

About Quality and Using of IKONOS Satellite Image in Estonia

Ave KARGAJA, Ina MELNIKOVA, Natalja LIBA,
Tarmo KALL and Taavi VEERMETS Estonia

Key words: satellite image, geometric quality, geometric accuracy, interpretation.

SUMMARY

In given paper the quality, accuracy and interpretation of high-resolution satellite image are investigated.

Used 1-meter resolution IKONOS satellite image belongs to CARTERRA Geo accuracy category. Image was made about part of East-Estonia in scale of 1: 10 000 in three different colour type.

To find out the accuracy of satellite image 48 “control-points” were chosen. Co-ordinates determined by GPS were compared with co-ordinates got from interactive method. To control accuracy and quality different methods were used.

It is recommended to use Geo product in field demanding less accuracy such as visualisation and interpretation works.

For users of such satellite images instruction for distinguish different objects is needed. For that purpose the catalogue of interpretation of objects in satellite image was compiled.

By eliminating the systematic errors, rotations and distortions elicited by terrain, and with using “control points” and accurate terrain model it is possible to improve significantly the accuracy of satellite image.

SUMMARY (Estonian)

Antud uurimustöös uuriti kõrge lahutusvõimega satelliitpildi kvaliteeti, täpsust ja dešifreerimist.

Kasutatav 1-meetrise lahutusvõimega IKONOSe satelliitpilt kuulub CARTERRA Geo täpsusklassi. Pilt oli tehtud kolmes erinevas värvitüübis Ida-Eesti ala kohta mõõtkavas 1 : 10 000.

Satelliitpildi täpsuse leidmiseks valiti 48 kontrollpunkti. GPS-ga määratud koordinaate võrreldi interaktiivselt mõõdetud koordinaatidega. Pildi täpsuse ja kvaliteedi kontrolliks kasutati mitmeid erinevaid meetodeid.

Geo toodet on soovitatav kasutada töödeks, mis nõuavad vähem täpsust nagu näiteks interpreteerimine ja muud visuaalsed tööd.

Satelliitpiltide kasutajatele oleks vaja luua andmebaas, mille põhjal on võimalik erinevaid objekte eristada. See oligi eesmärgiks dešifreerimise kataloogi koostamisel satelliitpildi objektide näitel.

Süsteematiliste hälvete, pöörete ja reljeefist tingitud moonutuste kõrvaldamisega sidumispunktide ja täpse reljeefimudeli kasutamise abil on võimalik oluliselt parandada satelliitpildi täpsusklassi.

About Quality and Using of IKONOS Satellite Image in Estonia

Ave KARGAJA, Ina MELNIKOVA, Natalja LIBA, Tarmo KALL, Taavi VEERMETS
Estonia

1. INTRODUCTION

In land management, in land surveying, in cartography and in other fields of activities connected with land and land using, the aim of successful work is existence of maps and plans with necessary accuracy and content. Nowadays in this fields of activities satellite images have found their place by air maps. The resolution of satellite images has already risen to 0.62 meters (Quick Bird) and it means we can interpret all objects that are bigger than 0.62 meters.

In Estonia people mainly use air maps and orthomaps to interpret landscape objects and for other activities. But Estonian digital base map is made using SPOT's satellite images and Landsat satellite images have been used in satellite sensing to interpret the landscape.

Before we can use satellite images or other images we have to know the quality of them. Assigning quality we also have to consider the aim of work and know how accurate product we need to use.

2. AIMS OF RESEARCH

In this research are brought out two main aims:

- Estimate the geometric accuracy of IKONOS satellite image *CARTERRA Geo* using image about district of river Emajõgi situated in East-Estonia (Figure 1). Is it possible to correct the image accuracy ourselves and does it compensate done work?
- Investigate contents of digital satellite images. Can we interpret objects on the images at all and which objects can we interpret? Testing some methods which help us to interpret, finding out some regularity between tones and objects and getting visual assessment to interpret satellite images.

First purpose was to estimate the geometric accuracy of satellite image comparing measurements made in nature with measurements made on digital image.

Understanding the contents of satellite images was the second purpose. To interpret objects on satellite images the best result will be find out using changing contrast and enlarging and lessening satellite images. The purpose itself is related with the tones because of different objects specific tones. There was relation between object tones on satellite image and objects tones in nature.

In Estonia no one has investigated the satellite images for interpretation purpose and their accuracy.

