PRODUCING A STATE-WIDE HIGH-RESOLUTION SATELLITE DATA MOSAIC AND USING THE DATA IN PLANNING PROCESSES

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ABSTRACT

Means of producing state-wide mosaics using high-resolution satellite data (IRS-1C) are discussed with reference to Saxony in Germany. Special attention is given to optimisation of exhaustive image-data coverage taking account of data quality, recentness of data, and price. Strategies for georeferencing and attainable geometric correctness are discussed. The optimum scale for picture data of 5m-pixel resolution is 1 : 25,000 and the average geometric error is <0.8 pixel. A variety of algorithms for the computation of fusion products of high-resolution panchromatic and middle-resolution multispectral pictures are tested and an optimised strategy is developed. The handling of gigantic volumes of image data in Geographic Information Systems is then outlined. Four examples of how the data can be used in planning processes are cited: as a means of qualifying regional plans (by creating settlement masks), creating maps of city-block structures (for environmental monitoring), updating biotope maps for landscape planners and visualising landscapes in the context of construction approval for wind-power installations.

1 INTRODUCTION

The demands made of the concreteness of spatial planning are rising constantly. Against a background of increasingly dynamic change notably in urban development, industrial and commercial trends, and encroachments on Nature and landscapes, the need for up-to-the-minute information about spaces is growing. The cost factor alone precludes this need being wholly met with the aid of conventional information sources such as aerial images or on-site mapping. Hence calls for innovative information sources and methods of keeping spatial information systems up-to-date for regional planning purposes are becoming ever more urgent.

One often-mooted solution to this problem involves gaining information from satellite imagery. Up until recently, however, the degree of geometrical resolution of the images produced was not sufficient to support regional planning operating at a scale of 1 : 25,000 or above. Similarly, the average 24-day image replication time as a factor of weather-related information downtime resulted in a recording density that was not sufficient to inclusively cover large planning areas with high-quality, up-to-date image data. This situation has changed in the last few years. The panchromatic images produced by the Indian remote-sensing satellite IRS-1C since the summer of 1996 mean that for the first time satellite imagery with 5m ground resolution is available for operational purposes. Since the related IRS-1D satellite was commissioned in the autumn of 1998, the image replication rate has been reduced from 24 to 12 days. 1999 is set to see IKONOS 2, the first commercial satellite with 1m ground resolution, coming on stream.

Options for maintaining spatial information systems on the basis of IRS-1C satellite imagery and deriving information of relevance to planning processes from these data were investigated within the framework of the “Potential Uses of High-Resolution Satellite Imagery for Regional Planning” project funded by the Germany Research Association (DFG). Using one panchromatic and one multispectral satellite image, first efforts were made to apply IRS-1C data to, amongst other areas, regional planning. The findings suggested the data have considerable potential as a means of qualifying regional planning (concreteness, planning protection) as well as landscape planning, urban planning, and urban ecology initiatives.

These first efforts then needed to be lent added depth as regards both range and subject matter. To this end, a set of satellite image data covering the entire territory of the federal state of Saxony was procured within the framework of a research and development contract with the Saxon State Ministry for Agriculture and the Environment and was prepared to suit the needs of area planning and regional development. The goal was to harness data for day-to-day operations in the Saxon State Office for Geology and the Environment, the three government presidia, and the five Regional Planning

Centres in Saxony. In close co-operation with these bodies, the information potential of IRS-1C data was likewise pointed up. The findings from these studies are set out in the report that follows.

2 SELECTING SATELLITE IMAGES

The state-wide image mosaic being generated is to form a suitable basis for planning work at a scale of 1 : 25,000. This indicates a geometrical resolution at present achieved operationally only by the Indian remote-sensing satellites IRS-1C and the like-design IRS-1D. Further specifications besides the provision of b/w imagery were the computation of colour infrared and natural colour products at a 1 : 25,000 image scale, which presupposes the procurement of multispectral image data. Since there is no sensor at present available that can deliver colour pictures of the resolution required, it is necessary to compute these image products using image fusion techniques. The data of principal relevance for multispectral image data are Landsat-TM, SPOT-XS and IRS-1C-LISS. So as to acquire a high proportion of panchromatic and multispectral image data taken on a single day, a factor of the greatest importance for the computation of good image fusion products, IRS-LISS data were selected for the image mosaic.

