# KNOWLEDGE TRANSFER - FORMALISING AN INTERPRETATION KEY

T. Bauer, G. Kaiser

Institute of Surveying, Remote Sensing and Land Information, University of Natural Resources and Applied Life Sciences, Vienna – (t.bauer, georg.kaiser)@boku.ac.at

**KEY WORDS:** Agriculture, Interpretation, Automation, Expert System, Knowledge Base

**ABSTRACT:**

The paper deals with the transformation of an interpretation key, established for a visual interpretation, into a rule base applied for automated image analysis. An object-based approach is used for that purpose. The methodology is demonstrated for the detection of coca fields on medium resolution satellite imagery. The monitoring of illicit coca cultivation in Colombia is currently based on a visual interpretation of various types of satellite images. Medium resolution satellite imagery is used due to economical restrictions. The detection of relatively small coca fields (average field size: 1.8 ha) on medium resolution satellite imagery as Landsat makes a per-pixel classification difficult. Thus a visual interpretation is applied. An interpretation key is being developed together with experts in order to conduct a rigorous interpretation and to document the experience of the interpreters. Beside spectral characteristics of the image data, contextual information and results from previous surveys or classifications of previous images are used for the interpretation. The interpretation key is used to establish a rule base that can be applied for an automated interpretation of coca fields. The tools of the commercial software package eCognition are used for this purpose. An advantage of automation is the improvement of the transparency of the interpretation process.

**KURZFASSUNG:**

Der Beitrag behandelt die Transformation eines Interpretationsschlüssels, der für eine visuelle Interpretation entwickelt wird, in ein Regelwerk, das für eine automatisierte Bildauswertung verwendet werden kann. Zu diesem Zweck wird ein objektbasierter Ansatz gewählt. Die Methode wird anhand der Erkennung von Kokafeldern in Satellitendaten mittlerer Auflösung demonstriert. Die Überwachung von Kokafeldern in Kolumbien wird derzeit auf Basis einer visuellen Interpretation von verschiedenen Satellitenbildern durchgeführt. Satellitenbilder mit einer mittleren Auflösung werden dabei aus Kostengründen verwendet. Die Erkennung von relativ kleinen Kokafeldern (die Durchschnittsgröße liegt bei 1.8 ha) auf Satellitenbildern wie z.B. Landsat erschwert eine pixelweise Klassifikation. Daher kommt eine visuelle Interpretation zur Anwendung. Zusammen mit Experten wird derzeit ein Interpretationsschlüssel entwickelt, um eine strukturierte Interpretation durchzuführen und um die Erfahrung der Interpreten zu dokumentieren. Neben spektralen Eigenschaften der Bilddaten werden Kontextinformationen und die Ergebnisse von vorangegangenen Überwachungen sowie Klassifikationen von älteren Bildern in die Interpretation miteinbezogen. Der Interpretationsschlüssel wird für den Aufbau eines Regelwerkes verwendet, der für eine automatisierte Interpretation von Kokafeldern verwendet wird. Zu diesem Zweck wird die kommerzielle Software eCognition eingesetzt. Ein Vorteil einer Automatisierung liegt in der Verbesserung der Transparenz des gesamten Ablaufes.

## 1. INTRODUCTION

The goal of the current research activity described in this paper is to support the coca monitoring project in Colombia by developing techniques to make the interpretation of the remotely sensed data as objective and transparent as possible. As stated by many authors (e.g. Langanke et al., 2004), reproducibility, transparency, transferability and the increased possibility for quantification are among the advantages of mapping approaches based on Earth observation.

At present, the interpretation of coca fields in Colombia is performed by a visual interpretation of Landsat images (Figure 1). One of the critical aspects is bias that may be introduced, as any visual interpretation is subjective. Among several approaches that can be followed to minimize subjectivity, focus is laid on two topics:

- *Application of an interpretation key:* a detailed interpretation key is a prerequisite for any visual interpretation. The key should guarantee that all interpreters adhere to a common standard.
- *Digital automated classification:* Digital processing of the data can help to reduce subjectivity and to enhance transparency.

