Object-based detection of LUCC with special regard to agricultural abandonment on Tenerife (Canary Islands)

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ABSTRACT

The island Tenerife has always been used for intensive agriculture, whereby the natural landscape was continuously altered. Especially mountainous areas with suitable climate conditions have been drastically transformed for agricultural use by building of large terraces to get flat surfaces. In recent decades political and economic developments lead to a transformation process (especially inducted by an expansive tourism), which caused concentration- and intensification-tendencies of agricultural land use as well as agricultural set-aside and rural exodus.

In order to get information about the land use and land cover (LULC) patterns and especially the agricultural dynamics on Tenerife, a multi-scale, knowledge-based classification procedure for recent RapidEye data was developed. Furthermore, a second detection technique was generated, which allows an exact identification of the total ever utilised agricultural area on Tenerife, also containing older agricultural fallow land or agricultural set-aside with a higher level of natural succession (under the assumption that long-term fallow areas can be detected mainly together with old agricultural terraces and its specific linear texture). These areas can hardly be acquired in the used satellite imagery. The method consists of an automatic texture-oriented detection and area-wide extraction of linear agricultural structures (plough furrows and field boundaries of arable land, utilised and non-utilised agricultural terraces) in current orthophotos of Tenerife. Through the detection of recent agricultural land use in the satellite imagery and total ever utilised agricultural area in the orthophotos, it is possible to define the total non-active agricultural land as well as hot spots of agricultural decrease.

Keywords: Object-based LULC classification, Texture-oriented detection, Agricultural land use changes, RapidEye

1. INTRODUCTION

Since the beginning of the Spanish colonialism, the island Tenerife has always been used for intensive, mainly export-oriented agriculture, whereby the natural landscape was continuously altered. Especially mountainous areas with suitable climate conditions have been drastically transformed for agricultural use by building of large terraces to get flat surfaces. In recent decades political and economic developments on Tenerife lead to a transformation process (especially inducted by an expansive tourism), which caused concentration- and intensification-tendencies of agricultural land use on the one hand and agricultural set-aside as well as rural exodus on the other hand. Starting in the 1960's, the mass tourism on the island increased from 1.3 million in 1978 to about 6 million tourists a year nowadays [1]. Today more than 75% of the employees in the service-based sector are working for the tourism industry, whereas in 1978 it constituted only 56%. At about the same time the cultivated area decreased considerably [2].

Due to these modifications in the economic sector the changes in land use and land cover increased. The trend leads recently to a spatial concentration of the population and settlements near to the coasts and increasing agricultural fallow land in higher and backward areas [1]. However, these land use and land cover changes (LUCC) will also have an impact on the future development of natural ecosystems on Tenerife. The formerly cultivated land in peripheral regions can generally be seen as potential area for natural reforestation and renaturation. It provides space where adjacent ecosystems can spread and hence a natural regeneration of the formerly cleared and agriculturally used land can come into effect.

To address and valuate the spatial increase of ecologically valuable areas, it is proposed to analyse the agricultural land use changes and to locate the main areas of agricultural decrease on Tenerife by GIS- and remote sensing based methods.

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Earth Resources and Environmental Remote Sensing/GIS Applications II,
edited by Ulrich Michel, Daniel L. Civco, Proc. of SPIE Vol. 8181, 81811I · © 2011 SPIE
CCC code: 0277-786X/11/$18 · doi: 10.1117/12.897583

After detecting those potential hot spots of natural regeneration, a resettlement analysis can be done. This will provide information about how the non-active agricultural land has been recolonised by the adjacent sensitive ecosystems.