2.1 IRS-1C Satellite imagery search

IRS-1C satellite image data are generally logged in the ISIS satellite image search system within 24 hours of their acquisition. Run by the German Aerospace Research Establishment (DLR), this database system facilitates rapid online searches of IRS satellite image data using the search criteria geographical location (dot or rectangle), time/date taken, and maximum degree of clouding. Within a few seconds the user is provided with details in tabular form of all available image data together with the date they were taken, path and row details, and the degree of cloud. Individual pictures can be loaded as survey shots (Quicklooks). This enables a rough preliminary assessment of image quality (large cloud and haze areas) to be made and the approximate image location to be established (geographical coordinates of the four corners).

2.2 Image selection criteria

When compiling the images needed to generate an all-inclusive image mosaic, the criteria of image quality, recentness of data, time of year taken, area coverage and cost need to be optimised, a complex process at times requiring conflicting relative benefits to be weighed up against one another.

Image quality:

Satellite images are recorded and offered for sale regardless of atmospheric conditions obtaining at the time they are taken. The level of cloudiness of shots taken can be inspected in the search database in 10% stages relative to the overall area. If the level of cloudiness of a shot is greater than 0 and there is no other sufficiently recent cloudless shot available, it is important to be able to evaluate the cloud in terms of location and the area it covers by means of the Quicklook function. It may be possible to access cloud-covered sections of an image in neighbouring scenes, or else the areas involved may be rural ones in which no change of use over earlier shots is to be expected, in which cases image information can be dispensed with. Since IRS Quicklooks are only available at 1 : 500,000 scale, only larger patches of cloud or haze can be discerned in them. Of a total of 17 panchromatic and 5 multispectral IRS image products processed, only a few were completely free of cloud.

Recentness:

Data need to be as recent as possible, since this is precisely the advantage of satellite imagery. Thanks to the good weather in the summer of 1998, 100 % of the area of the state-wide image mosaic is covered by very recent high-quality LISS shots and 99.7 % of the area by PAN shots from 1998 and 1997. Table 1 provides exact figures.

<table>
<tr><th>Sensor</th><th>When taken</th><th>Number of images</th><th>Area [sq. km]</th><th>Share of overall area [%]</th><th>Proportion of overall area with cloud cover [%]</th></tr>
<tr><td rowspan="3">PAN</td><td>1998</td><td>10</td><td>9,715.2</td><td>52.6</td><td rowspan="3">0.27</td></tr>
<tr><td>1997</td><td>5</td><td>8,709.3</td><td>47.1</td></tr>
<tr><td>1996</td><td>2</td><td>53.9</td><td>0.3</td></tr>
<tr><td>LISS</td><td>1998</td><td>5</td><td>18,480.3</td><td>100.0</td><td>0.06</td></tr>
</table>

Table 1. Overview of IRS-1C scenes in the state-wide image mosaic

Where the location of satellite data images was such that areas were covered twice, it was ensured following image rectification that the most recent data were incorporated into the image mosaic by making appropriate use of Cutlines.

Time of year recorded: Besides the recentness of shots, the time of year they were taken also plays an important role of course. In this case recourse was had exclusively to summer shots, since these shots facilitate in-depth assessment of vegetation for the purposes, for instance, of biotope mapping or image classification. With the sun at or near its highest, shadows are likewise at their shortest in summer.

All shots for the image mosaic being generated were to originate as far as possible from the same time of year, ideally having been taken on a single day. This is only possible for shots within a path (from north to south), since these data are captured continuously during overflight. Neighbouring scenes in an east-west direction originate from different overflights, meaning that there are 3 days between these shots (during which time cloud conditions will have completely changed as a rule). It is also frequently necessary to make use of images from different times of the year when putting an image mosaic together. Radiometric matching of shots is required in such instances. Where an image fusion of panchromatic and multispectral data is to be effected, the satellite image scenes should be from the same date. If this point is not observed, there is the possibility with some image fusion procedures, such as for instance the main component transformation method, of serious colour discrepancies between shots owing to the divergent spectral behaviour of the different areas (cf Section 4.2).