The benefits of both topics will be combined in the methodology applied in this study. An interpretation key for coca monitoring is currently being developed together with experts from Colombia. This key will be the basis for an automated image interpretation.

Interpretation keys are a valuable source of information. The extensive knowledge of one or more interpreters is stored in a structured manner. Well defined interpretation keys offer the possibility to use the knowledge for an automation of the visual interpretation. The objective is to emulate the visual interpretation, i.e. to formalize the interpretation key. An overview of the recent developments on the field of knowledge-based image interpretation is given by Richards and Jia (2006) or Mota et al. (2005). In this project a knowledge-based interpretation based on image objects is necessary because human perception and thus visual interpretation is based on image objects.

Within the last years the application of object-based image processing techniques was increasing rapidly. An object-based approach relies on image objects or segments rather than on single pixels. According to Benz et al. (2004) the advantage of object-based analysis are meaningful statistic and texture calculation, an increased uncorrelated feature space using shape and topological features and the close relation between real-world objects and image objects. The introduction of GIS functionality in image processing is considered as one step to overcome the classic 'pixel-centered' image analysis (Blaschke et al., 2005). In addition it is possible to overcome the focusing on one single scale.

While many studies focus on the analysis of very high resolution satellite data when applying an object-based approach, it is also feasible to apply object-based analysis to medium resolution data such as Landsat. In medium or low spatial resolution satellite images, distinct land cover classes produce similar spectral responses that make a discrimination difficult (Mota et al., 2005). For an experienced human interpreter, this is not a problem because supplementary information (e.g. shape, texture, context) is used for the analysis. It must therefore be tried to model the experience of the human interpreter.

Since 1999 the United Nations Office on Drugs and Crime (UNODC) is supporting the monitoring of illicit crops in several countries. With the Illicit Crop Monitoring Programme (ICMP) methodologies for data collection and analysis have been established. ICMP implements annual illicit crop surveys relying primarily on the use of remote sensing techniques to assess the area under illicit cultivation. UNODC-Colombia - a joint project between UNODC and the Colombian government - is responsible for the annual surveys (UNODC, 2005).

The Institute of Surveying, Remote Sensing and Land Information (IVFL) at the University of Natural Resources and Applied Life Sciences, Vienna, is collaborating with UNODC/ICMP in order to explore the use of remote sensing for illicit crop monitoring and to improve the applied methodologies.

After an introduction to the problem of coca monitoring the development of an interpretation key and the application with the help of the commercial software eCognition will be described.

## 2. BACKGROUND

The monitoring of illicit coca cultivation in Colombia is mainly based on visual interpretation of satellite images (Figure 1). In 2004 70 Landsat and 28 ASTER image were interpreted covering more than 800.000 ha of the country (UNODC, 2005). Medium resolution satellite imagery is therefore used due to economical restrictions.

Coca is grown throughout the year and harvested up to five times. A crop calendar for that geographic region does not exist. It is impossible to separate coca from other crops based on phenological differences. The detection of relatively small coca fields (average field size: 1.8 ha) on medium resolution satellite imagery such as Landsat makes an automatic per-pixel classification difficult. A per-pixel land cover classification is therefore not used to detect coca cultivation, but to study broadly the various land cover categories present in an image and to use the results as auxiliary information for the visual interpretation.

