ASSESSMENT OF THE VHRS IMAGES FOR ELABORATION OF THE TOPOGRAPHIC DATA BASE 1: 10 000 IN POLAND

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ABSTRACT:

In Poland, one commenced the works on creation of Topographic Data Base (TDB) of accuracy and contents equivalent to traditional topographic map scaled: 1:10 000. Such base is created on the grounds of orthophotomap with a pixel 0.5 m produced from aerial photographs 1:26 000. However the pace of its development is unsatisfactory, and the costs are enormous, specially as far as the vector data bases are concerned. One considers an option to produce TDB vector map of reduced contents, which are based upon the VHRS. The recently established Center for Regional Operations (ROC), triggered for reception and processing of Ikonos data, is very much in favor of this idea. One has undertaken the research project dedicated to evaluation of the option to elaborate the topographic vector data base based upon the satellite data. On the three tested areas covered by images from QuickBird, Ikonos and EROS one has generated the satellite ortho-photo-maps. On the grounds of such maps one has produced vector data in TDB structure. Results of these studies have been analyzed in terms of their contents coverage and conformity with TDB. One has found that for vast majority of classes of objects of the TDB data base, the images from QuickBird and Ikonos are as good as or just slightly poorer than traditional aerial photographs of scale 1:26 000. EROS images are insufficient for creation of vector data bases in standard TDB. In effect of the studies, one has established the new standard (TDB II) of slightly poorer contents, which is however suitable to be elaborated from the VHRS. It shall be applied to areas of lower degree of urban land development. One estimates that this standard shall facilitate and lower the costs of preparation of TDB. The implementation works are in progress.

1. BACKGROUND OF THE PROJECT

Presently Poland is in the phase of profound economic transitions. In the field of geodesy and cartography, one has undertaken the tasks of scale, scope and pace, which have been unknown up to now.

The present National Geographical Information System (NGIS) includes the following topographic data bases of full coverage:

- General Geographic Data Base (GDB) of details accuracy equivalent to scale 1:250 000,
- Vmap Level 2 of informative accuracy and details equivalent to topographic map scaled: 1:50 000.

One of the more ambitious and urgent needs is to produce the topographic data base of accuracy and details level more or less equivalent to traditional topographic map scaled: 1:10 000. Some years ago, the Head Office of Geodesy and Cartography (HOGC) undertook such works in form of a pilot elaboration. In result of these activities, one worked out a new standard described in the „Technical guidelines: Topographic Data Base (TDB)".

The Topographic Data Base (TDB) comprises the following main elements:

- Base of the Digital Terrain Model of height accuracy 1 m,
- The base of orthophotomaps in sectional division with the terrain pixel of 0,5 m and situational accuracy 1,5 m (i.e. 3 pixels),
- Spatially „continuous" vector topographic data base of accuracy and scope of contents equivalent to traditional topographic map scaled: 1:10 000.

The vector topographic data base constitutes a basis for cooperation between the Topographic Data Base and different systems of spatial information. The Base is constructed on the basis of the **vector model of data,** which is typical for GIS tools. Vector topographic data base is a „continuous" one in the meaning of its spatial range – there is no sheet division of data involved.

The adopted conceptual model of vector data bases assumes a coexistence of the class of objects subject to various levels of generalization used in traditional cartographic elaboration. Standard TDB defines three such levels. On level I, one has distinguished 10 classes of objects, on level II – over 50 classes, while on level 3 – some 220 classes of objects. Some of the objects from level III is recognized by an attribute assigned to corresponding object from level II. For each class of objects one has defined a set of obligatory and facultative descriptive attributes. Such construed conceptual model and accompanying systematics of objects enables for introduction and management in a single data base of objects subject to different levels of generalization, and it also provides for easy aggregation of data.

Informative scope of TDB generally corresponds to informative scope of formerly prepared Polish topographic maps. In the most general approach, their scope includes the following topical categories of data: hydrography, roads, railroads, utilities, plants, buildings, boundaries (units of territorial division), relief.

