

Chapter 15

CADASTRAL CHALLENGES FOR EARTH OBSERVATION

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15.1 Introduction

The International Federation of Surveyors (FIG) has recently stated that about 30 to 50 countries in the world have cadastral systems in operation. Another 50 countries are in the process of establishing one. The remainder of 90 countries do not have a land registry system and they do not have the funds to establish one.

Hernando de Soto has been a primary promoter of land registration systems. (de Soto 2000). His philosophy was adopted by the World Bank and by international donors in support of land registration because secure rights to land not only avoid conflicts, but they also permit to use land as a collateral in a widened capital market.

During the last 10 years US \$1.2 billions have been spent on the introduction and the renewal of land registration and cadastral systems. Most of the problem areas are institutional and political. These issues are not the topic of this chapter. But after legal and institutional issues have been solved, technological issues are important to be in a position to rapidly and cost-effectively implement cadastral registration systems. Purpose of this work is therefore to discuss the technical alternatives which have been brought about by the recent rapid advances of technology.

15.2 Definitions

A cadastre in general is a systematic collection of (spatial) data, which can be queried and maintained. A (land) cadastre in particular is a systematic collection of data on land on a land parcel basis. Such a cadastre consists of two parts: “the book”, which contains non-spatial data associated with the parcel and “the map” describing the parcel spatially.

15.3 History and Diverse Approaches

The “cadastral book” and the “cadastral map” has been introduced by Napoleon in the early 19th century in Europe as a “tax cadastre”. The recording of property rights was obligatory and the description of the property was assured by the map geometry with 1 m ground accuracy.

Starting from the tax cadastre an “ownership protection” cadastre has evolved by about 1900 rendering a service to land owners, in which parcel boundaries were monumented and surveyed to cm accuracy. This became practice in Switzerland and Germany.

During the 20th century it was realized that the cm accuracy was only desirable for private purposes, since the public only had an interest in a “spatial data infrastructure” for integrating cadastral with topographic and infrastructure data in form of a “multipurpose cadastre”.

The original establishment of a cadastre required an adjudication process, in which the owners of land rights had to state or prove their claims to legal and the survey authorities for a land holding. The maintenance of the cadastral system required obligatory registration procedures for the transfer of rights on land, which had to be recorded in books, with copies of the book entries in form of land titles.

The ability to maintain a cadastral register depends on the legal practices in use in different countries of the world. “Private Conveyancing” is used in parts of North America, when land transactions are privately arranged by sales contracts with no security to the purchaser unless he is able to purchase an expensive “title insurance”. Somewhat more secure is a “deed registration”, also practiced in North America, where the transfer of land in form of a sales contract is registered at the courthouse and attested by a lawyer or a notary public. “Title registration” requires the existence of an obligatory registration. The proof of the registration is the title granted to the owner. In Central European countries there is no need to issue a title, since all valid property rights are registered in the “cadastral book” with the guarantee of the state. The owner can, if needed, request a copy of the book entry.

15. 4 Requirements for Cadastral Registration

- There must be a unique description of the right (e.g. ownership, lease, encumbrance)
- The parcel must be characterized by a unique parcel identifier
- The person holding the land right must also be uniquely identified (e.g. birthplace and date, or social security number)
- Every land transaction must be updated in “near real time” (e.g. at the end of a working day).

15.5 Cadastral Maps

In some countries cadastral maps may be useful, but they are not required. In these countries the maps are helpful in identifying the general location of a parcel, but the relative location of the boundaries is described in relative field survey measurements without the need for georeferencing. The map then only serves to identify the parcel, but not its accuracy. Such a map is called an “Index Cadastral Map”. Nevertheless, an accurate cadastral map is an asset to a multipurpose GIS, in which cadastre, topography and utilities can be overlaid.

Some cadastral maps also have the disadvantage that they only show the boundaries and the parcels of private owners, but not of the public lands (roads etc.) which lie between them. A multipurpose cadastre must include all land parcels, including those of street sections.