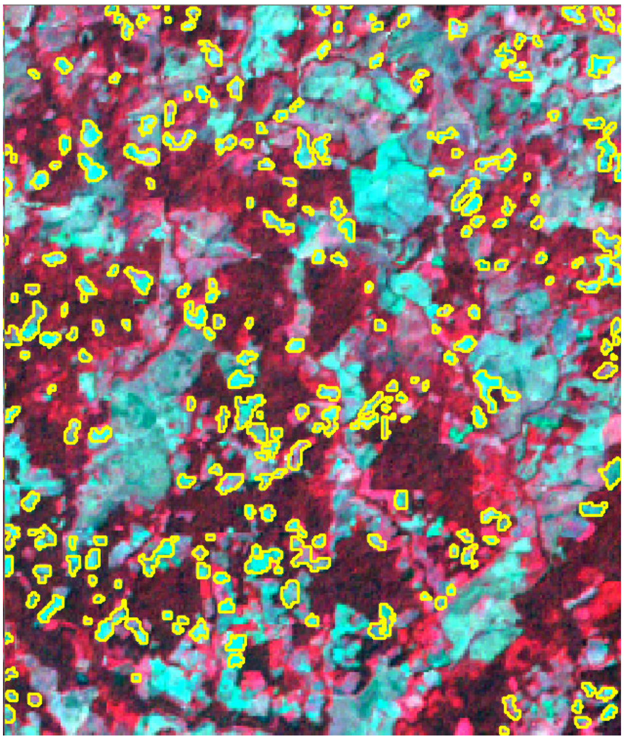

Figure 1. Example of visually interpreted coca fields (yellow polygons) on a Landsat ETM+ image (false colour composite; image data available from USGS/EROS, Sioux Falls, SD) of the 2005 census.

First tests at UNODC-Colombia on an automated interpretation of coca fields revealed that an object-based approach offers advantages in comparison to per-pixel classifications. A detection of single coca fields solely based on spectral information is not possible. The identification of coca can be supported by an object-based approach including contextual information (Ardila and Lopez, 2004).

The same study revealed that an automated classification cannot replace a visual interpretation. It could, however, serve as a valuable support tool and help to speed up the interpretation process. As stated above, in order to make the interpretation more transparent and objective, automation of the whole process would be a major advantage. An interpretation key was not considered for this study.

## 3. DATA SOURCES

The following datasets are used in the interpretation process. Numerous vector datasets are included beside satellite imagery.

### 3.1 Raster Data

The annual interpretation is performed on the most actual Landsat ETM+ imagery. Due to economical restrictions very high resolution satellite data or aerial photographs are not affordable as nearly the whole territory of Colombia is being monitored. For this pilot study a subset (11x11 km) of a Landsat 7 ETM+ scene is chosen.

### 3.2 Vector Data

A number of vector datasets are available that are used during the interpretation. Beside the results of the previous surveys, important information is provided by the recordings of spraying planes. During the spraying, GPS points are recorded and later processed as buffers around the flight path. Important information is the date of the spraying in relation to the acquisition date of the satellite image.

## 4. INTERPRETATION KEY

The success of an interpretation of remotely sensed images strongly depends on the knowledge of the interpreters and how this knowledge is used within the interpretation process. The development of an interpretation key is a prerequisite for a reproducible interpretation of all kind of remotely sensed images. An interpretation key can be defined as a legend that describes the object categories and their characteristic features on the images. It is a guide for the visual interpretation and forces interpreters to organise and exploit findings in a logical system. It serves as reference material for novice interpreters and as a decision finding tool for experienced interpreters in case of doubts. An interpretation key is most important for large projects to coordinate the work of the interpreters to obtain homogeneous results. For an automated image interpretation, the key serves as a basis for defining a rule base.

As stated in standard literature on remote sensing (e.g. Lillesand et al. 2004), interpretation keys can be organized in two ways:

- A selective or example key is a series of examples of images of different object (terrain) classes to be interpreted.
- A decision tree or elimination key assists the interpreter to proceed step-by step from the general to the specific.

A selective key provides examples of categories that can be used especially as training sets for a per-pixel classification. An elimination key is established in a structured manner and can be more easily adapted for knowledge-based image interpretation.

In a first step, the features used for the interpretation have to be determined. In general the following features are used during a visual interpretation to characterise objects to be interpreted: size, shape, shadow, tone and colour, texture, patterns and contextual information.

Parts of the key developed together with UNODC-Colombia are available for the study area. According to discussions with the interpreters the detection of coca fields is mainly based on the features colour, size and contextual information from previous surveys or land cover classifications. These features represent the knowledge that will be used for the automation. Parts of the key are shown in Figure 2. The example describes the decisions to be made according to the features *size* and contextual information as spraying lines.