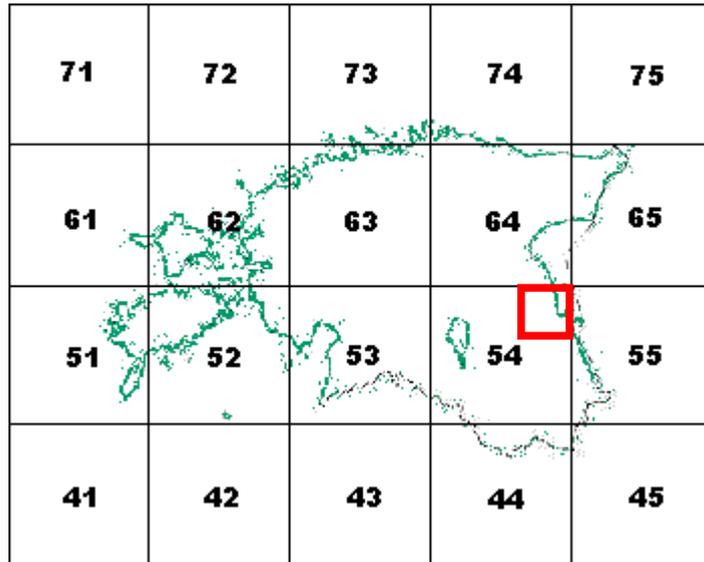


Figure 1 Mäksa district on the Estonian Basic Map in scale of 1:200 000.

3. MATERIALS AND METHODS

In this work was used IKONOS *CARTERRA GEO* 1-meter resolution image in digital form. IKONOS, launched on September of 24th in 1999 is the first commercial high-resolution satellite, collecting 1-meter panchromatic and 4-meters multi-spectral images. The orbital radius is 681 km and weight is 730 kg. IKONOS is equipped with an on-board recorder, so it can acquire data almost over area of Earth's surface. IKONOS records data on five bands and with two different pixel sizes (table 1).

Geo is geometrically corrected product, rectified to a specified ellipsoid WGS-84 and in map projection. Required diffuse circle on the 90% level of satellite image is ± 50 m and square error is 23.3 m. The image is taken to the projection only with the parameters of projection and without consideration of terrain model or control points.

The used image was made in September of 2001, in Lambert conformal-conical projection and in map scale of 1 : 10 000. The area on image is 10 x 10 km in nature, pixel size 0.8 – 1.2 m. Image type we used was mosaic containing four separate images and was cut to six map sheets. Image was in tree color types: gray tone, false color and true color (which made from gray tone picture). Gray tone is black and white (panchromatic imagery); false color – 3 bands in one fail: near infrared, red, green; true color – 3 bands in one fail: red, green, blue are pan-sharpened imagery. Pan-sharpened imagery is with four meters multispectral imagery that is combined or fused with the one-meter panchromatic imagery to produce one-meter natural, true color or false color infrared imagery.

Table 1 IKONOS satellite image resolution and spectral content.

Band	Wave-length	Resolution
Blue	445-516 nm	4 m
Green	506-595 nm	4 m
Red	632-698 nm	4 m
NIR (near infrared)	757-853 nm	4 m
Pancromatic (black-white)	445-900 nm	1 m

The field of research is separated in two different investigations:

1. Estimating the accuracy of image
2. Interpreting the objects on image

3.1 Accuracy of satellite image

To find out the geometrical accuracy of image both co-ordinates in nature and on the image need to be measured. For those measurements three different kind of objects are counting:

- point objects (comparing points co-ordinates in nature and on the image),
- line objects (comparing line object's co-ordinates or comparing lines between points co-ordinates in nature and on the image),
- area objects (comparing different measured areas in nature and on the image).

From different objects point's co-ordinates were measured both in nature with GPS and with interactive method on the digital satellite image.

To evaluate the geometrical accuracy of image the control points on the high-resolution satellite image were chosen, to which co-ordinates in nature and several times on the image were measured. Comparing calculated results, many different methods were used for analyzing. The accuracy of measured points in nature was better than inside on digital satellite image, so the co-ordinates of them were handled like erroneous.

48 control points (Figure 2) were chosen homogeneously all over the area. Location of the points has to be clearly visible and recognized on the terrain, to enlarge location accuracy. Thus, the control points located on the road's intersections. We also have to consider the shadows of the objects on the satellite image that may let wrong location to mind.

