

MAPPING POTENTIAL OF REMOTE SENSING SENSORS

by

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Abstract:

The cartographic potential of existing remote sensing sensors for medium scale mapping has been investigated. These activities mainly concern ground resolution requirements but also include geometric and radiometric aspects. Based on these results, requirements for future needs in sensor characteristics are specified.

To detect objects, to be shown a 1:50 000 map, pixel sizes of about 3 m are required for monocular observation and of about 6 m for stereoscopic observation as well as for monocular updating.

Keywords: Mapping, Sensor, Standards

1. DEMAND FOR MAPS

Nowadays every country in the world has an increasing demand for maps in quantity and quality, to provide Geo-referenced data concerning human activities and natural phenomena, to satisfy the different requirements of society, such as environmental protection, aid for planning purposes, resources management, property protection, etc..

The current status of world mapping leaves much to be desired, see figure 1. Especially countries, with low gross earnings show a lack in medium scale mapping. In particular there is a global deficit in maps of scale ranges between 1:50 000 and 1:250 000. According to recent releases of the United Nations, the world-wide demand for maps of the earth surface at scale ranges of about 1:50 000 is 45 % and of 1:250 000 is 15 % . The annual progress in map production for the 1:50 000 scale range is 2.5 %

and for the 1:250 000 scale range is 1.5 %. According to practical requirements here the scale range 1:50 000 includes 1:25 000 and 1:50 000 maps, the scale range 1:250 000 includes the scales from 1:100 000 to 1:250 000.

In a study for the requirements for mapping from space, prepared for the German government, Konecny and Bähr (1979) already estimated, due to inadequate map revision, about 50% of the available maps are limited in usage.

Consequently the map coverage reported (55% for the 1:50 000 and 85% for 1:250 000 scale range), does not represent the total mapping stage. The annual update rate for maps of the scale range 1:50 000 is 5% and for maps of the scale range 1:250 000 is 3.5 %.

2. MAPPING METHODS

Up to now map production and map revision is carried out by 5 alternative data acquisition methods:

1. Terrestrial survey:

In view of the relatively slow speed and high costs, the classical surveying method is limited to small areas, which eliminates this method for a serious world-wide production and revision of maps.

2. Conventional Photogrammetry

For the task of the world-wide map production and revision of large scales, conventional Photogrammetry using aircraft, is the only acceptable method to obtain maps or orthophotos.

However, the global demand for maps at the scale 1:50 000 cannot be fulfilled by traditional