The basic source material for production of components for TDB are the aerial photographs and their photogrammetric processing. Obtaining the products of quality meeting the „Technical Guidelines" calls for the photographs from range 1:20 000 – 1:30 000. In Poland, as a standard, one makes the photographs scaled: 1:26 000.

In the framework of preparations for accession to the European Union, one initiated very intensive works concentrated on the development of LPIS (Land Parcel Identification System), constituting the main element of IACS (Integrated Administration Control System). Construction of such system constituted the basic prerequisite for benefiting from the system of direct subsidies from the EU addressed for Polish farmers. This system has been based upon a digital ortho-photo-map. Taking into consideration the needs of LPIS, but also some other needs of the country (including a construction of TDB), the entire country has been covered by the new digital orthophotomap in two standards:

- Standard I: with a pixel 0.25 m for 25% of the country area (scale of aerial photographs: 1:13 000),
- Standard II: with a pixel 0.50 m for 75% of the country area (scale of aerial photographs: 1:26 000).

In the framework of these works, one has also produced DTM of parameters meeting the standard TDB.

The works focused on the development of TDB data base are in progress. However, one should consider the fact that this is really huge undertaking: the country is covered by over 17 thousand TDB modules (TDB module corresponds to a sheet of topographic map in scale 1:10 000). This product is prepared in the most modern technologies, however the pace of its development is unsatisfactory, and the costs are enormous. The production of vector data bases in TDB standard is especially expensive and time consuming. It results, among others, from the richness of contents of this particular data base. One even considers an option to produce TDB vector map of reduced contents. It is worthwhile noticing that this concept provides for creation of **a map of reduced contents, but of still high positional accuracy.** Such product would be produced on less urban developed areas, and in the future it would be supplemented and updated, if needed.

In the meantime, one developed and introduced the Very High Resolution Satellites (VHRS). In autumn of 2004 one initiated in Poland the Center for Regional Operations (ROC) serving for receipt and processing the satellite data from Ikonos system. In this context one may reasonably ask a question whether the VHRS are useful for the production of components for topographic data bases TDB, in particular the vector data bases. It is the very background for establishment of the project entitled: **„Elaboration of elements for vector topographic data bases as well as the methods and technologies of discrete multispectral analysis of surface changes based upon the VHRS",** which is co-funded by HOGC and the Committee of Scientific Research of Poland, and executed by the Institute of Photogrammetry and Cartography in the Warsaw University of Technology.

As far as the task connected with obtaining vector data for topographic data bases TDB are concerned, the goal of the Project is to answer a question about the scope of usefulness of the VHRS for establishment and updating topographic data bases TDB in different technical, organizational and economic conditions. It has been assumed that in result of this very Project, one will also produce some recommendations for HOGC regarding the direction to modernize TDB standard in order to create an option for using VHRS for establishment of TDB.

Implementation constitutes an important part of the Project. In order to obtain highly reliable results, the stage of experimental elaboration of TDB vector elements takes place in the selected production facility.

2. TEST FIELDS AND SATELLITE IMAGES

Evaluation of creation of the TDB vector data bases on the grounds of the VHRS was conducted by vectorisation on orthophotomaps obtained from such satellite images.

Research and experimental works were conducted in two directions:

1. Evaluation of possibility for orthorectification of the VHRS in terms of accuracy in generation of ortho-photo-maps.
2. Evaluation of creation of the TDB vector data bases on the grounds of the satellite ortho-photo-maps.

Taking into consideration the above mentioned goals, one selected three tested objects:

1. Tested object „Warszawa" (flat terrain of strong urban land development).
2. Tested object „Nowy Targ" (terrain of very strong de-leveling, up to 600 m within a given scene).
3. Tested object „Włocławek" (flat and open terrain, dominated by agricultural cultivation).

Such selected objects are representative – in terms of land coverage and relief – for the majority of areas in the country.

For the areas of tested objects one purchased the VHRS from available systems:

- EROS A 1 (Image Sat Int.),
- Ikonos – 2 (Space Imaging),
- Quick Bird (Digital Globe).