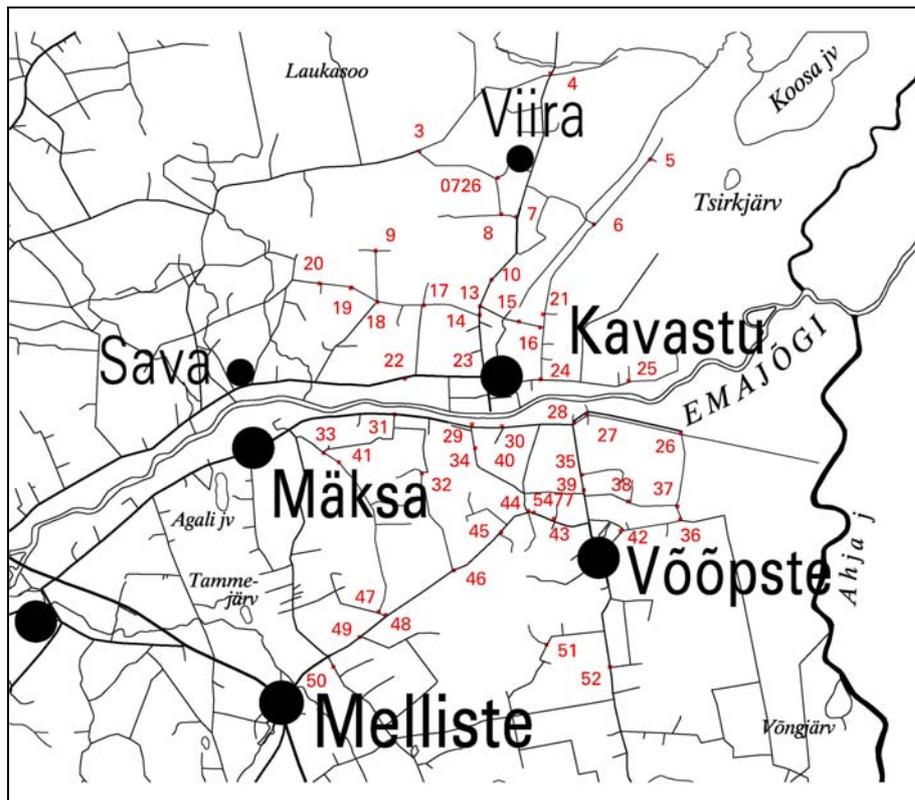


Figure 2 Location of control points.

For GPS-measurements it was necessary this location of points that was distant from objects that are causing signal multipath, needed horizontal openness and access by car. Measured points based on five geodetic reference network points. According to the location of points and to the method of measuring (number of GPS receivers) it was necessary to chose appropriate surveying technique.

Measurements in nature lasted three days from 8.th to 15.th of November in 2001. Two single frequency GG24 receivers and geodetic antennas from Ashtech were used. The measuring based on radial-quick static GPS-method. The length of session was 5 minutes and data recording interval was 2 seconds. Every time the measured point was mounted with woody stick, the abriess was made, the openness of horizon was fixed on and data paper was filled out.

To the ground point co-ordinates, the co-ordinates based on interactive method also were calculated using programmers MicroStation and I/RAS_C. Before doing that the image were connected to one image in program Idrisi 32. Values of the co-ordinates in Estonian Map system were got in MapInfo program. To find out the real location of the points on the satellite image abriesses were used. To measure co-ordinates on digital satellite image three methods were used. The first one's points were measured on original image. Second measuring time the picture was registrated with 4 control points and finally 10 control points were used to register the image. Registrations of image took place in MapInfo program. Every time co-ordinates were measured on three different layers and on the same points three

times to maximize the measuring quality and reliability. To increase accuracy of the point location the original digital satellite image was enlarged.

Data processing of GPS-measurements was made using program GeoGenius where every point co-ordinate was calculated in national co-ordinate system L-Est'92. Both, co-ordinates from GPS-measurements and from interactive method, were exported to *Excel* program on the form of table where eventual processing took place.

As the co-ordinates measured in nature were considered as erroneous the accuracy of them expresses direct influence to the creating accuracy of satellite image. The RMS of all the measurements was 5.42 mm and this accuracy met requirements.

Every time at first the arithmetic averages of co-ordinates gotten from triple interactive measurements were calculated and they were the base co-ordinates to the eventual processing. To get errors, from average co-ordinates were subtracted every measured result, from this calculated results RMS was calculated using formula

$$m = \pm \sqrt{\frac{[v^2]}{n-1}}, \quad (1)$$

where v – error between absolute average and concrete result
 n – number of points.

Measurements of three sets were unvaried and measuring accuracy met requirements (size of one pixel).

To get the preliminary accuracy of satellite image differences from measurements in nature and at the first time on the image were calculated (dX_1 and dY_1). Then calculated differences were squared and summarized, taking square roots from sums, offsets were gotten. To find out the accuracy the sums of differences and square roots were calculated also differences of average and maximum and minimum values. Now the satellite image has calculated RMS 22.1 m with formula

$$m = \pm \sqrt{\frac{[\Delta^2]}{n}}, \quad (2)$$

where Δ – difference between co-ordinates
 n – number of points.

Table 2 Accuracy indicators of different satellite images

	Before registration			After I registration			After II registration		
	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	
	dX_1	dY_1	offset	dX_2	dY_2	offset	dX_3	dY_3	offset
Abs average	19.52	.80	20.96	2.36	1.32	2.90	3.15	2.06	3.32
Max value	35.36	12.38	35.74	6.57	3.54	7.29	7.15	4.64	6.89
Min value	9.85	1.89	10.14	0.12	0.00	0.62	0.29	0.07	0.42
RMS	21.07	6.39		2.84	1.64		3.09	1.98	
RMS of image		22.01			3.28			3.67	

As in table 2 co-ordinates difference to the X-direction (average 21.2m) is bigger than to the Y direction (average 7.1m). This result will confirm that we have systematic error because the difference between co-ordinates is mostly to the one direction (Figure 3). But we have proved that the accuracy of satellite image met requirements when *Geo* products own RMS is 23.3 m.