15.6 Cadastre 2014

In 1994 the FIG Commission 7 on the Cadastre has drafted a “road map” where the development of the cadastre is developing, under the title “Cadastre 2014” (20 years from then, Kaufmann et al. 1998). Six requirements for the creation and maintenance of a modern cadastre were stated:

- The cadastre should cover all lands (public and private) including all rights and restrictions. Geocoding and a topological boundary structure is a requirement to assure, that parcels do not overlap.
- In a data system there should be no separation between (analogue) maps and (analogue) registers.
- The use of paper and pen shall be replaced by computer systems to permit automation.
- Cadastral mapping as a standalone activity shall be abolished.
- The public and the private sectors will closely work together in establishing and in maintaining a cadastral system.
- The cadastre will be cost recovering.

15.7 Cadastral Surveys

15.7.1 Geocoding of Parcels

With today's capabilities geocoding of images, digital maps and survey data should solely be done based on GNSS technology (GPS/DGPS) . Simple code receivers can only assure accuracies of about 5 m; with corrections transmitted by a service to 0.5 to 2 m. This is sufficient for attribute data collection for an area already mapped for high resolution satellite image data or for orthophoto data.

The geocoding may simply consist of determining the coordinates of a point within a land parcel (a pointer, a "centroid", or a "TOID" as it is called in the Ordnance Survey of Great Britain). The point permits to specify a geo-location defined on a datum within the bounds of a parcel. This permits to relate alphanumeric attribute data contained in a land parcel register in form of a relational database. Such an attribute can be the name of the owner or right holder for the parcel. Fig. 15.1 depicts the use of pointers shown as points in a digital map. To these points attributes are geographically attached in a relational database.

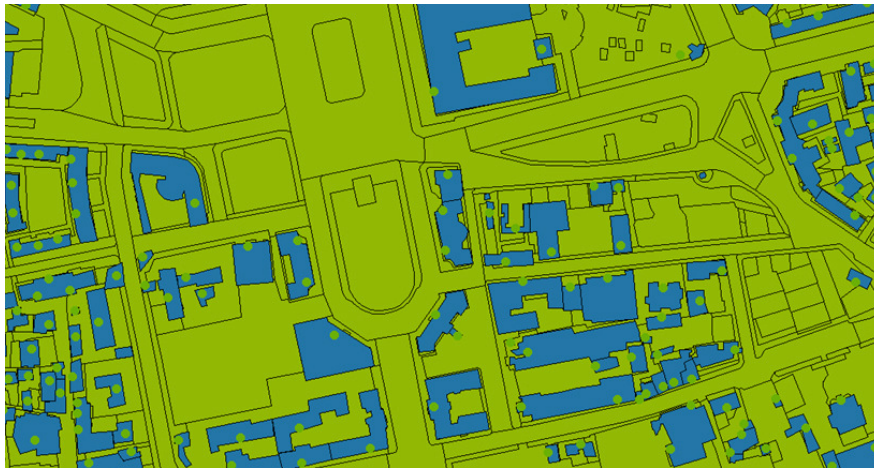


Fig. 15. 1 Pointers located in the digital map or image as points to attach attributes in the database

The process of adjudication, to be discussed later, then merely consists of identifying the rightful owner or right holder of the land. He is asked to provide documentation certified by a notary (a deed), that the rights belong to the identified person. This can be done without the description of the property boundaries. Even during this simple process the use of aerial photos or satellite images, as well as of updated topographic maps, may help to identify the existence of a parcel in a unique way.

15.7.2. Survey of Parcel Boundaries

Obviously it is better, if the interrelationship of all existing parcels in the neighbourhood is described by the tracing of the parcel boundaries from boundary point to boundary point, determined by its coordinates. In this way the topology of the boundary points and boundary lines determines the parcel fabric, and assures, that the land area is totally covered without gaps, particularly if the parcels are not only restricted to land parcels but also to adjacent road sections. A parcel may then be treated as a uniquely identifiable object, to which sub-objects, such as buildings erected on the parcel may be linked. Objects and sub-objects may have their own attributes attached.