3. ORTHORECTIFICATION PROCESS AND RESULTS ANALYSIS

All the 8 satellite images were subject to the process of orthorectification. On each of the images one measured the GCPs determined by means of GPS technology. Geometrical adjustment was conducted with the application of two basic methods:

- A method based upon parametrical model (strict method),
- A method based upon the Rational Polynomial Coefficients (RPC).

In experimental works one used two software packets, which are rudimentary in the process of orthorectification of satellite images:

- PCI Geomatica 9.0, enabling for a use of both methods of correction,
- Erdas Imaging 8.5, enabling for the application of polynomial method (RPC).

All the investigated images were subject to geometrical correction, and then one generated from them the digital orthophotomaps with the terrain pixel respectively:

- for the source image EROS – orthophotomap with the terrain pixel 1.8 m,
- for the source image Ikonos – orthophotomap with the terrain pixel 1.0 m,
- for the source image QuickBird – orthophotomap with the terrain pixel 0.6 m.

In the framework of experimental works one additionally produced a colorful pan-sharpened composition.

For orthorectification one used different available Digital Terrain Models.

Analysis of the obtained results enables for the formulation of the following general conclusions:

1. For the flat terrain (tested object „Warszawa") with a use of digital terrain model DTED Level 1 (SRTM data) and Level 2, RPC method enables for correction of Ikonos image on the level of accuracy 1,0 – 1,3 m almost independently from a number of GCPs. In order to obtain similar accuracy in parametrical model, one has to use at least 8 GCPs.
2. In the same conditions, QuickBird image may be corrected with accuracy of some 2,0 m with a use of 2 GCPs. Application of 8 GCPs and parametrical methods enables

to obtain accuracy of 1,3 m. Impact of DTM is similar for both correction methods.

3. For the foot-hills area (tested object „Nowy Targ”), RPC method enables for correction of Ikonos image with accuracy of some 1,5 m almost independently from the used DTM and a number of GCPs. Application of parametrical method and minimum 10 GCPs gives similar effect.
4. For the QuickBird image and RPC method, one obtains a correction with error a little higher than 3,0 m already when just 2 GCPs are applied. Parametrical method with 9 GCPs gives two times lower errors in correction of the QuickBird images.
5. Digital Terrain Model DTED Level 1 coming from SRTM is sufficient for orthorectification of the VHRS.
6. Even in the case of strongly corrugated areas, the Digital Terrain Models DTED Level 2 and DTED Level 1 (SRTM) give similar results for both images and both correction methods.

Results from this part of research have already been published (Wolniewicz, 2004b; Wolniewicz, Jaszczak, 2004; Kurczyński, Wolniewicz, 2005).

4. EVALUATION OF THE OPTION TO CREATE VECTOR DATA FOR TOPOGRAPHIC DATA BASE (TDB) BASING UPON THE VHRS.

Evaluation of cartographic potential of the VHRS should take into consideration two aspects:

- Geometrical aspect, i.e. answer to the question whether the product obtained on the basis of the VHRS meets a requirement of positional accuracy;
- Interpretation aspect, i.e. answer to the question on the scope of possible extraction of terrain objects and their attributes as compared with the contents of the produced digital map, for example in TDB standard.

Ikonos satellite images enable for generation of orthophotomaps with a pixel as small as 1 m, while the QuickBird images – with a pixel 0,7 m. Such orthophotomaps can be characterized by situational accuracy on the level of 1.0-1.5 m.

Answer to the question regarding the contents of satellite images is far more difficult and unclear. Comparison of required resolution of digital images for creation of vector topographic map and orthophotomap confirms this well-known fact that for the production of digital orthophotomap it is enough to have images of lower resolution than for the production of vector map of the same scale (example: photographs 1:26 000 enable for the production of orthophotomap of scale 1:5 000, but the vector map only of scale 1:10 000).

Comparing both criteria that define cartographic potential of images, i.e. geometrical accuracy of elaboration and interpretation potential, one may easily notice that available satellite images more easily meet the requirements for geometrical accuracy than requirements for the richness of contents. **Critical factor that limits cartographic potential of available satellite images is their limited contents, and only in the second instance their geometrical accuracy.**

In literature we can encounter opinions on usefulness of the VHRS (Jacobsen, Passini, 2003; Nale, 2002). Also the opinions on cartographic potential of such images are diversified.

