

COMPARISON OF INFORMATION CONTENTS OF HIGH RESOLUTION SPACE IMAGES

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ABSTRACT:

The information contents of high resolution space images, usable for mapping, are not only depending upon the image resolution that means in case of digital data, depending upon the pixel size in the object space. Important is also the contrast, the spectral range, radiometric resolution and colour beside the atmospheric condition and the object contrast.

From the area of Zonguldak, Turkey different space images are available like taken by IKONOS, KVR-1000, SPOT 5, IRS-1C, TK350, ASTER, Landsat TM, JERS and SRTM X-band. Of course the information content is mainly depending upon the pixel size on the ground, but this is still quite different for the RADAR images taken by JERS and SRTM. The object identification in these images disturbed by speckle cannot be compared with optical images having the same pixel size. There is a rule of thumb for the relation of the pixel size to the possible map scale, but it cannot be used for ground pixels with a size exceeding 5m because this is leading to a loss of important information which must be available also in small scale maps. The limited radiometric resolution of IRS-1C images is still a disadvantage, especially in dark and shadow areas. The KVR-1000 available with 1.4m pixel size cannot be compared directly with the information contents which should be included with this resolution. The colour information of IKONOS supports the object identification, so the 4m ground pixel size includes a higher information contents like a panchromatic image with the same resolution and the object identification is quite easier. With IKONOS pan sharpened images maps up to a scale 1 : 7000 can be created.

1. INTRODUCTION

The generation of topographic maps by means of space or aerial images requires a sufficient relation between the pixel size on the ground and the map scale. Even if today maps are available in a GIS with their national coordinates, the information contents and level of generalisation corresponds to a printing scale. The required semantic information is depending upon the map scale. So for example individual living houses are not shown in a map 1 : 50 000, only the general structure of the area is presented in such a scale. Of course this is different for a scale 1 : 2000 where also the extensions of a building are available. Under usual conditions there is no problem with the mapping accuracy based on space images, the real limitation is coming from the information contents, that means, which object can be identified during interpretation. Here we still do have the difference between detection and interpretation of the object. We may detect a line, but we may have problems with the interpretation if the line is just a separation between agricultural fields or if this is a path or even road. For military mapping (STANAG 3769) we do have the differentiation between detection, recognition, identification and technical analysis where identification always includes details about the situation of the object not shown in civilian topographic maps. The required pixel size according to STANAG 3769 does not take care about the characteristics of the used image and cannot be a rule for civilian mapping. A rule of thumb for the relation of the pixel size and the map scale is 0.05 up to 0.1mm pixel size in

the map scale – that means for a map 1 : 50 000 a pixel size on the ground of 2.5m up to 5m is required. But the pixel size is not the only criteria for the quality of the images; also the contrast (modulation transfer function) is important like the spectral range and colour information. This may also depend upon the situation of the atmosphere and the sun elevation. In addition the area may be different – we may have some wide roads and large buildings like for example in the USA or in Saudi Arabia or we may have small and bending roads without pavement. Also the specified information contents for the maps may be different – for example in Switzerland we do have a lot of details in the maps, in the USA the maps are quite more general. So there is still a range within the relation map scale to pixel size on the ground.

2. GROUND PIXEL SIZE

The nominal pixel size of the different space sensors is only one indicator for the information contents. For example panchromatic IKONOS images are delivered as projections to a plane with constant elevation with a fixed ground pixel size of 1m independent upon the incidence angle. For an incidence angle of 45° the area covered by a physical pixel size is 1.15m x 1.62m. Of course the information contents of an image taken with 45° incidence angle is not the same like for a nadir view. Also the sensor quality has to be respected. The effective pixel size can be determined by an edge analysis. At a location in the image with a sudden change of the grey value in the object

space, grey value profiles over the edge should be measured in the image. The response to the edge in the image will not be so sharp like on the ground. The inclination of the grey value profile in this location includes the information about the effective pixel size.

