LAND PARCEL IDENTIFICATION AS A PART OF THE INTERGRATED ADMINISTARTION AND CONTROL SYSTEM (IACS)

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ABSTRACT:

The European Union (EU) grants financial aid to farmers, producing a certain kind of useful crop. In order to administrate and to control the farmers' declarations, the EU Commission asked the member states to establish an Integrated Administration and Control System (IACS) in the year 1992. During the years of experience with the system it was found, that a high percentage of declared areas were incorrect, compared to the real situation. Therefore, the process of declaration has to be improved by the establishment of a Land Parcel Identification System, preferably based on Orthophotos. Additionally, these Orthophotos are the basis to carry out administrative checks. The images, necessary for Orthophoto production, can be either recorded by high-resolution digital airborne and spaceborne systems, by conventional aerial photography or already available Orthophotos could be used. One target of the system is, to detect the differences of real and declared agricultural area, in future based on Orthophotos. In this context, the problems of image rectification will be discussed. A case study generally shows the possibilities to simplify administrative checks as well as the determination of cultivated areas by means of image classification. Finally, an initial stage for a solution based on SPOT 5 multispectral data and panchromatic Orthophotos will be suggested.

KURZFASSUNG:

Die Europäische Union (EU) gewährt Landwirten, die bestimmte Kulturen anbauen finanzielle Unterstützung. Zur Verwaltung und Kontrolle der Förderanträge von Landwirten wurde von der EU Kommission im Jahre 1992 ein EU-weit geltendes 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 für die Landwirte ein Identifizierungssystem für landwirtschaftliche Parzellen, vorzugsweise auf der Basis von Orthophotos aufgebaut werden. Diese Orthophotos sollen auch der Verwaltungskontrolle dienen. Die notwendigen Luftbilder können entweder durch Satelliten und flugzeuggetragene Kameras erfasst werden, oder es wird auf vorhandene Orthophoto Ressourcen zurückgegriffen. Ein Ziel des Identifizierungssystems ist die Erkennung von Differenzen zwischen beantragter und tatsächlich vorhandener Förderfläche, zukünftig unterstützt durch den Einsatz von Orthophotos. In diesem Zusammenhang werden die Fehlerquellen der Orthophotoherstellung diskutiert. In einer Fallstudie werden grundsätzliche Möglichkeiten des Einsatzes von Klassifizierung auf der Basis von Luftbildern zur Vereinfachung der Verwaltungskontrolle erörtert. Abschließend wird ein möglicher Lösungsansatz, der auf SPOT 5 multispektralen Daten und panchromatischen Orthophotos basiert vorgestellt.

1. INTRODUCTION

The European Union grants financial aid to producers of certain kind of useful 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) had been established in a non-graphical version since the year 1992.
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'

1.1 Land Parcel Identification System (LPIS)

During the years of experience with the IACS it was found, that the declared areas often do not represent the real situation. These anomalies have to be minimized; therefore, a system has to be established, in order to enable a farmer to identify his parcels without any doubt left by visual inspection (LPIS). This system should be preferably based on Orthophotos.

Figure 1. Problematic area (Oesterle, 2003)

Figure 1 shows the problems in declaring areas:
The reference for declarations in the state of Baden-Württemberg, Germany was chosen to be cadastral parcels (shown as black outlines in Figure 1). A farmer usually knows the area of his cadastral parcel, however subsidies will be paid on basis of real situations only (shown as white outlines in Figure 1). This might cause a problem, if the declared (cadastral) area is too large. It is not easy to decide whether a farmer knew about the differences between cadastral and real area or not. If a farmer would be provided with images, as

shown in Figure 1, the risk of declaring incorrect areas can be definitely reduced. This system has to be in production until 1.1.2005.

1.2 Administrative Checks

Administrative checks are used to check the plausibility of declarations, such as land cover and declared area. This task can be optimized by means of image interpretation or digital image classification.

1.3 Net Area Determination

The agricultural area, a farmer gets financial aid for, is called the Net Area. In Baden-Württemberg it is defined as the area of a cadastral parcel, which can be used as arable or forage land. Trees, buildings, wasteland etc. inside a cadastral parcel have to be subtracted from the cadastral parcels area.

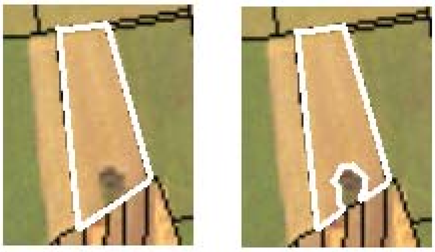

Figure 2. Net Areas (Oesterle, 2003)

The image on the left side (white outline see Figure 2) shows the cadastral parcel, the image on the right side the parcels Net Area.

