

THEMATIC ACCURACY ASSESSMENT FOR OBJECT BASED CLASSIFICATION IN AGRICULTURE AREAS: COMPARATIVE ANALYSIS OF SELECTED APPROACHES

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ABSTRACT:

Over the past few years, the significant increase of request for spatial information is observed. Land cover and land use databases are needed for land management, urban planning, agriculture, environment protection and many other purposes. New sensors are able to provide very high spatial, spectral and time resolution data, what made the representation of earth surface more accurate but at the same time more difficult to classify in more objective and recurrent way. The object-based classification becomes frequently alternative approach to traditional pixel-based analysis. The paper presents the results of comparative analysis of different approaches applied to thematic accuracy assessment process of land cover classification with object-based methodology. The tests were done for the terrain with the diverse level of spatial and spectral complexity. The examples of images with different resolutions, including VHRS one, were used in the study. The different variants of thematic accuracy assessment strategies were exploited for the results of object based classifications. Considering certain input assumptions, the results showed the positive aspects as well as limitations of applied approaches to thematic accuracy assessment.

1. INTRODUCTION

Satellite imagery technology provides a wide range of valuable data about the earth surface. The continuous development of this technology during last tens of years with simultaneous progress in hardware and software domain caused that satellite data is used in many broad application areas like for instance: different scale mapping and analysis, change detection, environmental monitoring, and so on. The successive satellite systems have been released with better and better sensor parameters, with spatial resolution as one of main key indicator of the progress.

Especially the parameters of VHR satellite sensors and resulted from that the image quality show their usefulness in many disciplines and area of applications. New classification algorithms allow to receive a better land cover maps which are so important in many analyses.

One of many examples can be Control with Remote Sensing (CwRS) which is one of methods for verification (in the frame of IACS) of area-aid applications made in the regulatory context of the UE's Common Agricultural Policy. Basically, the images can be used there for determination of the land use area of agricultural parcels which are part of the area aid application. The part of CwRS method which concerns the land cover (land use) and crop identification traditionally uses the multitemporal and multispectral set of images. The identification process can be done either entirely by CAPI (computer aided photointerpretation), or by a combination of automatic classification followed by CAPI.

In a pixel based automatic classification, commission to (or omission from) a class is carried out per pixel. After that, a relative pixel count within the parcel boundary determines whether that parcel belongs to the land use class or not. For instance, if 90% of pixels inside the boundary belong to certain class, the parcel may be accepted to have been classified as this

class (after which comparison to the declared crop class can be made). Since at this stage, parcel boundaries are supposed to have been adjusted to the right parcel outline (e.g. based on the VHR ortho-imagery), the other classes are usually due to spectral confusion. This, on its turn, may be due to within-parcel variability of the multi-channel signature, spectral heterogeneity of the class, the quality of the original data, the selection of the channels, or the parameterisation of the classification method, etc. The commission percentage should not be set too low (e.g. below 80%) and classification results should be checked to determine whether the omitted pixels are not spatially correlated (i.e. possibly outlining systematically over-declared crop parcel areas); EC, 2007. For pixel based classifications: the relative pixel count of correctly classified within the parcel should reached the pre-defined limit (e.g. 75% or other choice).

For a proper use of remotely sensed based products the right accuracy evaluation procedures should be selected and applied. It is important, that the quality of thematic maps derived from remotely sensed data should be assessed and expressed in a meaningful way (Foody, 2002). In practice, many procedures and methods of accuracy evaluation is in use.

According Foody (2002), the confusion matrix is currently at the core of the accuracy assessment literature. As a simple cross-tabulation of the mapped class label against that observed in the ground or reference data for a sample of cases at specified locations, it provides an obvious foundation for accuracy assessment; it provides the basis on which to both describe classification accuracy and characterize errors, which may help refine the classification or estimates derived from it.

The above mentioned paper says that accuracy assessment has been a topic of considerable debate and research in remote sensing for many years, and this is in part because the promoted standard methods such as the kappa coefficient are not always appropriate. Foody (2002) in his paper describes

the status of land cover classification accuracy assessment, showing also some problems in accuracy assessment. Liu *et al.*, (2007) presents comparative assessment of the known measures of thematic classification accuracy. Fourteen category-level measures were investigated in his paper with totally twenty map-level measures studied and described. There are of course other papers dealing with the thematic accuracy issues of remotely sensed classification data. All considerations show the importance of the problem of a proper selection of accuracy measure and evaluation procedure to the certain category of mapping with different classification methods and approaches. As it was mentioned above, the typical measures used in practice are related to so called error matrix (e.g. user's accuracy and producer's accuracy, the overall accuracy, kappa per class and overall kappa, etc). They are used generally for the results of pixel and object based approaches in image classification. In case of using object based classification for agricultural areas, the other approaches to accuracy assessment seem to be interesting in use, for example the crossing of classification result with adequate vector layer including representatively selected test parcels, which were spectrally homogenous in the respect of interior.