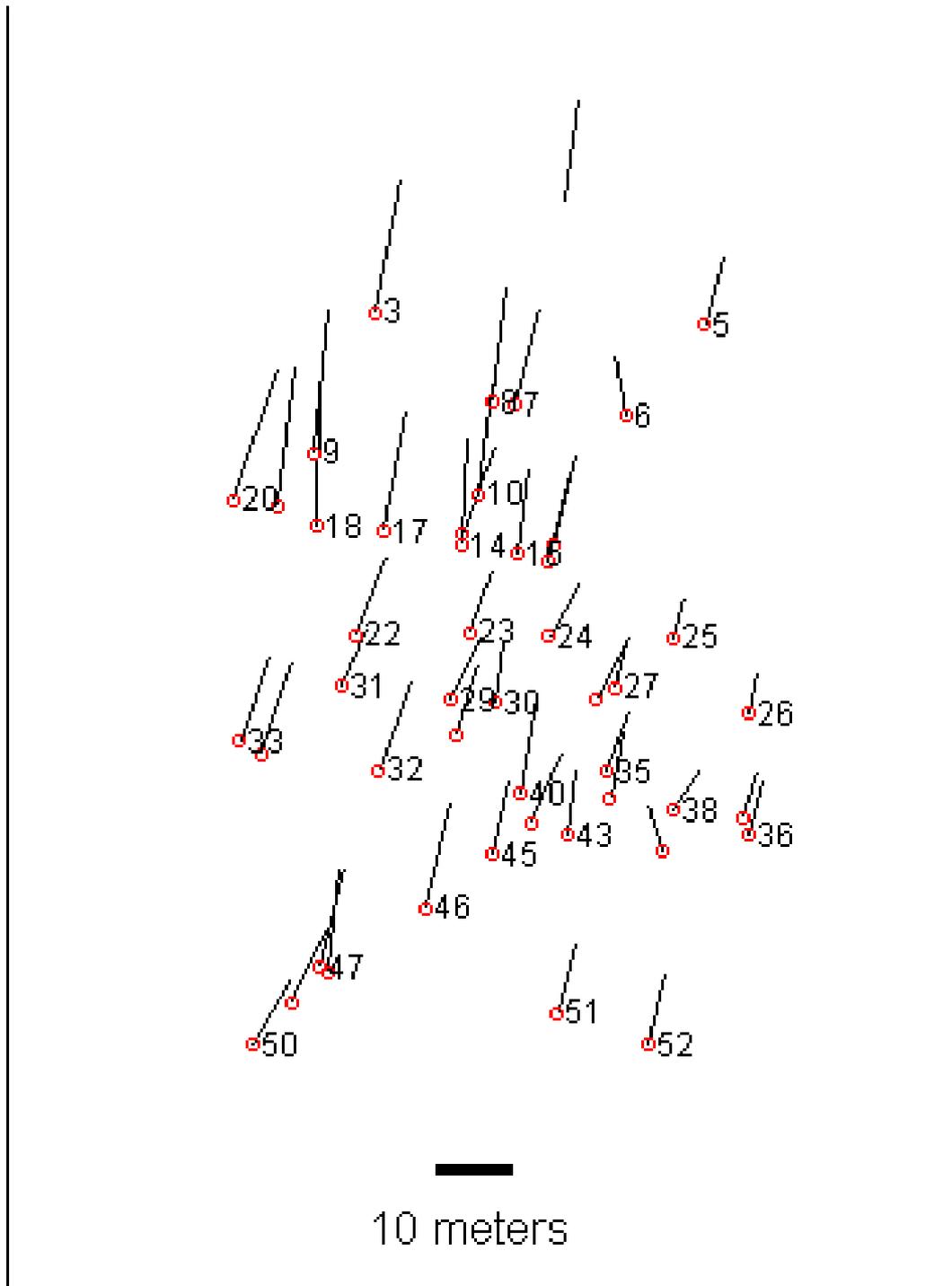


Figure 3 Directions and lengths of offsets before registration

Doing this research the authors became to wonder if it possible with removing systematic error to correct the product's accuracy class. That's why at first four control points were chosen to registrate the image. Again the control points were measured on registered satellite image and calculated the averages and RMS (Formula 1). Comparing the results to those got

in nature, differences and offsets from different measurements were calculated (dX_2 and dY_2). Finally the satellite image RMS was calculated using formula 2. The results were quite good (Table 2) because RMS is 3.28 m and now we have the accuracy what is suitable to Reference or even Pro product (11.8 m and 4.8 m). As we could see in Figure 4 there are not anymore systematic error – the co-ordinates have differences to different directions.