1.4 Inference

Obviously there are three different basic tasks to solve; however, all of them are based on Orthophotos:

- Land Parcel Identification
- Administrative checks
- Net Area determination

The subsequent chapters will show, how these tasks could be solved, starting from image acquisition, continuing with image rectification and ending with classification.

2. IMAGE ACQUISITION

A great variety of imaging systems, like conventional aerial cameras, digital airborne sensors as well as spaceborne (satellite) sensor systems are available nowadays. Furthermore, providers such as the State Surveying Authority B-W offer rectified images, covering the state area of Baden-Württemberg. In case of discussing image acquisition, the ground coverage of imaging systems has to be considered, as this is an important economic factor.

2.1 Requirements on Orthophotos

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

- Absolute one-dimensional RMSE ≤ 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 ≤ 1m
- Panchromatic images (minimum requirement)
- Must not older than five years

2.2 Orthophotos

The State Surveying Authority of Baden-Württemberg offers panchromatic Orthophotos, produced from aerial photos, taken by a normal angle lens with an image scale of 1:18,000. The images are offered with a ground resolution of 25 cm as standard. The two dimensional accuracy is given as a rule to ± 3 meter. Each year a photo flight covers a fifth of the state area, therefore the complete state area is renewed every five years (State Surveying Authority). These images would fulfill the minimum requirements defined by the JRC. However, panchromatic images are not suited for digital image classification and therefore land cover classification would become difficult.

2.3 Conventional Aerial Photography

The JRC also defined technical requirements/recommendations on images to be implemented in the LPIS, taken by these systems:

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

Dependent on the recommended image scale, the ground coverage is calculated as 9,200 m², the corresponding flying heights 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 dependent on focal length and image scale 1:40,000

The flying height of 12,200 meter, calculated for a normal angle camera is too high for aircrafts, usually used for photo flights such as Piper or Cessna. The flying height of these aircrafts is in between 4,000 and 8,000 meter. Higher flights require a Lear Jet (Oesterle, 2003).

2.4 Digital Imaging Sensor Systems

In the early 60th, the first digital systems were established and they are in practical use nowadays (Breuer, 1997). These days, new airborne imaging systems have been developed in order to compete with conventional aerial photography. The advantage of these systems is their possibility to record different spectral bands simultaneously and the fact that the images are already in digital format. This avoids a scanning process and the required 1-meter pixel resolution is in direct connection with the aircrafts flying height. The ground coverage of these systems is dependent on the sensors number of Charged Coupled Devices (CCD) only (Oesterle, 2003).

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 / Integrated 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

The systems, listed in Table 2 are in commercial use or in a final test phase. Obviously, these systems either cover a wide area on the ground or they record a large number of spectral bands. The ground coverage is an important factor of economy, whereas the number of spectral bands is an important factor in classification.

The limit of ground coverage for newly developed systems like ADS 40, HRSC and DMC is not the number of pixels, but the flying height.

Camera	Flying height [m]	Image scale
ADS 40	≈ 9,000	≈ 143,000
HRSC-AX	≈ 23,000	≈ 154,000
DMC	≈ 10,000	≈ 83,000

Table 3. Calculated flying height of an aircraft, if 1-meter ground resolution is required

The flying heights calculated for these systems are more or less theoretical values. To record data in a flying height of more than 9,000 meter a Lear Jet is required and flying heights as calculated for HRSC are far from the capabilities of any aircraft in commercial use. Therefore, the required 1-meter resolution would be fulfilled in any case.

2.5 Satellites

In the past years, commercial satellite images were characterized by coarse resolutions. A new age in remote sensing began in the year 1999 when IKONOS, the first commercial 1-meter resolution satellite was launched. Commercial satellites have the advantage, that they are available to everyone. The hiring of aircrafts for image flights becomes unnecessary. However, there is a certain disadvantage in ordering satellite imagery. All new age satellites are constructed to point their sensors to the region of the customer's interest. They do not cover the whole surface of the earth in nadir looking position. This makes it difficult to guarantee a certain time of exposure.