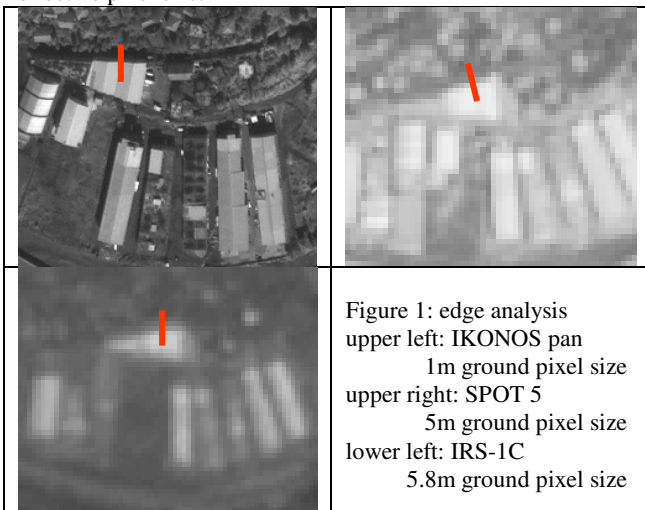


Figure 1: edge analysis
 upper left: IKONOS pan
 1m ground pixel size
 upper right: SPOT 5
 5m ground pixel size
 lower left: IRS-1C
 5.8m ground pixel size

The same edge available in different space images (in figure 1 marked by red line) has been investigated for the edge response.

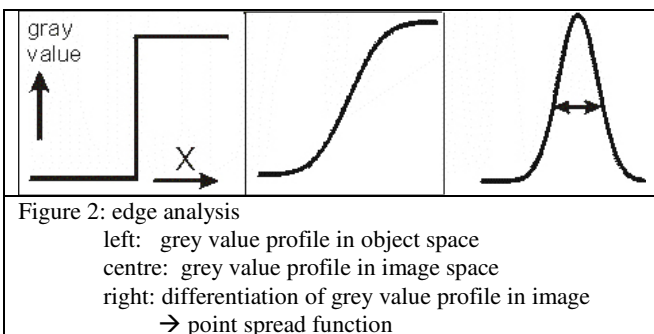


Figure 2: edge analysis
 left: grey value profile in object space
 centre: grey value profile in image space
 right: differentiation of grey value profile in image
 → point spread function

The differentiation of the grey value profile in the image leads to the point spread function. The width of the point spread function at 50% height can be used as effective pixel size. In the area of Zonguldak, Turkey, different space images have been analysed at the same location. Of course not only a single profile has been used for the analysis but all possible profiles at the edge.

	nominal pixel size	effective pixel size
ASTER	15 m	16.5 m
TK 350	(10 m)	13 m
IRS-1C	5.8 m	6.9 m
SPOT 5	5 m	5 m
KVR 1000	(1.4 m)	2.2 m
IKONOS pan	1 m	1.0 m

Table 1: effective pixel size determined by edge analysis

Only the digital images ASTER and IRS-1C do show an effective pixel size larger than the nominal pixel size. The TK350 and the KVR 1000 are originally analogue space photos. The KVR 1000 was delivered digitized with 1.4m pixel size on the ground and the TK 350 has been scanned with a pixel size of approximately 10m. For analogue images of course it is the question if the pixel size used for scanning corresponds to the image resolution and so it is not astonishing if we do have here

larger differences between the nominal and the effective pixel size. Sojuzkarta talks about a smaller pixel size for the Russian space photos, but they are always a little optimistic.

3. IMAGE OVERVIEW

A simple comparison of the different space images available from the area of Zonguldak gives a good impression about the information contents. The Synthetic Aperture Radar (SAR) image from JERS with 18m pixel size includes only some rough information about the area (figure 3). The information contents of Radar images cannot be compared with optical images having the same pixel size. Also based on other data there is approximately the relation of 5 between them – 18m pixel size of a SAR images includes approximately the information of an optical image with 90m pixel size. But this is only a rough figure because some details can be identified very well in SAR images. For example in the JERS-image in figure 3, the white spot in the upper left corner is a ship which can be seen more clear in Radar images than in optical images. The Landsat TM image (figure 4) includes with the 30m pixel size quite more topographic details like the JERS image.