2. THE STUDY AREA AND ITS AGRICULTURAL SITUATION

The study area is located about 350 km far from the western coast of Morocco. Tenerife is the largest and highest (2052 km^2, 3718 m at Pico del Teide) island in the Canary Archipelago (27° - 29° N, 13° - 18° W).
Due to the different mountain ranges in conjunction with the exposure to the humid northeast trade-winds, the research area furthermore shows an enormous spatial variation in precipitation with a subtropical-arid climate in the south (mean annual precipitation of approximately 100 mm) and a more humid northern part with a mean annual precipitation of 300 - 600 mm (to over 900 mm in the highest northern and northeastern parts of the Anaga massif) [3, 4].
Today almost 1/4 of the total area of Tenerife are agriculturally affected [2]. Both parts of the island (especially the South) present developed agriculture, that drastically transformed the landscape of Tenerife, mainly by building of large terraces to get flat agricultural surfaces. The agricultural areas can be divided into two types: A dynamic and more developed one with the aim of exportation (plantations) and a more traditional second type for local consumption and the domestic market. The main crops grown for export are bananas and tomatoes (mainly cultivated in greenhouses up to 300 m above sea level). Agriculture for domestic market consists mainly of potatoes, wine grapes and fruit orchards. These crops are primarily localised in a region between 300 -800 m above sea level [5].

3. RESEARCH METHODOLOGY

The study is based on three main working steps: (1) The object-based LULC classification of recent satellite imagery to get information about the current agricultural land use distribution, (2) The texture-oriented detection of the total ever utilised agricultural areas, implying fallow land with a higher level of natural succession and (3) The GIS-based comparison of working step 1 and 2 to define the total non-active agricultural land on Tenerife. Within this zone hot spots of agricultural decrease will be detected. The different working steps will be explained in detail below.

3.1 Object-based LULC classification for detecting recent agricultural land use

In order to get information about the LULC patterns and especially the agricultural dynamics on Tenerife, an object-based classification procedure for recent RapidEye data (recording date April 2010, spatial resolution: 5 m) was developed (Software: eCognition Developer 8.6). Main advantage of this technique is the possibility to deal with image objects or segments and not pixel. These objects consist of neighbouring pixels that have been grouped together by image segmentation. During this segmentation process homogenous image objects are extracted from the image based on the spectral similarity of neighbouring pixels, contrast with neighbouring objects and the shape characteristics of the resulting objects. In this regard, the spectral information of multiple bands and multiple co-registered images of different resolutions as well as ancillary geodata like a Digital Elevation Model (DEM) can be included into the segmentation process [6]. For the later classification process, the object characteristics such as mean value, standard deviation, ratio (OSAVI, NDVI), etc of the spectral bands can be calculated and used for classification. Besides this, there are numerous shape and texture features of the objects available which can be used to further differentiate land cover classes with similar spectral information [7]. The object based approach thus offers a high potential for the identification of agricultural land use in medium resolution satellite imagery, as agricultural parcels are besides its spectral characteristics also detectable on the basis of geometrical attributes (e.g. rectangular fit etc.).
The object-based segmentation and classification procedure was developed with a main focus on the exact differentiation of different forms of agriculture, namely cropland, greenhouses and short-term fallow land (Fig. 3). To achieve this aim, additional geodata like a Digital Elevation Model (DEM) with a spatial resolution of 10 m, digital soil and geological maps etc. have been integrated into the segmentation and classification algorithm. The results of the LULC classification are presented exemplarily in Figure 1, which shows the region around San Juan in the south western part of Tenerife, an area with intensive agriculture, mainly in form of plantations.

