A CASE STUDY FOR UPDATING LAND PARCEL IDENTIFICATION SYSTEMS (IACS) BY MEANS OF REMOTE SENSING

M. Oesterle [a], M. Hahn [b]

[a] State Authority of Land Consolidation and Land Development B-W, 70803 Kornwestheim, Germany - doesterle@t-online.de
[b] Department of Geomatics, Computer Science and Mathematics, Stuttgart University of Applied Sciences, Germany - michael.hahn@hft-stuttgart.de

KEY WORDS: Remote Sensing, Agriculture, Land Cover, Change Detection, GIS, High resolution

ABSTRACT:

The European Union (EU) grants financial aid to farmers, growing a certain kind of crops. In order to administrate and to control the farmers' declarations, the EU decided to establish an Integrated Administration and Control System (IACS) in 1992. Over the years it was found, that the declared areas often do not represent the reality. As a result, the process of declaration should be improved by the establishment of a Land Parcel Identification System, preferably based on orthophotos. This identification system has to be developed and established before 1.1.2005 and has to be updated at least every five years. In this paper an updating process based on image classification and change detection is investigated. For this purpose the usefulness of the most common commercial high-resolution satellite systems as well as newly developed airborne camera systems is discussed. In order to get reliable information about agricultural parcels areas, the images have to be rectified. Problems in image rectification are outlined and a classification case study using the eCognition software shows chances and limits for land parcel update.

KURZFASSUNG:

Die Europäische Union (EU) gewährt Landwirten, die bestimmte Nutzungsarten anbauen finanzielle Unterstützung. Zur Verwaltung und Kontrolle der Anträge von Landwirten wurde aufgrund einer Entscheidung der EU im Jahre 1992 ein Integriertes Verwaltungs- und Kontrollsystem (InVeKoS) eingerichtet. Im Laufe der Jahre wurde festgestellt, dass die von den Landwirten beantragten Flächen oftmals nicht mit den Gegebenheiten in der Örtlichkeit übereinstimmen. Als Folge hieraus soll ein Identifizierungssystem für landwirtschaftliche Parzellen, vorzugsweise auf der Basis von Orthophotos aufgebaut werden. Dieses Identifizierungssystem soll bis zum 1.1.2005 im Einsatz sein und mindestens alle fünf Jahre aktualisiert werden. In diesem Zusammenhang wird das Potential hochauflösender flugzeug- und satellitengetragener Aufnahmesysteme diskutiert, wobei vor allem auch Probleme der Bildentzerrung besprochen werden. Die Möglichkeiten zur Aktualisierung der Parzellenkartierung innerhalb des Identifizierungssystems mittels Klassifizierung werden in einer Fallstudie untersucht.

1. INTRODUCTION

The European Union grants financial aid to producers of certain kind of crop (Eur-Lex, 1999). In order to get this assistance, the farmers have to declare their parcels area. These declarations have to be administrated and controlled. For these purposes an Integrated Administration and Control System (IACS) was established in 1992 in a non-graphical version.

The requirements on the IACS were expanded to graphical applications by regulation amendments. Nowadays the system shall comprise five elements (EUR-Lex, 1992):

1. 'a computerized database'
2. **'an identification system for agricultural parcels'**
3. 'a system for the identification and registration of animals'
4. 'aid applications'
5. 'an integrated control system'

The highlighted issue is the topic of this research.

1.1 Land Parcel Identification System (LPIS)

After a couple of years of experience with IACS it was found, that the declared areas do often not correctly represent the real situation. This might either be deception or, more likely, caused by a lack of knowledge of the farmers or the fact that farmers do not seriously enough care about the real situation. In order to minimize these irregularities, a system supporting a farmer in identifying his parcels by visual inspection should be developed. This system could be based on a GIS, preferably using orthophotos.