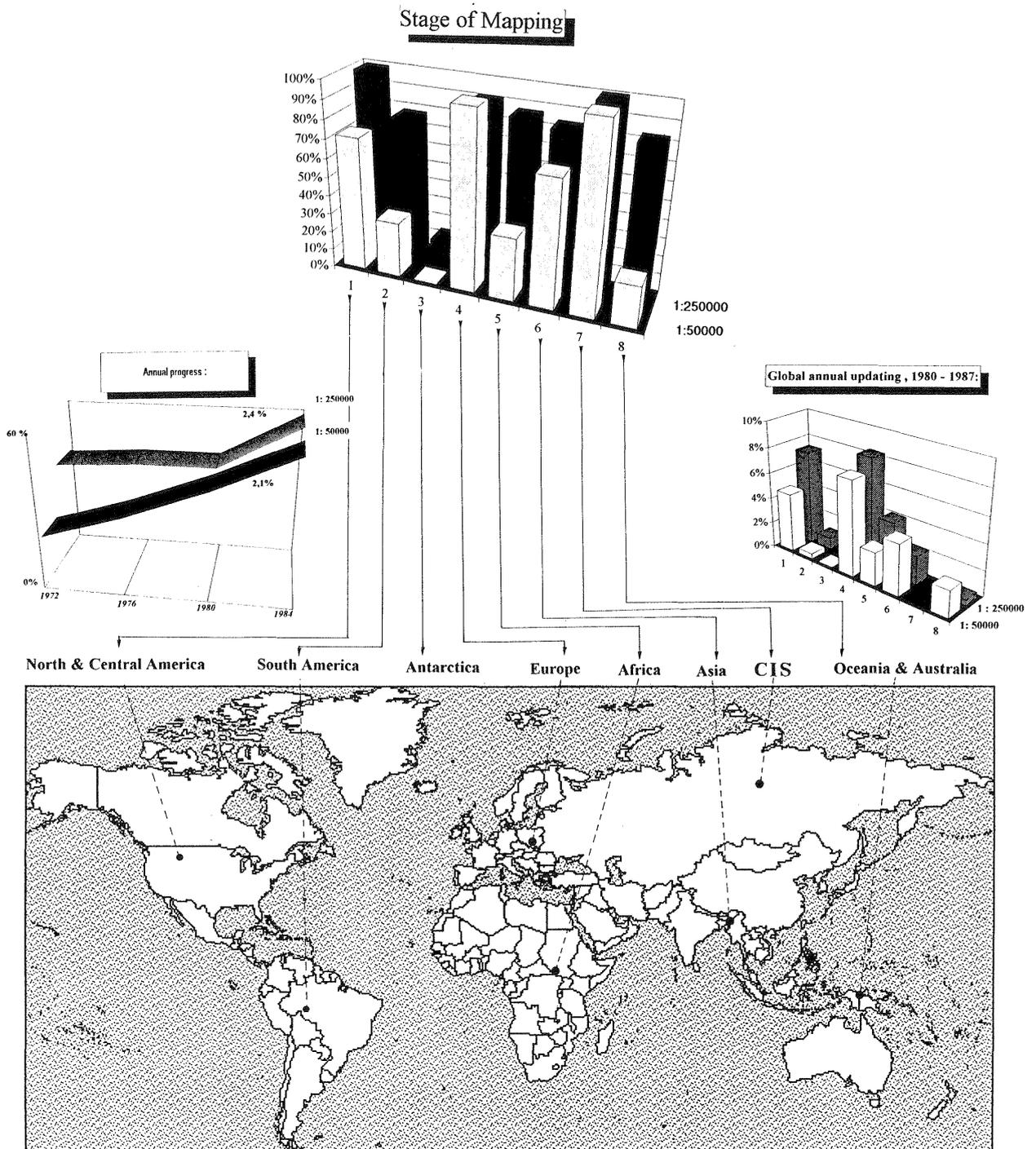


Figure 1: Global stage of Mapping in scale ranges 1:50 000 and 1:250 000, annual progress and updating

photogrammetric methods, because the progress of mapping by this method is still too slow, facing the real requirements of map production and revision, even if orthophototechniques are preferred.

In order to meet the world-wide demand for maps it is necessary to explore remote sensing possibilities from Space:

3. Photogrammetry from Space

The usage of Frame cameras from space platforms is a logical alternative for world-wide mapping of medium scales. This method has been tested very successfully by the Metric Camera and Large Format Camera Mission as well as by KFA, KATE missions etc..

The advantages of frame cameras for Photogrammetry from space are:

- extremely high resolution :

An equivalent pixel size of 2m on the ground is a realistic figure of the mapping potential of modern frame cameras. Therefore a systematic application of space photography seems to be the only alternative, seriously to meet the mapping needs and mapping standards.

- large area coverage:

The coverage of an image taken at an orbital height of 250 km with a frame camera of 30 cm focal length image is about 192 x 192 sqkm.

- available conventional evaluation technique:

The photographs can directly be evaluated with existing technology, like analytical plotters or rectifiers.

- high geometric fidelity

due to stable simultaneous imaging in two dimensions and verifying a strictly controlled camera calibration.

For these reasons frame camera missions from space platforms are suitable to produce and to update world-wide

1) base maps of the earth surface at medium scale ranges around 1:50 000.

2) the Digital Terrain Model(DTM) for the derivation of contour lines.

3) the determination of control points using GPS and the bundle aerotriangulation adjustment.

The disadvantages of applying frame cameras from space are the necessity to carry large film rolls into space and to retrieve them. However the shuttle missions and orbital stations obviously offer this opportunity.

4. Use of scanner and array systems

Space missions with passive scanners (push broom-CCD and line-scanner) are characterised as one dimensional line images. The second dimension is verified by the movement of the scanner with the platform. For topographic mapping purposes CCD video cameras are only acceptable if the images show a ground resolution in the 10 to 30 m range.

Advantages of scanner systems are:

- The CCD sensor operates as a digital system without the need to carry film. The data may be transmitted. Therefore CCD systems are more adaptable to long-life satellites and to multitemporal imaging of cloud free regions.

- Change detection due to multitemporal images.

- The information can easier be separated in different spectral bands. Spectral information may also be significantly extended beyond the visible range.