The topology of the parcel fabric describes the geometric neighbourhood relationship between adjacent parcels, even though the coordinates of the boundary points may not be of the highest accuracy. While for a more precise geocoding to dm or even cm level with a survey on the ground by more expensive phase receivers used in RTK mode or in conjunction with CORS systems are required may be possible. In areas where GNSS surveys suffer from disturbances (urban canyons and power lines) such surveys are supplemented by local total station surveys. In any case such surveys are the most time consuming and costly.

Only few countries, such as Germany, Austria and Switzerland have been able to maintain cadastral data bases, which contain object oriented cadastral information with coordinates of boundary points at cm accuracy and the topology formed by boundary lines for all parcels and buildings. The accuracy of boundary points is reached by GPS Continuously operating reference stations (CORS) at distances of about 50km, which correct the GPS-GNSS phase signals for the atmospheric disturbances at cm level. But for other areas in the world may benefit of a similar technology, which corrects inexpensive GPS code receiver signals by world wide networks, such as Fugro-Omnistar to dm level. The corrections are transmitted by special communication satellites, such as EGNOS, shown in Fig. 15.2.

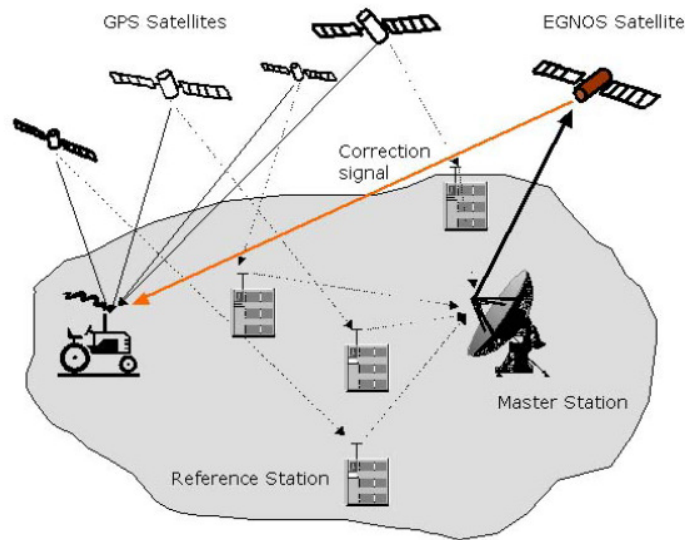


Fig. 15. 2 GPS Corrections

15.7.3. Use of Images for Cadastral Mapping

A much more rapid and cost effective procedure is to use aerial photos, satellite images and even updated topographic maps for the purpose of interpreting parcel boundaries from the grey level contrasts of the photographic or satellite images, or the mapped topographic objects. There is no guarantee, however, that the images or maps permit to identify the actual legal boundaries unless they are legally established as so called “un-sharp boundaries”, or unless they are accepted by the adjacent owners in a “photo-adjudication process”.

In many countries index cadastral maps are used (e.g. Sweden and Australia) in which the approximate boundaries are described on a map containing the unique parcel numbers and the graphic location of the boundaries. This can be done at a rather small scale, e.g. 1:5000 or 1:10 000. The accurate survey measurements are then separately contained in survey plans at larger scale (e.g. 1:1000) for each parcel by relative survey measurements or by a plan showing the coordinates of the boundary points. These survey plans may be drawn in analogue form and raster scanned to be part of the parcel database, or they may be issued as computer graphic outputs.

15.7.4. Image Scale

The ground resolution of an analogue photograph or an orthophoto depends on the image scale. The image should be observable by the human eye at a resolution of 5 lp/mm. At that resolution a physical object on the ground should be recognizable (e.g. field corner, house corner). This ground resolution naturally depends on the physical parcel size. In rural areas with field size dimensions of greater than 100m an orthophoto scale of 1:10 000 is appropriate, and for the settlements a scale of 1:2000 is recommended. For example the Ukraine is being covered entirely by orthophotos 1:10 000 and the villages and cities with orthophotos 1:2000. In more densely settled areas, such as Thailand the orthophoto scales should be 1:5000 for rural areas and 1:1000 for settlements. But as the production of orthophotos from analog images has become an automated process, which depends on generating digital images by a scanning process, the required resolution is also determined by the required pixel size. This orthophoto generation process is at least 5 times faster and more cost effective than manual plotting operations.