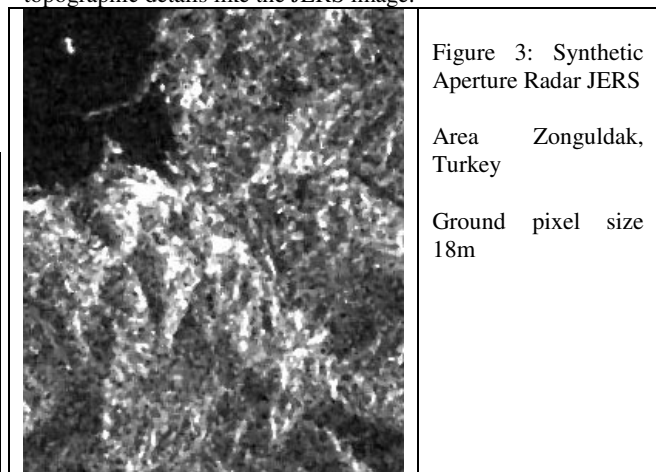


Figure 3: Synthetic Aperture Radar JERS
 Area Zonguldak, Turkey
 Ground pixel size 18m

A comparison between the colour image of Landsat 7 TM (bands 432) and the panchromatic Landsat image with 15m pixel size shows more or less no advantage of the higher resolution of the panchromatic band, but in general, the quality of the panchromatic Landsat image is not so good in relation to other space images with 15m pixel size like for example ASTER. ASTER images do have usually a very good contrast. The combination of the green, red and near infrared band includes the advantage of a very good differentiation also in the forest areas. The colour images in the visible spectral range (red, green, blue) are influenced by the low contrast of the blue channel caused by the stronger atmospheric scattering of the shorter wavelength. In addition the blue and green band do have a stronger correlation, that means in addition to the green and red band the blue band includes quite less information like the near infrared. By this reason also the visible and near infrared (VNIR) combination of Landsat is shown in figure 3.

Landsat TM images are optimal for the classification of the land use. The large pixel size of 30m is averaging the details which are causing problems for an automatic classification based on images with a small pixel size. But only few details required for the generation of a topographic map can be identified. Highways, especially in forest and agricultural areas can be seen, but no more details. Under the condition of a geometric mapping accuracy not better than 1 pixel and a requirement of

