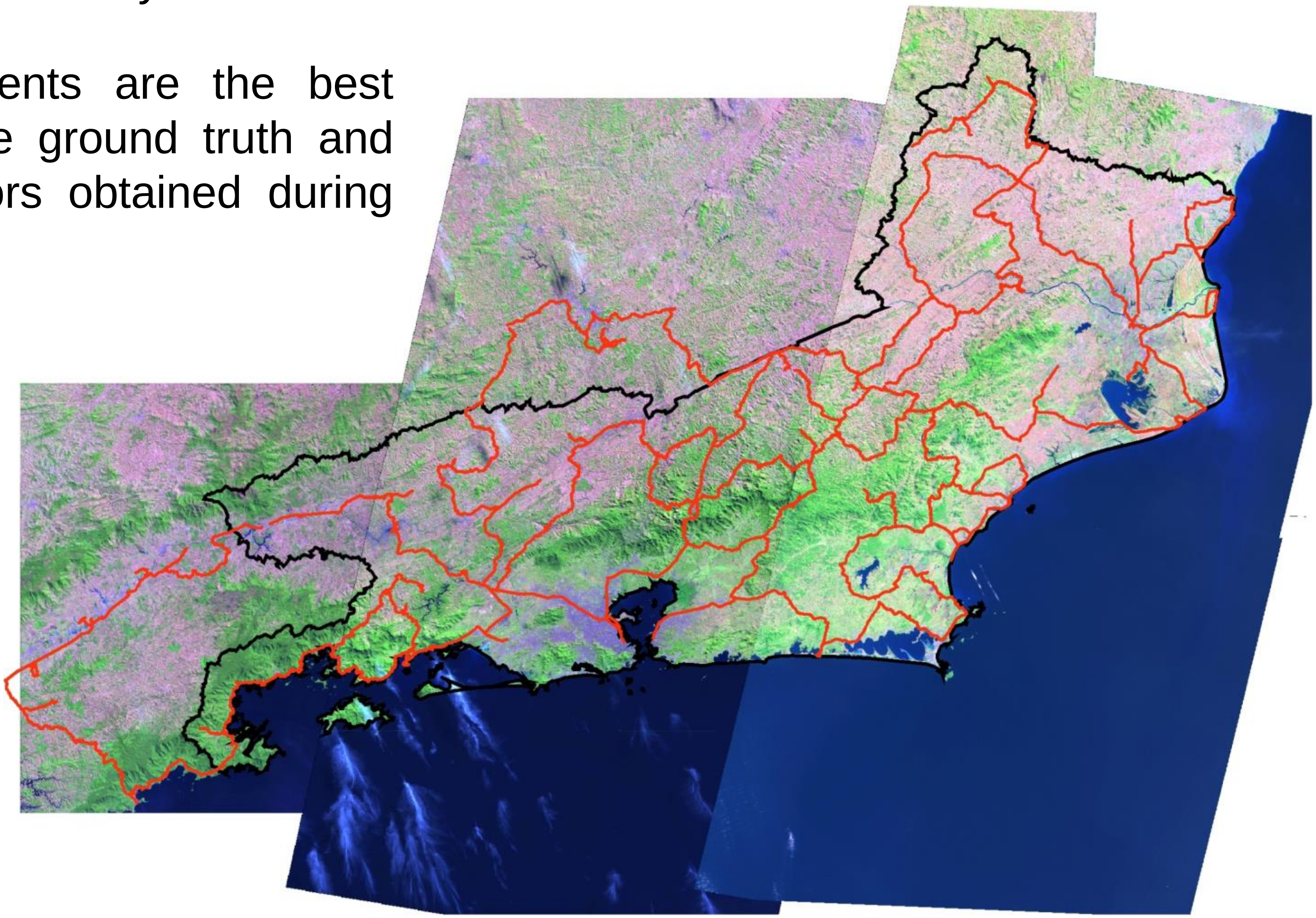
Source: Foody (2004)

CNRD Center for Natural Resources and Development

VALIDATION OF THE CLASSIFICATION

Is important that at the end of the classification, some efforts are made to the evaluation of its accuracy.

Field measurements are the best way to verify the ground truth and quantify the errors obtained during the mapping.



It's essential to plan a sampling strategy!!

VALIDATION OF THE CLASSIFICATION

Types of Errors

Omission Errors (those that reflect elements left unmapped in a given class of the mapping, in other words, how much was underestimated).

Comission Errors (those that reflect what was wrongly mapped in a given class of the mapping, in other words, how much was overestimated).