The paper presents the results of different approaches applied to thematic accuracy assessment process of land cover classification with object-based methodology. The tests were done for the terrain with the diverse level of spatial and spectral complexity. The examples of VHRS images with different resolutions were used in the study. The different variants of thematic accuracy assessment strategies were exploited for the results of object based classifications achieved in previously done works.

2. SHORT CHARACTERISTICS OF OBJECT BASED CLASSIFICATION

Object based approach allows to explore in image classification not only digital value of pixel (in spectral domain, as the pixel based approach does) but also other features (attributes) like e.g. shape, size, texture, pattern, context, which can be as discriminators of visually perceptible objects on the image. In that point the approach can be considered as significant step in overcoming the recognized limitations of traditional pixel based classification. Unlike the traditional classifiers, which are widely accessible in many software packages, the object oriented image analysis software is still a unique solution. The key procedure in processing flow of raster object oriented analysis is segmentation - the patented technology enabling to extract the homogenous structures of objects at different levels of resolution (spatial scale) by applying relevant spectral and spatial related object discriminators. The eCognition package (presently Definiens) was the first general object-oriented image analysis software on the market (Benz *et al.*, 2004). This software was used for obtaining the results analysed in the paper, and the further consideration about algorithm and methodology are related to it. The key issue of segmentation is the heterogeneity criterion which considers as primary object features color and shape. The scale parameter is the stop criterion for optimization process.

The resulted objects can be characterized by different sets of features defined in spectral and spatial domain. Between sequential layers of different resolution segmentation results a hierarchical network of image objects is constructed. The

vertical child – parents relationships in which small objects are sub objects of larger object create together with horizontal context (neighborhood) based relationships a very crucial set of relational information useful for classification steps.

The whole classification domain is based on fuzzy logic. The frame for the knowledge base for classification is the class hierarchy, which contains all classes of the classification scheme.

Each class can be described by fuzzy rules, defined either on one-dimensional membership functions (enables the user to formulate knowledge about the image content) or on a nearest neighbor classifier (the desired class's properties are determined by 'training' sample objects). Different classifiers can be combined within one class description using fuzzy logic, which provides different operators such as "and" and "or," for instance.

Classification results can be differentiated and improved by using semantic context information: as soon as objects are classified according to their intrinsic and topological features, classification can be refined using semantic features—mostly by describing neighborhood relationships or the composition of sub-objects. Successful information extraction by classification is usually a kind of iterative process with certain sequence of segmentation and classification runs. Image objects as processing units can continuously change their shape, classification and mutual relations. This circular processing results in a sequence of intermediate states, with an increasing differentiation of classification and an increasing abstraction of the original image information. In each step of abstraction, new information and new knowledge is generated and can be beneficially used for the next analysis step.

The eCognition package was the first general object-oriented image analysis software on the market (Benz *et al.*, 2004). Next name of the software was Definiens Professional (or Developer). Detailed discussion about software and the strategies of object oriented analysis presents for instance the paper Benz *et al.*, 2004.

3. STUDY AREAS AND DATA

For the purpose of the paper, as it was mentioned in Introduction chapter, the results of object based classification were used for analysis from two previously done works. The study areas selected for the considerations are named adequately as test area '1' and test area '2'.

Test area '1' with the area about 20 km² (Figure 1) was situated in the middle of Germany, in Mittelhessen. There were market crops and cereals like sugar beets and wheat up to the foot-hills of the volcanic and basaltic soils of the Vogelsberg with smaller farms, mainly with grassland and milk producing cattle.

The QB image has been acquired on 8 of June 2003 with GSD = 0.65m for panchromatic and GSD = 2.6m for multispectral image. As an ancillary data the shape file with agricultural parcels declared in 2003 season was used what was useful for preparing the training and test areas. The analyzed classification accuracy is related to the results of object based classification done for part of 'Glau' VHR-test area (Chmiel, J., 2004). The classification was based on multispectral image with pixel size equal 2.6m.

Test area '2' is located in North eastern part of Poland (near Elk town). The terrain is an example of postglacial rolling landscape with significant presence of moren hills, water areas, forests, and swamps. The terrain elevation is approximately between one and two hundred meters; the differences for majority of the area are generally not high. It is typical agricultural region with soils of average quality and with size of parcel and farms generally bigger than ones occurred for example in central part of the country.