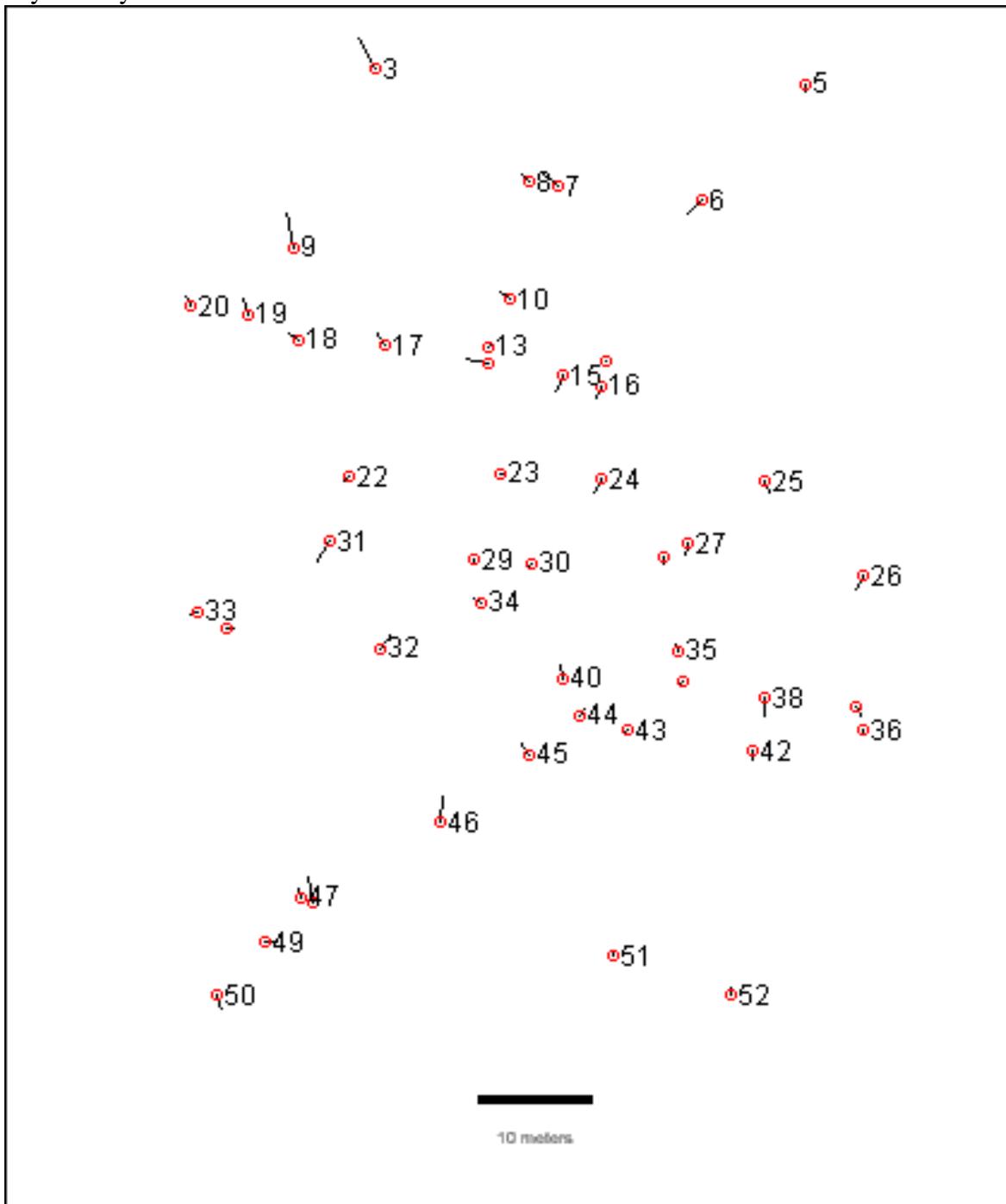


Figure 4 Directions and lengths of offsets after first registration

Getting so good results the authors again wanted to know is there the possibility to correct the image accuracy yet using more control points for registration.

Third measurements on digital image took place after image was registered with 10 control points. From three times measurements the averages were calculated using formula 1. Again these results were compared to the results got from nature. Offsets and differences between co-ordinates were calculated and image RMS also (Formula 2). But the results we got were the same as on picture registered with 4 control points or even worse (Table 2). With this calculations we also have removed systematic error as we can see in figure 5.

