# OBJECT CONTEXT INFORMATION FOR ADVANCED FOREST CHANGE CLASSIFICATION STRATEGIES

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**KEY WORDS:** Forest change, deforestation, context classification, object oriented, change detection.

**ABSTRACT:**

This paper describes a contextual classification approach to classify complex forest change classes. Multi temporal forest change classifications are performed comparing the 1989 baseline for the Kyoto definition of ARD (Afforestation, Reforestation and Deforestation) with the status in 2000 for test territories in Siberia with extensive ground truth information from forest inventory. The differentiation of human induced forest cover change (e.g. logging and clear cutting) and changes by fires (that are potentially a non-human induced change) is usually very much complicated by similar spectral signatures. Tests with object based change detection approaches showed that object shape can increase the classification accuracy of these change classes. This work concentrates on contextual information that is used as a secondary information type for change class differentiation. Logging is usually only possible with infrastructure, road or path networks to transport larger amounts of timber. The existence of linear road objects can therefore be used as a prerequisite for the classification of specific change classes using neighbourhood relationships and distance measures in different scales. An analysis of the results of a direct two-date change detection and post classification procedure shows the effect for the classification of deforestation classes in Siberia with atmosphere corrected multitemporal Landsat data and forest inventory information. The presented work is part of the Siberia-II project that was finished in 2005.

## 1. INTRODUCTION

The work on forest cover change detection presented in this paper is part of the EU project SIBERIA-II (Multi-Sensor Concepts for Greenhouse Gas Accounting of Northern Eurasia) (Schmullius and Hese 2002, Hese et al. 2002, Santoro et al., 2002). The scientific objective of the SIBERIA-II project was to integrate Earth observation and biosphere process models such that full greenhouse gas accounting within a significant part of the biosphere can be quantified. Global estimates of the net carbon flux due to land cover changes are complicated by critical uncertainties like distribution and rate of deforestation and biomass burning, conversions from natural land cover and rate of reforestation and re-growth of deforested or burned land. The Kyoto Protocol (KP) carbon emission inventory is related to land cover changes with respect only to areas directly affected by human action through ARD (Afforestation, Reforestation, Deforestation) (Scole and Qi, 1999).

It is important to differentiate the needs by the KP and by full carbon accounting (FCA). FCA accounts for all possible sources and sinks and not only for those related to ARD under a specific and restricting definition of forest.

Differentiation between natural and human induced forest changes (as required by the KP) is a complex task and asks for an analysis of underlying causes of disturbances. As noted already in Scole and Qi (1999) forest management practices which change growth rates of forests and selective logging are not considered in the KP. Interpretation of the possible causes of forest changes is often impossible with Earth observation. Analysis of contextual and structural information using post classification analysis with contextual GIS analysis systems in multiple scales can however improve the potential of remote sensing for Kyoto ARD mapping. There will remain restrictions to extract underlying causes of land cover changes with remote sensing. A combination of Earth observation with extensive ground truth and local forest enterprise information to deliver precise information to these questions is essential.

Different forest cover change detection approaches have been proposed in the past. Coppin and Bauer (1994) analyzed vegetation indexes using standardized differencing and selective principal component analysis. 14 change features were generated and the Jeffries-Matusita distance for best minimum separability was used as a measure of best statistical divergence to select the best change feature dataset. Copping and Bauer (1994) concluded that the most promising change features are the standardized difference of brightness, the second principal component of greenness, the second principal component of brightness, the second principal component of the green ratio and the standardized difference of greenness. This pointed towards the Kauth-Thomas brightness and greenness indexes and the green ratio as the vegetation indexes with the most relevant forest cover change information. It was also noted that analysis of change that is beyond the spectral-radiometric information would need the incorporation in a GIS framework with artificial intelligence capabilities. Other studies used direct multi-date classifications or hyper clustering (Leckie et al. 2002), change vector analysis, parcel-based change detection procedures, artificial neural networks (Gopal and Woodcock 1996), cross-correlation analysis (Koeln and Bissonnette, 2000) and various post classification

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change detection methods. Important reviews of change detection methods have been published by Singh (1989) and Coppin and Bauer (1996).