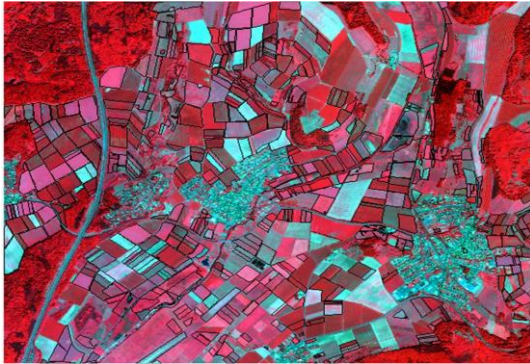


Figure 1. Test area '1'; color composite with parcels

The structure of crops is also very diversified with most of types which occurred in the rest of country.

The analyzed classification accuracy is connected with the results of object based classification done for part of QuickBird scene image (Fig. 2) registered on 30 of May 2005. (Chmiel, *et al.*, 2007, 2009). The object analysis was based on pan sharpened multispectral bands.

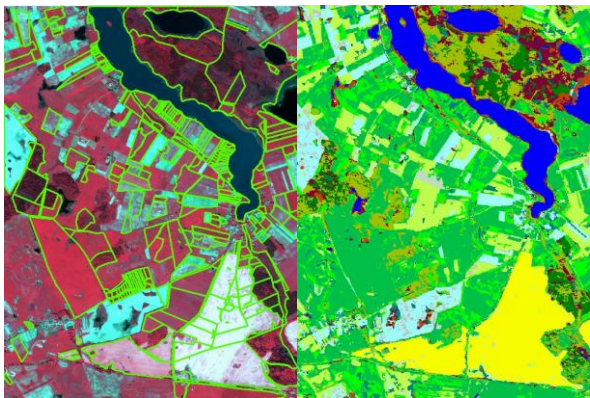


Figure 2. Test area '2'; left part pansharp color composite with parcels, right part: result of object based classification

For the majority of the agricultural areas the vegetation was already well grown (winter crops, grass on the arable land). Significant part of vegetation cover is on the sprout stage (spring crops). The rape was very easy to identify due to its phenological stage on that time. There were still quite big areas with not growing yet crops (potatoes, maize, beets, and other vegetables).

4. METHODOLOGY AND RESULTS

As it was mentioned above, the sample-based nearest neighbour classifier with supervised approach was used for

object based classification, assuming the preference for effective variant of procedures which at the same time should be generally less scene dependent and not too complex to be also easier for repetition. The last assumption was especially dedicated for object oriented type of analysis with Definiens software used for object classification where a lot of options and levels of complexity are possible in practice.

The set of target classes assumed for each test area was consistent with adequate list of classes included in Figure 4 and Figure 8.

The classification accuracy for the results was controlled in two different and independent ways:

a) using classic approach with the set of tests areas (random samples obtained using classic rules) and resultant error matrices with selected measures based on it,

b) by crossing the each classification result with adequate vector layer including representatively selected test parcels, which were spectrally homogenous in the respect of interior.

As a result of mentioned crossing operation, for each parcel boundary the area of dominant class was counted and next converted into percentage of whole area of parcel. This was kind of measure useful in preparing special histograms and final evaluation.

Based on error matrices, the kappa index of agreement (with kappa per class and overall kappa) was selected as one of measure for accuracy evaluation.

4.1 Test area '1'

The distribution of parcels size (as area distribution) considered for accuracy analysis is shown on Figure 3. The vector layer including selected parcels was used for crossing with the object classification result.

The Figure 4. presents received accuracy measures 'kappa per class' for final object based classification. The analyses of classification accuracy show certain problems located typically in more problematic classes. The overall value of Kappa for this case is equal 0.619. The value '% of area correct' as a result of calculation taking into account the sum of dominant class area in relation to total area of considered test parcels is equal 69.5%.

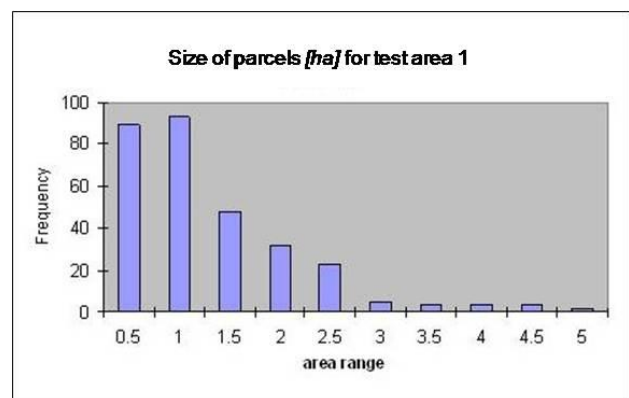


Figure 3. Size of parcels - test area '1'

The statistics received as a result of crossing of two layers i.e.: object based classification and parcel layer were used for creating the histogram showed on Figure 6.