The resolution of digital images is determined by pixel size. It should be related to ground sample distance (GSD) and not to image scale. When compared to image scale 5lp/mm corresponds to 10 lines/mm. This corresponds to a GSD of 1m for the scale 1:10 000 and of 20cm for the scale 1:2000. In the Ukraine GSD's of 40 to 60cm are being used for the smaller orthophoto scale covering the entire country and of 10 to 15 cm for the larger scale orthophoto coverage of the settlements.

The satellite images, orthophotos (or maps) to be geocoded need to be contained in digital raster (or vector) form and they need to be geometrically transformed by shifts, affine, polynomial or least square fitting models to control in a digital workstation.

The images or maps can be loaded in sections (tiles) into a tablet PC or a PDA for use in conjunction with GPS/DGPS) or total station ground surveys. The image or map helps in identification of a point, the survey in the precise coordinate determination. This is not only of advantage in surveys for the first establishment of a cadastre (as it was done in Georgia or Cambodia). But is particularly recommended in update surveys, which have to be done on a transaction basis, when a parcel boundary is to change.

If a cadastral database consists of a correct topologically closed parcel fabric, which has been established at lower accuracies of 0.5m by photo adjudication or of 1 to 5m by satellite image adjudication, then there is the possibility, that sporadic surveys done on a transaction bases will gradually improve the accuracy of the parcel fabric for a cadastral registration system.

Fig. 15.3 illustrates the relationship between resolution of images from satellites and aircraft versus the repeatability to be able to obtain images. Only meteorological satellites with 1 to 5 km resolution systematically permit imaging several times per day, an aerial photographic coverage at dm to m resolution is practically not affordable except at intervals of a few years, and the original sur-

vey at cm to dm accuracy took historically in Europe more than 50 years on the ground.

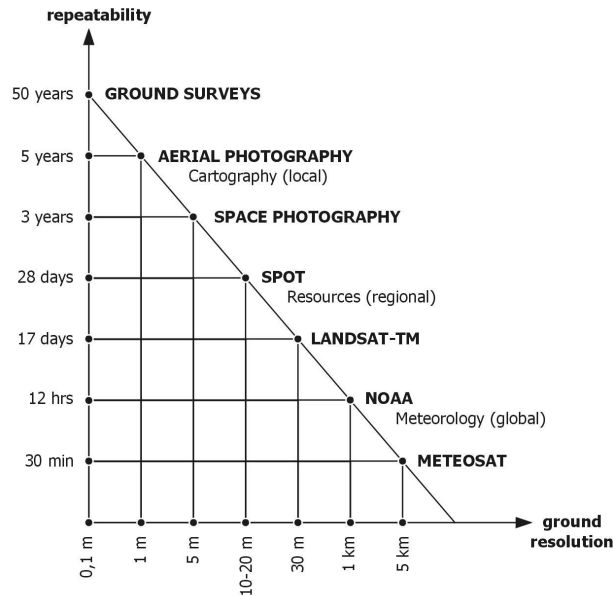


Fig. 15. 3 Resolution versus repeatability

15.7.5 Adjudication

The adjudication is a process in which the owners of a land parcel present their contracts, deeds or titles to the adjudication team. These documents, if not otherwise available to the authorities, are photographed on site. Then owners and neighbours identify the boundaries of their parcel. They confirm by signature the location of eventually marked and DGPS surveyed boundaries or boundary monuments.

Modern technology permits to send the signed and photographed documents via mobile technology to the field office. Such an adjudication is possible in case of actual field surveys on the ground, when the neighbouring owners agree to the surveyed and eventually even monumented boundary points. The involved owners confirm this in an adjudication protocol.

