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REPORT ON NRSP PERI-URBAN INTERFACE PRODUCTION SYSTEM

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REPORT ON NRSP PERI-URBAN INTERFACE PRODUCTION SYSTEM

Acknowledgement

This project was funded by the NRI as part of the ODA Natural Resources Systems Programme - Peri-Urban Interface, under contract number R6203, Airborne Videography for High Resolution Mapping and Monitoring.

EXECUTIVE SUMMARY

The project was directed to Purpose 1 of the Natural Resources Systems Programme Peri-Urban Interface research; management of peri-urban resources optimised through improved productivity, control of environmental degradation and energy efficiency. It was designed to evaluate the use of airborne small format digital cameras in assessing the landuse of part of the city of Kumasi, Ghana, with a view to developing techniques which could estimate the agriculturally productive land within the city.

Two panchromatic digital cameras were mounted in the Airborne Digital Photographic System [ADPS] developed by the RSGIS Unit at BCHE. These cameras had sensors configured to respond to a peak wavelength of 640 nm with half max of 10.4 nm for the red band and a peak wavelength of 840 nm with half max of 11.7 nm for the near infrared band, and used 18 mm Nikon lenses. The system was installed in a PBN Defender. Data acquired during the aerial survey was stored on PCMCIA hard disks. The area covered by the survey was approximately 3 km east-west by 6 km north-south (see fig.1), located in the south east sector of the city of Kumasi featuring land cover types including industry, housing, infill areas and the peri-urban zone. Aircraft altitudes were at 200 m and 500 m above ground level [AGL] to acquire imagery with ground pixel resolutions of 10 cm and 25 cm respectively. Flight line control was achieved using a GPS and procedure turns.

The 25 cm pixel imagery was used to produce photomaps of the project area which incorporated basic geometric correction. The 10 cm imagery was used to provide high resolution imagery of the city at regular intervals along a predefined transect. The data derived from this was used as a surrogate for the entire area. The data acquired during the missions were archived onto recordable CDs.

A number of constraints were successfully overcome, these relating to weather conditions, pilot experience and base map availability.

The research outputs comprise the original single frame images which have also been formed into large scale mosaics of the study area in the red and infrared bands, as well as False Colour Composites. These are presented on CD as TIF files. In addition, very high resolution images have been geolocated for insertion into a GIS and used as a transect based analysis of city structure from which city zoning can be discerned and, with the addition of crop data, productivity could be estimated

The transect analysis provides a relatively accurate estimation of the cultivated area of the city, and represents the fastest and most cost-effective method. Whole area mapping has value not only within the context of the peri-urban project defined here, in particular revealing the longer term

dynamics of the city, but is also capable of mapping the urban environment at relatively low cost. Multiplicity of use of the photo based products emphasises the cost effectiveness of integrated urban programmes.

REPORT

1.0 Background

The development of more efficient and inexpensive methods of capturing natural resource management information is an important aspect of ODA's peri-urban interface production systems research. The background to the peri-urban research programme is set out else where, for example in the report on the Kumasi Workshop of August 1995. Here comment is limited to the contribution of airborne digital imagery to such data collection.

The Remote Sensing and Geographic Information Systems [RSGIS] Unit at Bath College of Higher Education [BCHE] have developed expertise in airborne High Resolution Videography [HRV] and Airborne Digital Photography [ADP] over a period of three years. Surveys have been conducted in Kenya, Madagascar, Central African Republic and Eritrea. The potential of the systems for use in urban environments has been briefly tested in Kenya. The Kumasi peri-urban project presented an opportunity to exploit the attributes of the ADP system, namely a low cost, fly on demand system that is not dependent on film. The ability to mount the ADP in any light aircraft makes it highly suitable for rapid deployment, and the use of GPS navigation should ensure photo-coverage. The ADP system was selected in preference to the HRV as it produces a higher resolution image which is more appropriate to the task of crop identification. The HRV has half the resolution of the ADP and for coverage of similar target areas at a given resolution, four HRV images are required for each ADP image.

The project brief required that a 6 km (N-S) x 3 km (E-W) area be surveyed at pixel ground resolutions commensurate with identification of the (cultivated) vegetation resource enclosed within the rapidly expanding city. This would include the identification of cultivation patterns (row crops, plantations, plantain groves etc.) as well as the areas devoted to crops. Previous survey work in Kenya had indicated that tree shape and structure, as well as row crops, could be identified at pixel ground resolutions of 15-20 cm. Images were to be mosaiced to form photomaps of the target area, and analytical techniques developed to assess the vegetation resource.

2.0 Project purpose

The purpose of the project was to assess the capability of ADP techniques to provide an informative, cost effective and timely method of natural resource assessment in urban and peri urban areas. More specifically, the project was to evaluate the use of airborne small format digital cameras in assessing the landuse of part of the city of Kumasi, Ghana, with a view to developing techniques which could estimate the agriculturally productive land within the city. The type, area and potential yield of crops, water courses, and urban features were, if possible, to be identified and mapped.

3.0 Research Activities

Two panchromatic digital cameras were utilised in the ADPS, with 18mm Nikon lenses set to infinity and sensors configured to respond to a peak wavelength of 640 nm with half max. of 10.4 nm for the red band and a peak wavelength of 840 nm with half max. of 11.7 nm for the near infrared band [NIR]. Automatic exposure was disabled. The system was installed in a PBN Defender by removal of the aircraft door and the rear seats. The camera mounting plate was attached to the floor of the aircraft and secured by means of the seat retainers. The system was managed by an integral control unit which supplied both power and framing instructions.

Framing rate is a function of the required resolution, aircraft speed and altitude, lens focal length, and sensor to hard disk download time. Data were stored on PCMCIA Type III hard disks each with a capacity of 260 Mb allowing storage of 162 frames of 1524 x 1012 x 8 bit greyscale images. The download time for each of the 1.53 Mb data files is 2.9 seconds. Photocoverage along track at 500 m AGL is 0.25 x 1012 m = 253 m. At an aircraft ground speed of 160 kph and a framing rate of 4.5 seconds a 20% forward overlap was achieved (Table 1).

The area covered by the survey was approximately 3 km east-west by 6 km north-south, located in the south east sector of the city of Kumasi featuring land cover types including industry, housing, infill areas and the peri-urban zone (Fig.1). Flight line control was achieved using a GPS and procedure turns to ensure complete photo coverage. An example of a pre-planned flight track sheet is shown in Table 2.

Approximately 500 images (approaching 1 Gb of data) were acquired in each survey. As far as possible, images were checked for quality and forward / side overlap between flights. Examples of NIR and red band images at 10 cm and 25 cm pixel ground resolution are included as Figures 2 to 5.

Three major difficulties were encountered. The first was the unsettled nature of the weather, and although local comment was that the optimal time for the survey had been selected (early December 1995), that is before the arrival of the Harmattan, daily development of cumulus cloud gave some problems. These were not so extreme as to limit the acquisition or usefulness of the images. In large scale surveys pilot experience is an important factor, and development of the vital co-ordination between the pilots and the surveyors was an essential pre-cursor. Both teams gained from the experience. Finally, limited map availability proved a major restriction in carrying out GPS ground survey work, and first order geometric correction was obtained from a SPOT Pan image of Kumasi (December 1994).

4.0 Image Processing

The data stored on the PCMCIA hard disks in proprietary TWAIN format must first be converted into standard image format e.g.TIFF, JPEG, using TWAIN compliant software such as Paint Shop Pro or Adobe Photoshop. The computer system requires a Type III PCMCIA reader and either an ASPI or Future Domain SCSI card. Some adjustment to the dynamic range is necessary to compensate for spectral brightness variation caused by minor changes in ambient lighting conditions during image acquisition, for example, changes in cloud cover and sun angle during the course of the survey caused such problems on each flight.

The 10 cm ground resolution imagery was geolocated using flight navigation data acquired by the onboard GPS. This information together with information derived from image interpretation was integrated using a GIS.

Techniques for mosaicing images from the ADP and HRV systems have been developed in house. It is not intended to cover the mosaicing techniques in detail, but use of Adobe Photoshop permits interactive mosaicing, allowing for changes in aircraft heading, as well as variations in altitude. Yaw, roll and pitch cannot be corrected directly in Photoshop but a good degree of geometric control was achieved by relating the ADP images to a panchromatic December 1994 SPOT image (level 1b) corrected to an Ordnance Survey map (scale 1:50 000) of the Kumasi region to supplement GPS data. Planimetric errors should be no greater than 1 - 2 metres. The area covered by the survey has been sub-divided into 8 photo mosaic maps, each file approximately 17 Mb in size. Mosaics in the greyscale red, and greyscale near infrared were produced. These were co-registered to produce false colour infrared composite mosaics (R,G,B = nir, red, red).

5.0 <u>Outputs from the ADP Survey</u>

The Kumasi GIS

The Kumasi Geographic Information System [KUPIS] has been developed as an analytical interface for the management of remotely sensed digital photographic data. After suitable processing the airborne survey data can be used to estimate urban landuse. In the case of Kumasi, it is possible to demonstrate changes in city structure along the line of the flight track transect. For this purpose the highest resolution images (pixel ground resolution of 10 cm) have been used, producing a series of georeferenced images extending approximately 6 km from the rural to the urban environment. The structure of the GIS used in the pilot transect is shown below.

Information Browsers	Information System Browser Image Database Browser	
Data Browsers	Buildings Browser Vegetation Browser Infrastructure Browser	
Layer 3	Digitised layer	
Layer 2	ADP Image	[Georeferenced ADP Images]
Layer 1	Map base	[WGS84]

Details of the browser structures are shown overleaf.