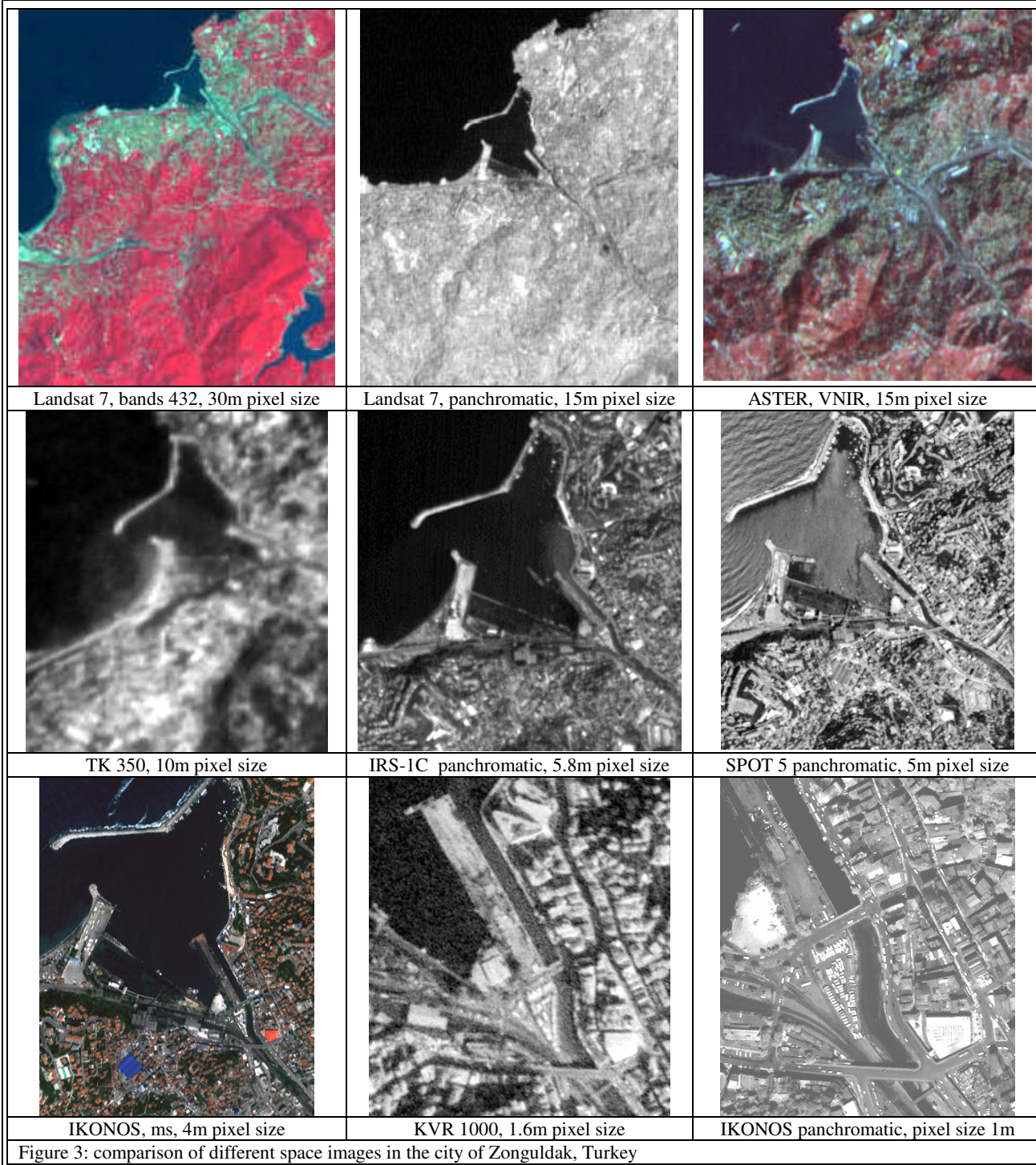


Figure 3: comparison of different space images in the city of Zonguldak, Turkey

0.3mm for the map, this would be sufficient for a map scale 1 : 100 000, but the details required for this scale cannot be seen.