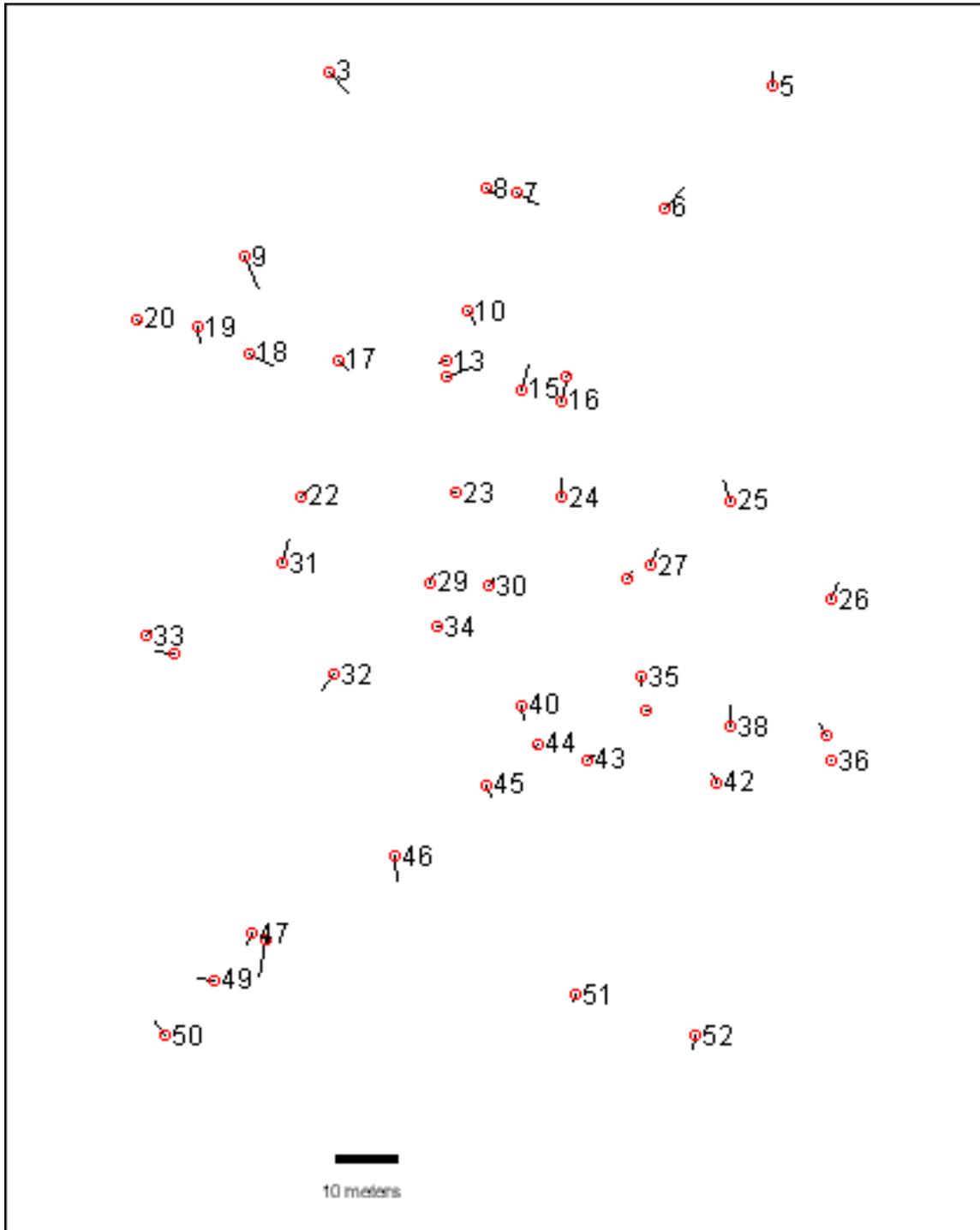


Figure 5 Directions and lengths of after second registration

So we may conclude that it is possible to correct the accuracy of image ourselves and the best number of control points to registrate is 4 because using more points RMS of registration is larger and results are not too accurate.

3.2 Interpretation of Satellite Image

Knowing the accuracy of satellite image we can use it in interpretation. The visual analysis and the visual interpret help us settle different tasks. When the images are numeric like remote sensing digital images are, it is possible to use numeric picture processing solutions to show the images or to process them. We can produce different solutions from picture that satisfies special requirements of users. Changing the picture and improving the picture appearance, the information on the image is brought forth, so that image is visually better interpret for the fulfillment task. For changing the appearance of picture, there are three main methods:

- Changing the contrast of picture to compensate such picture shortage as in photography is named “expose”. Some pictures are too dark – picture is under lightening but some pictures are too bright. In both cases the information on the image is better realized when the contrast of the picture is bigger. Under contrast we can understand the distance of pixel size. To raise the contrast of picture we have to change the contrasts scale so that all the colors from palette, from black to the white, are used. To do it we have many different ways. The best method depends on the picture itself and on wanted result. One way is to change only the image appearance (data on picture should stay same). The other way to change contrast is to create new image so the data values are also changed.
- Changing image from gray tone to color image is sometimes necessary because eye differentiates not only light differences but also color shades. The number of color shades is bigger than number of light differences.
- Sometimes it is necessary to change color image to gray-tone image because then we can understand some situation better.
- One way to bring forth on the picture is compound picture making. Three previous methods have pictures with one band but on compound picture we can present light differences of three band pictures at the same time. On the picture there are millions color tones and on every compound picture we can set the contrast separately from two other compound pictures. The made picture is called false color picture because we see that blue, green or red color is not really blue, green or red.

The purpose of the work was not to do out- or inside interpretation, because it takes too much time and needs helping materials. In the research was investigated satellite images by first visual seeing and got known how is possible to differentiate the objects without any helping maps and plans. To get a generalized result the thematic choice wasn't made.

To interpret the landscape, object's essence and contents were found out using direct and indirect symptoms of interpretation.