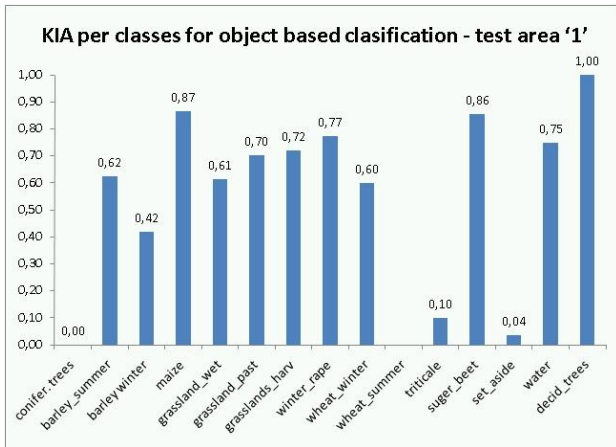


Figure 4. KIA per classes for object based classification result - test area '1'

From such figure it is easily to read different quantitative relationships between % of area corrected (ratio of dominant class area to total area of each parcel) and number of parcels in single and cumulative counts.

The important analysis can be done for example, assuming certain threshold i.e. minimum area correct and show the areal distribution of all parcels passing such threshold, like it is illustrated on Figure 6. Some useful observations can be achieved by comparing Figure 6 with Figure 3.

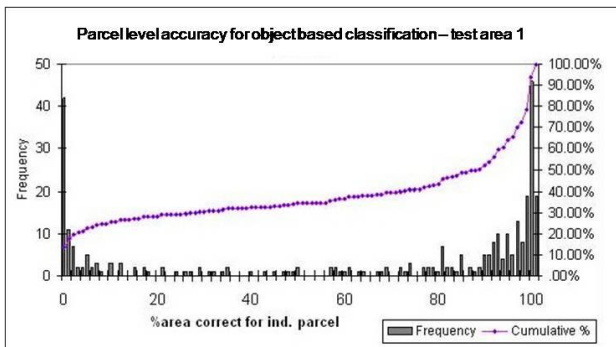


Figure 5. Parcel level accuracy for object based classification - test area '1'

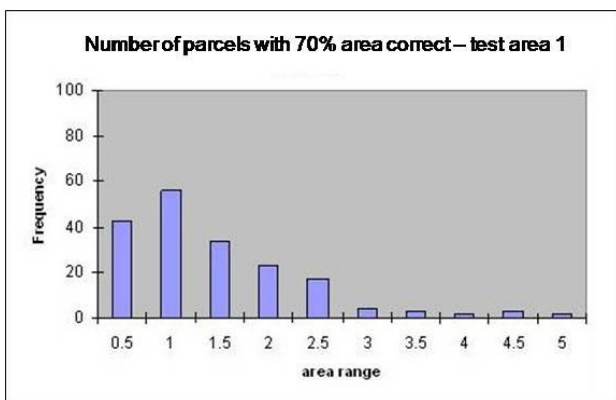


Figure 6. Number of parcels with minimum 70% area correct - test area '1'

4.2 Test area '2'

The areal distribution of selected parcels considered for accuracy analysis is shown on Figure 7. The Figure 8. presents received accuracy measures 'kappa per class' for final object based classification. The overall value of Kappa for this case is equal 0.696. The value '% of area correct' as a result of calculation taking into account the sum of dominant class area in relation to total area of considered test parcels is equal 58.2%.

For this test area, the statistics received as a result of crossing of two layers i.e.: object based classification and parcel layer were used for creating the histogram showed on Figure 9. This is the basis for further identification and interpretation of different quantitative relationships between % of area corrected (ratio of dominant class area to total area of each parcel) and number of parcels in single and cumulative counts. Similarly as it was mentioned for test area '1', other important analysis can be done for example, assuming certain threshold i.e. minimum area correct and show the areal distribution of all parcels passing such threshold, like it is illustrated on Figure 10. Some useful observations can be achieved by comparing Figure 10 with Figure 7.