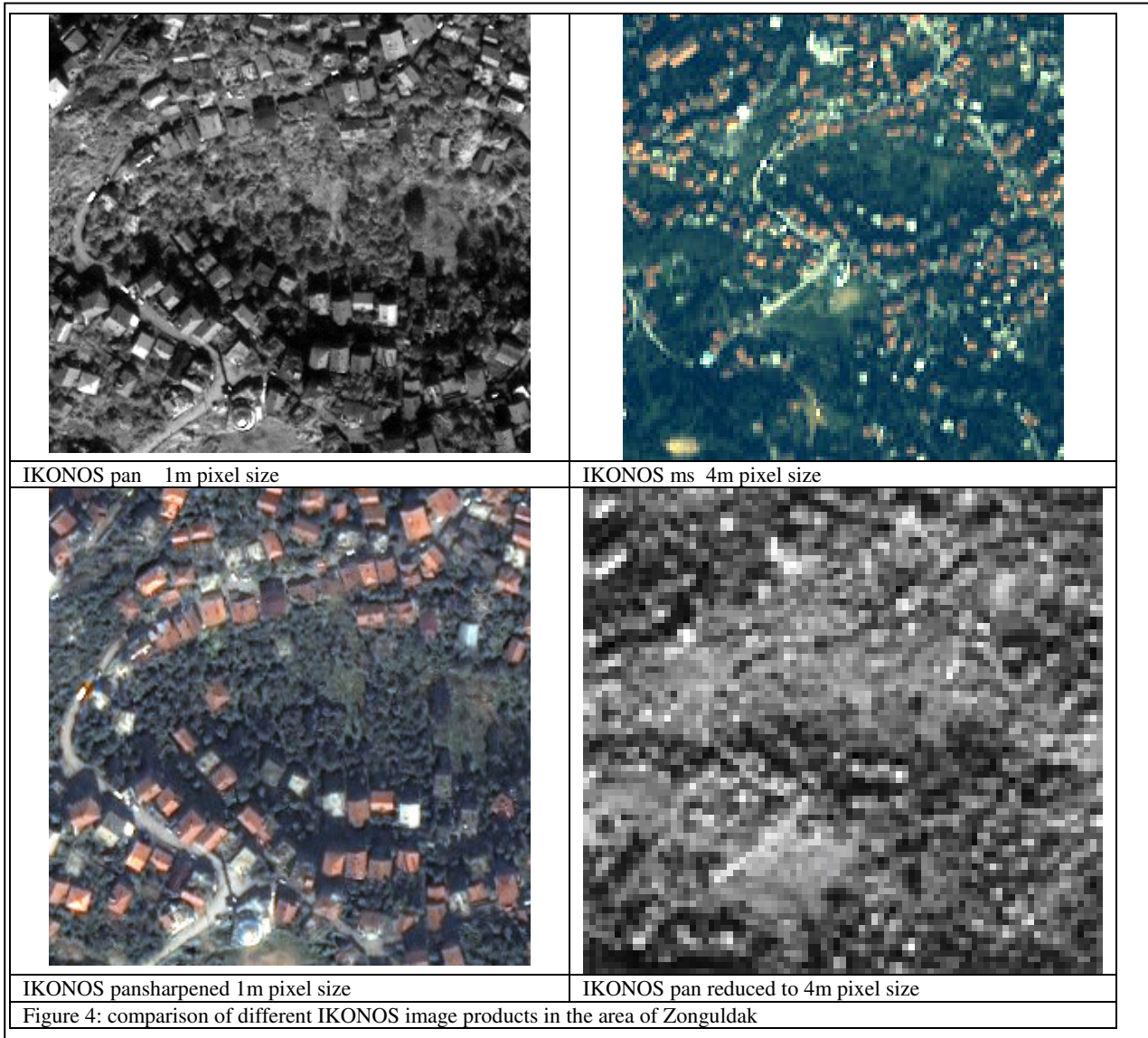
ASTER images do show quite more details like Landsat. Wide roads can be seen but not the details usually shown in topographic maps. The panchromatic TK350 photos available from the Zonguldak area with an effective pixel size of 13m (table 1) do not show all the details visible in the ASTER VNIR image. At first the ASTER image includes the advantage of the colour, but also the contrast of the TK350 photos is not so good. TK350 photos have been flown together with the KVR1000. The concept for the use of both together is the generation of a digital elevation model (DEM) based on the stereoscopic coverage by the TK350 and a monoplotted of the not stereoscopic KVR1000 photos based on such a DEM. So the real use of the TK350 was not directly for mapping purposes. IRS-1C with a nominal ground pixel size of 5.8m includes quite more information like TK350. On the first view the details usually included in a topographic map 1 : 50 000 can

be seen. Nevertheless the effective pixel size in the Zonguldak area was just 6.9m. This may be caused by the limited contrast of the original images resulting on the 6bit radiometric resolution (52 different grey values) but of cause also on the atmospheric conditions at the day of imaging.

The panchromatic SPOT 5 images with a ground pixel size of 5m include quite more the details like the preceding SPOT images with just 10m pixel size. In comparison to the IRS-1C it has the advantage of a quite better contrast and the individual details can be seen clearer. The nominal relation of IRS-1C to SPOT5 and SPOT5 to multispectral IKONOS is approximately the same, but in comparison to SPOT5 the multispectral IKONOS image has the advantage of the colour information. The colour improves the potential of object recognition and interpretation. Especially the interpretation is quite better based on colour images than just with black and white.