Infrastructure Browser	**Type**	
	Tracks	
	Minor roads	
	Main Roads	
	Rivers	
Buildings Browser	**Type**	
	Homestead	
	Outhouse	
	Commercial	
	Unfinished	
	Unknown	
Vegetation Browser	**Type**	**Activity**
	Oil Palm	Commercial
	Oil Palm (Immature)	Domestic
	Row Crop	Unknown
	Plantains	Uncultivated
	Grassland	
	Mixed	
	Mixed (River)	

Interrogation of these digitised features yield information on absolute and relative values of area, density, number and length, which can be used to analyse the structures and activity along the line of the transect. Figure 6 shows several classified digitised frames along the transect. Figures 7, 8, 9 and 10 provide examples of graphical analysis based on the digitised ADP images included in the transect.

Analysis of the data contained in the vegetation browser can be used to estimate the potential productivity of the city. For example, non plantation oil palm, row crops, plantains and mixed cultivation are either for domestic consumption or sale at local markets, are important elements in the productivity of the city. By completing a series of transects, stratified to take into account soil type, gradient, physical features such as river valleys etc, a whole city estimate of cultivable area can be determined.

This methodology is relatively efficient, and images can be analysed on site, without recourse to expensive film processing. GPS flight track data can be used to rapidly identify near centre of image locations, enabling ground control data to be acquired. Once the bounds of the images are known, assessment of crop production at these locations can be determined over a period of time.

Photomosaics

Photomosaicing of images is a time consuming task. It is time intensive in three areas, namely survey flying time, collection of positional data and image processing. The survey achieved 90% coverage of the survey area. Examples of extracts from the mosaiced images in the NIR and Red bands are shown in Figures 11 and 12, whilst a CIR mosaic is included as Figure 13.

In the case of the Kumasi survey, ground control points using GPS receivers were very difficult to obtain because maps were last surveyed in 1965X, and access roads to the image locations could not be found. Details of mosaicing technique have been reported elsewhere, but the geo-correction of images was achieved with reference to a SPOT image (Dec 1994) (Figure 14). This in itself has particular use in that the ADP survey occurred 1 year later, and considerable change could be detected between the SPOT image and the recent survey (see Figure 15, sand mining sites near Kumasi).

If photomosaics are to be constructed, then the payback must be substantial bearing in mind the effort involved. The advantages gained from the Kumasi survey are listed below:-

a) Urban / rural dynamic zone is clearly defined.
   The expansion of urbanisation can be defined through current building work, and track-road development. In Kumasi this front is advancing very rapidly. Villages outside the city proper exhibit clusters of new houses and heavily worn dirt roads. This is often associated with sand mining.
b) City infill. The process of infill is rapidly depleting the available cultivable land within the city. This dynamic should be considered in estimates of future productivity. By plotting the unfinished buildings Figure 16 demonstrates the rapid city infill and growth around the margins of the city.
c) Through the use of colour infrared images the density of vegetation within specific areas can be determined. It is clear that as the city infills and matures there is a progressive loss of vegetation - and therefore productivity. This dynamic should also be considered during assessment of future productivity (Figures 17a - 17c).
d) The rapidly expanding city has particular impacts on tree cover, and except for some near river locations, much tree cover has been removed (Figure 17b).
e) Finally, the photomosaic itself is a valuable product where no maps exist, or where they are rapidly being outdated.

6.0 Contribution of Outputs

The outputs described above serve to indicate the potential of this type of low cost survey technique. It is important to emphasise that the analyses shown here have been carried out by the technical operators of the survey team, and examination of the mosaics or the individual images by peri-urban experts may suggest alternative and more fruitful methods of analysis.

In terms of cost effectiveness, ultra-high resolution images structured into a transect represent the most effective way forward. An off-the-shelf SCSI-based PC can be used to acquire images from the cameras and MapInfo is a modestly priced GIS. Training of operators would not be a substantial cost. Most aircraft carry a GPS, and transects flown across the city could be processed in a matter of weeks. Aircraft survey time would be minimised in this approach, further reducing cost. One way forward would be to structure a whole city analysis based on a series of transect runs. This could be set up by the survey team with technology transfer, training of data processors, and a copy of the data could be left in country for analysis. This would minimise all costs of production, including aircraft time, image processing time and ground truthing. Based on the levels of equipment and the high levels of skill apparent at Kumasi University of Science and Technology [UST], technology transfer would not be difficult, and this would form a useful test of technology uptake of the ADP system. In country processing of data would markedly reduce costs.

Local (village level) access to the data could be encouraged through the use of balloon technology, enabling imaging of individual sites on an easily repeated basis. The technology already exists for this procedure. Crops could be harvested from such plots, and such data collection would not only involve the local populace in the project, but would provide calibration data on which to base estimates of city productivity.

There are clear benefits in using experienced pilots and navigators to complete surveys. These skills might take rather longer to transfer, and unless there is a special requirement for whole area maps, then low level imaging for photomosaics should be reserved for special problems. High level imaging at pixel ground resolutions of 1 m to 2 m and across track photocoverage of 1.5 km to 3 km would be of great benefit to the transect approach listed above, enabling the high resolution images used in the transect to be related to the surrounding urban structure. This would not be onerous on aircraft time and would rapidly produce a useable base map of all but the largest conurbations. For instance 3 flight runs would have encompassed almost the whole of Kumasi.

Two advantageous development steps remain to be taken with the ADP in this type of survey. The first is the automatic logging of aircraft attitude during surveys, enabling image centres to be more accurately determined. Hardware and software developments are under way. Secondly, the RSGIS Unit is about to take first delivery of a Kodak Digital Science camera; this is the Colour Infrared [CIR] version of the DCS420 camera, which will not only provide CIR images without the need to co-reference images from independent cameras, but will also enable the extraction of individual bands in the green, red and near infrared parts of the spectrum. This will again reduce processing time and increase the functionality of the cameras.

Finally, the authors are grateful to all Ghanaians who contributed their efforts, advice and help during the preliminary visit in August 1995, and during the survey, in December 1995. In particular, Lt Col. Otchere and his aides from the Kumasi Metropolitan Assembly, the airborne survey team of the Ghanaian Airforce, and colleagues at the UST.

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1st May 1996, 6th December 1996