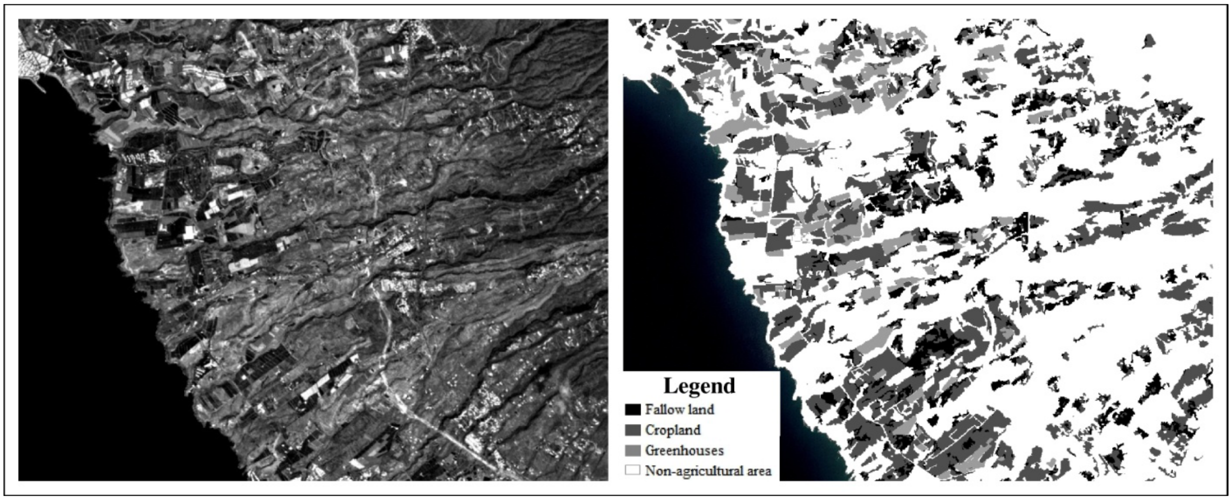

Figure 1: Example of the RapidEye imagery (NIR) and the results of the object-based classification process.

An accuracy assessment with 500 test points (selection method: stratified random) was carried out to statistically evaluate the quality of the object-based classification of the RapidEye data. The results are shown in Table 1.

Table 1: Results of the accuracy assessment for the detection of recent agricultural areas in the study area.

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Clouds	104	100	100	96,15%	100%	1,00
Cropland	85	100	83	97,65%	83,00%	0,80
Greenhouses	91	100	90	98,90%	90,00%	0,88
Fallow land	99	100	90	90,91%	90,00%	0.88
Non-agricultural area	121	100	99	81,82%	99,00%	0,99
Total	500	500	462	92,40%		0,95

3.2 Object-based detection of the total ever utilised agricultural land

A general problem concerning the investigation of agricultural land use dynamics with remote sensing methods is the detection of areas which have been agriculturally used in the past and now lie fallow for several years. These long-term fallow areas are hardly identifiable in the used medium resolution satellite imagery. Depending on how long they have been left fallow, ecological succession has begun or has already reached an advanced stadium (middle or advanced secondary succession with an increase in biomass and a high growth rate). At this time the only solution is to assign such areas to other land cover classes.

Previous field trips on Tenerife showed that especially in mountainous areas, crops are solely planted in terraces. This leads to the assumption that long-term fallow areas can mainly be detected together with old agricultural terraces and its specific linear texture. Besides this, cultivated areas also present linear structures, such as plough furrows and field boundaries.

To get closer information about the total ever utilised agricultural area on Tenerife, also containing older agricultural fallow land or agricultural set-aside with a higher level of natural succession, a second algorithm for the texture-based detection and area-wide extraction of linear agricultural structures in current orthophoto images (recording date 2009, spatial resolution: 40 cm) of Tenerife has been developed. To prevent false classifications of non-agricultural linear structures in the imagery, additional geodata about the road network from Tenerife, the distribution of the urban areas and a DEM of the study area have been integrated into the procedure. The object based algorithm is a multi-step-process consisting of five different operations, exemplarily shown in Figure 2.