When the adjudication is carried out on the basis of images, the neighbouring parties agree to the identified locations in the images and attest this by signature,

15.7.6 Monumentation

While monumentation of parcel boundaries was an issue around 1900 (in Germany it was made obligatory at that time), coordinate surveys to control via total stations or by DGPS have made reconstruction of a point inexpensive and fast. Monuments are often lost due to construction after a short time. Therefore, monumentation now becomes optional, if the client wishes to pay for it.

15.7.7 Surveyed Objects

The basic objects of a cadastral survey are boundary points. Some countries (Germany) do not accept curved boundaries. Curves are realized as chords with the line connecting the boundary points as the actual property limit.

Important are furthermore “permanent” buildings, which in most countries are considered part of the cadastre (e.g. Germany and the Netherlands). In some countries building outlines even refer to separate parcels (e.g. Serbia).

Topographic features are, however, not part of the cadastre. In Germany, cadastral maps are at the scale 1:1000. At that scale topography is a value added survey, which is not part of the base data provided by the cadastral administration. Municipalities may contract inclusion of topographic features as value added data to the private sector. This is done for street furniture (parking lots), utilities and trees (tree cadastre). The basic German topographic map is not at the scale 1:1000 but at the scale 1:5000. The AAA concept (AFIS = control monuments; ATKIS = topographic dataset 1:5000; ALKIS = Cadastral basemap 1:1000) attempts to integrate topography with respect to the cadastral base map.

In Britain, the opposite approach is taken. There a basic topographic map is maintained at the scale 1:1200 by the Ordnance Survey, and the Land Register only adds a cadastral layer for its own use. Maps at smaller scales should use the base map via generalization. The Ordnance Survey in Britain has committed itself to have an update goal of topography of not more than 6 months.

In Germany the updating of the cadastral basemap is in near real time with the update of the 1:5000 topo maps every 5 years. Due to changes of topography (new construction) this is not fully acceptable, but a remedy is possible by producing digital orthophotos every 2 to 2 ½ years at the scale 1:5000. Orthophotos may thus be considered as a map substitute which only cost 1/5 of a line map and are producible in 1/5 of the time. An added advantage is that such orthophotos may be inserted into browsers, such as Google Earth for urban areas, for which Google has an interest and will purchase the products.

15.8 Cadastral Data Bases

A modern cadastral system only makes sense, if it is organized in a digital data base.

15.8.1 Data Models

The basic cadastral data model shall be simple; a land object (parcel) is linked to a certain type of right, such as

- ownership for a private parcel
- encumbrance for access of an object
- building located on a parcel
- land use for a parcel or a group of parcels
- environmental restrictions for a defined area
- informal status of an object (tribal land).

All objects must be continuously maintained.

The object is geometrically defined in a “map”. Preferably this is done in form of shapefiles with topology. The attributes are linked either directly to the object or they are attached to the defined area via label point. Otherwise, it is also possible to use CAD geometry without topology. The label point is again the link to the attributes.

Attributes for land objects are stored in a relational database. They contain:

- a) - an application ID for the transaction
 - the application status
 - the status of the workflow (start)
 - the date of registration (end)
- b) - the unique parcel ID
- c) - the type of right (ownership, encumbrance, lease, building, land use, environmental zone)
- d) - the claimant (name, personal ID, % of ownership)

15.8.2 Software Needs

Relational Database

Depending on the size of the database may be used

- Access (personal database)
- SQL Server (enterprise database)
- Oracle (enterprise database)
- Open Source databases

GIS tools

The most widespread use is with ESRI tools, such as ArcGIS (with ArcView for personal database), ArcEditor or ArcInfo via ArcSDE or ArcServer for enterprise database.

Other usable tools

- Oracle Spatial
- Intergraph Geomedia
- Bentley's Microstation and Geographics
- Autodesk's AutoCAD

15.8.3 Specialized cadastral software

A number of specialized cadastral software products have been developed:

- Arc Cadastre (Swedsurvey) which is not entirely up to date technology
- LM by AED SICAD for European workflows
- ESRI Cadastral Parcel Manager for US and Australian workflows.

Another option is the customization to ArcGIS or other products using local expertise. This approach has been followed in

- Serbia
- the UK
- Germany

In Germany this customization is being done by dedicated software companies (ConTerra) for the Government.