The object-based strategy for data classification as part of the eCognition software (Baatz and Schäpe (1999), Benz et al. (2004)) uses as a first stage a segmentation into different scales of image object primitives according to spatial and spectral features. This segmentation is a bottom up region merging technique starting with one pixel sized objects. In numerous subsequent steps smaller objects are merged into bigger objects (pair wise clustering) minimizing the weighted heterogeneity of resulting objects using the size and a parameter of heterogeneity (local optimization procedure) (Benz et al. 2004). This concept has the advantage to account for contextual information using image objects instead of the pixel based concept used frequently as the basic element in remote sensing image processing. In a second stage rule-based decisions can be used to classify the multi scale image objects. Class based feature definitions (integrating a post classification analysis) are possible as well as the inheritance of class descriptions to form a class hierarchy. Image processing tasks can be performed using vector shape and vector characteristics. Results can be also analyzed and presented in vector format (polygons with attributes) instead of the raster cell format. This increases the flexibility of this image processing concept and integrates GIS-like data queries in an attribute database directly into the image processing and analysis approach. New attributes (like object shape or structural characteristics e.g. distance to other objects) can be used on the basis of the vector data format.

Object based image analysis has been used since 1999 for different forest classification approaches. Halounova (2004) used the object oriented approach to classify B&W aerial photos with textural features. Yijun and Hussin (2003) classified tropical deforestation in East Kalimantan using the object oriented approach and Mitri and Gitas (2002) developed an object oriented classification model for burned area mapping. Flanders et al. (2003) tested the object oriented approach for forest cut block delineation.

Different advantages over pixel-based approaches have been published mainly using very high resolution airborne or orbital Earth observation data. The primary advantage of reducing spectral variability in high spatial resolution data sets (spatial resolution better 1 m) is only one aspect of object oriented image analysis. For the development of change detection procedures new GIS-like analysis concepts are important. Object shape in different scales based on a simplification through vectorisation can aid to differentiate clear cuts from other deforestation processes that do not show specific object shapes with a high rectangular fit (Hese and Schmullius, 2004). Multi-scale object information can be used to increase the classification accuracy of classes that have to be defined using textural information instead of spectral information (e.g. the spectral variability in urban areas is preferably classified using larger objects). Class related classification can be used to build rules for complex neighborhood relations to already classified image objects. This can be used to function as a classification of object structure. Such an approach can be applied e.g. to connect the classification of clear cuts to the classification of linear road objects beyond a parent change class. Transportation is prerequisite for logging activities and can be used as GIS-like context information. Road networks that were created in forested areas are secondary information for the detection of logging processes.

Using the class hierarchy with inheritance of features, simple change – no-change masks can be developed that provide a powerful global (inherited) approach for the adaptation to other data sets. One drawback of the combined use of post-classification procedures using class related features and direct two-date change detection in one procedure is the complex error propagation logic that can lead to unstable classification results.

## 2. DATA

Ground truth information from test territories with extensive forest inventory data from forest enterprises in Russia is used for this analysis (on ground forest inventory and planning (FIP) for intensively managed forests).