Satellite	Ground swath [km]	Pan res. [m]	MS res. [m]	Rev. time [days]
IKONOS (Space Imaging, 2002)	11	1	4	1 - 3
QuickBird (GigitalGlobe, 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 4. Satellites

IKONOS and QuickBird with their 1-meter resolution (panchromatic images) have to be taken into consideration for image acquisition. The 2.5-meter SPOT 5 resolution in "Supermode", two 5-meter resolution instruments, staggered by half the pixel size (Spotimage - a) is too coarse, but the satellites sensor has the advantage to cover a wide area on the ground. Considering the multispectral resolution, all systems do not fulfill the JRC requirements (1-meter ground resolution), however, pan sharpening would unite the resolution of panchromatic images and information of multispectral images.

2.6 Inference

It seems to be difficult to find an image acquisition system, taking images, suitable for Land Parcel Identification, Net Area determination and Classification as well. It is always the fact that a large swath width competes with spectral and spatial resolution. In this context, economy competes with accuracy.

3. IMAGE RECTIFICATION

As the images, implemented in the LPIS are recommended to be Orthophotos, image rectification becomes necessary. There are at least two factors, which have to be discussed, as they directly influence the accuracy of rectification.

- Height information
- Leaning effect

3.1 Height Information

Height models, describing the earth's surface are usually used in order to rectify airborne or spaceborne images. An error in these height models will cause a position error in the Orthophoto.

$$\Delta R = \frac{\Delta Z}{c/\rho' + \tan\alpha * \cos\beta} \qquad (1) \text{ (Kraus, 1986)}$$

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

In order to minimize this position error, it is required to get height information as accurate as possible.

As the aim is, to get data covering the state area of Baden-Württemberg it is advisable, from an economic point of view, to use already existing height models.
The Height Model of the State Surveying Authority Baden-Württemberg is calculated in a 50-meter raster with a given accuracy of ± 2-3 meters. The accuracy in steep wooded hills like the Black Forest is less and given to approximately ± 10-15 meters (State Surveying Authority). MONA is a height model covering most of Europe and parts of North Africa. The model is available in four grid sizes, whereas the smallest is a 75-meter grid. The accuracy is given as ± 3.5 meter in flat and ± 12.5 meter in mountainous terrain (GEOSYS, 2003)

The following Table shows position errors, calculated based on:

- 10-meter height error assumed
- $\beta = 90°$
- image corners / edges considered
- the ground slope of $\alpha = 30°$ was chosen; as it is the maximum slope, special 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 5. Position errors, caused by height errors (Oesterle, 2003)

It is obvious, that the position error is dependent on the relation of ground coverage and flying height. Therefore, a first conclusion will be, to use systems with a good relation of ground coverage and flying height in order to get accurate Orthophotos.
The availability of highly accurate height data would neglect this error factor. The State Surveying Authority of Baden-Württemberg already started to record Laser scanned data, covering the state area. A DTM as well as DSM is expected to be available in 2005/2006. First checks on measured height data compared to reference data showed maximum differences of up to 80 cm, the mean value of all height differences (nearly 50,000 measurements) is in the range of 25 cm (Schleyer, 2002). Height models, calculated based on these measurements are expected to be very accurate. This implies, that position errors caused by height errors are not a problem any more.

3.2 Leaning Effect

This is an effect, identical to the position error (see 3.1) calculated for flat terrain (alpha = 0). The leaning effect is caused by depicting a 3D reality on 2D film and 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 only, where all objects protruding the earth's surface will be straightened up. However, this process requires break line measurements of the mentioned objects, furthermore it requires image overlaps, in order to get information about hidden areas.
The production of True Orthophotos covering Baden-Württemberg is less recommended, as the measurement of break lines is a time consuming and therefore expensive task. However, if the new height model, based on Laser scanned height data (see 4.1) will be offered with morphological information such as break lines, this method of resolution should be again taken into consideration.

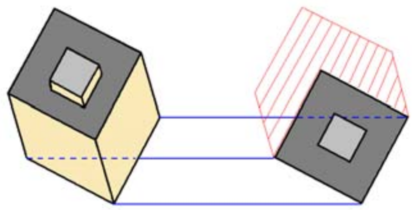

Figure 3. Building shown with leaning effect, compared to "True" building representation (Oesterle, 2003)

The left side building (Figure 3) shows a leaning effect, whereas the right side building is straightened up and the hidden part of the image is shown as hatched area.
Considering the task to obtain information about the area of agricultural usable land, the leaning effect is a serious problem, especially at forest borders.