Direct symptoms are geometrical and natural:

- Object's imagery is the main symptom. By this can we recognize many topographical elements like villages, woods, fields, rivers, roads, buildings and ditches. Imagery objects can be geometrically regular – manmade (house, road, garden) or irregular – natural (river, lake).
- Imagery's tone or darkness step of satellite image depends on spectral ability of landscape objects to reflect and on smoothness step of surface. Object's tone depends on season when the picture has been taken: in summer, when weather is more dry - tones are more bright, in spring and in autumn when the ground is damp – tones are more dark.

- Object's shadow on the satellite image may be the objects own shadow or someone else's falling shadow. Sometimes the shadow is the only way how to recognize or to determinate object characteristics. Sometimes the shadow may have negative effect – it can cover up objects or elements. Own shadow, other words object's unlighted side, helps determinate spatial form of objects. The clear border between lighted and unlighted part (house) referees to angular form but the slow over going tells about round form. The falling shadow, other words objects shadow on the ground or on the neighbor object helps interpret object contents giving the imagination about its real form.
- Texture of images is the feature which combines all others direct symptoms and complements in turn images tone. Texture does not depend on condition how picture was taking. To interpret the satellite images that are in small-scale the texture has decisive importance. For example woods have typical irregular granular texture, in the sowing of technical crops – usually streaked texture. Some objects have characterized by homogeneous texture – homogeneous grassland, water surface, asphalt square, cornfield.

Indirect symptoms are natural and anthropological:

- Mutual location of objects (road and ditch, houses in the village)
- Mark of human action (field, hayfield)
- Belonging to other object (bridge over lake, crossing with roads) or typical features connections (connection between vegetation, damp and ground type). For example we can take the determination of road classes. If the road is connected with two villages then it is road between villages; if the road ends to one field massive, it's field road; road that crosses the river without the bridge, its ford place; road that crosses the railway – places of carrefour; the break of railway in the mountains – tunnel.

Though the analyzed images are changed with lots of methods to satisfy aims of users, there still is the possibility that the object on image is not identified. Therefore to identify the objects anyway we have to enlarge the images and to rise the brightness.

The readableness of any single object depends on its zooming step. Little objects like a stone, hole, building, single tree, road, buss stop, telephone post need usually bigger zooming than large objects like fields, body of water, woods. But first of all a need to use the zooming depends on the kind of interpretation. For example to determine border of cultivated land the zooming is necessary, it helps to find out where the border is exactly.

Different image types need different contrast. The true color images need to be darkened because it is easier to identify the objects. To identify the types of forest we must use bigger step of darkening and the same is valid to large objects. On the figure 6 is brought the comparison of brightening and darkening steps of the same objects on true color image.

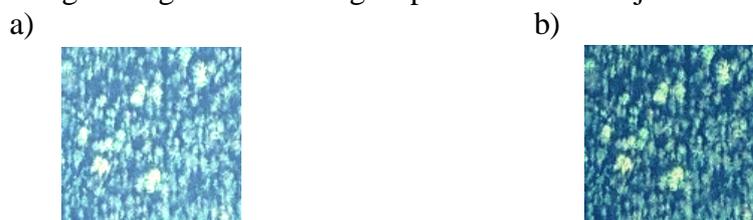


Figure 6 Mixed forest in the primary tone (a) and the mixed forest after darkening (b)

On the false color image the bigger darkening step for body of water was used. To identify different kinds of fields there was used brightening of images. On the figure 7 and 8, there are brought the brightening and darkening steps of same object on false color image.

a) b)



Figure 7 Lake in the primary tone (a) and lake after darkening (b)

a) b)



Figure 8 Field in the primary tone (a) and field after brightening (b)

On the gray tone imagery every object was darkened. On the figure 9 are brought the brightening and darkening steps of same object on gray tone image.

a) b)



Figure 9 Mixed forest in the primary tone and mixed forest after darkening

In the research were used three kind of images because depending on image type one concrete object is better interpretable on one kind of image and the other object on other image. Finally there was found out which object on which kind of image was better to identify on what kind of image.

On true color image the best are to identify:

- bodies of water (dark tone);
- buildings (with typical form and bright color);
- orchard (trees and bushes locating regularly, they are more bright than surface);

- some types of fields like green fodder fields (the place which is cut is bright and place, which is not cut is dark), hayfield with silage packets (hay is in packed to packets), fields with different crops (different crops are with different bright);
- forest (broad – left trees are more bright and coniferous trees are more dark);
- roads (in bright line).

On false color image the best are to identify:

- bodies of water (outstanding dark tone);
- cover of roads (asphalt is darker than gravel);
- some types of field like cut cornfield (straw is on a dark line), ripe cornfield (bright area);
- buildings (with typical form and brighter)

On gray tone image the best are to identify:

- bodies of water(dark tone);
- some types of fields like cut cornfield (straw is on a dark line), green fodder field (area, which is cut, is bright and place, which is not cut is dark), ripe cornfield (bright area);
- building (with typical form and brighter).

When every object in nature has its own typical form and first of all color – water is blue, plants are green, then each color reflected from ground to sensor of satellite is different, but fixed tone. Knowing these tones helps perceptibly to identify the objects. In table 3 is brought the comparison between different satellite image tones with tones in nature on different object.