The KVR1000 photo with an effective pixel size of 2.2m (table 1) has some advantages for mapping against the multispectral IKONOS image. As a typical analogue photo it is still influenced by the film grain, but nearly all individual buildings can be identified. Of course there is no discussion, the

a required pixel size of 2m for a map scale 1:50000. The rule of 5 pixels is not a fixed value; it is quite depending upon the contrast and colour information. For the interpretation this size may be required, but if we do have additional information like the location of an object on the road, by the size we may get the

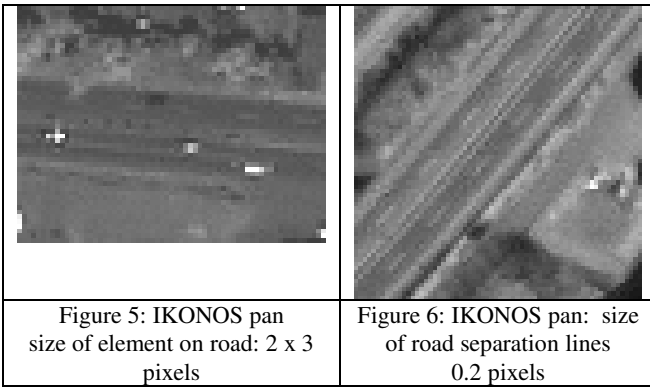


panchromatic IKONOS image with 1m pixel size is quite better. The range of grey values shows also details in areas where we do not have a differentiation in the KVR1000 (see top of building in lower right corner of figure 3) and it shows quite more details (see the cars on the parking place in figure 3, lower centre). Of course the advantage of the colour can be combined with the high resolution of the panchromatic image by a pansharpening (figure 4). This still improves the interpretation.

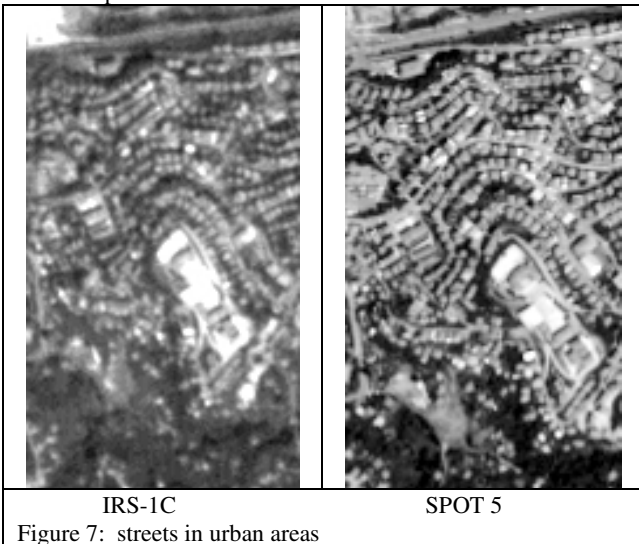
4. VISIBLE OBJECTS

The smallest individual object which can be shown in a map has a size of 0.2mm caused by the printing technology but also the resolution of the human eye in a usual reading distance. For the identification of individual objects approximately 5 pixels are required under usual conditions. If individual objects shall be shown in a map, under this condition a pixel size of $0.2\text{mm}/5 = 0.04\text{mm}$ is required in the map scale. This would correspond to

information of the object (see figure 5). In addition in such a topographic map only under special conditions individual objects are presented. A topographic map in this scale range includes more vector elements like roads, railway lines and water courses. Vector elements can be identified with a much smaller width. In the extreme case the separation lines on roads can be seen even if they do have only a width of 0.2 pixels (figure 6). The required pixel size for mapping is also depending upon the contrast, spectral range and colour information, so in general the situation is quite more complex than just expressed by the pixel size in relation to the map scale.