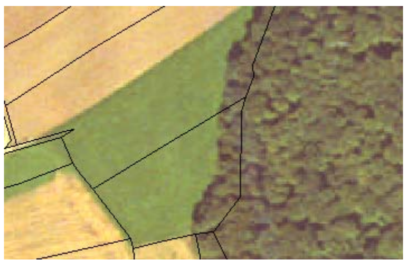

Figure 4. Leaning effect in an Orthophoto (Oesterle, 2003)

Figure 4 shows an Orthophoto, superimposed by outlines 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 situation or maybe a leaning effect. This image might not be very helpful to a farmer applying for subsidies.
The leaning effect principally follows the same rules like a position error caused by a height error, therefore the same conclusion are valid to reduce the problem: "Use systems with a good relation of ground coverage and flying height". By use of line scanner (push broom) systems, the leaning effect nearly can be avoided in flight direction, as the ground coverage of one CCD is too small to produce leaning effects.

3.3 Inference

In image rectification, errors are always left. The importance is to know about these errors, especially the leaning effect, as this is an error, which cannot be avoided without a big effort. Using imaging systems with a good relation of ground coverage and flying height can minimize the errors.

4. CLASSIFICATION

The land covers, which have to be classified in the context of Land Parcel Identification, Net Area determination and administrative checks, are reduced in a first step to:

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

4.1 Classification with eCognition

For classification, the program eCognition was used. The program is based on the idea of supervised classification of image objects with fuzzy logic. eCognition supports a wide range of raster formats and has the possibility to process images of different resolution (Definiens, 2001).

4.1.1 Object Based Approach: This approach implies, that objects/segments, representing real world objects, has to be established in a first step. The eCognition segmentation algorithm is called "Multiresolution Segmentation", which is a bottom-up region merging technique, starting with one pixel object. A homogeneity criterion designates whether pixels or clusters should be merged. This criterion describes the heterogeneity of a segment in terms of color, smoothness and compactness. A scale parameter, defining the maximum allowed heterogeneity, influences the size of the segments (Definiens, 2001).
As the objects should represent real world objects, it might become necessary to define segments of different sizes. A forest area segment might be calculated with a large scale factor, a tree inside a field requires segmentation with a small scale factor. Therefore, eCognition allows establishing a hierarchical network of image objects. A classification can be processed on each level and the results can be merged afterwards.

4.1.2 Fuzzy Logic: Lotfi Zadeh introduced the concept of Fuzzy Logic in 1965. It is based membership functions, which are one-dimensional single conditions, defining the grade of membership of objects to a class in between true and false.
Fuzzy systems consists of three steps:

1. Fuzzification: Membership functions describes the situation
2. Rule evaluation: Fuzzy Rules (If-Then statements) will be applied to the region of interest.
3. Defuzzification: The objects are either assigned to a class or not.

4.1.3 eCognition Features: With eCognition, membership functions can be defined on two feature types. Object features describe the image objects properties like mean value in each spectral band, standard deviations, shapes, texture etc., whereas class-related features refer to the classification of other objects, situated in any location in the image object hierarchy. They are based on classification results.

4.2 Classification Case Study

In order to proof, whether classification could be applied for Net Area determination as well as for administrative checks, a classification, based on a color image taken in September had been processed. Training samples were selected, based on image interpretation, as the information of land cover in Baden-Württemberg, based on field visits is usually not available to the operator. Therefore, this was a simulation of real situations. However, the identification of wasteland is nearly impossible, for example compared to set aside areas and therefore a classification, in lack of training samples, too.
As already seen, the leaning effect, especially at forest borders, might cause serious identification problems. However, the same problem occurs with shadows caused by forest borders. They are shown as dark outlines and untrained users might identify a shadow as forest area. Therefore, it would be an advantage, if it becomes possible to classify forest shadows, too.

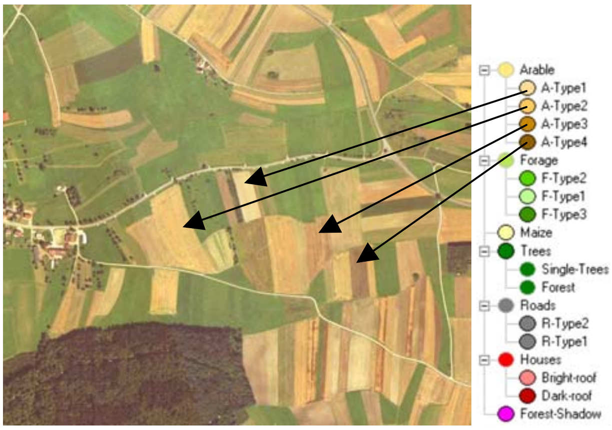

Figure 5. Image to be classified with eCognition class hierarchy (Oesterle, 2003; Image by courtesy of State Authority for Land Consolidation and Land Development Baden-Württemberg, Germany)

It is obvious, that arable as well as forage land has different properties such as color and brightness. For this reason several subclasses for each land cover, as well as training samples had been defined. In order to represent real world objects by image objects (segments), four levels from fine to coarse segmentation 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 had been carried out. This result was not satisfactory, as house roof could not be detected. In a second step, the classification had been improved by applying class related features and the classifications on different levels had been merged afterwards.