Table 3 The accordance tones on different kind of satellite images and on nature

Object in nature	Color on true color image	Color on false color image
Water areas	Dark blue	Dark violet
Fields, which are cut	Bright	From bright violet to dark violet
Planted areas	From bright to dark green-blue	From rose to red
Areas without tall plants	From bright to dark green-blue	From rose to dark violet

4. DISCUSSION AND CONCLUSIONS

The using of satellite images in remote sensing is growing field and this is the reason of handling the problem. Surely we have to know and take into consideration depending on the purpose of work which quality and accuracy product we have.

In this research the goal was analyze the accuracy of satellite image and creating database for using satellite image in interpretation. To find out the accuracy of high-resolution (1 meter) satellite image which was *CARTERRA Geo* product comparing co-ordinates on digital image, both in original satellite image and after registration with control points, and in nature were used. Knowing the quality of images we also know their using areas and one of them is interpretation or other visual works.

The results of research were following:

- From differences between control points measured in nature and on the original image we get results that RMS of satellite image was in expected scale (*Geo* product) but the image itself was a bit stretched out and had a systematic error.

- After registration the original satellite image with using control points it is possible to get more accurate image product like CARTERRA Reference or Pro.
- Interpretation catalogue was made being one of the possibilities to use satellite image.

Analyzes of these measurements show that one source of errors would be the way how we connect our control points in nature to those which are on the satellite image. The results we get affirm problems associated with nowadays processing methods of satellite images in enhancing the accuracy of connecting and in counting errors in terrain. The errors connected with taking satellite image to the projection don't exceed the resolution of one pixel and so they stay in required limitations.

Modern methods and technical facilities to orthorectify the satellite images completely according to the demands of projection modification with 1-meter and less resolution images. By eliminating the systematic errors, rotations and distortions caused by terrain topography, and with using "control points", registration and accurate terrain model, it is possible to improve significantly the accuracy of satellite image.

The catalogue is the result of all work in textual and figurative form. The catalogue may be standard to interpret different cartographic works. In catalogue there are the illustrations from each object on three different types of satellite images. There is also seen how difficult it is to identify the object, it is easier to confound with something, is the interpretation at all possible without any helping material or does it need over controlling with outside interpretation. In catalogue there are given those elements, which are helping to interpret, because some of objects can be recognized only through the help of other objects. The catalogue may be the standard, which helps better to interpret satellite images.

In present society there is very important to get fast and high quality information. Different countries are using satellite images because of these features. Although the satellite images are rarely used in Estonia Estonian Land Board has already adopted results of this research.

REFERENCES

- Aaviksoo, K. To the performer of program GLOBE determining landcover types in Estonia . Tallinn, 1996.
 [http://www.ael.physic.ut.ee/globe/globe.UUS!/kiiralandcover.htm]. 11.02.2002 (in estonian)
- Avery, T. E., Berlin, G. L. Fundamentals of remote Sensing and Airphoto Interpretation. New York, Macmillan Publishing Company, 1992.
- Aunap, R., Eilart, J., Peterson, U. Estoina seen from Space. Tallinn, Koolibri, 1998. (in estonian)
- Gibson, P. J. Introductory Remote Sensing: Principles and Concepts. London, Routledge, 2000.
- Meiner, A. Estonian Landcover Database. Geodeet 20/1999. (in estonian)
- Nilson, T. Basics of Remote Sensing of Forests. Tartu, 1994. (in estonian)
- Randjärv, J. Geodesy I part. Tartu, 1997. (in estonian)
- Randjärv, J. Geodesy III part. Tartu, 1999. (in estonian)
- Sabins, F. Remote Sensing Principles and Interpretation. New York, W.H. Freeman and Company, 1987.
- Toutin, T., Cheng P. Demystification of IKONOS.
 [http://www.eumorline.com/common/arhives/july 00/toutin.htm]. 12.02.2002

CONTACTS

Ave Kargaja
Estonian Agricultural University
Kreutzwaldi 5
Tartu
ESTONIA
Tel. + 372 0731 3119
Fax + 372 0731 3154
Email: ave.kargaja@mail.ee

Ina Melnikova
Estonian Agricultural University
Kreutzwaldi 5
Tartu
ESTONIA
Tel. + 372 07313119
Fax + 372 07313154
Email: ina.melnikova@mail.ee

Natalja Liba
Estonian Agricultural University
Kreutzwaldi 5
Tartu
ESTONIA
Tel. + 372 07313119
Fax + 372 07313154
Email: nataly@eau.ee

Tarmo Kall
Estonian Agricultural University
Kreutzwaldi 5
Tartu
ESTONIA
Tel. + 372 07313119
Fax + 372 07313154
Email: ktarmo@eau.ee

Taavi Veermets
Estonian Land Board
Taara Puiestee 2
Tartu
ESTONIA
Tel. + 372 07385107
Fax + 372 07385120
Email: taavi.veermets@maa-amet.ee