In figure 4, upper right, in the multispectral IKONOS image with 4m ground pixel size, buildings with a red roof can be identified even if they do have only a size of 2 x 2 pixels. The neighbourhood of the buildings do allow also a save interpretation. Without the support by the colour the identification of the buildings is quite more difficult. In figure 4, lower right, the multispectral IKONOS image has been changed to grey values. In this image the detection and interpretation of single buildings is quite limited and needs a size of 5 pixels.

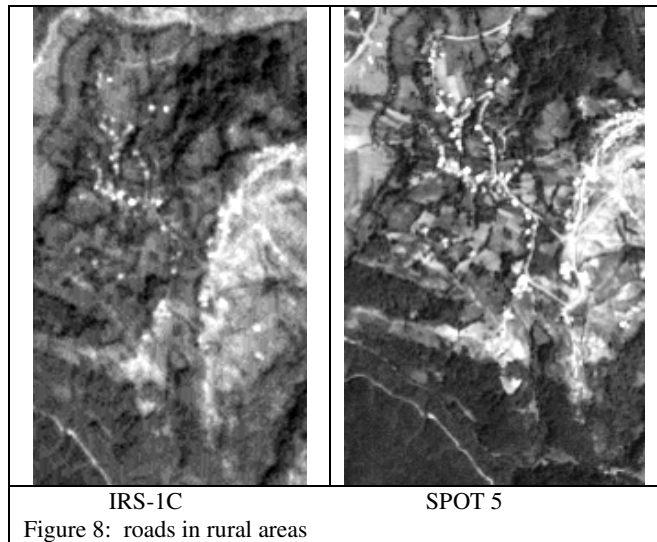


Topographic maps with smaller scale do not show individual buildings, only building blocks or even only the build up area. The identification of the build up area is not a problem with all used space images. The identification of building blocks even can be made with ASTER images having 15m ground pixel size.

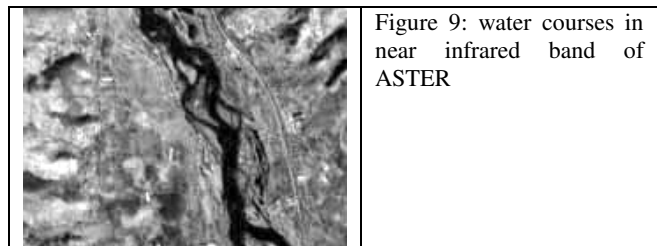
The identification of the road network is very important for topographic maps in the scale range of approximately 1:50000. As obvious in figure 3, in the ASTER and the TK350 images the major roads can be identified but not the minor roads. This is quite different in the images starting with IRS-1C and smaller pixels. In the build up areas in IRS-1C images not in any case the streets can be seen, but the structure of buildings includes the information of a street between two lines of buildings (figure 7 left). The slightly smaller pixel size and better image quality of SPOT 5 (figure 7 right) shows quite better the details of the street network.

In rural areas not 100% of the roads could be identified in the IRS-1C image (figure 8, left). Here we do not have major problems with SPOT 5 (figure 8, right). On the other hand, the

examples in figure 8 do show very clear the difference between detection and interpretation – if we do have the information about the location of a road from the SPOT image, we can see it also in the IRS-1C image. The visible fractions of the road can be connected if we do have some information about the location.



Of course with the better resolution of IKONOS and KVR1000 there are no problems with the identification of the minor road network. The IKONOS images are always in the range of a competition with aerial images. Standard aerial images do have a photographic resolution of approximately 40 line pairs/mm. Based on experiences this can be compared with 80 pixels/mm or 12µm pixel size in the image. Corresponding to this a ground pixel size of 1m is available in aerial images with a scale 1 : 80 000, or QuickBird images do correspond to a scale of the aerial photos of 1 : 50 000.



In the test area Zonguldak not so many smaller water courses are available. For the mapping of water courses the spectral range is very important. In the near infrared band, there is nearly no reflection of the energy from the water bodies, that means, the water courses are black and do have a very good contrast to the neighbourhood (figure 9).