Figure 6. Final classification result (Oesterle, 2003)

The result was an 89% correct classification. This was found by comparison of real (known) land cover, acquired by field checks, with the classification result.
The class outlines can now be exported and intersected with available vector data of cadastral parcels in a GIS for Net Area determination. Therefore, as a first preliminary conclusion, it could be assumed that Net Area determination as well as land cover checks can be solved in parts by classification. However, no classification can solve the problem to 100%, there are always errors left.
Until now, it was one proof, based on one example. It is not yet checked, if the workflow will work on other image examples, too. In order to test the classification workflows stability, another part of image mosaic had been processed (identical image flight). It was shown, that the workflow including class hierarchy could not be transferred without any adaptations. The reason for this is the quite large variety of colors and brightness of forage and arable land. Furthermore, the color of some types of arable land is very similar to roads or building roofs. Therefore, additional information such as additional training samples, spectral bands or multitemporal data would be necessary in order to improve or stabilize the result (Oesterle, 2003).

5. SUMMARY

In order to recommend a workflow, how to best solve the tasks, all requirements and preliminary conclusions will be presented once again:
Orthophotos are recommended to be implemented in the LPIS and the system has to be in production in the year 2005. The Orthophotos can either be bought from the State Surveying Authority Baden-Würtemberg (panchromatic) or image flights (airborne and spaceborne) can be carried out. Panchromatic images are not suited for classification; therefore, color/multispectral images are required. For land cover classification, the time of exposure is of importance. The images have to be taken in seasons, when arable and forage land is distinguishable. The time of exposure of all images should be nearly identical in order to guarantee nearly the same appearance of arable land in the image. This is a certain problem with very high-resolution satellites and aircraft remote sensing, recording narrow strips on the ground. Taking images by systems with a large swath like SPOT 5 could minimize the problem; however, the spatial resolution of this satellite is not sufficient.
In Orthophoto production we have to deal with position errors, caused by leaning effects, and height model errors. Using systems with a good relation of flying height and ground coverage can reduce these errors, therefore satellites might be well suited; however, we do not have any information about the geometrical accuracy of satellite Orthophotos.
Classification can help to solve net area determination as well as administrative checks, however errors in classification will always be left.

6. CONCLUSION

The period to establish the Land Parcel Identification System is very short, therefore, no further research, which guarantees a result, especially in accuracy check of Orthophotos, based on satellite images and classification is possible until the year 2004/2005. The panchromatic Orthophotos of the State Surveying Authority Baden-Württemberg fulfills all requirements of the JRC. For Land Parcel Identification as well as Net Area determination, the use of panchromatic data is not as perfect as color/multispectral data; however, the images are already available, therefore, it is recommended to use them in a first step.

Each time the images will be renewed (five year cycle as maximum), the process of Net Area determination as well as land cover determination starts from scratch. In order to speed up the process, further research on land cover classification should be done. As color/multispectral images are required for classification, the possible image sources have to be checked again. It would be an advantage for classification, if the images would be recorded in a short period. This guarantees a nearly same appearance (color) of identical land cover. Another problem is the season of taking the image, because 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.
Considering these facts, further research on SPOT 5 data is recommended. This satellite covers 60 km of the ground with one revolution. Therefore, the chance is very high to record one fifth of the state area in a "short" period. However, we know, that the resolution is not sufficient. In order to solve this problem, the tasks should be split in two parts:

- Land cover classification
- Net Area determination / Land Parcel Identification

As soon as the LPIS is established and Net Areas are determined, a reference data is available.
A land cover classification, based on new SPOT 5 images with a coarse resolution will represent the actual situation. By intersecting the reference data with the classification result, changes in land cover could be detected and the search for changes becomes unnecessary, this will definitely speed up the procedure.
The operator will check the "changes" by image interpretation whether there will be a faulty classification or the real situation changed. In case of changes, the new Net Areas can be digitized, based on the panchromatic images offered by the State Surveying Authority.
With this solution, digital image classification gives hints to changes only. However, it is assumed that this approach is much faster than checking the whole area for changes manually.
This is a theoretical solution until now. The success is not yet proven; therefore, a further investigation on classification with images, recorded by SPOT 5 becomes necessary.

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