Appendix I

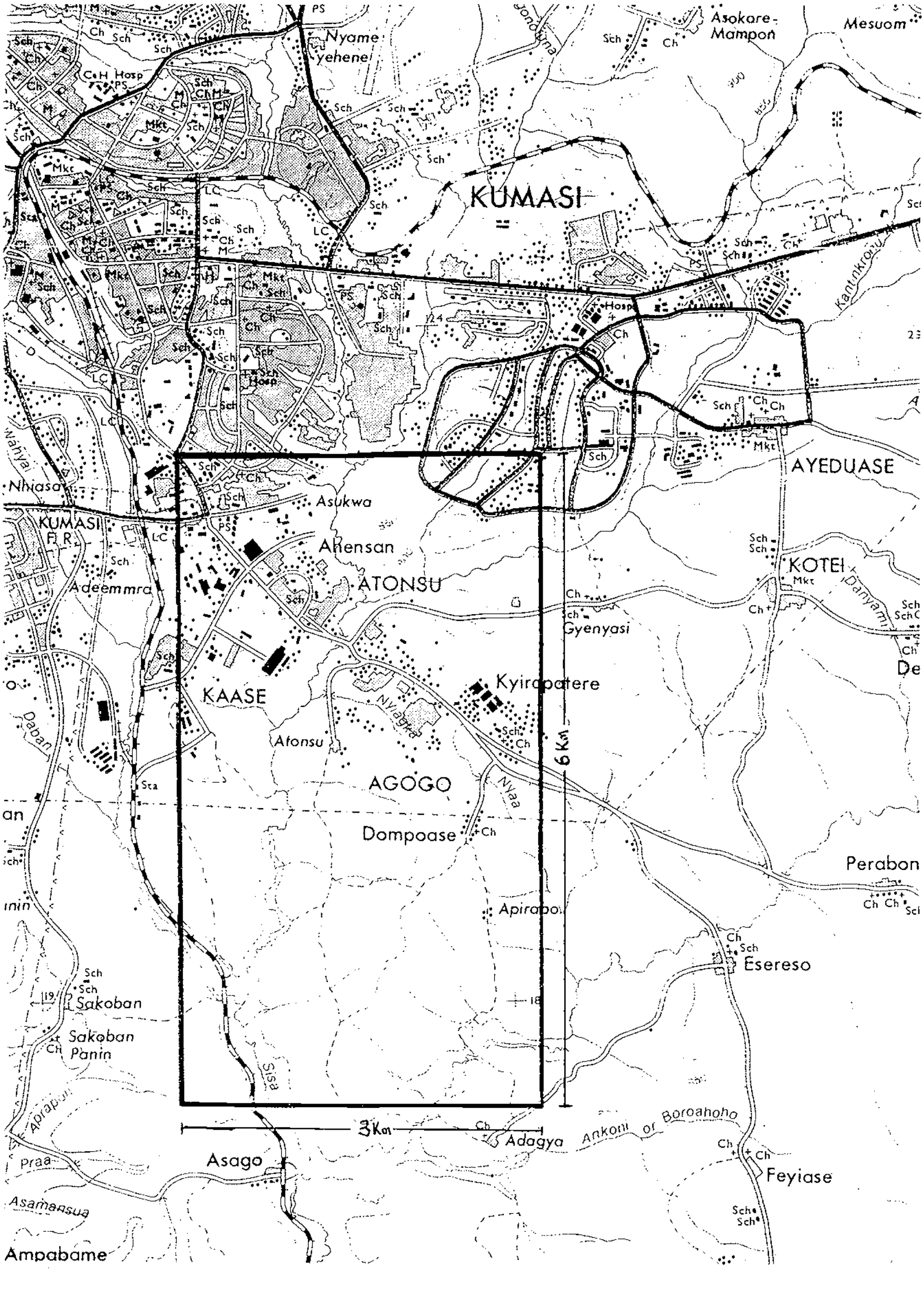


Figure 1 - Survey Area

Figure 2 - Near Infrared ADP (840 nm), 10cm ground resolution

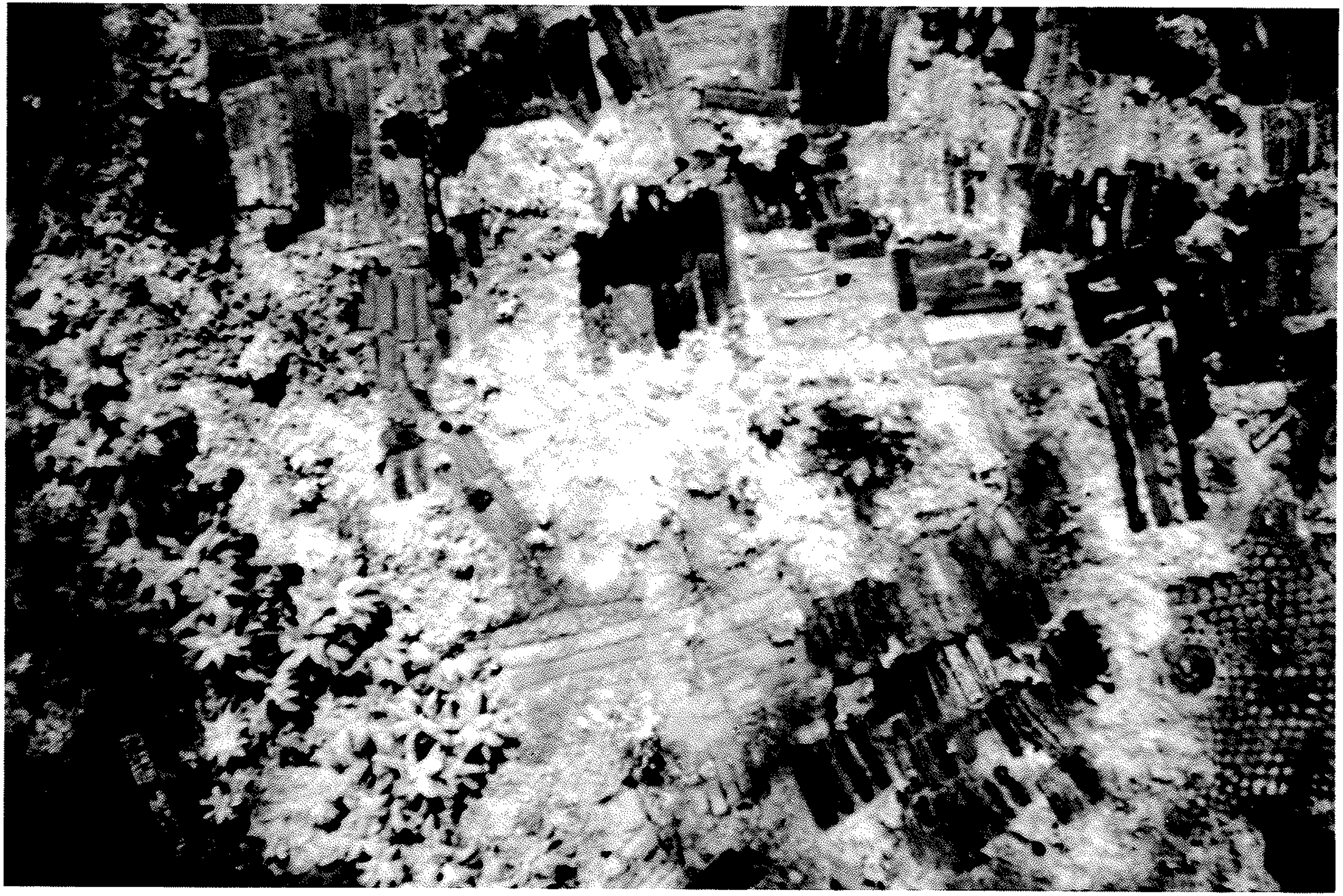


Figure 3 - Near Infrared ADP (840 nm), 10cm ground resolution

Figure 4 - Red ADP (640 nm), 25cm ground resolution

Figure 5 - Red ADP (640 nm), 25cm ground resolution

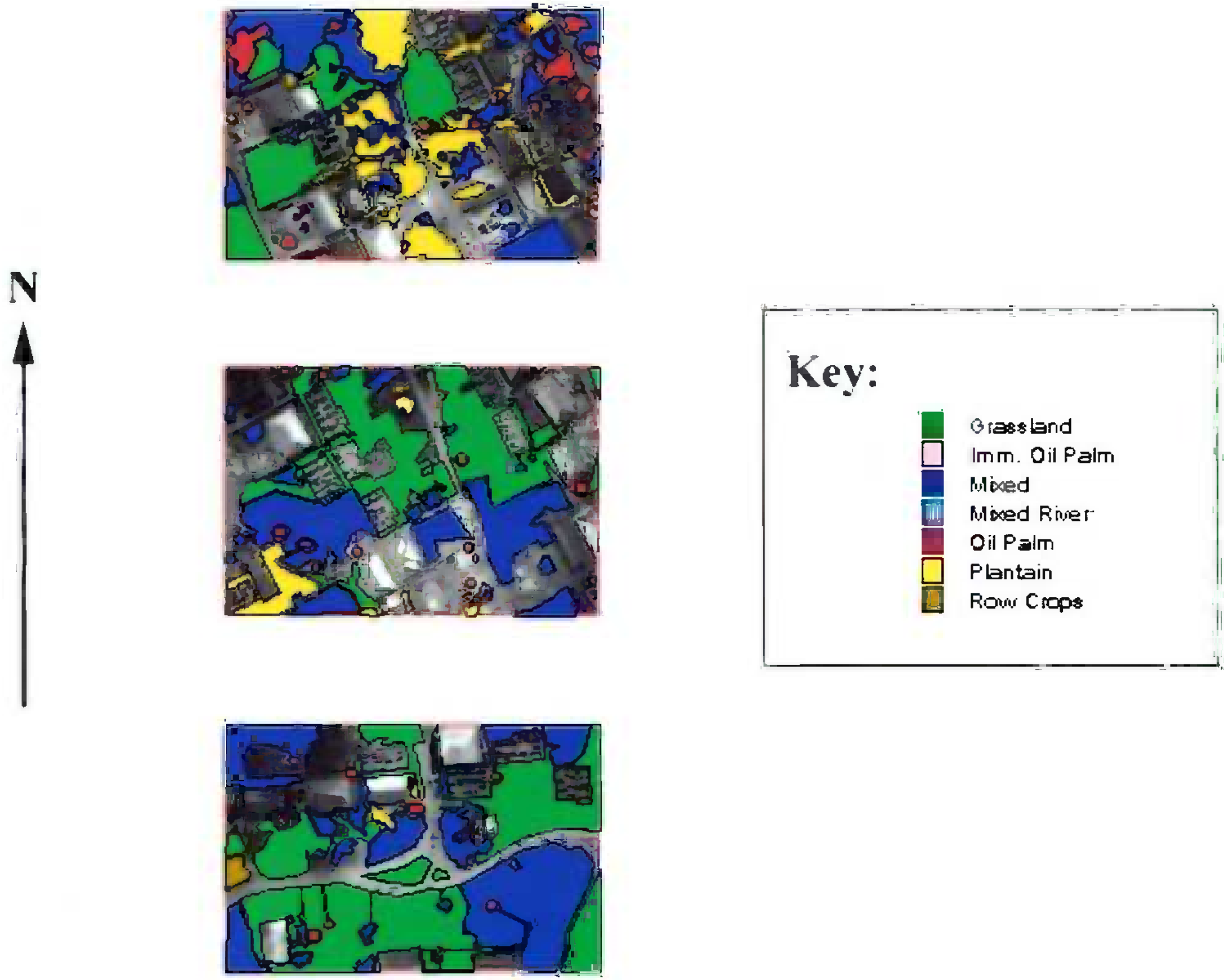


Figure 6 - Images classified by vegetation type

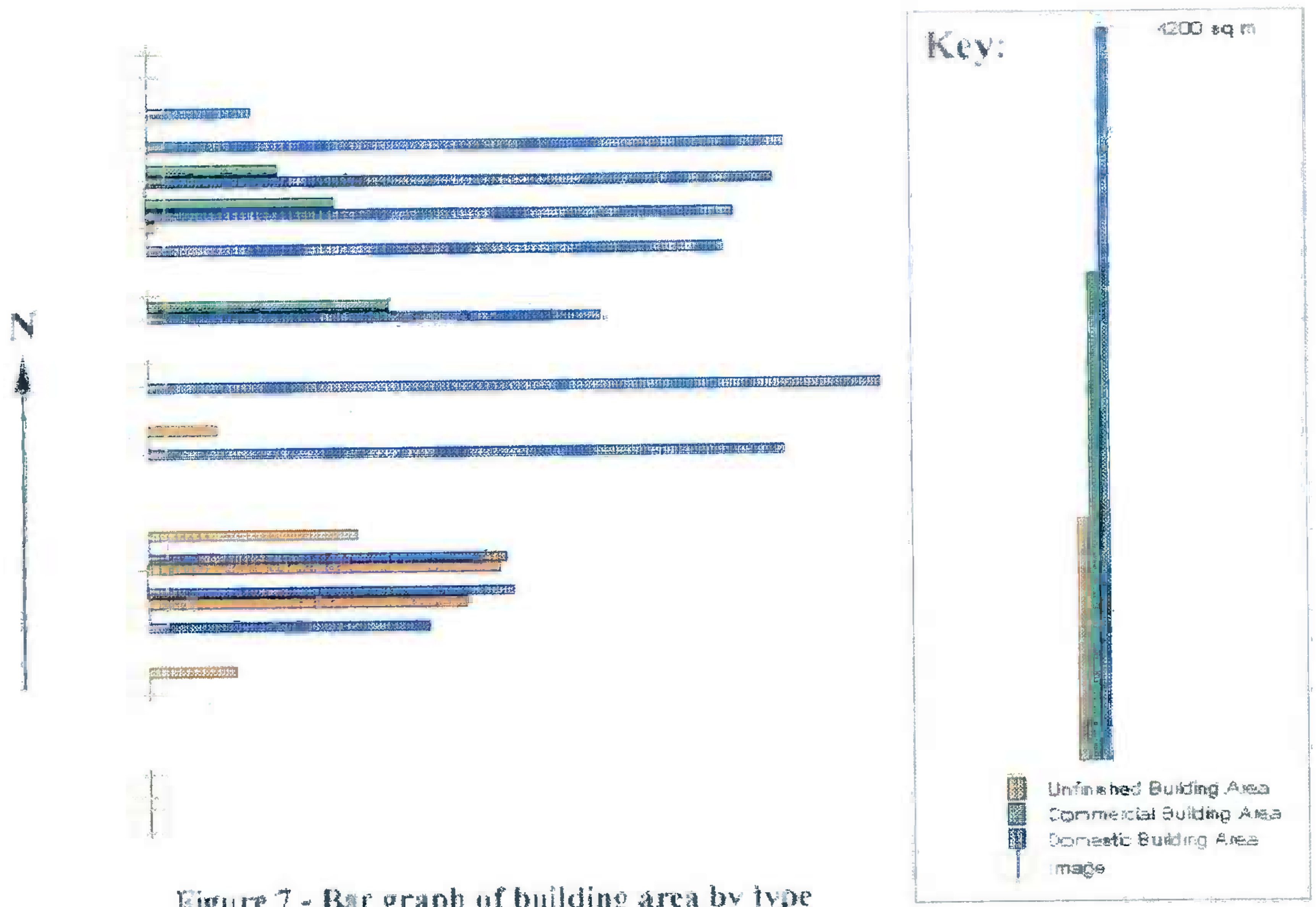


Figure 7 - Bar graph of building area by type

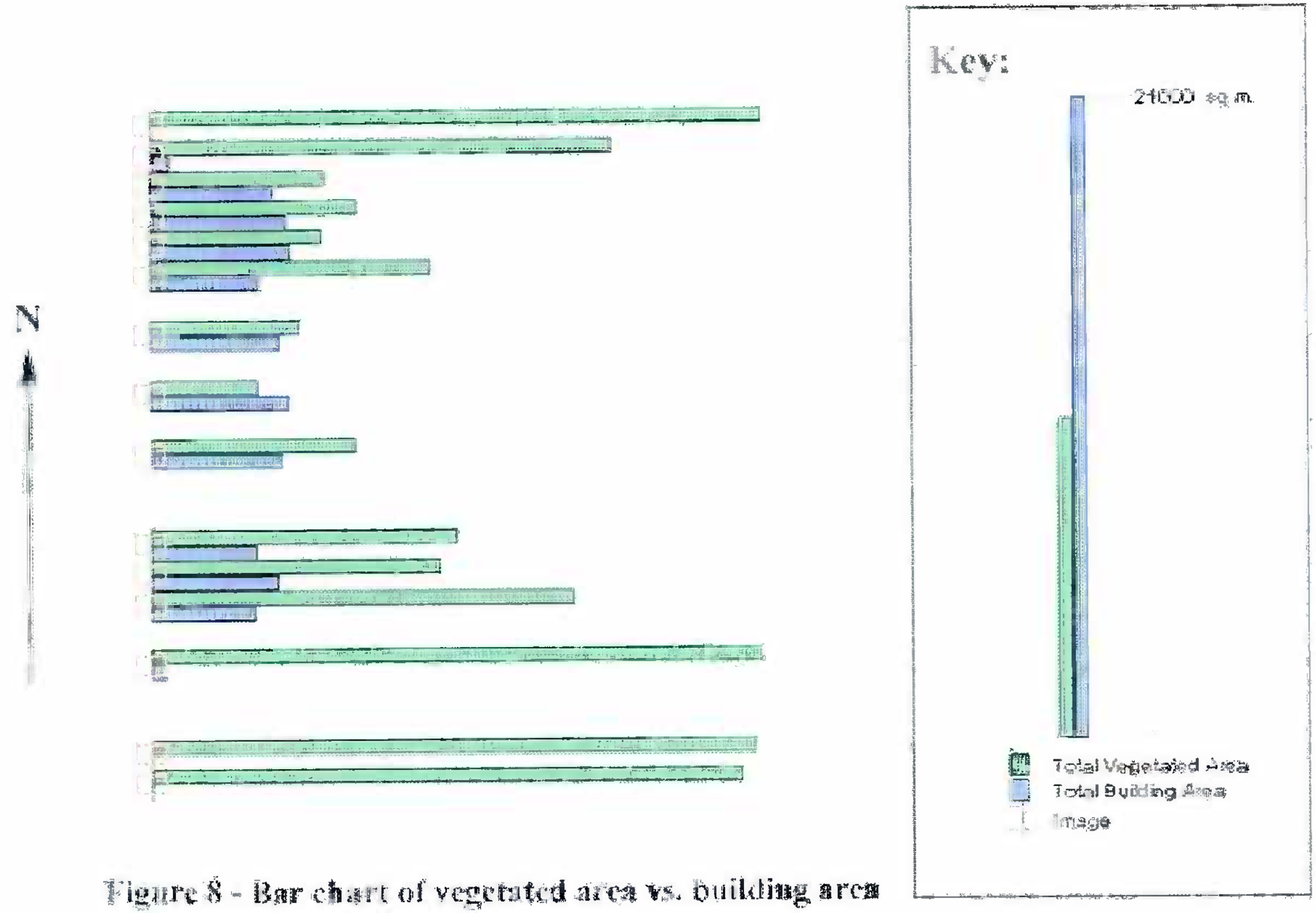


Figure 8 - Bar chart of vegetated area vs. building area

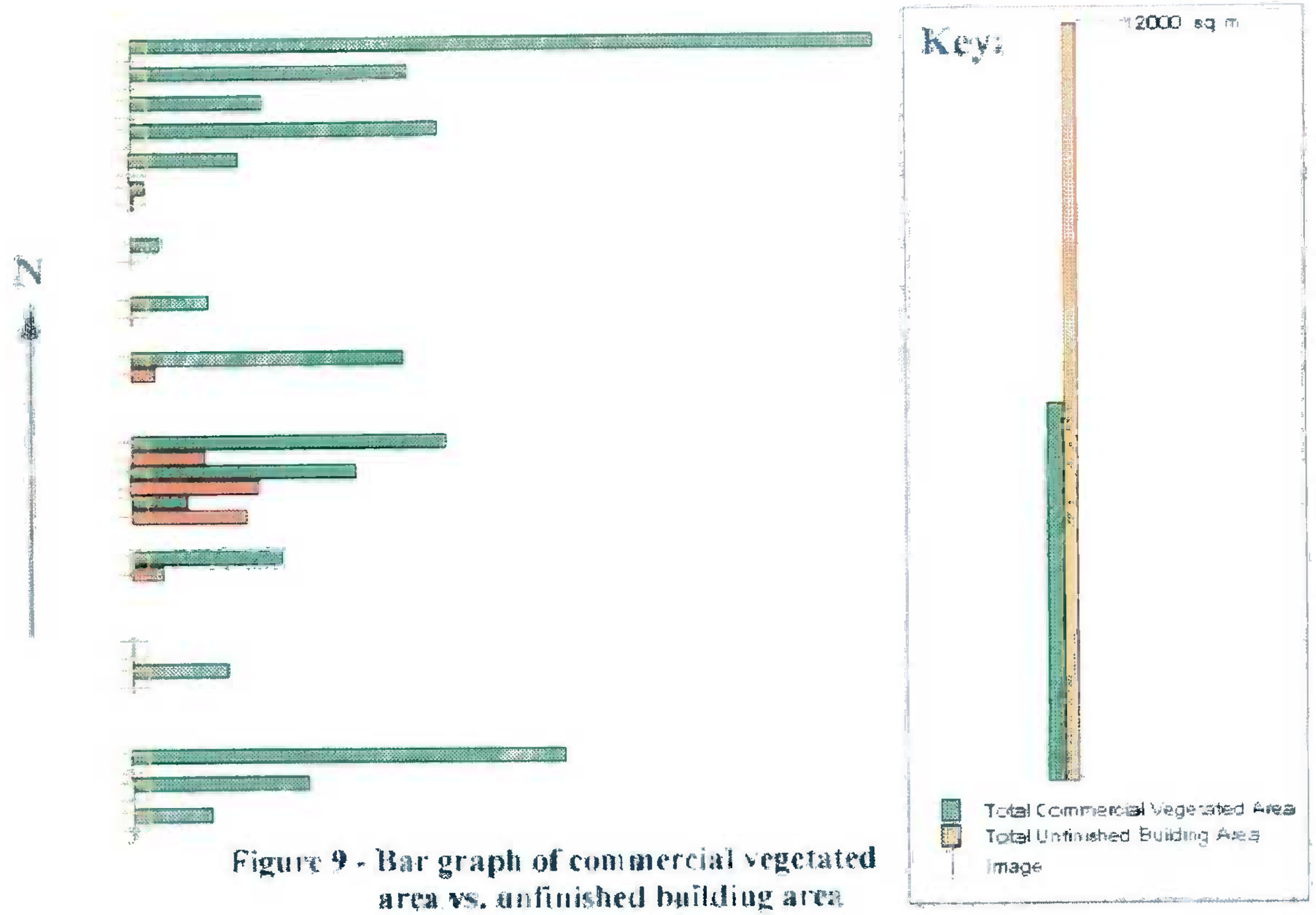


Figure 9 - Bar graph of commercial vegetated area vs. unfinished building area

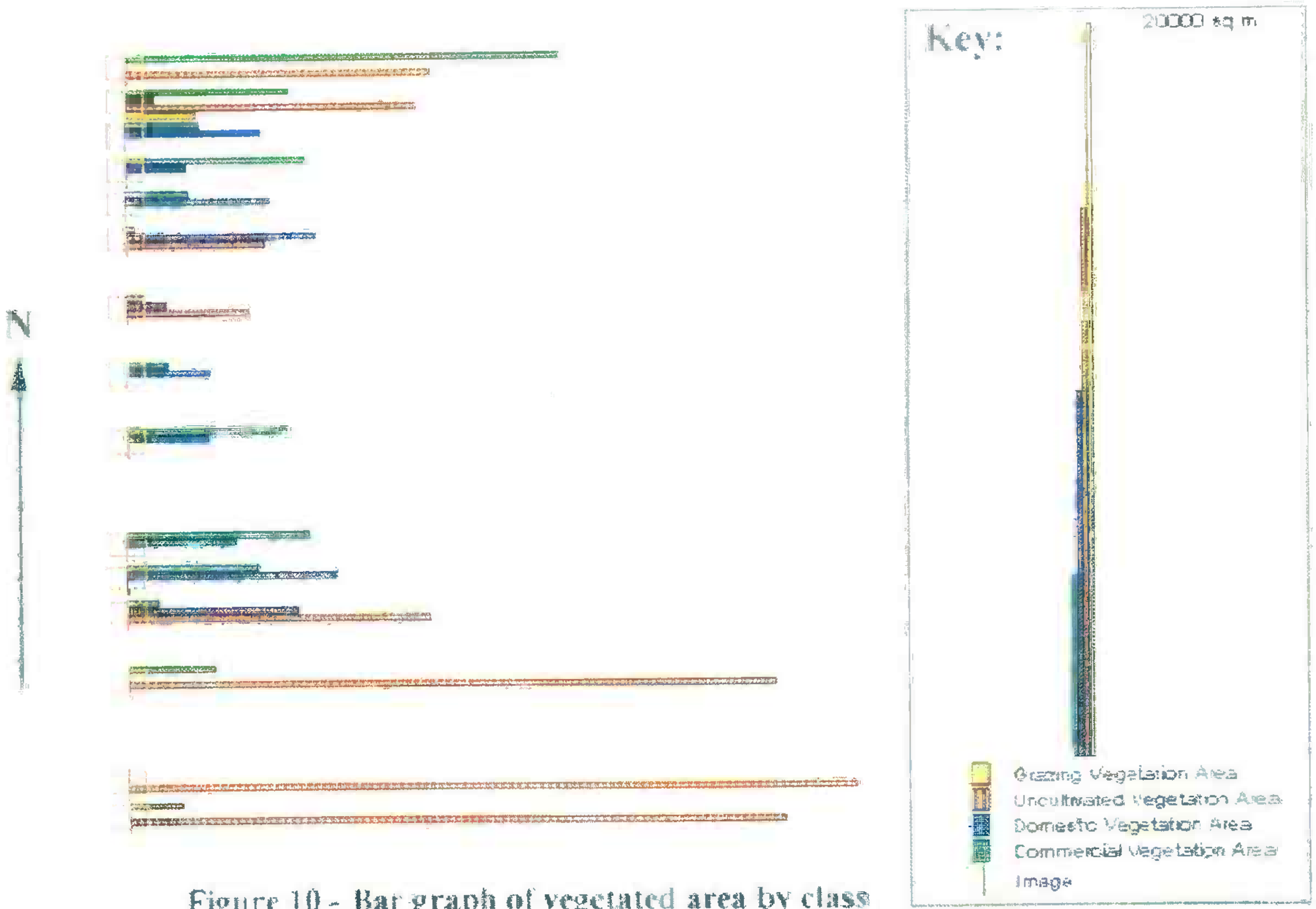


Figure 10 - Bar graph of vegetated area by class