Coca fields are composed of a high percentage of bare soil with small rows of coca bushes. In a Landsat image, these fields appear in a bluish colour on a false colour composite (Figure 1). Therefore, colour is the first feature used for a decision rule. Subsequently, the results of previous surveys and the information gathered during the spraying of the fields are analyzed. Then the size of the fields plays a key role as 90% are less than 1.5 ha. In addition, older satellite images are consulted to determine land cover change. The key leads to one of three conclusions for every image object: no coca fields, coca fields and coca field that have to be verified during overflights with airplanes.

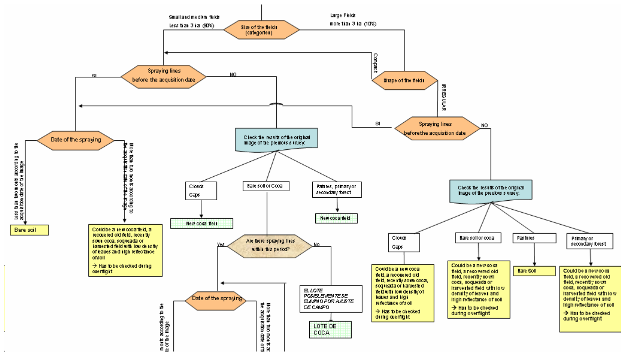

Figure 2. Part of the interpretation key

## 5. METHODOLOGY

For the automation of the visual interpretation, the software package eCognition is used. A two step process is applied. After the segmentation, the image objects are classified according to the rule base which is derived from the interpretation key.

### 5.1 Segmentation

Image segmentation is a crucial step as it determines the size of the image objects that will be used for the subsequent classification. Image objects should correspond to delineations as detected by the human interpreter, a nearly unrealisable requirement. eCognition offers the advantage of the multi-resolution image segmentation. Objects are created on different scales and can be linked together to a hierarchical object network. Different scale combinations can be used for the extraction of information. For example small coca fields can be detected within large areas composed of bare soil. The levels are generated during the segmentation process. The concept of this approach is described by Benz et al. (2002).

For the study area, segmentation was performed on four different levels. Information on the size of the objects (fields) is an important feature for the classification. It is not advisable to set one scale for deriving this kind of information. Rather, to the size of the fields on different scale levels are taken into account.

## 5.2 Classification/Interpretation

Contextual information is included for the classification of the image objects. Coca fields of the previous survey, spraying lines and land cover information of the previous year are available for that purpose.

A hierarchical rule base is established which follows the interpretation key mentioned above. The class hierarchy implemented in the software supports semantic grouping of classes (Figure 3). A fuzzy classification approach is used. For the class *Colour,* parameters for the thresholds have to be determined by a human interpreter. The subsequent decisions are implemented as described in the interpretation key. Figure 4 shows the class description of one of the final coca classes.