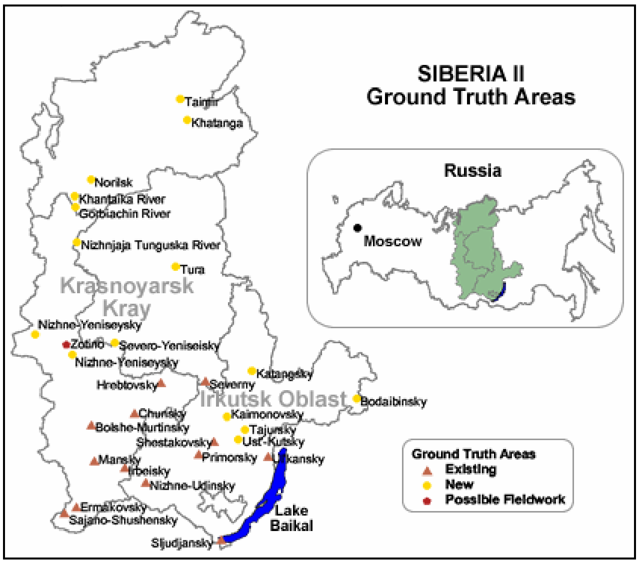


Figure 1. Ground truth test sites from forest enterprises in Russia (ground forest inventory and planning (FIP) for intensively managed forests). Only the testsites Chunsky, Bolshe-Murtinsky, Shestakovsky and Primorsky were used for the ARD study.

These datasets cover different regions in Siberia (Figure 1). Multi-temporal Landsat ETM and TM5 data stacks for these areas were acquired from 1989 and 2000 covering areas in the Krasnoyarsky Kray and Irkutsk Oblast (Landsat path and row: 140/20, 141/20, 142/20, 143/20, 135/21, 136/21). To correct for path radiance in multi temporal data atmosphere correction algorithms were employed using algorithms from Richter (1996). Some Landsat TM5 data sets showed a “salt and pepper” effect which appeared randomly at different places in the image geometry and without correlation between the different sensor bands. This noise was corrected using a threshold based selective filter technique that changes the effected pixels to the mean of the surrounding 8 pixel values if a defined threshold is exceeded. Adjacent Landsat scenes were relative corrected to an atmosphere corrected multi temporal master scene using histogram matching techniques to allow the application of training areas and signatures to larger areas. Reprojection to the specific Siberia-II “Albers Equal Area Conical WGS84” projection was performed for all datasets.

## 3. METHOD

### 3.1. Afforestation, Reforestation and Deforestation Classification

The first step in object oriented image analysis is the segmentation into object primitives using a bottom up region merging algorithm. Three different object levels are generated for the forest change detection approach using different thresholds for object merging based on multitemporal data from 1989 and 2000. The class hierarchy that is created (Figure 2) is based on parent classes that link to the primary segmentation levels. A change and no-change parent class is created using a standardized change ratio (Coppin and Bauer, 1994) of the red Landsat band. Clouds, cloud shadows and water objects are classified with the brightness calculated for Landsat ETM+ and TM5. These classes are grouped together to form one class and are excluded from the change detection classification process (masking). This is done by inheriting an inverted expression through the change – no-change parent class of the finest segmentation level.

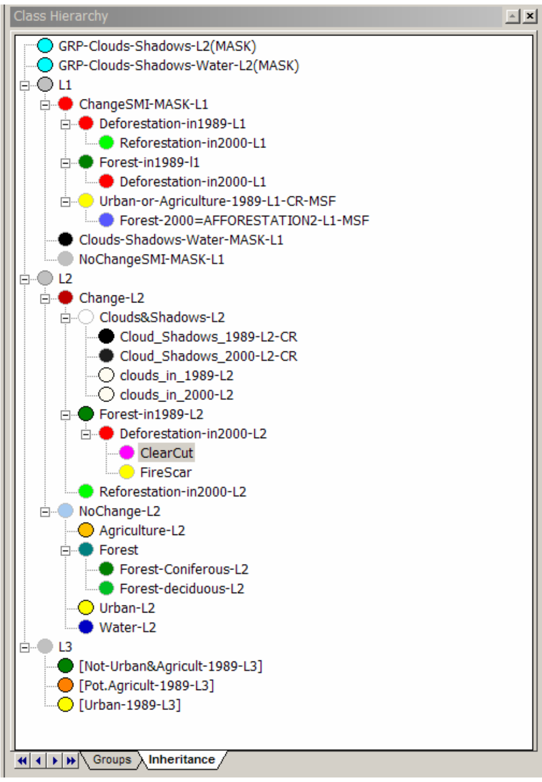


Figure 2. Class hierarchy for Afforestation, Reforestation and Deforestation classification in the SIBERIA-II project using class related and shape features in different segmentation scales.