Area coverage: Area coverage can be optimised through the selection of appropriate image products (full scene, quarter scene, sub-scene) or else by making use of the shift option, it being possible to shift image scenes within an overflight from north to south in 10% stages. If allowance is made for cloud in a neighbouring scene, this function can aid the cause of area coverage in a major way. Scene shifts are only possible for full scenes though.

The aim was to completely cover the surface area of the federal state of Saxony using one panchromatic and one multispectral set of IRS satellite images. To save on costs, every effort was to be made in the process to avoid double coverage due to the location of scenes. Neighbouring IRS scenes overlap by as much as 50 % in our geographic latitudes (50°), whilst at the same time there is no assured overlap with the next path but one. A significant amount of "double coverage" was thus inevitable. Progress was further hampered by the fact that, as became evident in the course of the project, the exact scene location is only cognisable once geometric rectification has been concluded. Prior to purchasing an IRS satellite image, it is only possible to assess the location on the strength of the four corner coordinates. According to statements by Euromap, however, these deviate on average by up to 5 km from the actual scene location. More precise information on the location of images is only accessible, using the four corner coordinates in the image header, once the images have been bought. Here, too, however, mean deviations of 3 km were identified. (In one case there was a 7 km deviation. A sensor had been swivelled without this being entered in the image header.) In the final analysis, then, only georeferencing can establish the true location of the satellite image.

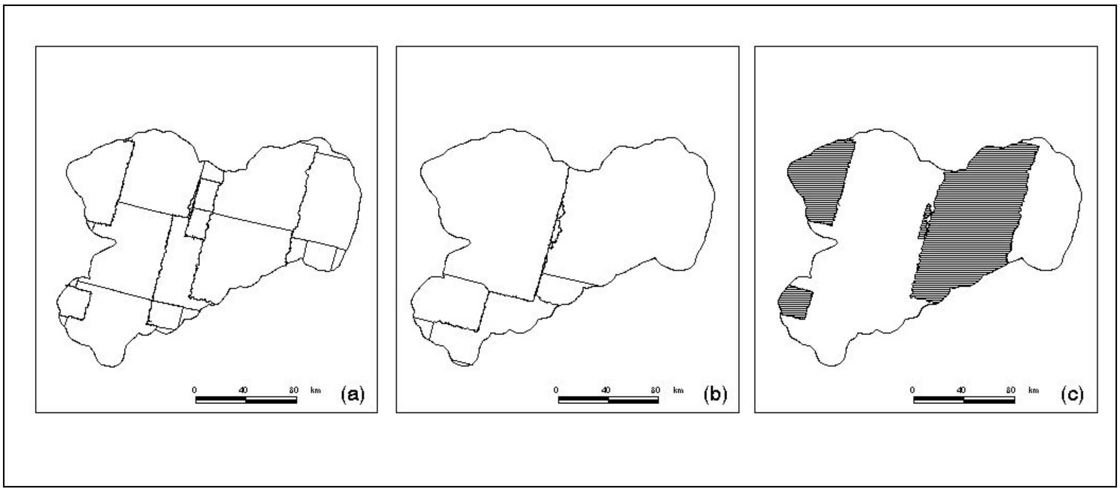

Figure 1. Locations of image scenes in the state-wide image mosaic (a) pan, (b) liss, (c) areas covered on same day

The imprecise particulars concerning scene location led to a situation once rectification and superimposition had been carried out whereby a strip approx. 500 m wide to the south of Riesa was not furnished with panchromatic image data for a length of over 30 km. Two panchromatic sub-scenes had to be additionally ordered here, the costs for which were assumed by the satellite image distributor Euromap. The locations of image scenes are shown in Figure 1.

Cost: Satellite image data are still sold more or less at a fixed price. This is the case as regards the various distributors (who ultimately acquire all data of a given type from a single source), image quality (no deductions for high levels of cloud or hazy areas), and the number of image data bought. Volume discounts of at most 5-10 % are given for recent data. The greatest problem, however, and this is something that is very counterproductive to the marketing of satellite images is the dearth of options for choosing one's own area boundaries. It continues to be the case that full, quarter, or sub-scenes have to be bought even if only a few square kilometres are required. This is an area where urgent action is needed. The cost of generating the state-wide image mosaic is shown in Table 2 below.