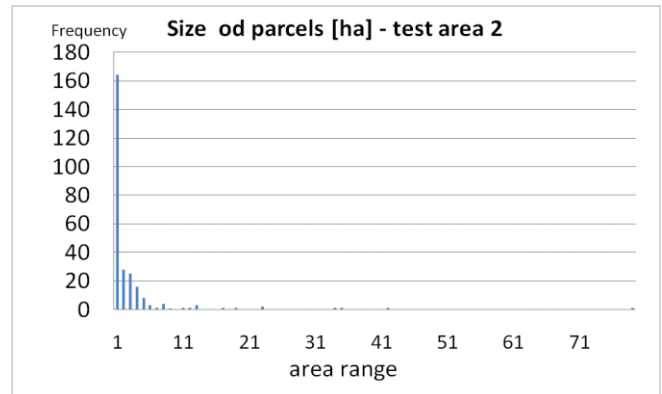


Figure 7. Size of parcels - test area '2'

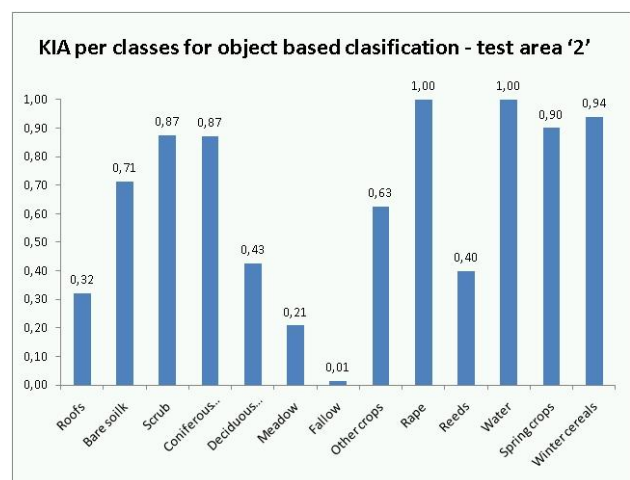


Figure 8. KIA per classes for object based classification result - test area '2'

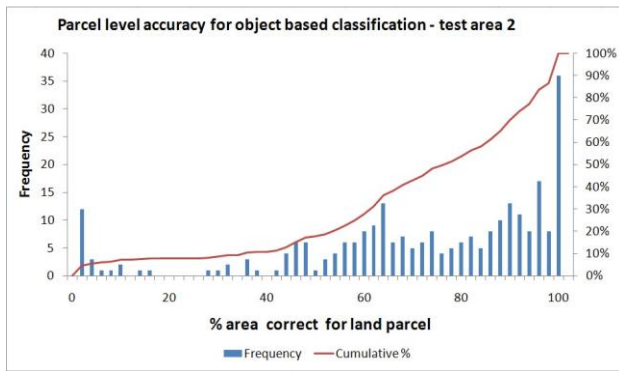


Figure 9. Parcel level accuracy for object based classification - test area '2'

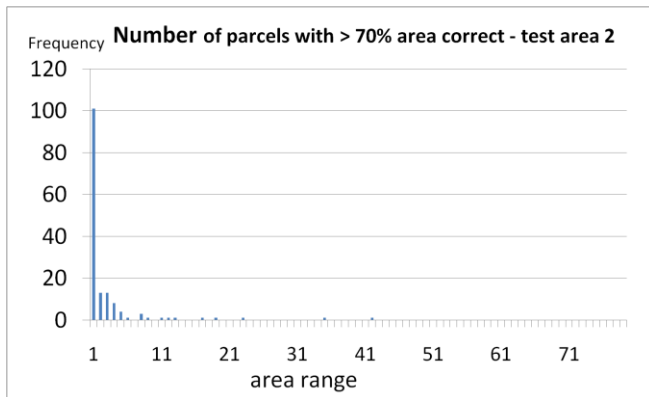


Figure 10. Number of parcels with minimum 70% area correct - test area '2'

The selected accuracy measures allow for different approach to accuracy evaluation as well as diverse interpretation of achieved figures. The observations are of course related to the given results, and ought to be considered together with all assumptions taken for the presented research work as well as characteristic of data set and study area.

5. CONCLUSIONS

The presented results of different approaches applied to thematic accuracy assessment process of land cover classification with object-based methodology confirmed that this evaluation process is very sensitive and can be dependent to different factors. Proper selection of accuracy indicators to be calculated and evaluated and generally more objective applied procedure can allow for achieving a useful accuracy figures. The obtained results of object based classifications can be seen as next example in this field of considerations. Considering certain input assumptions, the results showed the positive aspects as well as limitations of applied approaches to thematic accuracy assessment.

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