The final forest change classification is done in the segmentation level with the smallest objects. A no-change and change "decision tree" is created using a standardized multi temporal change ratio of the red and the green channel. "Forestation on deforested areas" and "Deforestation" is classified using the multitemporal near infrared difference and NDVI thresholds. "forestation on deforested areas" is defined as deforested in 1989 and reaching an age of 10 years in 2000. Deforestation is defined as not forested in 2000 but in a forested state in 1989. The classification is done using a NIR difference image and NDVI thresholds.

The human induced landuse conversion of agriculture land (that has not been forested land before) to forested land is named "Afforestation". For the classification of this specific change class differentiation of urban areas, agricultural used areas and forested areas in 1989 is important. To integrate this additional information into the change analysis system, class related features are used. Using class related features a landuse change classification is combined with a forest change mapping approach.

It should be noted that these definition do not follow exactly the definitions for Afforestation, Reforestation and Deforestation as defined in the KP annex. The improvement of ARD classification with Earth observation is still subject of ongoing research using context information to classify human induced changes and differentiate different types of changes with probability estimations. The limitations to derive these class definitions using Earth observation (EO) and image processing techniques have already been mentioned. Results of the forest change classification with deforestation classified without context information can be found in Hese et al. (2004).

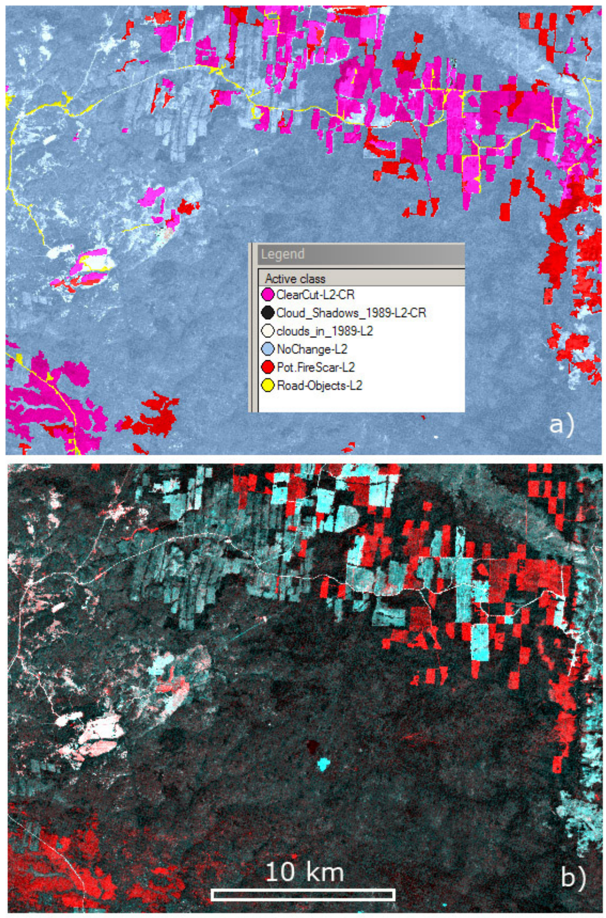


Figure 3. a) Class related deforestation classification using "distance to class" roads (t=2500 m), classification with reduced class legend for deforestation analysis b): Multitemporal change RGB composite using the Landsat channel 2

### 3.2. Object Context Information for the Differentiation of Deforestation Classes

The differentiation of deforestation classes “clear cut” and “fire scar” (referring to the unprecise definition of human and “non-human induced” forest change) using neighbourhood information was tested in this work with two different feature sets. Distance to the class “linear objects” and neighbour hood to the class “linear objects” - assuming (and simplifying) that linear object are road objects.