The research conducted is to determine degree of usefulness of the VHRS for the production of vector data bases in standard TDB, i.e. the vector data bases of positional accuracy and level of details more or less equivalent to traditional topographic map scaled: 1:10000. Pursuant to the applicable standard, the main source of data for vector data bases is the orthophotomap with the pixel 0,5 m produced from aerial photographs in scale 1:26 000. The digital data base itself is produced by screen digitalization of this orthophotomap and grouping of data in proper structures, pursuant to standard TDB. Evaluation of usefulness of satellite images for this very task is conducted by attempts of independent study based on digital orthophotomaps coming from different satellite systems. Technological process of making individual studies is definitely close to current process of TDB production, with such a difference that the source materials for obtaining data are solely the digital satellite ortho-photo-maps.

Contents of vector data bases produced in this way were analyzed, both in terms of measurement and interpretation. Such works were performed for all three tested areas. On each of these areas one determined a representative coverage of terrain for which the vector data bases were prepared.

The studies were performed on the basis of satellite orthophotomaps but also from orthophotomaps coming from aerial photographs. In order to obtain a reliable answer to the question on the scope of vector topographic data possible to be obtained from satellite images and replacement of aerial photographs with such images, the vector-operated works were conducted by operators of cartographic stations who were much experienced in the production of TDB. During these works, the operators used no additional sources of data whatsoever (for example, no paper topographic maps). They based solely on measurement (vectorisation) and interpretation of orthophotomaps in order to obtain geometry of the objects as well as their attributes.

5. ANALYSIS OF RESULTS

In result of experimental works on tested areas, one obtained altogether 11 vector data bases: 9 of them were produced by vectorisation on the satellite orthophotomaps and 2 from aerial photographs. For two tested areas (Warszawa and Włocławek) one additionally had at his disposal the existing and complete data bases produced in standard TDB in a regular production process, i.e. on the basis of aerial photographs scaled: 1:26 000.

The obtained data bases were analyzed in the following terms:

- Degree of completeness of objects possible for elaboration on the basis of different source materials,
- Degree of satisfying the attributes of these objects possible to be obtained by interpretation of the source data.

The studies were compared against each other as well as with the exemplary (reference) studies, which constituted elaboration of vector data on the basis of aerial photographs (i.e. the very basic source of TDB data); also, the complete TDB data bases were available (for Warszawa and Włocławek).

In the satellite studies, there are over 60 classes of topographic objects, i.e. so many classes of objects (included in range of TDB on the 3rd level of generalization) one managed to detect, measure and assign selected attributes. The analyses were conducted independently for each study and each class of objects.

In the analysis and conclusions one distinguished as follows:

- Degree of the objects possible for elaboration on the basis of individual satellite studies as compared with elaboration of aerial photographs,
- Degree of the objects possible for elaboration on the basis of aerial photographs as compared with the full range of TDB data base (aerial photographs themselves enable only for elaboration of a part of entire scope of TDB).

One analyzed a population of the objects present as well as their attributes in each individual study. In such analysis one took into consideration and compared not only a number of objects in each class existing in every study, but also the total area of analyzed objects or their length. The obtained results were compared against each other as well as with the reference studies. Figure 1 shows the example of statistics of elaboration for the class of „buildings”.