Image type	Image size [km]	Price of one image [€]	Price per sq. km [€/sq. km]	Number of images	Total price [€]
PAN full scene	70*70	2,450.-	0.50	8	19,600.-
PAN sub-scene	23*23	750.-	0.14	7	5,250.-
LISS full scene	140*140	2,650.-	0.14	3	7,950.-
LISS quadrant	70*70	1,650.-	0.34	2	3,300.-
Overall (LISS and PAN)			1.90	20	36,100.-

Table 2. Overview of data costs for the individual scenes of the image mosaic

As Table 2 indicates, the figure of 1.90 €/sq. km represents a realistic all-in data price in respect of the area required. The surplus sum compared with the individual shots is an inevitable result of double coverage of the area and superfluous image components following the sizing of scenes from the satellite shots.

2.3 Problems selecting and procuring images

To encapsulate, it needs to be stated that the compilation of an all-inclusive satellite image mosaic continues to represent a difficult optimisation task that will have to be given better support in future if satellite image data are to become part of planning practice on a large scale. The following points require attention in the near future:

– More accurate details of scene location. Ultimately an accuracy <1 km is required, especially given a low degree of overlapping of image data or at the boundary between two areas under examination. The current mean accuracy of 3-5 km is not sufficient.
– Better software support in the selection and compilation of large image mosaics. It is possible, for instance, to imagine a GIS-driven program tool which computes an optimised image selection with regard to scene location, possible image shifts, image quality and the area to be covered.
– The purchase of data for random area sizes, by the square kilometre for instance, would be desirable.

3 IMAGE PREPROCESSING

Given the very good quality of data and in the absence of a suitable software program, atmospheric correction of image data was dispensed with.

3.1 Georeferencing

To be able to knit satellite image products into a mosaic and superimpose them with other geodata, it is necessary to georeference them. The greatest possible rectification accuracy needs to be achieved here, since the non-scale digital image products can, for instance, also be displayed at large scales and superimposed with other geodata. But the resolution of the image data puts limits on the accuracy of georeferencing and hence, ultimately, on the degree to which the images can be enlarged.

In the course of the project, the panchromatic image data were rectified on the basis of TK25 maps and the multispectral LISS scenes subsequently treated in the same way using georeferenced PAN data. Georeferencing is effected on the basis of a mean 45 pass points following non-parametric rectification of the second order. Ground elevation data were not available for the whole area and it was necessary as a result to forego orthorectification. Despite the fact that the terrain in the approx. 20,000 sq. km of area under examination reveals differences in elevation of 1,100 m, a high mean rectification accuracy was achieved (Table 3). So as to likewise achieve high geometrical accuracy at the boundaries between the individual part-images, homologous pass points were used in image overlap areas.

Sensor	Number of images	Number of pass points	Error (x) [pixel]	Error (y) [pixel]	Overall Error [pixel]
PAN	17	47(20.9)	0.61(0.32)	0.50(0.08)	0.80(0.30)
LISS	5	45(7.2)	0.16(0.02)	0.15(0.03)	0.23(0.03)

Table 3. Rectifying errors with IRS-1C image data mean value with standard deviation in brackets

Overall it can be deduced that the inner geometry of the IRS-1C data is very good and can be rectified with a mean error of <0.8 pixels (corresponding to 4 m) for the PAN data and <0.25 pixels (corresponding to 5 m) for the LISS data. With the aid of orthorectification it ought to be possible to achieve mean rectifying errors of <0.5 pixels for panchromatic shots.

3.3 Mosaic formation

The aim of this process stage is to generate an overall image using the individual rectified satellite scenes. It may be necessary to this end to effect radiometric matching of scenes. Where areas are covered more than once it needs to be decided which image is best-suited for the final mosaic. The image mosaic was compiled applying the “best quality goes before greatest recentness” principle.

Where images recorded on different dates are fitted together, the image edges are always very pronounced due to recording-related differences in colour and grey scale values, and these impair the overall impact of the image. This is particularly noticeable in rural regions, in which large, comparably homogeneous stretches of field display differing grey scale values depending on the nature of the vegetation. To avoid this, lines (Cutlines) along use boundaries were digitised. These lines, which determine image selection in the overlapping areas of individual shots, yield image mosaics devoid of troublesome image edges.