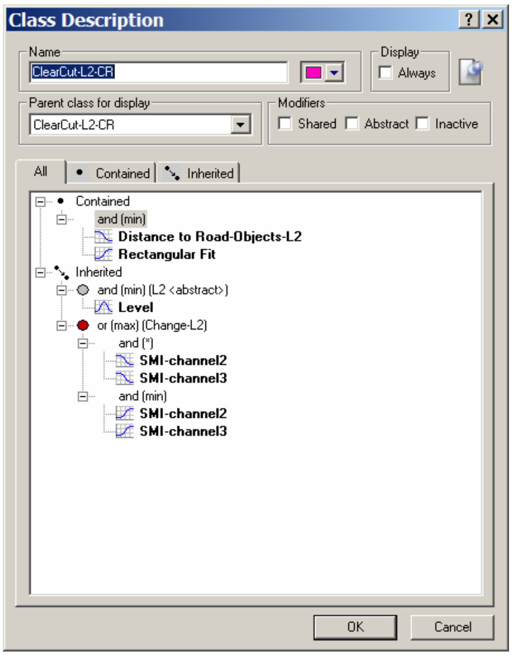


Figure 4. Class description (in eCognition) for the class “ClearCuts” using inherited change feature ratios, class related distance measures to road objects and shape features.

Additionally we tested how the road objects merged into larger objects in upper (coarser) segmentation scales and how the “Existance of class road” feature could be utilised in this analysis. Figure 3a shows the classification of fire scar objects and clear cut objects using “distance to roads” and shape features. Due to the fact that not all roads were identified correctly the class related feature propagated this error into the classification of clear cuts.
It was also noted that road objects appeared in burned areas and misclassification of fire scars as clear cuts appeared as a consequence. There is obviously a high variability of the contextual image characteristics for these classes in the area under investigation. Therefore class related features were combined with shape and spectral features to increase the classification accuracy. The shape features “density” and “shape index” were used to differentiate more compact “clear cut” objects from “fire scar” objects. There is however an overlap in the feature spaces of these classes (compare with Figure 5 and Figure 6).

The used data sets with spatial resolution of 30 m limited the outcome of this analysis. Small road networks could not be detected precisely in Landsat data due to the mixed spectral signal.


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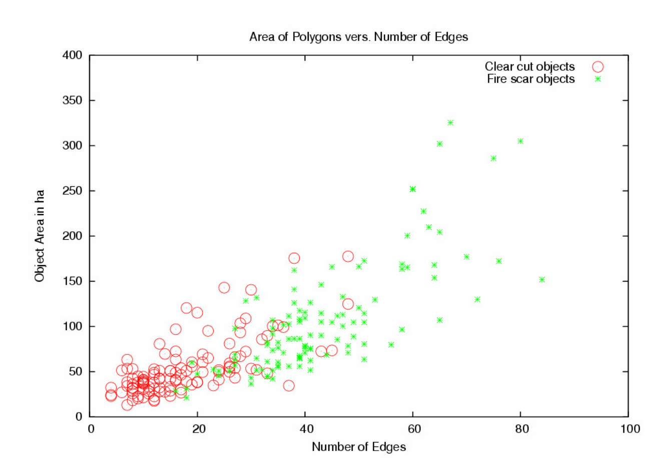


Figure 5. Object area versus number of object edges of clear cut and fire scar deforestation objects.

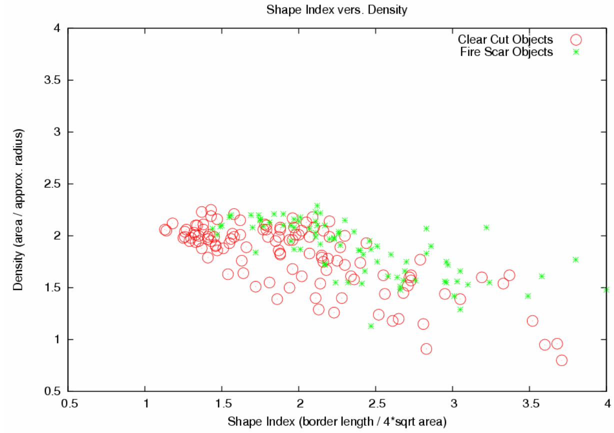


Figure 6. Object density (area/radius) versus shape index (border length/area) for fire scar and clear cut deforestation objects.

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