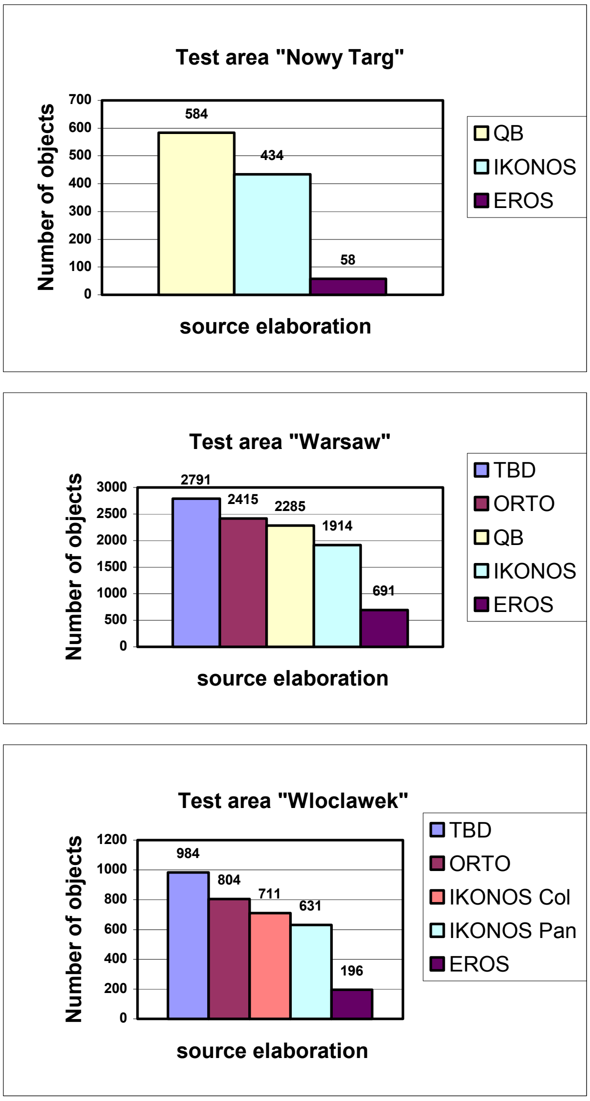


Figure 1. Class of objects: buildings. Total number of objects in each tested area present in individual studies of the source data

On each tested area one can observe a distinctive trend: a number of detected objects (i.e. the buildings) decreases as the quality (resolution) of the source orthophotomap deteriorates. It can be easily observed in the case of Warsaw, and even more distinctively in the cases of Nowy Targ and Włocławek. Undoubtedly, this fact is connected with a resolution, so a feasibility to recognized a building limited by the image resolution capacity. This trend is more easily recognized in the cases of Włocławek and Nowy Targ than in the case of Warsaw, because the first two have smaller buildings and their recognition depends more on resolution capacity of ortho-photo-map. Against such background, we can observe a rapid fall for EROS research. It refers to all the tested areas. In the case of this study, one detected 3-4 times less buildings than in any other. These observations have been confirmed by the analysis of obtained vector map with a layer of „buildings”. Figure 2 presents the fragments of such maps for the area of „Warszawa”, obtained from various source data.

As compared with aerial photographs (ORTO):

- for the area of Warsaw one detected: on QB 95%, on Ikonos 79% and on EROS 29% buildings,
- for the area of Włocławek one detected: on Ikonos Col. 88%, on Ikonos Pan 78% and on EROS 24% buildings.

Color helps a little bit to distinguish between a building and a group of trees or a shadows produced by such group.

Aerial photographs (ORTO) also do not enable for elaboration of all the buildings.

- in TDB data base for Warsaw there is 16% buildings more than on ORTO,
- in TDB data base for Włocławek there is 22% buildings more than on ORTO.

Analysis of the obtained attributes of the buildings prove that a degree of details in attribute table is relatively low, and the general and specific functionality cannot be recognized on ortho-photo-maps. However, such limitation also applies also to aerial photographs (ORTO). In TDB data base the attributes are defined not by interpretation, but on further steps of the study (in this case: the field inspection).

Summarizing the results in this class of objects, one may state that recognition of the buildings depend on resolution capacity of the source elaboration. EROS produces the worst results, where recognition of the building is at the level of 25-30% of what can be found on aerial photographs (ORTO). On QuickBird recognition of the buildings is on the level of 95%, and respective on Ikonos – on 80%.