15. 9 Fast, Low Cost Realization of Cadastral Systems

It has been the experience, that large operating cadastral systems in Central and Northern Europe place their emphasis on maintenance of the records.

In the transformation countries some old cadastral information may exist from the 1940's. In former Soviet areas such information is not available:

In Serbia, Bulgaria, Poland, Albania the task is therefore to superimpose the existing situation contained in satellite images or orthophotos with outdated, not properly geodetically referenced and perhaps not yet digitized or scanned cadastral maps for an updating process.

Fig. 15.4 illustrates, how in Tirana, Albania at least the buildings of a not maintained cadastral database could be digitized to 2m accuracy from a geocoded QuickBird satellite image with 60cm ground sample distance. The orthophoto and buildings could be visualized by ArcView from an ArcGIS database.

Fig. 15.5 demonstrates, how the ArcGIS capabilities are also able to display attributes derived from the pointers, such as land use.

In former Soviet controlled areas a new cadastral fabric needs to be created. Particularly in these areas it can be done without the existence of a survey profession, if a group of talented young individuals are trained on new technology, as was done in Georgia.

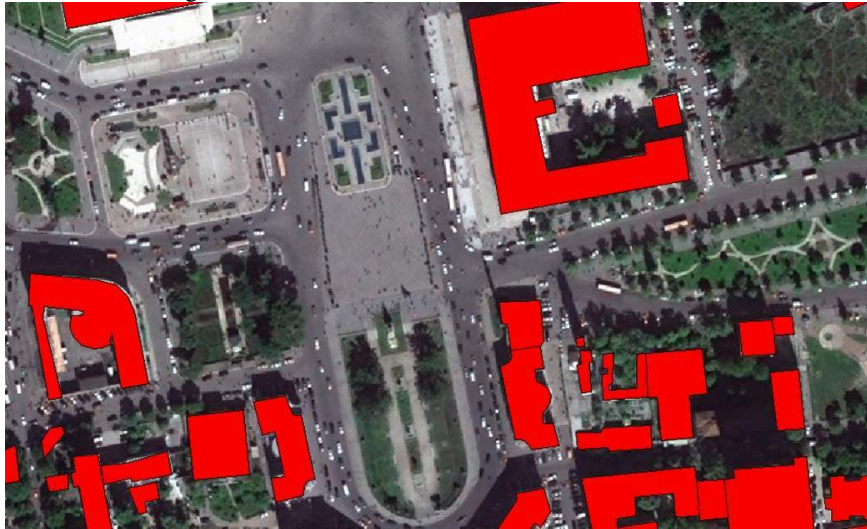


Fig. 15. 4 Digitized buildings

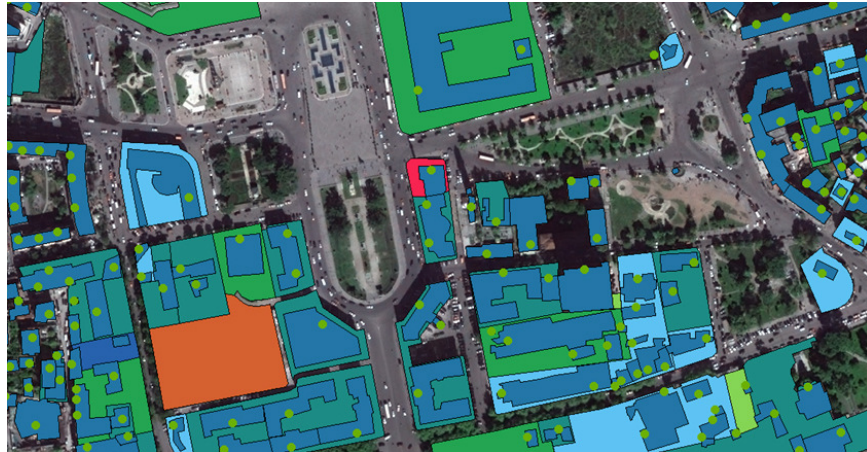


Fig. 15. 5 GIS use of parcels; the attributes from the relational database permit to display the parcels in different colors (dark blue = building; red = shops; orange = commercial building; dark green = garden; light green = meadow; light blue = gravel surface)