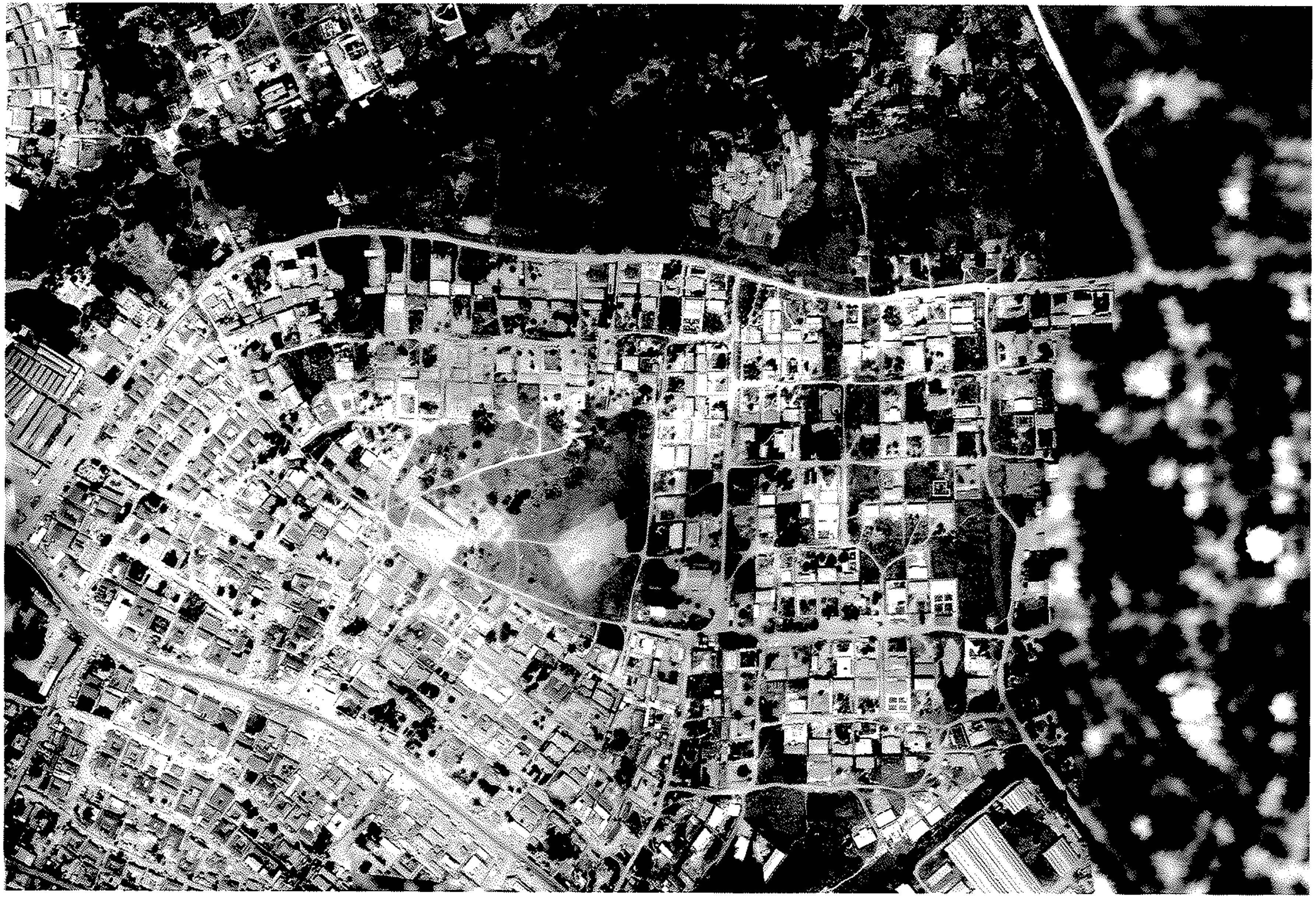


Figure 11 - Red ADP mosaic (640nm), 50cm pixel resolution

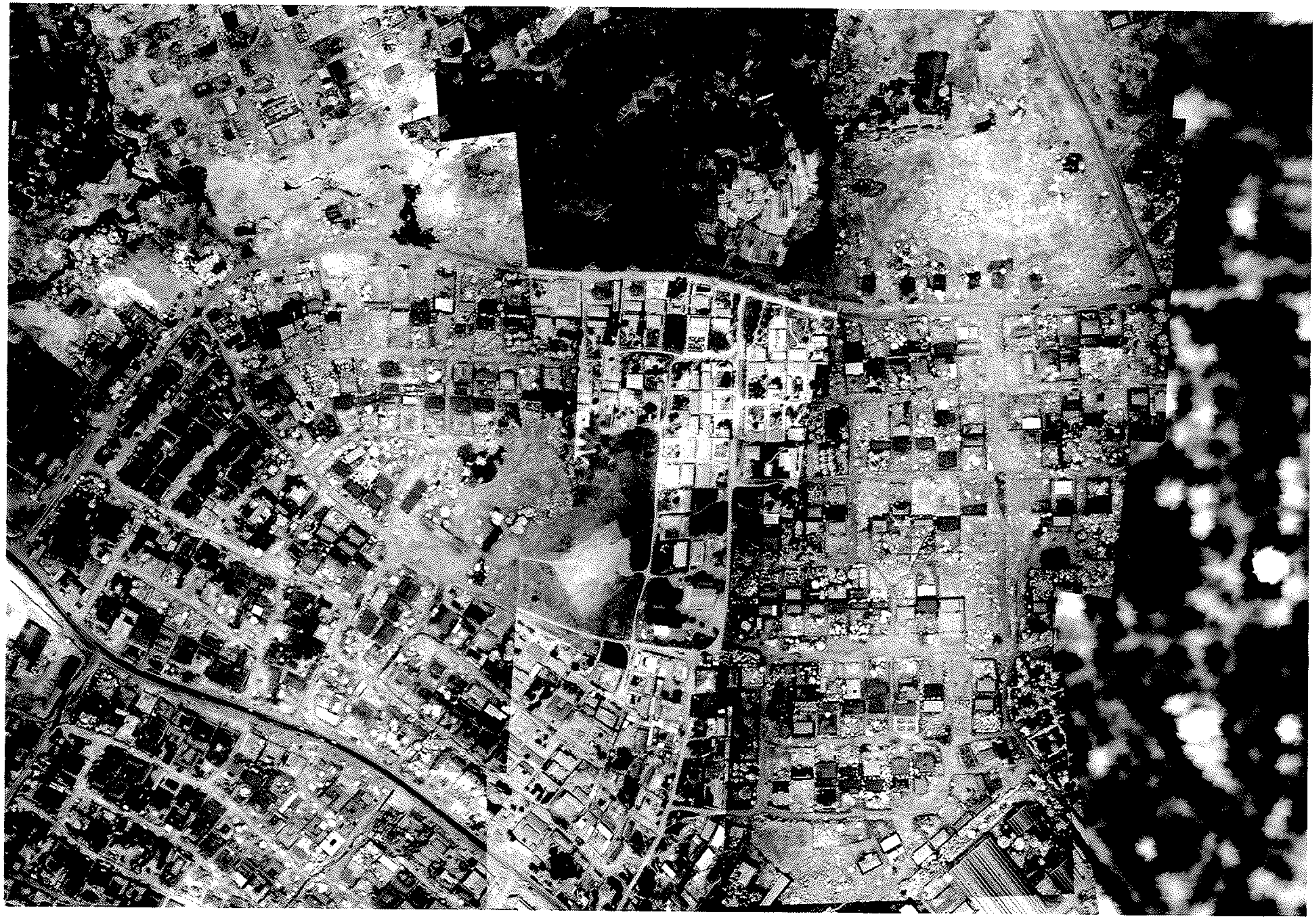


Figure 12 - Infrared mosaic, overlayed onto red mosaic

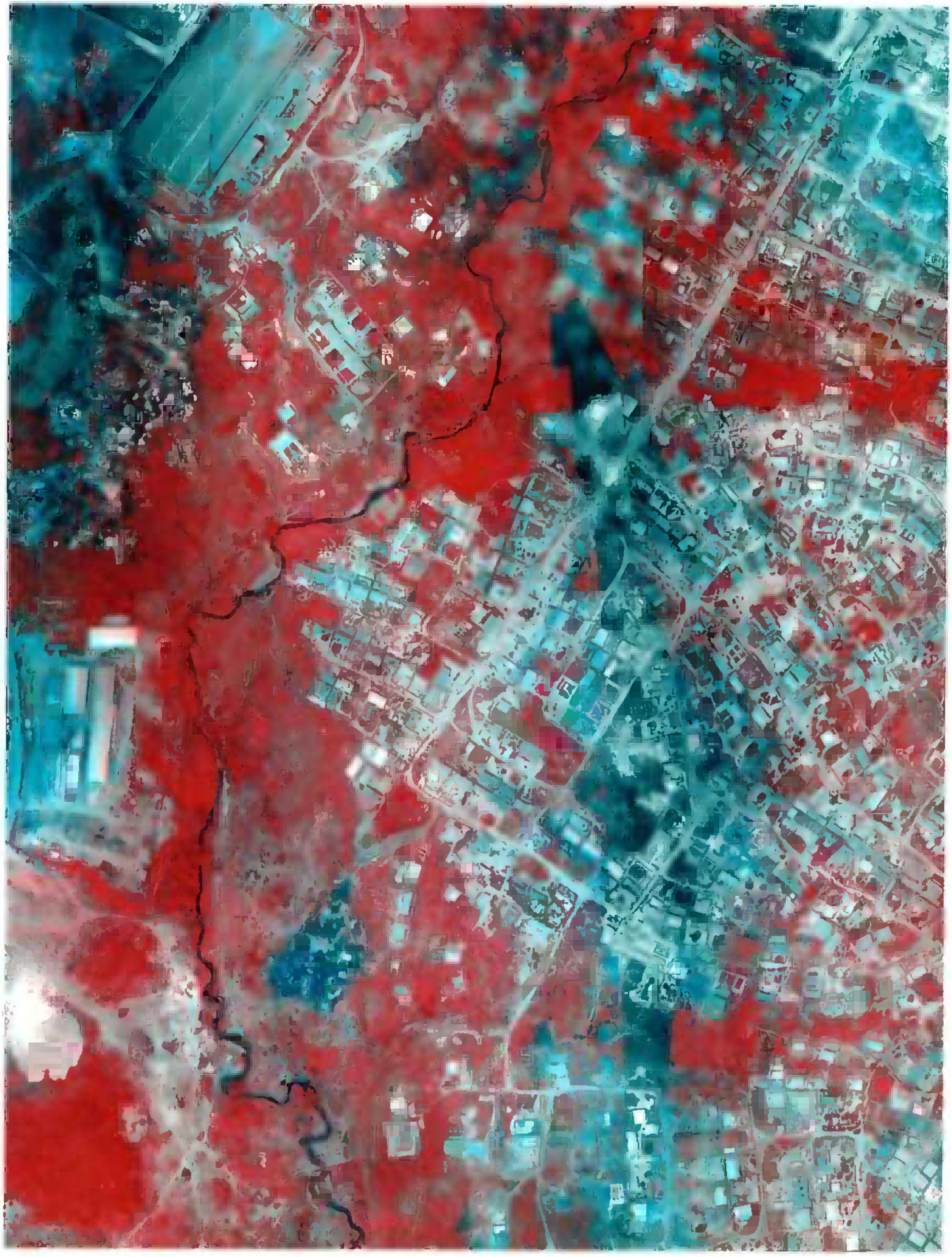


Figure 13 - CIR mosaic, 50cm pixel resolution

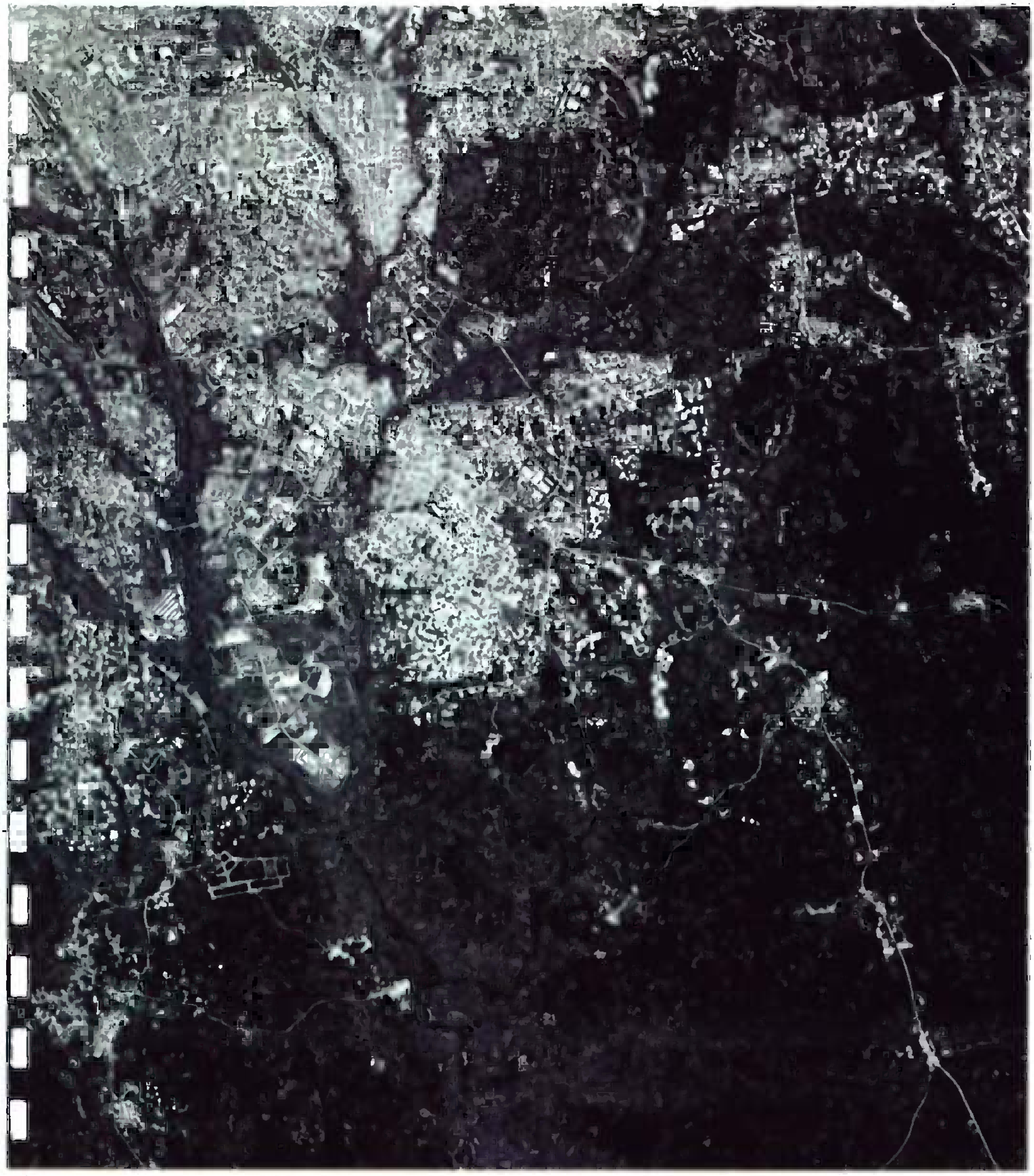


Figure 14 - SPOT Image, Kumasi Dec 1994

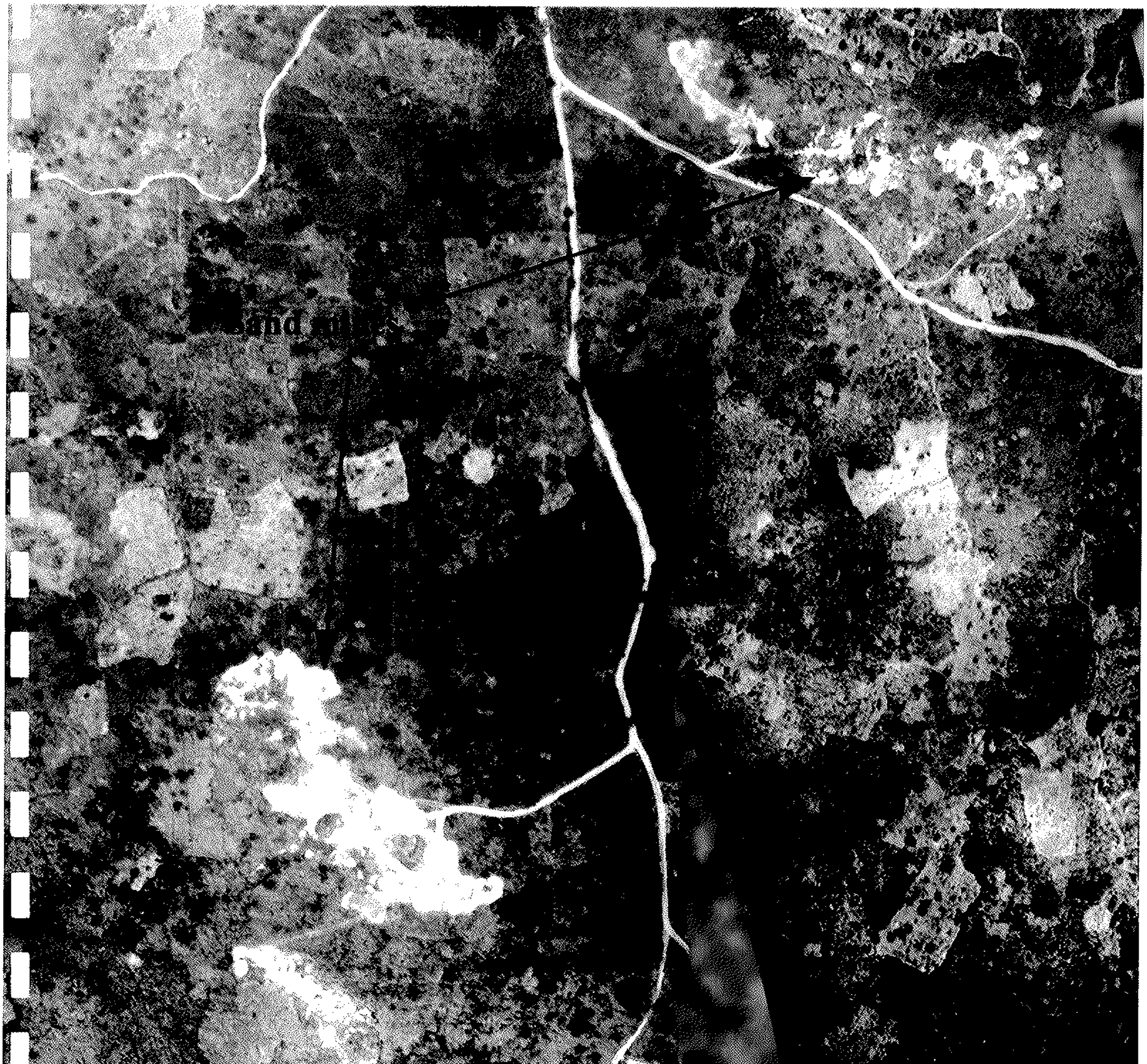


Figure 15 - Sand mining sites near Kumasi

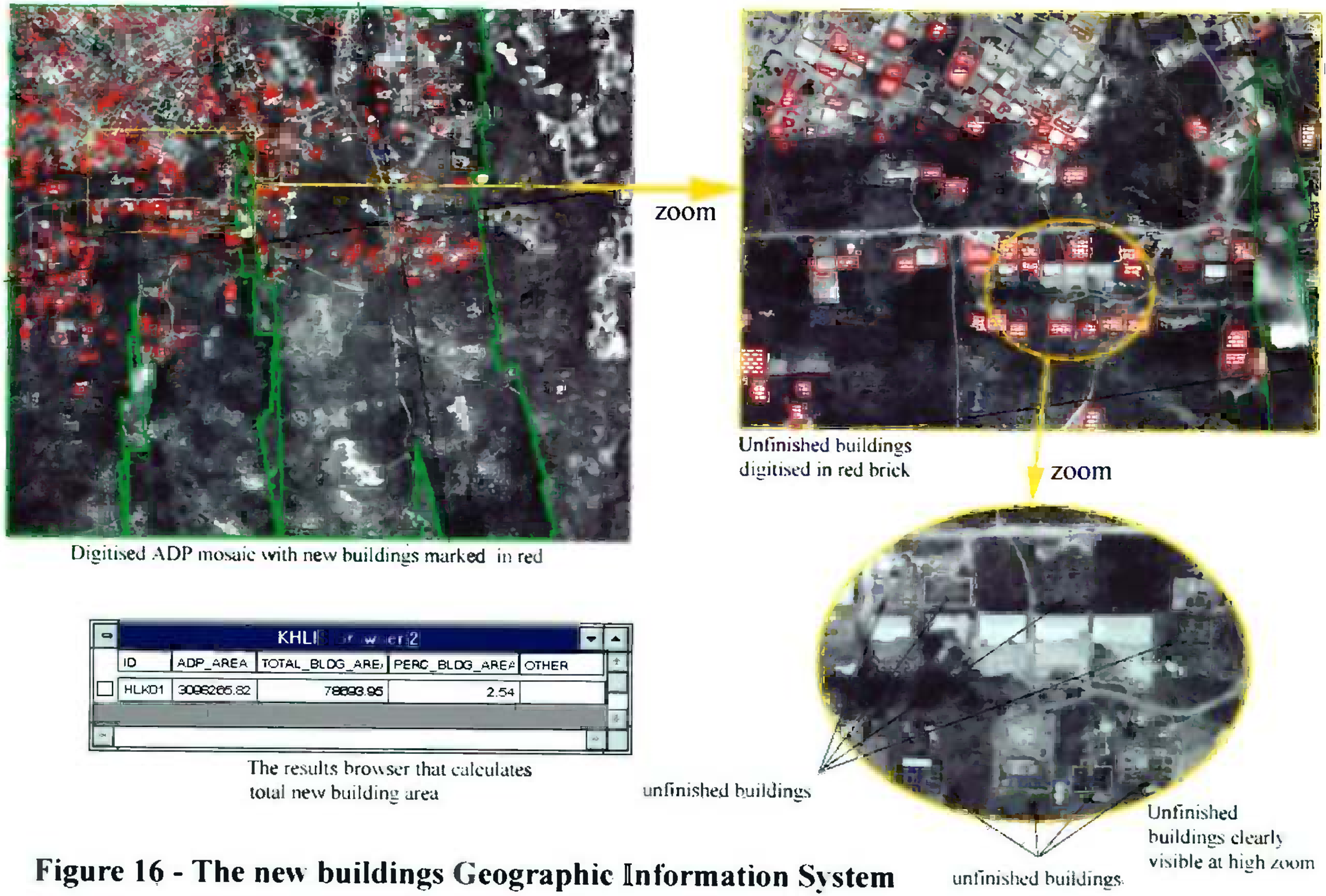


Figure 16 - The new buildings Geographic Information System

Fig.17a - Section from CIR mosaic

Fig.17b - Thematic map of section indicating forested land within peri-urban zone

Fig.17c - Thematic map of section indicating degraded land with sparse vegetative cover within peri-urban zone