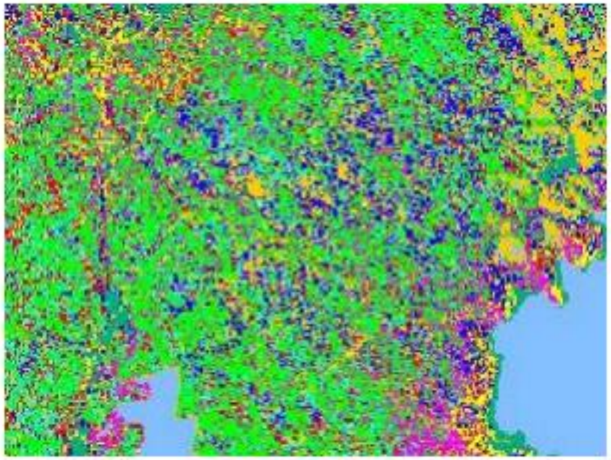
The generation of a Confusion Matrix or Error Matrix is essential to quantify and qualify those errors. Through this matrix it is also possible to evaluate the Global Accuracy of the mapping and calculate the Kappa Index.

Random Points		Classified									
		Water	Urban Low	Urban High	Agriculture	Forest Ever	Forest Dec	Totals	Producer's	Omission	Commission
Ground Truth	Water	3	-	-	-	-	-	3	100%	0%	0%
	Urban Low	-	7	6	6	-	-	19	37%	63%	53%
	Urban High	-	-	3	-	-	-	3	100%	0%	200%
	Agriculture	-	8	-	20	1	3	32	63%	38%	41%
	Forest Ever				4		1	5	0%	100%	20%
	Forest Dec		2		3	1	25	31	81%	19%	13%
	Totals	3	17	9	33	2	29	93			
	User's	100%	41%	33%	61%	0%	86%				

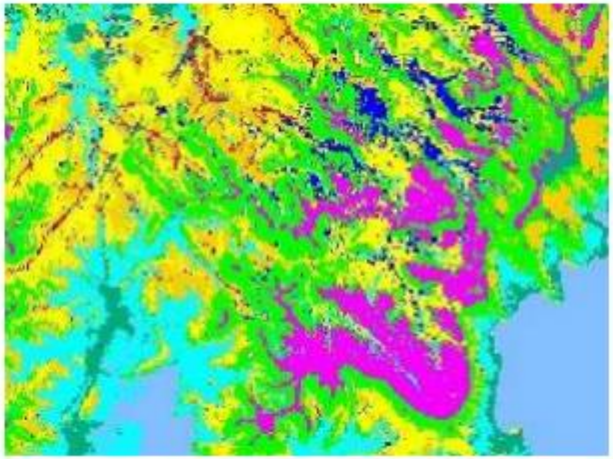
How different the results from different classifiers can be?

Once there are different techniques of digital classification, each one based in particular algorithms and rules, the same remote sensing image can originate different maps.

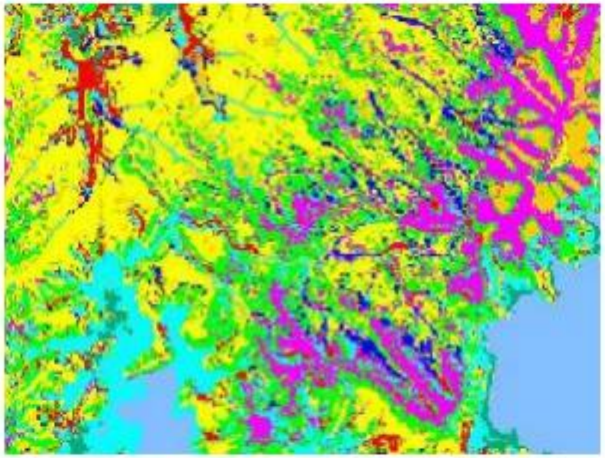
Knowledge about the spatial distribution of the theme in the area under analysis, and verification through the execution of fieldworks, are the best ways to evaluate which result fits best!



Maximum likelihood



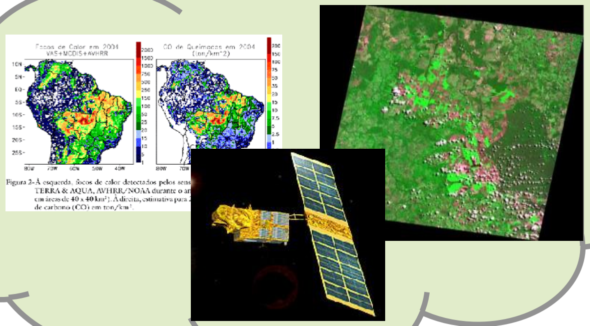
Artificial Neural Networks



Decision tree

Further reading in Remote_sensing_tutorial_mar06.pdf

CONSULTING…



To know more about digital classification of remote sensing images, consult some of these websites:

http://eoedu.belspo.be/en/guide/classif.asp?section=3.6
http://www.grsgis.com/image-processing.html

Complementary materials...

Jensen, J.R., 1996, Introductory digital image processing: a remote sensing perspective, Upper Saddle River, NJ: Prentice Hall, 2nd Ed.

Fundamental of Remote Sensing: A Canada Centre for Remote Sensing (Fundamentals_e.pdf)