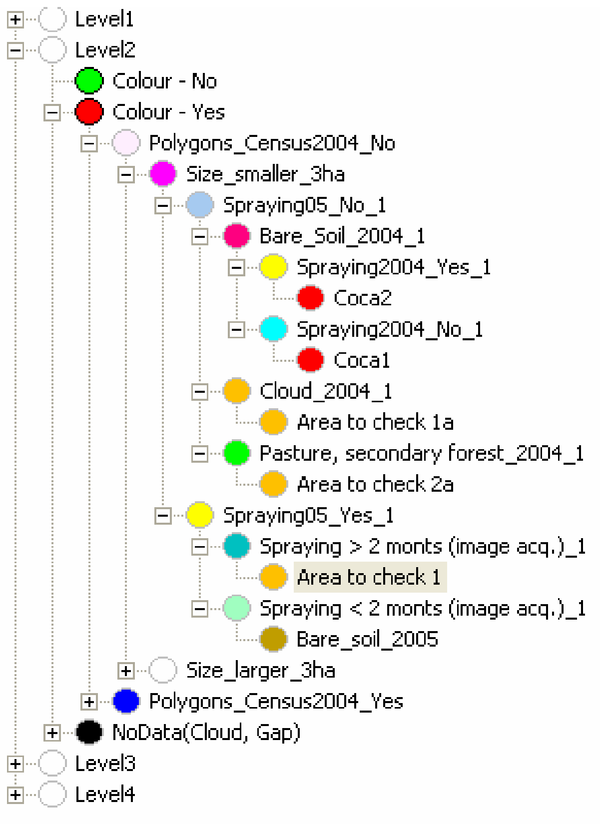


Figure 3. Class Hierarchy in eCognition

If the colour indicates a potential coca field, it is checked if coca fields were detected during the previous survey. Subsequently, the occurrence of spraying lines is checked, then the size of the fields and so on.

During the visual interpretation, the interpreter often makes use of previous satellite images for comparison with the land cover classes of previous surveys. For the automated classification the scene used for the previous survey is classified using a sample-based standard nearest neighbour algorithm as provided by eCognition. The following broad land cover types are distinguished: bare soil, pasture, primary forest, secondary forest and clouds plus corresponding shadows.

As for the key used for a visual interpretation, different kind of coca categories are the result of the analysis. On the one hand, fields are identified that are coca fields with a high degree of certainty, according to the evidence. On the other hand, areas are highlighted that have to be checked during overflights as important information is missing (e.g. because of clouds in previous images or missing spraying lines).

## 6. RESULTS

The resulting categories for the test area are shown in Figure 5. The outcome is compared with the results of this year's survey which relies again on a visual interpretation. Red colour indicates coca fields while orange colours represent areas that have to be checked. Yellow polygons represent the results of the recent survey which is used as reference information.

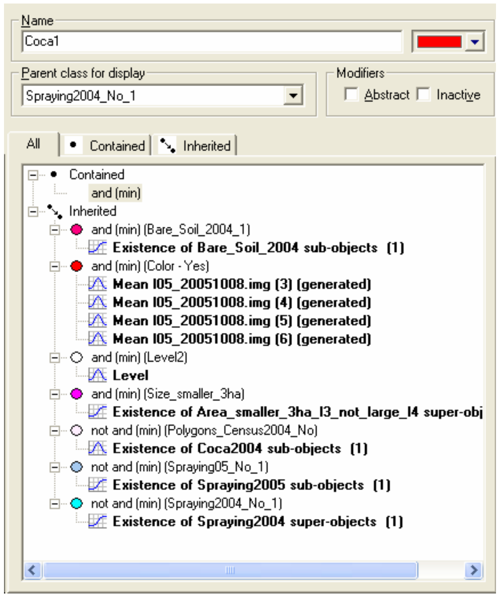


Figure 4. Example of a class description of one *coca* class

A visual comparison of the identified coca fields (red colours) clearly shows that the object-based approach can be used for screening the area. In many cases the result is overestimated. That means that more coca fields are detected by means of an automated interpretation than during a visual interpretation.

A detailed accuracy assessment has not been applied so far, as the reference data available represent "corrected" data. I.e., the original data of the visual interpretation were corrected after overflights with airplanes over the area. Uncorrected data that represent the result of the visual interpretation are not available. Furthermore, a second satellite image was used during the visual interpretation that was also not available for the automated approach at the time of the analysis. An accuracy assessment will be part of the ongoing research.

## 7. CONCLUSIONS

The study has proven that a detailed interpretation key is a prerequisite for automating the visual interpretation. The elimination key can easily be transformed into a knowledge base. While the overall goal is to exclude human interaction as much as possible, for the definition of some features, human interaction is still necessary.

The automated approach as suggested in this paper will not replace the visual interpretation but it could be used for screening the area and help to reduce the operator's interactivity and speeding up the interpretation process. The automated interpretation serves in this case as a control mechanism. This will improve the transparency of the interpretation process. Once more it could be demonstrated that it is necessary to include information from different kind of sources into the interpretation process of remotely sensed data.

An interpretation key as described in this study is only valid for a geographic region with similar land cover units and for similar images within this area. The key has to be adapted for other regions and other types of images. Parts of the key can be transferred, other parts have to be newly developed. Further research will focus on the transferability of the key.