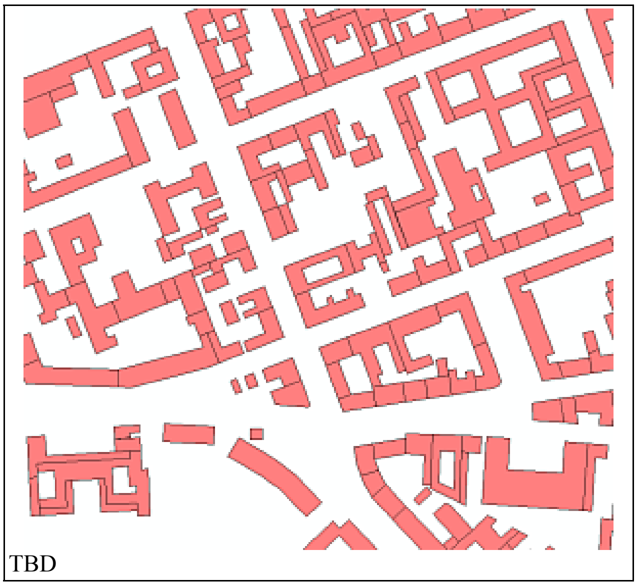
In the same way one analyzed a degree of satisfaction in all other classes of objects.

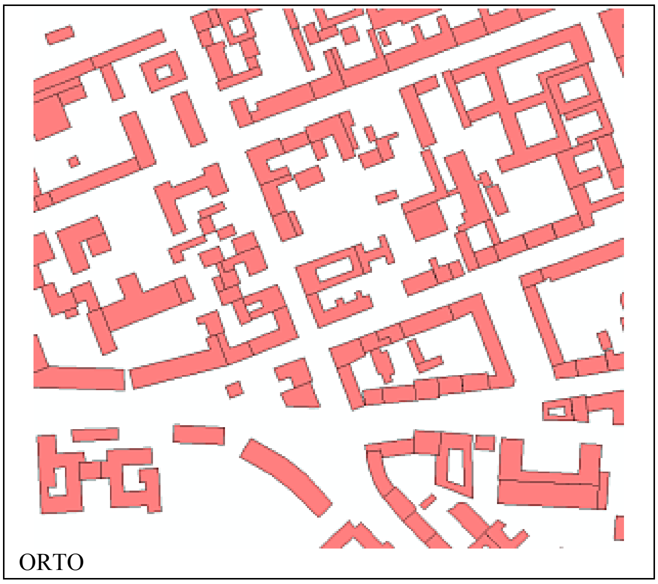
Generally, on the grounds of conducted analyses one may say that the VHRS type QuickBird and Ikonos may constitute a source of data for creation of TDB vector data bases. In terms of the contents subject to analysis, for majority of classes the images are of the same or slightly poorer quality as the traditional aerial photographs scaled: 1:26 000. From these two sources, QuickBird slightly prevails, especially if one is up to detection of smaller objects. EROS is much worse, and it offers considerably deteriorated opportunity for detection and elaboration of the objects. Images obtained from this system are insufficient for creation of vector data bases in standard TDB.

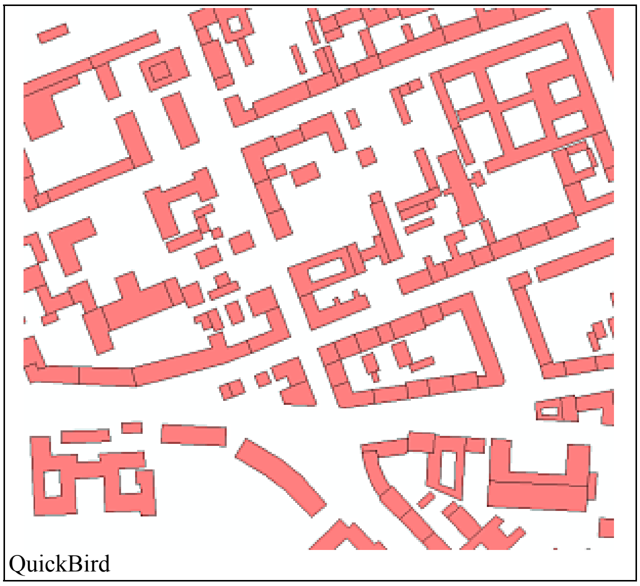
The following type of objects can be properly recognized on images obtained from QuickBird and Ikonos systems: watercourses, roads, railroads, building, monuments of nature, power lines on pillars (on QuickBird only). The following type of objects ca hardly be recognized: fences, water defenses, monuments, fountains, and similar „point” objects.