Lesser geometrical inaccuracies at image edges were mitigated by taking a sliding grey-scale-value mean within a strip with an overall width of 4 pixels (corresponding to 20 m in PAN and 160 m in LISS) along the boundary lines (intersection type: feathering with Cutline). Histogram matching was only performed within this narrow overlapping area and then only if the scenes had not been shot on the same day. This procedure allows the original intensity values to be largely retained.

4 IMAGE COMPOSITES AND IMAGE FUSION

4.1 Computation of natural colour composites

Multispectral LISS data from the IRS-1C sensor display colour infrared composites owing to their channel location. This form of display is particularly appropriate as a means of assessing vegetational vitality, though it presupposes greater interpretative experience on the part of the image interpreter than a natural colour composite. The ever more widespread use of remote sensing data, most recently also in the consumer sphere (D-SAT1, D-SAT2 etc.), is enabling natural colour products to become increasingly established in the marketplace. Since IRS-1C LISS data do not feature a blue channel, it was necessary to compute a synthetic blue colour channel from the green, red, and infrared channels. Simple synthesis procedures such as computation using the formula

$$\text{blue channel} = (3*\text{green channel} + \text{infrared channel})/4 \qquad (1)$$

did not produce satisfactory results. To achieve optimum results resort was had here to the extensive experience of the satellite image provider Euromap(GAF), which augments the original LISS data through computation of a synthetic blue channel on request. Further information on the processing technique is corporate know-how and hence was unobtainable.

4.2 Image fusion

Image fusion of a high-resolution panchromatic and a lesser-resolution multispectral image enables a colour image product with the geometric resolution of the panchromatic image to be computed. The goal of the image fusion process is a fusion product of high geometrical image quality (retention of the structural information in PAN) and at the same time high spectral image quality (retention of multispectral image information). Comparison of image fusion products within the framework of process evaluations must accordingly also be effected separately in respect of these two target criteria. For the purposes of determining spectral image quality, therefore, the present study establishes the correlation coefficients of 3-channel LISS images with the 3-channel image fusion products computed on the basis of those images for various fusion methods investigated. The geometrical image quality was determined and compared through visual assessment of the fusion products and the evaluation of profile lines through highly frequent image structures in the fusion images.

Diverse fusion procedures such as main component and IHS transformation act on the principle that the panchromatic image signal is identical to the sum of the three colour channels in the colour image. In the case of IRS-1C data this does not apply, since the LISS image does not feature the visible blue channel (contained in the panchromatic image) but does have an infrared channel (not present in panchromatic data). Hence, when assessing procedures for fusion computation of IRS-1C image data, it is necessary to differentiate between infrared and natural colour products.

The following six fusion methods were implemented and the image quality of the respective fusion products visually and quantitatively compared:

IHS	-	RGB-IHS colour space transformation
WTA	-	modified RGB-IHS colour space transformation
PCA	-	main component transformation
BROVEY	-	fusion on the basis of averaging spectral channels
LMM	-	fusion on the basis of local mean values
LMVM	-	fusion on the basis of local mean values and standard deviations
HPF	-	fusion using high-pass filters

The following conclusions can be drawn from quantitative and qualitative comparisons of the fusion products:

– The best fusion results notably with regard to geometrical quality are produced using the PCA method, though only when applied to LISS data with a synthetic blue channel. Where the original LISS channels are used, results are unsatisfactory, since there is no spectral overlapping here between PAN (0.5-0.75 µm) and LISS data (0.52-0.86 µm).
– In the case of computation of a fusion product with the original LISS bands for the purpose of generating a high-resolution infrared image, the best results were produced using the high-pass filter (HPF) method.
– The best spectral quality was achieved with the LMM and LMVM processes, though in these cases geometrical quality was less than impressive.
– HPF, LMM and LMVM, and WTA fusion proved to be robust and largely non-dependent upon the image provided.

On the strength of these findings the natural colour product was computed using main component transformation and the infrared product using the high-pass filter method. Though the overall results in the case of the natural colour product were very good, attention needs to be drawn to the following image faults that did to an extent arise. Agricultural areas display unrealistic red, green, and indeed yellow colouring in some cases. This is due to differing image signals in these image zones as a result of differing vegetation cover where the PAN and the LISS scenes were not shot on the same day. Haze and cloud areas likewise take on unrealistic blue or yellow/red shades.