Figure 17 - Thematic maps of CIR mosaics indicating vegetative cover within peri-urban zone

Appendix II

INTRODUCTION TO THE KUBIS GIS

About MapInfo

Mapinfo is a desktop mapping package for PCs that has been designed for use from a Windows environment. Desktop mapping and Geographical Information Systems allow the user to handle and quantify large quantities of geographical data. This is done by enabling the user to visualise the data in the form of thematic maps and relational charts as well as utilising standard data analysis techniques available with textual databases. Desktop mapping can provide new, fast and efficient ways of analysing geographical data, for patterns and trends that could remain hidden for hours within text only databases.

Some of the features MapInfo includes are:

- Direct import/export of many data file formats (dBASE, FoxBASE, delimited ASCII, Lotus 1-2-3, Micosoft Excel).

- Direct import of RASTER graphic file formats.

- Multiple views of data in three formats; Map windows, Browsers and graph windows. These views may be opened simultaneously and update interactively.

- Querying capabilities ranging from simple data selection to complex selection and attribute queries from more than one file.

- A comprehensive array of drawing and editing tools.

- Easy export of data to printer via a layout window.

- Easy maintenance of data using workspaces to save current position.

About Kumasi GIS

The large quantity of data obtained during the RSGIS 1995 Kumasi peri-urban survey indicated that a GIS package could be used to great advantage in handling the hundreds of megabytes of ADP data. MapInfos ability to import raster images and thus enable the incorporation of the ADP data as 'map underlays' meant that it leant itself very adequately to the development of a 'flightline transect GIS', one in which low altitude high resolution (and therefore data rich) ADP imagery could be used. The GIS interface would provide the means for analysing these large amounts of data.

The first step was deciding the basic structure of the GIS. Mapinfo works on a 'layer' system - each layer being an interactive part of the final desktop mapper. For the Kumasi GIS the first layer is the Map Base (stored within the GIS as KMB01) - a WGS 84 grid encompassing the survey area and stretching from 1.5 W to 1.677 W, 6.583 N to 6.75 N. The grid was created using AutoSketch and was then geo-referenced when imported into MapInfo. Following this proceedure the MapInfo cursor will give a Latitude-Longitude reading on the Map Base.