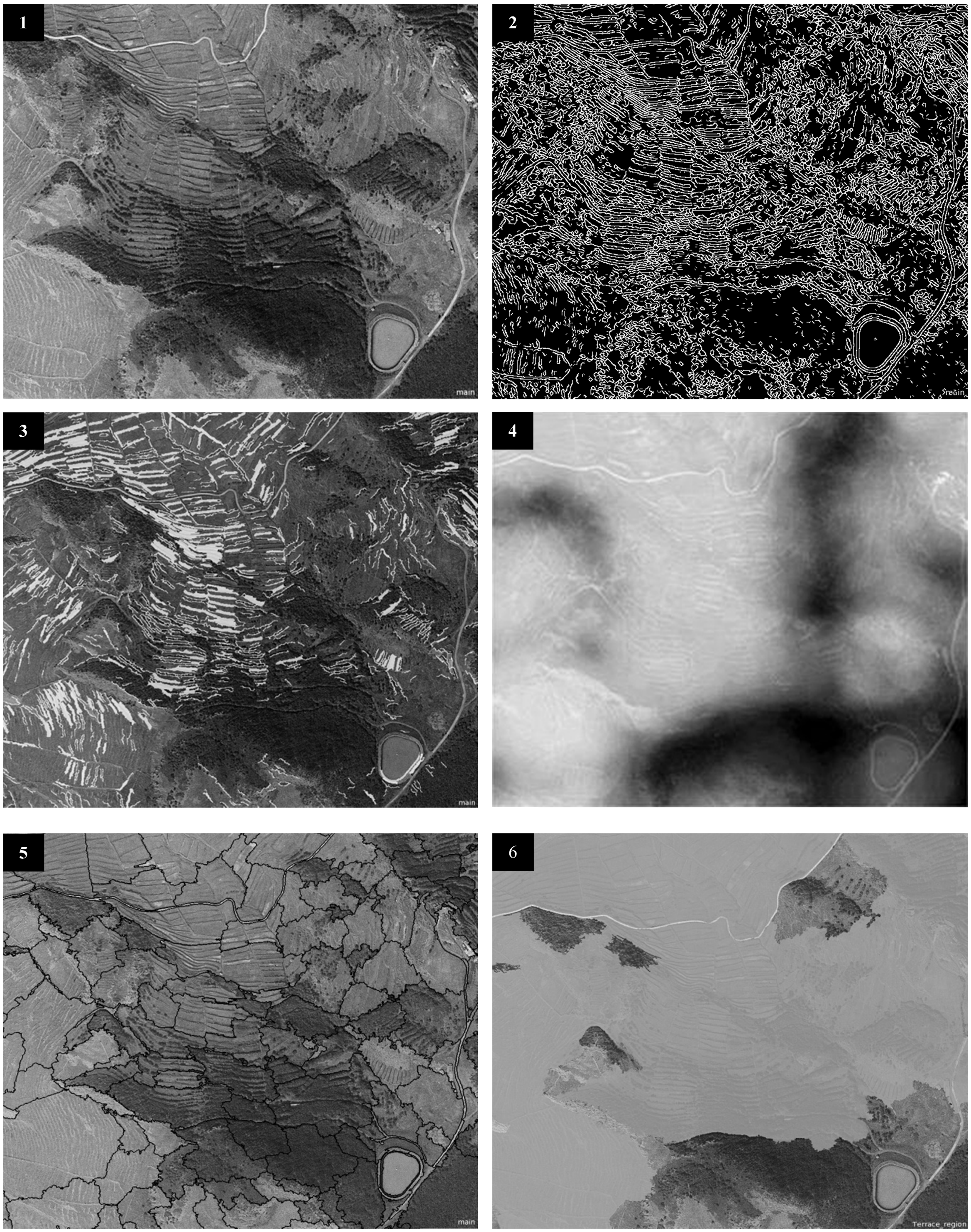

Figure 2: Processing steps of the object-based detection method for agricultural structures in current orthophoto images.

(1)(2) The information of the orthophoto has to be enhanced by the calculation of an edge detection filter. Such filters are generally designed to highlight linear features, such as roads or field boundaries. The Canny edge detector or Canny filter used within this method [8] is based on computing the edge strength and direction for each pixel in the smoothed grey image by differentiating the image in two orthogonal directions and calculating the gradient magnitude as the root sum of squares of the derivates. Local maxima of the gradient magnitude that are above some threshold are then identified as edges. Main advantage of this filter technique is, that the probability of multiply detecting an edge, the probability of failing to detect an edge as well as the distance of the reported edge from the true edge is minimised [8,9]. **(3)** Afterwards the image will be segmented on the basis of the canny filter. The subsequent classification aims at the identification of straight, long and thin segments with a small DEM-standard deviation value. This ensures that, in mountainous areas, only slope-parallel segments will be identified as agricultural structures. As an additional rule, segments have to be left unrecorded, if they are located within urban areas or streets. **(4)** The linear information of agricultural structures has now to be transformed into area-wide information by the calculation of a line density raster (density analysis). Within this method the density or concentration of lines in a given neighbourhood is calculated (in units of length per unit of area) for every output cell of the raster. **(5)** Finally a new segmentation based on the grey values of the orthophoto with a much higher scale of the segments has to be done**. (6)** Based on this segmentation, agricultural regions can be classified by defining a specific line density threshold.
An accuracy assessment with 1000 test points (selection method: stratified random) was carried out to statistically evaluate the quality of the detection method described above. The results are shown in Table 2.