5 IMAGE FILTERING AND COMPRESSION

5.1 Image filtering

Filtered images should only be used in conjunction with a specific interpretation task, i.e. by the user of the image data themselves. The situation in this respect in the federal state of Saxony is that neither the bodies that manage area planning registers nor the Regional Planning Centres – the former working with ArcInfo, the latter with ArcView – have facilities for filtering images. Whereas, with ArcInfo, image filtering is only possible via the GRID auxiliary module, with ArcView the Image Analyst auxiliary module is required. Neither of the above-mentioned entities has access to these auxiliary modules. The task thus involved prudent image filtering, which aids identification in most interpretation tasks.

Following comprehensive pre-tests, edge focusing in a window 5*5 pixels in size was selected from the wealth of potential image filters for this project. This yields a more sharply-focused representation, especially of richly structured urban areas – the interpretation of which is of particular importance – at the optimum scales for PAN and LISS data, i.e. 1 : 25,000 and 1 : 100,000 respectively. If larger image enlargements are chosen – scales of 1 : 50,000 upwards for the

LISS image and 1 : 10,000 upwards for the fusion products for instance – this can lead to incipient image artefacts (overdrawn edges, fuzziness in homogeneous image sections). For this reason, zoom displays should be effected on the basis of unfiltered, georeferenced data.

5.2 Image compression

Large image mosaics take up a huge amount of memory in uncompressed form. This increases at the same rate as area and to the power of two of image resolution. One extremely important aspect in geoinformation systems alongside the question of reducing file sizes relates to the handling of data. In GIS work satellite image data that often function as background information need to be on hand in virtually real-time form. That ultimately necessitates limited file sizes in conjunction with sophisticated viewer systems.

Image compression methods essentially fall into loss-free and “lossy” categories. Depending on the image contents, mean compression rates of no more than around 2-3 can be achieved with loss-free compression procedures, whereas compression rates of 10-50 are feasible using lossy methods. Wavelet-based procedures have now begun to prove superior to the widely available JPEG method, since they facilitate higher compression rates together with improved image quality (no block artefacts). The LizardTech company has developed an image compression program based on wavelet transformation that is called “Multiresolution Seamless Information Database” (MrSID). This program delivers high compression rates coupled with very good image quality. Besides the compressor, there is also a viewer for the program’s own SID image format that is very convenient to use with extremely rapid image loading times. In addition to the viewer, there is also an extension for ArcView available that is an integral constituent of ArcView from Version 3.1 onwards. There is also a plug-in solution for PhotoShop. All viewers are free of charge and can be called up via the Lizardtech homepage (www.lizardtech.com).

MrSID compressors and viewers were subjected to exhaustive trials as part of the project. These yielded very good results in respect of the compression rates achievable, image loading times, and the handling of very large amounts of image data in geoinformation systems. Minimal impairments of image quality only begin to arise given compression rates of 15 for panchromatic and 30 for multispectral image products in high-resolution displays. Accordingly, this technique was selected for image compression of the state-wide image mosaic. To preclude any image falsification, compression rates were consciously kept low – 10 for PAN and 20 for colour images. The actual compression rates were considerably higher since large areas at the edge of the rectangular images were devoid of information given the shape of the state of Saxony. Table 4 provides an overview of the five state-wide image products together with the file size of uncompressed TIFF data and compressed SID data, the compression rate and the image loading time in ArcView.

Name	Underlying data	Optimum scale	Filesize TIFF [MB]	Filesize SID [MB]	Compression factor	Loading time[1] [s]
NATUR100	LISS+synthetic blue channel	1 : 100,000	343	11.3	30	10.5
INFRAROT100	LISS	1 : 100,000	343	11.3	30	10.5
SW25	PAN	1 : 25,000	1,830	126.4	14.5	5.0
NATUR25	LISS+syn.blue channel+PAN	1 : 25,000	5,500	103.7	53	9.2
INFRAROT25	PAN+LISS	1 : 25,000	5,500	103.7	53	9.2

Table 4. State-wide image products, memory requirements, image loading times, [1]Loading time for the entire image mosaic as a full-image display in SID format using ArcView3.1 on a standard PC (PentiumII/350Mhz)

In addition to the five state-wide image products in SID format, the following were stored on CD-ROM: a vector layer with the boundaries of the scenes from the satellite image data including date taken, a layer with demarcation of cloud areas, and a layer with the administrative boundaries of the three government districts and the five regional planning areas in Saxony.