The "references" of the Land Parcel Identification System varies in the EU member states. A reference in this context is the unit a farmer declares. Generally there are three types of possible references: The cadastral plot, the agricultural parcel or the block. Common to all the three types of references is that

1. The LPIS has to be established, and
2. it has to be maintained / updated.

Figure 1. Cadastral plot (2); agricultural parcel (14); block (245)

If, for example, cadastral plots are used as references, it is most likely, that farmers got the information from surveying and mapping authorities. Subsidies, however, will be paid on the basis of real field patterns only (indicated by white outlines in Figure 2). This will cause a problem with the controlling instance, if the declared cadastral area is too large. By providing

maps as shown in Figure 2 to the farmers, the risk of declaring wrong areas can be reduced.

Figure 2. Problematic area, the black outlines represents cadastral plots, the white outline the real land use situation.

In several EU member countries, the LPIS is implemented in a GIS environment using the digitized boundaries of the references as one source and orthophotos as a second one. Farmers either will receive maps printed by the LPIS or will get Internet access to the system. Therefore proper information is made available to investigate the cultivated areas. The Land Parcel Identification System in each EU member country has to be in production by January 1, 2005.

1.2 Net Area Determination

Farmers get financial aid for so-called Net Areas. The Net Area is defined as the area, which can be used as arable or forage land. Trees, buildings, wasteland etc. inside a reference area have to be subtracted.
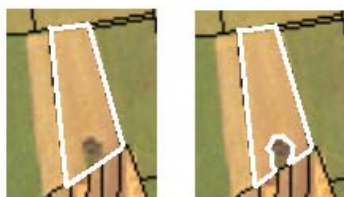

Figure 3. Net Areas

The image on the left side with the white outline in Figure 3 shows the cadastral parcel, the image on the right side the parcels Net Area. The information about the Net Area is important to a farmer for his declarations. Therefore, this area has to be determined and updated.

2. REVIEWING IMAGE SYSTEMS FOR LPIS

A great variety of imaging systems, starting from conventional aerial cameras to digital airborne sensors and satellite sensor systems are available nowadays. For using the imagery in an LPIS the ground coverage of imaging systems has to be considered, not at least because of economical reasons.

2.1 Requirements on Orthophotos

The Joint Research Center, a 'Directorate General of the European Commission' (JRC, 2003) defined technical requirements and recommendations for the accuracy, geometry, radiometry and temporal resolution for orthophotos, to be implemented in the LPIS (Léo, O., Lemoine, G., 2001).

- Absolute one-dimensional RMSE $\leq$ 2.5m
  (refers to EC regulation 1593/00 (EUR-Lex 2000)*:
  The orthophoto accuracy should guarantee at least an*

*accuracy, equivalent to cartography at scale
1: 10,000)*
- Pixel size smaller than 1m
- Panchromatic images (minimum requirement)
- Must not be older than five years

Panchromatic images are of course not a good choice for image classification purposes; therefore we will concentrate on color/multispectral images in this study.

2.2 Conventional Aerial Photography

The JRC also defined technical requirements and recommendations for aerial images to be implemented in an LPIS:

- Recommended image scale is 1:40,000
- The images should be scanned with a pixel size of 20 μm or better.
  (Léo, O., Lemoine, G., 2001)

This recommended image scale yields a ground coverage of 9,2 by 9,2 km². The corresponding flying heights for wide angle and normal angel camera are listed in Table 1.

Camera Type	Focal length [mm]	Flying height [m]
Wide Angle	153	6,120
Normal Angle	305	12,200

Table 1. Flying heights for standard cameras and image scale 1:40,000

2.3 Digital Imaging Sensor Systems

The advantage of these systems, compared to conventional aerial photography, is the option to record simultaneously different spectral bands and to deliver the data directly in a digital format. The required 1-meter pixel resolution for images implemented in a LPIS is directly linked to the aircraft's flying height and the ground coverage follows immediately by taking the number of sensor elements into account.