- The digital form of the data is well suited for automation. Linear push broom scanners as compared to line scanners with rotating mirrors have the advantage of a perspective imaging capability for

the imaged line.

The disadvantages of scanner systems are

- an expensive and complicated technology for data acquisition, data transmission, data receiving, data storage and data processing.

- Limited geometric resolution

The resolution of a CCD system is limited by the data transmission rate of the satellite system. Thus either an extended coverage or an extended resolution may be aimed for. The present technical limitation at an orbit of about 300 km can achieve a minimal ground pixel size of approximately 5m (panchromatic) for a strip width of 80 km. This also corresponds to a minimum integration time limit, considering the satellite velocity. Thus the equivalent photographic resolution of a CCD system is only 12.5 m.

Therefore the application of images of CCD systems for topographic mapping purposes is limited to scale ranges of about 1:100 000. An application of this images for 1:50 000 mapping does not meet the requirements of mapping standards.

- high requirements for the stability

of the spatial attitude behaviour of the sensor and the continuity of forward movement of the platform.

The geometric accuracy of satellite scanner imagery may be restored to +- 1...2 Pixels accuracy.

5. Use of active scanner systems(RADAR)

For topographic mapping purposes the advantage of RADAR, the possibility of cloud penetration, cannot be compensated by the disadvantage, a restricted general topographic detail detectability, e.g., for buildings. At present radar images might just be suited for mapping of 1:250 000 scale ranges.

Due to relative low geometric resolution, radar missions for topographic mapping purposes should concentrate on permanently clouded areas. According to ULABY the equivalent pixel size of, e.g., a nominal 6 m radar resolution for 5 looks is approximately 12 m. For further applications it is highly recommended to compare samples for radar images and conventional aerial photography of the same area, which for the most purposes gives an idea of the superiority of conventional aerial photography for topographic detail interpretation, see KONECNY, SCHUHR(1988). Preferable high resolution radar should be flown. The look direction has to be chosen with respect to topography, taking into account the final appearance of the pseudo plastic effect in the radar orthophoto map. In order to overcome radar shadow, opposite side look direction radar in addition to same side stereo radar should be promoted. For mosaicing purposes the acceptable depression angle, for image parts used for the mosaic, in particular depends on the topography. The geometric approach used, should follow the radar projection laws and not

only empirical functions, like arbitrary polynomial equations. For the future a great improvement in this field is anticipated. Radarmosaics and Radar blockadjustment can bridge areas with lack in ground controlpoints. If this gap extends about one strip width, polynomial equations used for an image to image registration, should be of first order, due to error propagation. In future on board GPS promises to register the flight path with acceptable accuracy, which allows to use a more realistic formulation of the flight behaviour in the radar blockadjustment. Also inflight GPS can replace ground control to a great extend.

In conclusion can be stated, sofar only the photogrammetric frame camera fulfills the requirements for topographic maps in scaleranges of about 1:50 000. Therefore a special space mission aimed at cartographic interests still is required to meet the worldwide demand for maps. Another question has to be answered with regard to the type of map products for the future(e.g., orthophotos at regular intervals instead of conventional linemap and their revision).

3. ESTIMATES FOR SENSOR PERFORMANCE

Sofar the alternatives to meet medium and small scale mapping needs have been discussed. The following shall be seen as a contribution to answer the question, how far acquired images, showing a particular pixelsize can actually be used for topographic mapping. To answer this question, several estimates have been given in literature. DOYLE, 1975, uses the formula: suited mapscale=2 times Pixelsize (in meter) times 10 power 4 to estimate the suitability of digital sensors for mapping. According to this for topographic maps of the scale 1:50000 a ground pixelsize of about 2.5 m is necessary.

At the Institute for Photogrammetry and Engineering Surveys of the University of Hannover three types of imagery have been used for interpretation with respect to the content of medium scale topographic map:

- 1) A stereo pair taken with a RMK 15/23 at the scale 1:50 000 of the City of Hannover(base-height ratio = 0.6) representing an urban area; for interpretation results see figure 2.
- 2) A stereopair taken over an area near Villefranche-sur-Cher with a RMK 30/23 at the scale 1:35 000 (base-height ratio = 0.3), representing a rural area under Western European conditions; for interpretation results see figure 3.
- 3) A stereo pair of a part of the island of Sylt(German North Sea Coast) with a RMK 8.5/23 at the scale 1:125000 (base-height ratio =1.1),

representing an uncultivated area with dunes; for interpretation results see figure 4.