6 USE OF IMAGE DATA IN PRACTICAL PLANNING

6.1 Use in Area Development and Regional Planning

Regional planning is rapidly gaining in importance in Germany. It has the task of acting as a link in the chain between the land-use plans of municipalities in a given federal state and the development policy of that state. The planning scale is 1 : 100,000, though the underlying data should generally be at a scale of 1 : 25,000. As this is also an ideal scale for displaying IRS-1C colour composites, regional planning bodies regard these data as a very good basis for planning. They enable current land use – which has hitherto been identified using topographical maps and field surveys and is hence very input-intensive, costly, and at the same time not very up-to-date – to be pinpointed using satellite imagery. The data also straightforwardly facilitate settlement masks. Area development bodies are able to gain invaluable information from IRS-1C data concerning the actual state of land use and the approval rating of building applications. One important conceivable area of deployment in future would be a close-to-reality 3D landscape visualisation in the context of major construction ventures such as wind-power installations, bridges, and large industrial and commercial structures, as a means of clarifying issues such as landscape adaptation and visual impact.

6.2 Use in Urban Development and in Municipal Environmental Protection Measures

IRS-1C data permit the mapping of urban structure types (detached/terraced housing, mansion district, block construction etc.) on the basis of a block chart. This form of categorisation readily points up major ecological characteristics of the areas in question such as mean levels of surface sealing. By meshing structure types with database information on population numbers, degree of motorisation, energy consumption etc., important information can be acquired for urban development purposes.

An evaluation of urban green areas using IRS-1C data is also eminently feasible. Roadside greenery can be assessed for vitality, parks can be visibly divided into meadow and woodland. The principal categories of urban biotope mapping can be identified well in the IRS colour composite, though sub-categories can only be discerned in isolated instances. IRS-1C data are capable of significantly reducing the extent of fieldwork when biotope maps are being revised. They are likewise an important source of information when data on newly incorporated municipal districts are required. Where the up-dating of land-use plans at a scale of 1 : 10,000 is concerned, these data are only of limited use. The geometric resolution is only sufficient for the mapping of major new land-use changes here.

6.3 Use in landscape planning

IRS-1C colour composites form a very good basis for the production of up-to-date working maps for landscape planning activities. A panchromatic IRS image with superimposed road, track, and waterway networks, for instance (ATKIS line objects) makes an excellent survey map for terrain mapping operations. Individual use types can be assessed well (green-park areas with a high proportion of single trees for example) and hence the input for on-site mapping cut back or else surveys conducted in a more targeted fashion. IRS data offer a far more detailed interpretation of the landscape inventory than ATKIS, this being of great importance for landscape planning and landscape ecology. Large trees and their state of health can be interpreted well, shrubbery along pathways is visible, and crop boundaries and field alterations can be made out.

7 SUMMARY AND OUTLOOK

IRS-1C are the first satellite image data with which it is possible to carry out planning work at a scale of 1 : 25,000. They form an excellent basis for land-use specifications, settlement masks, for monitoring the success of regional planning and for generating working maps for landscape planning. The problems associated with data mosaicking and data fusion are virtually eradicated. Wavelet-based fusion procedures enable large volumes of data to be compressed into manageable file sizes and data to be used virtually in real-time conditions in geoinformation systems. Thus the data can, as background information for instance, indicate the current area display in GIS, from which in turn spatial information with a bearing on planning can be derived.

A number of tasks need to be solved before IRS satellite data can become a fully-fledged tool in practice however. The satellite image providers need to provide a more flexible data product by offering data for areas of random size and shape and not as hitherto solely in full, quarter, and sub-scenes. At the same time, the licensing arrangements for multiple data use ought to be made more flexible, as the data are of equal interest to a variety of public institutions. The computation of large state-wide image mosaics makes sense in that it enables the data to be used at varying levels in the planning process and in public administration. In this way, multiple processing can be ruled out and hence savings made on data outlay. The relevant databases could be deposited and maintained in an authority's intranet. Given the currently limited bandwidths and the large volumes of data, offline data utilisation will continue to be preferred for some time to come. Procedures will ultimately need to be developed involving semi and fully automated information acquisition from satellite image data for the continuance of spatial information systems. In this respect there is still quite a bit of research work to be performed.

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