6. TDB II STANDARD

On the basis of results of research one may state that the contents of orthophotomaps generated from images type Ikonos or QuickBird is slightly poorer than from orthophotomaps with a pixel 0,5 m generated from aerial photographs scaled 1:26 000. This means that vector data base cannot be obtained in full contents coverage pursuant to TDB. One should expect such a result. However, this result has its practical application for it enables for definition of the new standard of vector data base of limited scope of contents but meeting the positional accuracy required currently by TDB. One worked out a proposal for such standard – **Topographic Data Base on the second level of contents generalization (TDB II)**.







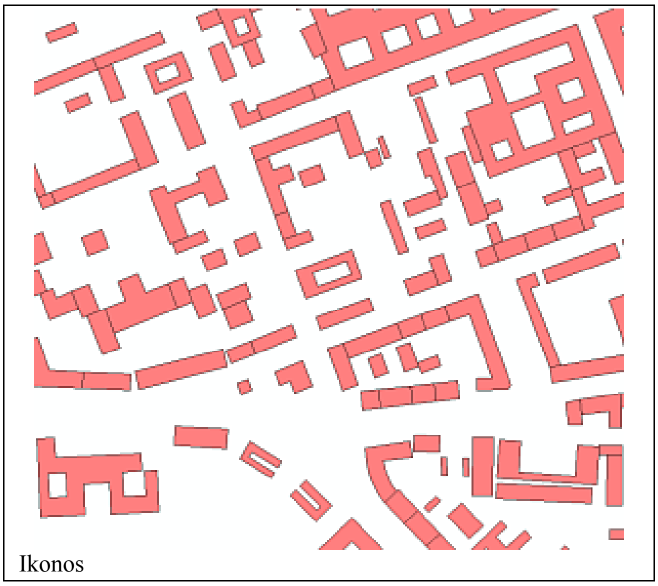


Figure 2. Fragments of vector maps with a layer of „buildings", scale some 1:5 000 (marks: TDB – contents of the complete TDB data base, ORTO, QB, IKONOS, EROS – results of vectorisation respectively on aerial photographs 1:26 000, and images: QuickBird, Ikonos, EROS)

Vast majority of the classes of objects for this base may be obtained from elaboration of images type QuickBird or Ikonos. Opportunity to obtain data from these sources constitutes an important, however not the only criterion. Presently, the works on implementation of this standard in selected production facility are in progress. Preliminary analyses show that the cost of production of vector data bases type TDB II may be even by 40% lower than in the case of full contents of TDB.

7. CONCLUSIONS

1. The analysis and the experiments conducted have proved that the very prime factor determining accuracy of orthorectification of VHRS images is the number,

localization and quality of the Ground Control Points (GCP) used in the process of geometrical correction.
2. Digital Terrain Model coming from SRTM is sufficient for orthorectification of the VHRS images.
3. The VHRS images type Ikonos or QuickBird can be corrected with accuracy of 1.0–1.5 m by applying parametrical method and 8-10 GCPs. Polynomial method (RPC) needs as few as 2 GCPs.
4. Evaluation of the cartographic potential of VHRS images should take into consideration both, geometrical and interpretation aspect. Critical factor limiting the cartographic potential of available satellite images is their limited contents, while only in the second instance – their geometrical accuracy.
5. Cartographic potential (in terms of measurement and interpretation) of the VHRS images type Ikonos or QuickBird with a pixel close to 1 meter constitutes an equivalent of the aerial photographs of the scale 1:25 000 – 1:40 000.
6. In Poland one commenced the works on creation of Topographic Data Base (TDB) of accuracy and contents equivalent to traditional topographic map scaled: 1:10 000. Such base is created on the grounds of orthophotomap with a pixel 0.5 m produced from aerial photographs 1:26 000.

   Results of experimental tests enable for the production of statement that the VHRS type QuickBird and Ikonos may constitute a source of data for TDB vector data bases. In terms of the contents coverage these images – for the majority of classes of the objects – are as good as or just slightly poorer than traditional aerial photographs of scale 1:26 000.
7. EROS images are insufficient for creation of vector data bases in standard TDB.

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