Table 2: Results of the accuracy assessment for the detection of agriculturally affected areas in the study area.

Class name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**	**Kappa**
Agriculturally affected area	386	432	365	94,56%	84,49%	0,74
Non-agricultural area	614	568	547	89,08%	96,30%	0,90
Totals	1000	1000	912	91,12%		0,82

4. RESULTS

The object-based classification of the RapidEye data 2010 showed that approx. 22.100 ha in total are recently under cultivation, whereof 3.280 ha are cultivated by use of greenhouses. Nearly 11.700 ha in total have been detected as fallow land. They include on the one hand areas which can be easily defined as short-term fallow land, identifiable through missing vegetation (almost no ecological succession) and strongly rectangular field boundaries. On the other hand areas with little vegetation, recognisable by a slightly higher NDVI value then the short-term fallow areas, are also classified as fallow land. These can consist of fallow land with arising ecological succession or arable land with arising field crops. This differentiation is, only on the basis of medium spatial and spectral resolution satellite imagery, difficult to perform.
However, it must be said, that the RapidEye imagery also included cloudy areas (Fig. 3), where current cropland could not be detected. The evaluation of the orthophotos showed, that within this cloudy area additionally 2700 ha have been defined as agriculturally affected land. Thus, the absolute values shown above, can be extended by up to 12,2 %.
The object-based detection of the total ever utilised agricultural land indicated, that 61.979 ha (without land inside cloudy areas) of Tenerife can be characterised as areas, which are currently cultivated or have been cultivated in the past (agriculturally affected). The latter partly present very advanced stages of ecological succession and therefore can be very old (approximately more than 50 years). Due to still visible linear structures, caused by the building of dry walls (terraces), these areas can nevertheless be detected as non-active agricultural land or agricultural set aside. Overall, it can be pointed out that only 1/5 of the total ever used agricultural areas are currently under cultivation.
The results have now to be examined with regard to the detection of spatial concentrations or hot spots of agricultural decrease. Figure 3 shows the relative decrease of the cultivated area in % (decrease from total ever used agricultural area to currently agriculturally used area with short-term fallow land) on municipal level. Here again, the influence of clouds, also shown in this figure, has to be considered when directly comparing the municipalities among each other.