This imagery has been digitized at pixel sizes 2,5 micron, 50 micron, 100 micron and resampled to 200 micron, 300 micron, 400 micron and 800 micron. The resulting images have been interpreted monoscopic and stereoscopic, to derive mapfeatures contained in 1:25000, 1:50000 and 1:100000 maps.

The following topographic features have been extracted: roads and paths, buildings, vegetation(forest, trees and shrubs), creeks and ditches and topographic forms. The mapping potential of this images with respect to these features has been judged as high, good, media, low or blank(meaning lack of particular features), see figures 2 to 4. According to the expectations, the interpretation of the original images is satisfactory for all cases. There is one slight exception, for building details such as ledges, etc., cannot be detected in the 1:125 000 scale image. However this is not significant for the required map content of 1:50000. In order to depict such building details, pixel sizes between of at least 2 and 5 m are required.

The most significant result of the interpretation test is, that stereo-observation is by far superior to monoscopic observation. The advantage of stereo nearly increases proportional with the base height ratio. The comparison between the different areas photographed clearly shows, that the interpretability of houses, roads, land forms, creeks and ditches also varies with the type of the terrain, since urban areas, rural areas and uncultivated areas generally contain different types of housing, roads etc, even though they are of the same topographic category of features.

Concerning the topographic requirements, the most critical features are the buildings. To map them monoscopically a pixel size of at least 3 m is required. Under stereo observation a pixelsize of about 6 m might suffice. This is the requirement for urban areas to map at 1:50 000. For the mapping of roads and vegetation this requirement may slightly be relaxed.

The results of the interpretation of digitized images at 25 micron were identical to those in the originals. Therefore they are not included in figure 2 to 4. This just proves, the observer's eye cannot resolve better than about 5 to 10 lp/mm.

Interpretation under stereo observation was possible for 50 micron and 100 micron pixelsizes. The stereo effect also appears for images showing pixelsizes of 200 micron and 400 micron, but does not aid the interpretation any more and does not permit contouring.

It is interesting, the stereo effect is still unexpected high, if images of different pixel sizes are

Figure 2: Mapping potential of rasterimagery and photos (testsite City of Hannover(Ger))

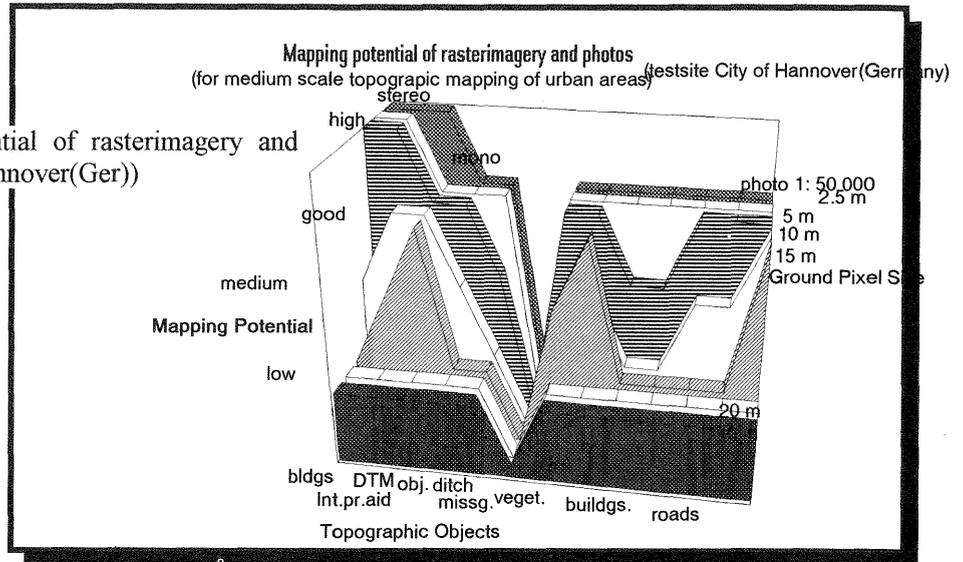


Figure 3: Mapping potential of rasterimagery and photos (testsite Villefranche (F))