Sensor System	FOV [deg.]	No. of pixels per scan line	No. of spectral bands
ATM (Wide Angle) (SenSyTech Inc., 2002)	85.92	640	11
HyMap / Intergated Spectronics Pty. Ltd. (Kramer, 2002)	60	512	100 - 200.
CASI 2 (ITRES Research Ltd., 2002)	37.8	512	288
ADS 40 (Leica Geosystems, 2002)	64	12,000	5
HRSC AX (DLR, 2002)	29	12,172	5
DMC / (Z/I Imaging, 2002)	44 x 74	8,000 x 13,000 frame	5

Table 2. Airborne sensor systems

Table 2 shows a selection of commercially used airborne sensor systems. Obviously, the systems either cover a large area on the ground or they record a large number of spectral bands. The ground coverage is an important economical factor, whereas the

number of spectral bands is of major importance in image classification.

2.4 Satellite sensor systems

The commercial high resolution satellites systems are the third group of sensor systems which might be useful for LPIS. The most important ones are characterized in the following table:

Satellite	Ground swath [km]	Pan res. [m]	MS res. [m]	Rev. time [days]
IKONOS (Space Imaging, 2002)	11	1	4	1 - 3
QuickBird (DigitalGlobe, 2003)	16.5	0.61	2.44	1 - 3.5
SPOT 5 (Spotimage - b)	60	2.5	10	1 - 4
EROS A1 (ImageSat, 2003)	13.5	1.8	-----	2 - 3

Table 3. Satellite sensor systems

IKONOS and QuickBird would fulfill the requirement of a 1-meter resolution (pan sharpened) and therefore have been taken into consideration for LPIS. SPOT 5 with a resolution of 2.5 meter in "Supermode" (Spotimage-a, 2003) does not fulfill the requirements, but would have the advantage of a wide ground coverage. Also not qualified is the 1.8 m resolution imagery of EROS A1.

3. IMAGE RECTIFICATION

As already mentioned, images used in LPIS should be ortho-rectified images. The two main factors influencing the accuracy of the rectified images, the

- Height information and the
- Leaning effect

will be discussed in the following. The influence of image orientation is almost similar for all image recording systems, thus a discussion of the orientation impact is omitted.

3.1 Height Information

The influence of height on the accuracy in orthophotos is basic knowledge covered in all textbooks of Photogrammetry. Based on the assumption that all, airborne or spaceborne, images are differentially rectified using digital elevation models the impact of a height error on a location in a orthoimage can be estimated by

$$\Delta R = \frac{\Delta Z}{c/\rho' + \tan \alpha * \cos \beta} \quad (1) \text{ (Kraus 1989)}$$

where ΔR = location error
ΔZ = height error
c = focal length
ρ' = distance from the image center to location of the considered object location
α = terrain slope
β = angle between the straight line beginning in the image center to the considered object location

The following table (Table 4) shows position errors, calculated based on:

- 10-meter height error as an example
- $\beta = 90°$
- image corners / edges considered
- a ground slope of $\alpha = 30°$ was chosen. This is the maximum slope agricultural machines can work on.

System	α [degree]	Position error [m]
Wide Angle Camera	0	9,15
Wide Angle Camera	- 30	19,40
Normal Angle Camera	0	4,59
Normal Angle Camera	- 30	6,25
IKONOS nadir	0	0,08
IKONOS nadir	- 30	0,08
IKONOS 30° pointing	0	5,14
IKONOS 30° pointing	- 30	7,31
SPOT nadir	0	0,37
SPOT nadir	- 30	0,37
SPOT 27° pointing	0	5,13
SPOT 27° pointing	- 30	7,30
HRSC - AX	0	2,62
HRSC - AX	- 30	3,08
ADS 40	0	6,24
ADS 40	- 30	9,75

Table 4. Position errors, caused by height errors
(for more details please refer to Oesterle 2003)

Obviously the position error gets smaller if a system with a large focal length is used. Therefore it can be concluded, that the use of systems with a good relation of ground coverage to flying height will benefit the production of accurate orthophotos. Highly accurate height data almost eliminate this type of error.