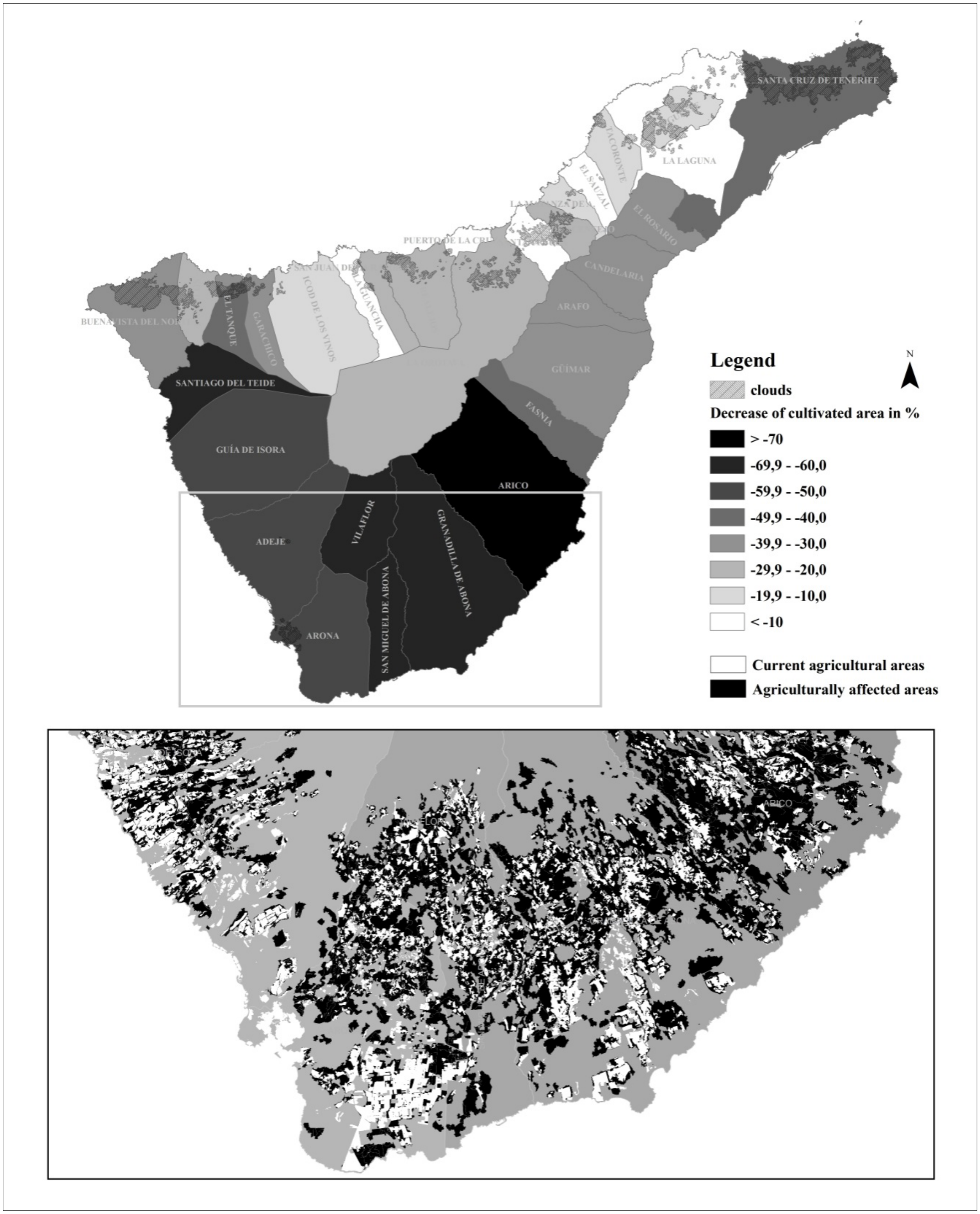

Figure 3: Relative decrease of the cultivated area in % on municipal level, and visualisation of current agriculture and agriculturally affected areas in the southern part of Tenerife.

It is apparent, that there is a gap in agricultural decrease between the northern and southern part of the study area. Especially southern municipalities, such as Arico (decrease of 75,9 %) and Granadilla de Abona (decrease of 66 %) have the highest agricultural decrease, whereas agriculture in municipalities like La Laguna (decrease of 9,7%) and El Sauzal (decrease of 9,2%) in the north changed only little. Further studies should now be carried out to investigate the reasons (such as depopulation or climatic changes etc.) for this development.
The detailed visualisation of current agriculture (RapidEye classification) on the one hand and agriculturally affected areas (Orthophoto classification) on the other hand (also given in Fig. 3) further shows, that an altitudinal concentration of agricultural decrease is not directly recognisable.

5. CONCLUSION AND OUTLOOK

The described approach for a comprehensive analysis of non-active agricultural land or agricultural fallow land by using objects-based classification and detection methods proved to be very effective. Additional studies should now be done to further analyse the hot spots of agricultural decrease on a very local level. Afterwards, it should be investigated, how these areas have been recolonised by adjacent sensitive ecosystems like laurel forest (Laurisilva) or pinewood (Pinar) [10] and what are the local conditions and parameters which have to be complied for a positive regeneration. This could for example be the type and intensity of the former land use or the characteristics of the neighbouring ecosystems, e.g. the kind of seed dispersal, growth rates etc.

ACKNOWLEDGMENTS

We thank the DLR for the allocation of data from the RapidEye Science Archive.

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