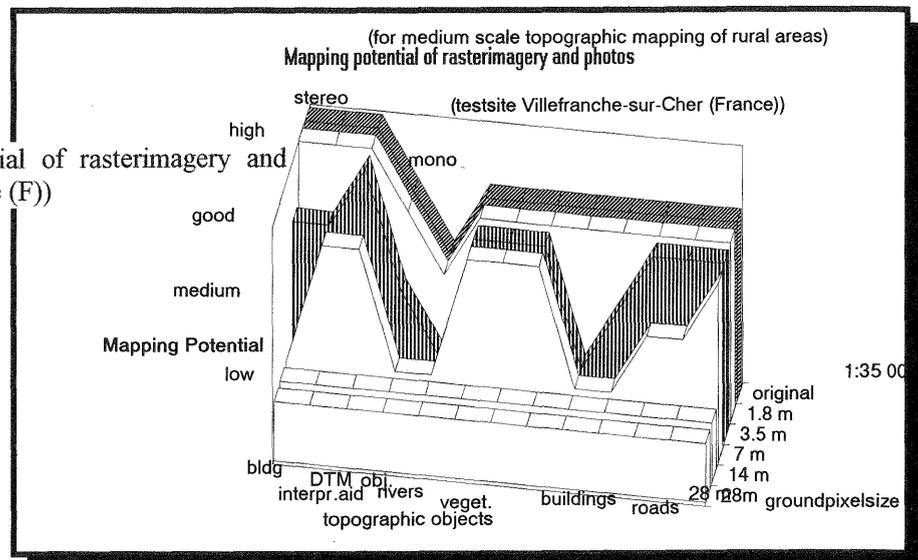
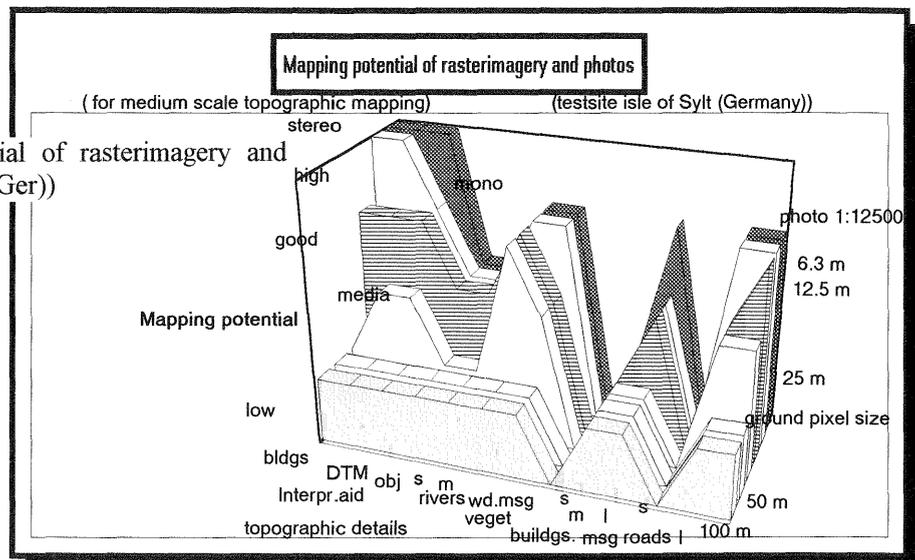


Figure 4: Mapping potential of rasterimagery and photos (testsite Isle of Sylt(Ger))



simultaneously interpreted e.g., a 50 micron image is observed in stereo in combination with a 200 micron stereo partner.

In order to clarify, whether the imagery generated by digitisation of aerial photography is characteristic for the topographic mapping task, using CCD scanners, of course additional imagery has been interpreted. As a sample, in figure 5 is shown the comparison of the interpretation of a Spot image of the City of Hannover (Germany) with the existing linemap of the original scale 1:25 000. Figure 6 shows the result of the suitability of Spot data for features to be shown in an ecological map of the scale 1:10 000.

A more sophisticated comparison shows, photographic images are more than competitive with existing digital methods.

Contrary to aerial photography radar images cannot properly be interpreted to derive the required topographic features, even though particular features relatively clear appear, such as metallic objects (fences, power lines vehicles etc), as well as rivers. The role of radar images should be more a supplementary part or exceptional exclusive for permanent clouded areas.