3.2 Leaning Effect

This effect is comparable to the position error, but calculated for flat terrain (alpha =0). The leaning effect is caused by depicting a 3D object on the 2D image. It can be observed at objects, protruding the earth's surface such as buildings and forest borders. The leaning effect can be avoided by producing True Orthophotos. However, this process requires measurements of the 3D objects. Furthermore it requires the use of overlapping image areas, in order to get information about hidden regions.

The production of True Orthophotos covering the usually quite big area of a state is less recommended, as the measurement of 3D object information is time consuming and therefore expensive. Airborne Laserscanning may help to reduce the costs of providing the data for True Orthophoto generation.
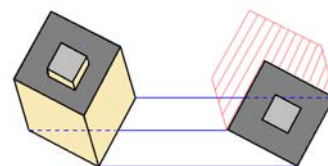

Figure 3. Building shown with leaning effect, compared to "True" building representation

The left side building shows a leaning effect whereas the right side building is straightened up and the hidden area is shown as hatched area.

Considering the task to obtain information about the area of usable agricultural land, the leaning effect is a serious problem, especially at forest borders.
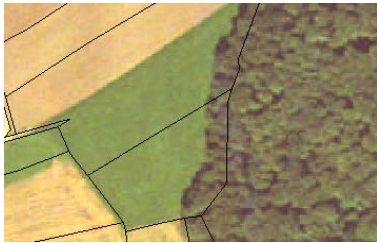

Figure 4. Leaning effect in an orthophoto

Figure 4 shows an orthophoto and the superimposed boundary of cadastral parcels. Without any further information such as orthophoto center position, there is no way to decide whether the image shows the real forest border or a leaning effect. Thus, this image might not be very helpful to determine Net Areas.

The conclusions related to the leaning effect are the same as the position error caused by a height error. It should be noted that due the nature of line scanner systems, the leaning effect in flight direction is totally avoided.

4. CLASSIFICATION

In the context of Land Parcel Identification and Net Area determination, the land cover types to be taken into account in this study is focused on:

- Arable Land
- Forage Land
- Forest
- Water bodies
- Infrastructure

4.1 Classification with eCognition

For the study of land cover classification, the software package eCognition was used. eCognition is based on the idea to carry out supervised classification based on "image objects" using concepts of fuzzy logic. The program supports a wide range of raster formats and has the possibility to process images of different resolution (Definiens 2001).

4.2 Classification Case Study

In order to proof, whether classification could be used for updating Land Parcel Identification Systems, color images taken in September 2002 had been used for image classification. Training samples for image classification were selected by the operator. However, the operator based identification of wasteland has been nearly impossible.
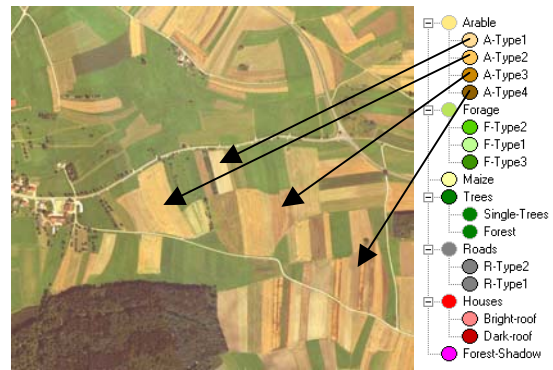

Figure 5. Image used for classification with eCognition and class hierarchy (Oesterle 2003; Image by courtesy of the State Authority for Land Consolidation and Land Development Baden-Württemberg, Germany)

Figure 5 shows clearly that arable as well as forage land varies significantly in color and brightness. For this reason several subclasses for each land cover, as well as training samples have been defined. To introduce scale into segmentation, four levels from fine to coarse had been established.