The trained individuals were able to use the KFW (Kreditansalt für Wie-

deraufbau = German International Development Bank) donated equipment forming competing companies managing to establish a cadastral survey system by high-tech adjudication in a 5 year period. In the first year the survey and adjudication cost per parcel was around US \$10. It diminished in the 5th year of operation to US \$2 per parcel. This shows that the establishment of a cadastral system is possible in the shortest possible time at low cost. It is now the government's task to show that maintenance of the system can be done in a sporadic manner.

Fig. 15.6 illustrates the components of the technology used in the project: a GPS base station, a DPPS rover, a bluetooth connected field pen computer.

Fig. 15.7 shows the adjudication process in the field combined with the ground survey (images of the orthophoto are used in the field pen computer for better orientation in the field).

Fig. 15.8 shows, how legal documents of the owners are copied during the adjudication process. The copies may directly be transmitted via bluetooth to the field office.

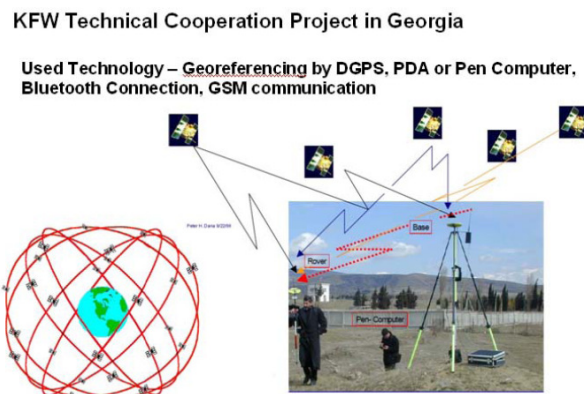


Fig. 15. 6 Georgia KFW project



Fig. 15. 7 Field survey and field adjudication



Fig. 15. 8 Copying of legal documents of the owners by digital photography

There are a number of possibilities to reduce the cost of a cadastral system.

1. If there is only one administration in charge of land registration and cadastral mapping (as this is the case in Serbia) duplications of data and mismatches of information can be avoided reducing administrative costs.
2. The adjudication does not have to be done by survey measurements, as long as the parcel boundaries are identified in satellite images or orthopho-

tos on which they are marked. If there is a need for a more precise survey due to construction activities (e.g. urban renewal or rural reallocation of parcels) then this could be done on sporadic ad hoc basis.

3. For the maintenance of the cadastre there are basically 3 scenarios:

Already buildup areas, for which very little changes are anticipated. In these areas sporadic surveys would be used. Modern technology for survey and data base design permit the possibility to improve the originally entered coarse accuracy of 2 m from satellite images or 0.5 m from orthophotos for boundary points to DGPS accuracy of a few centimetres in a sporadic way.

Areas in which new settlements are planned and computer designed on geocoded maps or orthoimages. The computer planned boundary points can directly be staked out by survey instruments in the field using DGPS and total stations. The record of these plans and stakeouts can immediately be used for the content of the cadastral geodatabase.

Rural areas, in which accurate surveys are lacking, and in which combined adjudication – survey procedures are recommended.

4. No cadastral adjudication and surveys should be undertaken, unless there is a firm commitment by the authorities to maintain the system.
5. This commitment will also generated trust in the cadastral system, so that it will be used for mortgaging. A secure cadastral system will allow to use up to 90 % of the value of the land as mortgage collateral, while unsecure systems may only lend 10 % of the value.
6. The main requirement is to create a rapid and low cost cadastral system, which should be designed in such a way, that it can be improved by subsequent transactions.

References

- de Soto, Hernando, “The Mystery of Capital”, Bantam Press, 2000, ISBN 3 87134 449 4
Kaufmann, Jörg & Steudler, Daniel, “Cadastre 2014”, FIG Congress 1998 (Brighton), Commission 7