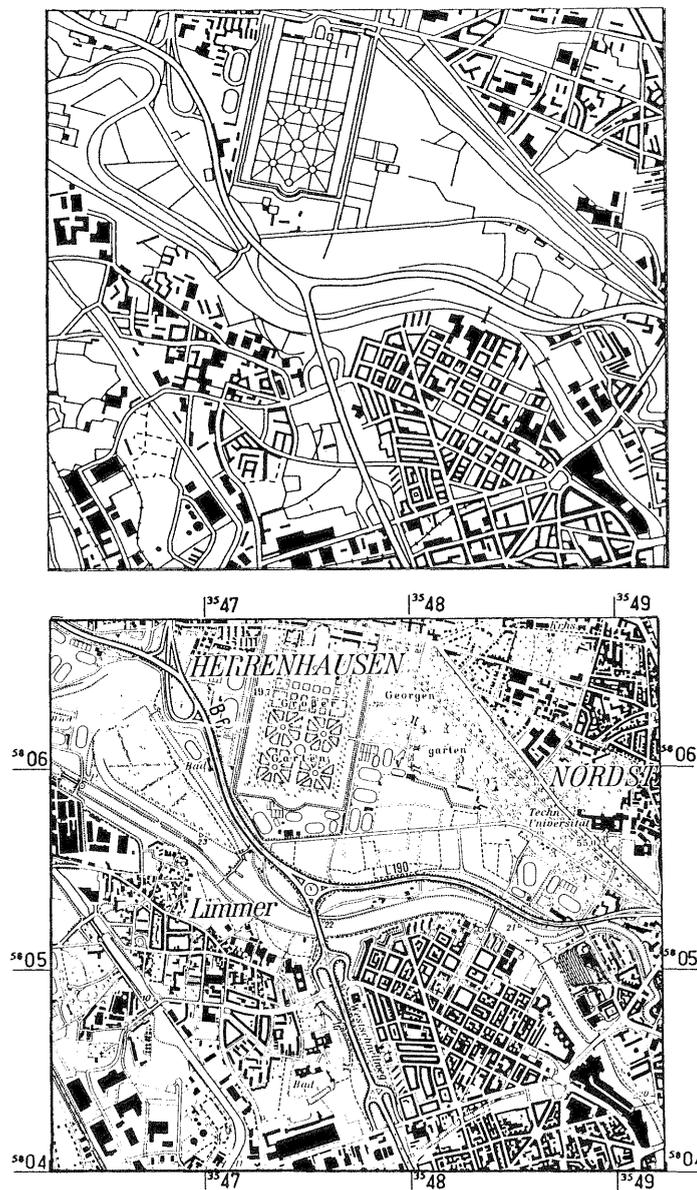


Figure 5: Comparison of the interpretation of a Spot image of Hannover with an existing line map

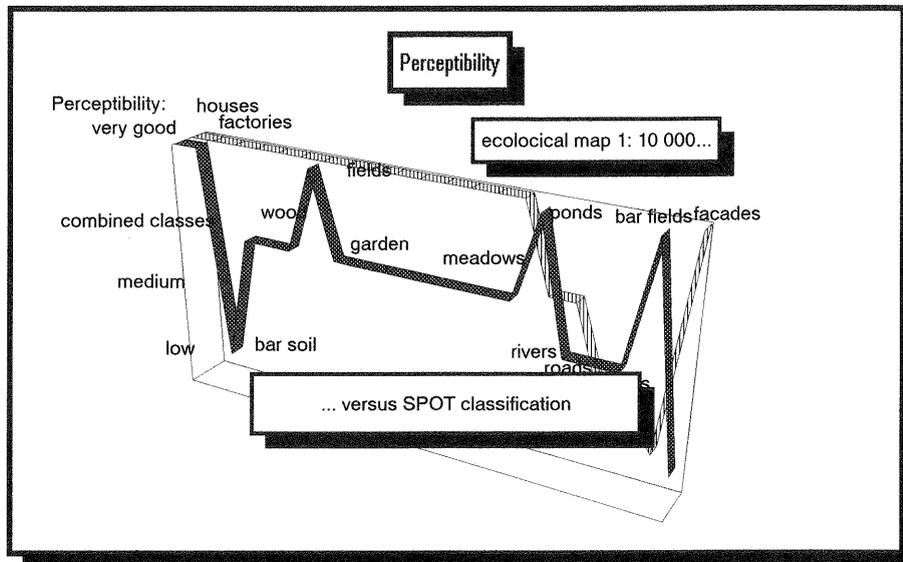


Figure 6: Perceptibility of an ecological map versus a Spot classification.

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