In Wegmann et al 1999 the information contents of an IRS-1C image has been compared with aerial photos 1 : 12 000. The sun elevation of the used space image was very low, so the quality was not so good like in the area of Zonguldak. In the IRS-1C image 56% of the road length was recognised and correctly classified. 9% has been classified as path and not as road, so finally 35% could not be seen. A higher percentage of the not visible roads by error were just identified as field separation. A smaller percentage was covered by trees in a forest. By this reason also in the large scale aerial images 6% of the road length could not be seen. 5% was classified as path. Compared

with the detailed information available in the German digital topographic map system (ATKIS) in aerial images close to 90% of all lines could be mapped without knowledge about the area. In the IRS-1C-images only approximately 55% of all lines could be seen. With knowledge about the area quite more elements could be recognised. As standard procedure for photogrammetric mapping also a field check will be made. By this field check information which cannot be achieved from the images, like names, will be added to the map like also the attributes of lines with no clear interpretation. The field check takes more time if the information contents of the used image are just at the limit of the requirements, so finally it is a question of economy if more expensive, but higher resolution space images should be used or not.

In Jacobsen 2002 topographic maps have been generated by means of a panchromatic IKONOS image and also higher resolution aerial photos. The IKONOS image was affected a little by haze, so the contrast was not so good like usual. In general the information contents of a map with a scale 1:10000 could be extracted. Only few details and some building extensions not important for a map 1:10 000 could not be seen.

	required pixel size
urban buildings	2m
foot path	2m
minor road network	5m
rail road	5m
fine hydrology	5m
major road network	10m
building blocks	10m
Table 2: required pixel size for object identification based on panchromatic images	

Based on several tests, the required pixel size for the identification of different objects in panchromatic space images like shown in table 2 has been found. Colour images may have a pixel size of 1.5 times as much. In relation to the scale of topographic maps, the rule of thumb of 0.05 up to 0.1mm pixel size in the map scale has been confirmed – this corresponds for the map scale 1 : 50 000 to 2.5m up to 5m required panchromatic pixel size on the ground or 3.75m up to 7.5m pixel size for colour images (see figure 10).

An automatic object extraction based on space images is usually not very successful. Even the human operators do have some problems with the object identification and do use the information of neighboured objects for a correct classification. Today the automatic object identification is not on the same level like trained human operators.

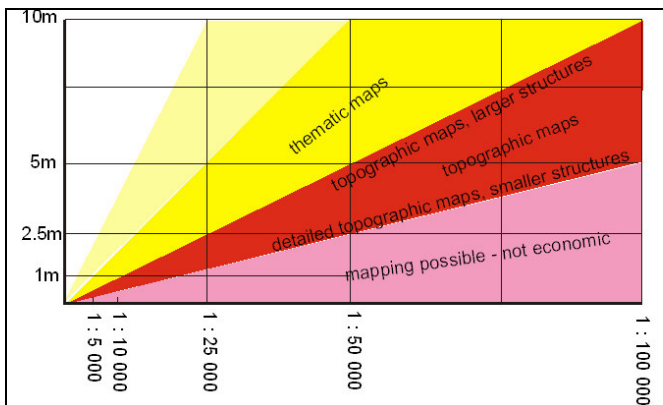


Figure 10: relation pixel size and map scale for panchromatic images, colour images may have a pixel size 1.5 as much

5. CONCLUSION

Space images are an economic tool for the generation of topographic maps. The rule of thumb of a pixel size of 0.05 up to 0.1mm in the map scale has been confirmed for panchromatic images. With colour images the interpretation is quite simpler, so the pixel size of colour images may be larger by the factor 1.5. The nominal pixel size is not in any case identical to the effective pixel size – this should be checked by an edge analysis. VNIR do have an advantage against colour images of the visible range. The blue band includes not so many details and it is strongly correlated with the green band. The near infrared band has quite different information, improves the classification and allows a better separation of the vegetation and water bodies. With the very high resolution space images today we do have a competition to aerial images. The Russian KVR1000 space photo is still also a good tool for mapping, but no actual images are available and no map update is possible.

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