- Level 1 (fine):   Single trees, infrastructure
- Level 2 (medium): Infrastructure (houses)
- Level 3 (medium): Arable, forage land
- Level 4 (coarse):   Forest areas

A first classification step based on object features only was not satisfactory, as house roofs could not be detected. In a second step, classification has been improved by applying class related features. The classification results obtained on different levels have been merged afterwards.

Figure 6. Final classification result

The result was an 89% correct classification, found by comparing ground truth land cover acquired by field checks with the classification result. This result is a very good basis for updating the LPIS. Nevertheless, the remaining uncertainty requires checking the results by visual inspection.

To prove these findings a second image from the same image flight was processed. The experiments have shown that adoptions of to training, including the class hierarchy have become necessary to get the excellent classification results shown above also in the second test site. The reason for this is the quite large variety of color and brightness values of forage and arable land in the image. Furthermore, the color of some

types of arable land is very close to the color of roads or building roofs. Therefore, additional information such as a more spectral bands would be necessary in order to improve or stabilize the result (Oesterle 2003).

4.3 Updating the LPIS

The classification result is a good source to direct an operator in detecting changes in the LPIS data set.
The class outlines can either be exported to a GIS for interactive work or an intersection of the classification result with the available data might be provided to the operator. The latter one might be a used a more convenient solution, as an operator can superimpose the original image and the detected differences.
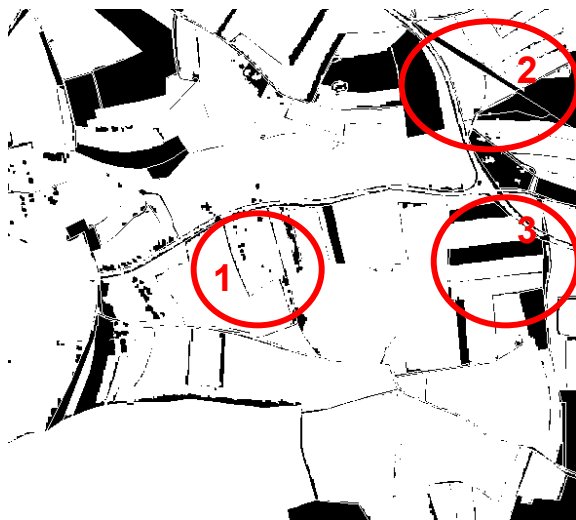

Figure 7: Intersection of LPIS data and classification result

The Intersection of LPIS data with the classification result is shown in Figure 7. The black areas show differences between the data sets to the operator. By visual checking it was found that

1. Trees had been rooted out or planted
2. A new non-concrete road had been built
3. The field pattern changed (agricultural parcels)

The decision how to deal with these changes is in the operators responsibility.

5. SUMMARY AND CONCLUSION

The paper investigated a variety of issues for updating a Land Parcel Identification system. A strategy is developed and recommendations have been drawn. These recommendations will be shortly summarized in the following.
Orthophotos are recommended to be implemented in the LPIS. These orthophotos can be produced, based on aerial images. The aerial image might be recorded by airborne or spaceborne systems. For classification color or better multispectral images have to be taken into account. For classification of land covers, the season of exposure is of importance. The images have been taken in seasons, where arable and forage land is distinguishable. To guarantee that this holds for all images used for updating LPIS is a certain problem with very high-resolution satellites and maybe also for airborne remote sensing. The problem could be minimized by taking images by systems with

a large swath like SPOT 5, however, the resolution of these satellite images is not sufficient for LPIS. In orthophoto production we have to deal with errors caused by leaning effects and height errors of the height models used for rectification. Using systems with a good relation of flying height and ground coverage can reduce these errors. In this regard high resolution satellite imagery has great benefits. Classification can help to update the LPIS, however a detailed methodology must be further worked out to guarantee a successful workflow.

It would be an advantage for classification, if the images are recorded within a short period. This guarantees a nearly same appearance (color, brightness) of land cover of the whole area. A problem is the season of exposure is that the land cover should be distinguishable. It is less recommended to take images in spring, when grassland as well as arable land is presented in green color all over.

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