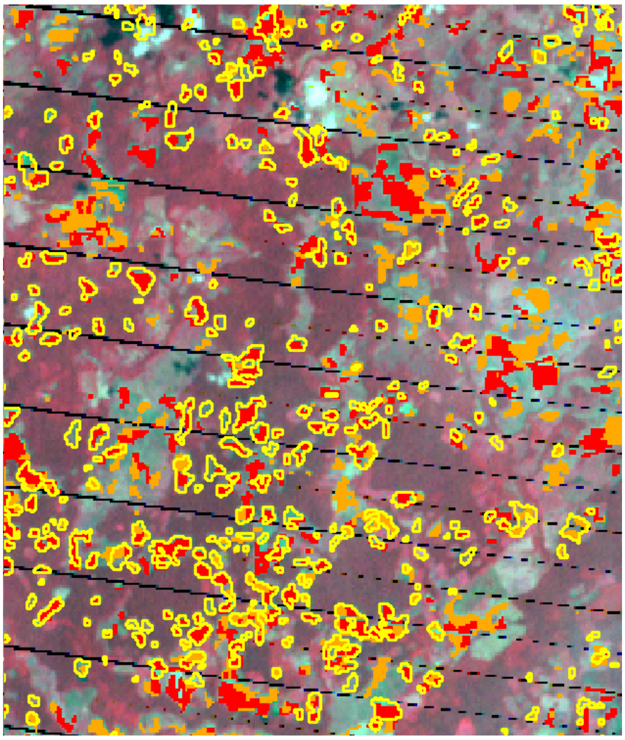

Figure 5. Results of the automated interpretation – red polygons are indicating potential coca fieds, orange polygons represent areas that have to be checked and yellow polygons indicate the results of the 2005 survey (image data available from USGS/EROS, Sioux Falls, SD).

## REFERENCES

Ardila, J.P. and Espejo O.J, 2004. Classificación y extracción de información temática en imagines satelitales de zones rurales mediante la validación y aplicación de una metodología orientada a objetos y clasificadores basados en lógica difusa. Diploma Thesis at the Universidad Distrital Francisco José de Caldas, Bogotá D.C.

Benz, U., Hofmann, P., Willhauck, G., Lingenfelder, I. and Heynen, M., 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. *ISPRS Journal of Photogrammetry and Remote Sensing,* 58, pp. 239-258.

Blaschke T., Lang S. and Möller M., 2005. Object-based analysis of remote sensing data for landscape monitoring: recent developments. In: *Anais XII Simpósio Brasileiro de Sensoriamento Remoto,* Goiania, Brasil, pp. 2879-2885.

Langanke, T., Blaschke, T. and Lang, S., 2004. An object-based GIS/remote sensing approach supporting monitoring tasks in European-wide nature conservation. In: *First Mediterranean Conference on Earth Observation,* April 21-24, Belgrade, pp. 245-252.

Lillesand, T.M., Kiefer, R.W. and Chipman, J.W., 2004. *Remote Sensing and Image Interpretation.*. Wiley, New York.

Mota, G.L.A., K. Pakzad, S. Muller, M.S.P. Meirelles, R.Q. Feitosa and H.l. d C. Cotuinho, 2005. A framework for automatic low-resolution satellite image interpretation based on spectral, contextual and multitemporal knowledge. In: *Proceedings of the 20th ISPRS Congress*, July 12-23, 2004, Istanbul, Turkey, pp. 216-221.

Richards, J.A. and Jia X., 2006. *Remote Sensing Digital Image Analysis – An Introduction.* Springer, Berlin.

UNODC, 2005. *Colombia – Coca Cultivation Survey*. United Nations Office on Drugs and Crime, Vienna.

## ACKNOWLEDGEMENTS

This research was possible through a grant of the Austrian Foreign Ministry to the United Nations Office on Drugs and Crime. The authors would like to thank the staff of UNODC-Colombia – especially Mrs. Sandra Rodriguez – for their cooperation and the provision of various data sets.