The second layer consists 18 georeferenced non-overlaping ADP images (imported as rasters into MapInfo) running in a 'flight-line transect' approximately 6 km from the rural to the urban environment (see fig.18). As this is a pilot model only one transect has been included. The nature of Mapinfo dictates that these first two layers have information browsers containing any relevant textual data. The Map Base browser for instance contains 22 entries relating to its 11 lines of latitude and its 11 lines of longitude. Each entry is simply a westerly or northerly value. The geo-referenced ADP layer also has a browser and is known as the image database (stored as KID01) (see fig.19). This contains information relating to each of the 18 images including image ID and filename, its waveband and resolution, and its location (x and y centroids) and area. This last entry (image area), was the first entry calculated by MapInfo using the geo-referencing attributes.

The next stage and the third layer of the GIS involved the classification of the data within the ADP images. The brief of the survey to the separation of the data into 3 groups, namely, Infrastructure (stored as KST01), Buildings (KNV01) and Vegetation (KVG01), each group having its own browser (see figs. 20-22). Each 'data group' browser contains every entry to which it is related (i.e.- the buildings browser contains an entry for every building within every image). Each entry was then given a series of attributes by which it could be identified and analysed. Thus the buildings browser contains the fields: Filename (the filename of the image within which the building can be found), the building type (chosen from a list of Homestead, Outhouse, Commercial, Unfinished and Unknown) and building area (calculated by Mapinfo from the geo-referenced images).

Thus the structure of the GIS is shown below:

Infrastructure Browser:	**Type**
	Tracks
	Minor roads
	Main roads
	Rivers
	Unknown
Buildings Browser:	**Type**
	Homestead
	Outhouse
	Commercial
	Unfinished
	Unknown

Vegetation Browser:	**Type**	**Class**
	Oil palm	Commercial
	Oil palm (immature)	Domestic
	Plantains	Uncultivated
	Row crops	Grazing
	Mixed	Unknown
	Mixed (river)	
	Grassland	

Each feature or item within each of the images was then digitised using the MapInfo drawing and editing tools (for further information see page 40 - Digitising). For each digitised item a textual/numerical entry was made within the relevant browser.

Within the Infrastructure browser roads,tracks and rivers were digitised with straight lines down there centres and colour coded for identification (see fig.23). Although length and distance calculations may be made using the '**ruler**' tool (see page 34) area calculations cannot be made.

Within the Buildings browser building perimeters were digitised to enable their areas to be calculated (see fig.24).

Within the Vegetation browser each seperately identifiable plant type or class had its perimeter digitised also enabling area calculations of vegetation (see fig.25).

The sizes of these three 'user entry level' browsers differ enourmously. The Infrastructure browser contains only 56 different entries recording the image locations of the roads, tracks and rivers and serving as little more than a simple information database. The Buildings browser contains many more (342 entries), and the Vegetation browser contains 1272 seperately digitised and area assessed entries.

As it has been described so far the GIS requires a user interface and the tools of the MapInfo program in order to exploit the database to its full potential. Many of the features and tools within MapInfo are described from page 32 onwards. However, it was considered necessary to develop an embryonic user interface that would interogate the three 'user entry level' browsers and list some analysis and results in the form of a fourth layer browser - the Information System browser (stored as KIS01) (see fig.26). This browser lists for each image information such as image area, vegetated area, vegetated percent, number of buildings, area of buildings and building percent. The Information System browser is used to store important results from the entire GIS in a concise and more user friendly context.

GETTING STARTED

Startup

The following instructions assume the successful installation of MapInfo 3.0 into the Microsoft Windows environment.

The first step is to copy the contents of the KUPIS CD into the root directory of the C:\ drive on the PC to be used. KUPIS must be operated from the C:\ drive in order to locate its constituent files.
NB - All CD files are **Read Only**. Please switch all files to **Read/Write** via File Manager, <File>, <Properties>.

Secondly follow the procedure listed below:

- Boot MapInfo from the Windows MapInfo Icon.

- Select <File> from header bar with mouse.

- Select <Open Workspace...> from <File> menu with mouse.

- Select C:\ drive and "**kupis**".

- Select "**startup.wor**" from the "**startup**" directory and click on <Open> with mouse.

The Screen

The Kupis startup screen will now load (see fig.27). The screen is set out with a large Map window in the top left showing a view of the Map Base grid and the ADP images outlined in red within it. Moving the cursor within this window will result in MapInfo displaying latitude and longitude coordinates at the bottom left of the screen. Below the Map window are icons displaying the minimised information browsers. By clicking on the icon with the mouse each browser may be restored for viewing. The browsers are:

KMB01 - Map Base browser.

KID01 - Image Database browser.

KIS01 - Information System browser.

KST01 - Infrastructure browser.

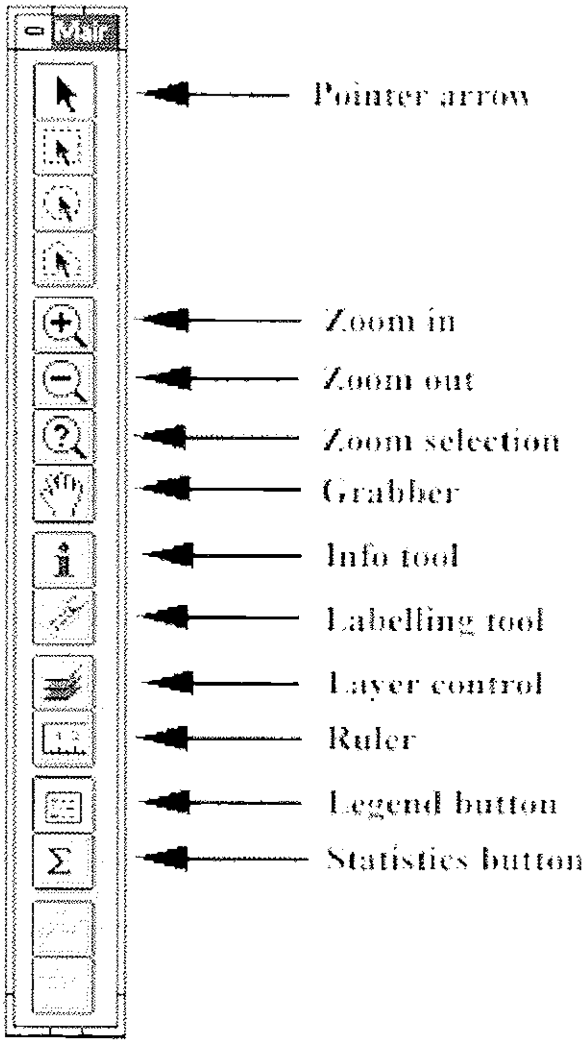
KNV01 - Buildings browser.

KVG01 - Vegetation browser.

On the far right hand side of the screen is the main MapInfo Tool Bar which will be explained in more detail later. Just to the left of these are four more windows - The Info window, the Legend window, the Statistics window and the Ruler window each of which are used in conjunction with the Tool Bar.

Using MapInfo & KUPIS

The Tool Bar



The most useful features on the MapInfo Main tool bar are labelled above. Although there are many other tools and also a separate tool bar for Drawing (see page 42 - Digitising) these functions should enable the user to adequately explore the Kumasi peri-urban GIS. A brief description of each lanelled tool follows:

Pointer arrow - The default tool when starting KUPIS. This tool should be used as a location cursor within the Map window and as a cursor to select other tools, menus and windows.

Zoom in - All the layers within the Map window are fully 'zoomable'. By clicking on the map window with this tool the map window will zoom in to the next level of zoom (i.e. the view will be magnified). If you wish to display the level of zoom select <Map> from the menu bar followed by <Change View> where you will be given the options: 1) Zoom (Window width) 2) Map scale or 3) Cursor Location (default).

Zoom out - Reverse effect to **Zoom in**.

Zoom selection - By clicking and holding the left mouse button down, a 'marquee' may be drawn around the required area which will then be resized to fit the Map window. This feature is useful for 'zooming' into a particular area of the screen.

Grabber - The grabber tool can be used to drag the map display within the Map window. Thus if the area required lies just outside the displayed Map window this tool may be utilised to pull the area into view. Click on the Map window with left hand button and hold whilst 'dragging' the mouse in required direction.

Info tool - The info tool is a standard cursor that displays selection information within the Info window (top right of screen). Thus when the cursor is clicked on any location or object within the Map window the Info tool interogates the browsers for any tagged information. The results are displayed in the Info window with reference to the browser within which they can be found.

e.g. Area of digitised vegetation selected with Info tool.

Info window displays : KVG01: VG394

This indicates that the selected item is within vegetation browser KVG01 and has the ID VG394 (i.e. It is entry number 394). By moving the mouse to the Info window the cursor will change to a pointing hand. By clicking on the entry VG394 with the hand the Info window will diplay the record VG394 from the browser KVG01.

e.g. **ID: VG394**
Filename : LIRB31.TIF
Type: Row Crops
Class: Commercial
area: 5898.06
units: 0
other:

If the Info tool cursor has selected more than one relevant data match the info window will display the corresponding number of data entries.

Labelling tool - This tool enables the user to label specific items within the Map window. It must be used in conjuction with the **Layer control** (see below). Once the desired layer has been made editable, use the Labelling tool to click on the position of the required label within the Map window. Dailog boxes will follow for the text positioning and style.

Layer control - The layer control tool provides the key to operating MapInfo succesfully. Each of the browsers in the Kumasi GIS is effectively a layer within the MapInfo program that can be switched on or off by using the layer control tool. On selecting layer control a dialog box appears listing all the layers currently available to the GIS (see fig.28).

e.g.

Layer:	**Visible**	**Editable**	**Selectable**	**Zoom Layered**
Cosmetic Layer	X			
KMB01	X	X	X	X
KID01	X		X	X
KIS01	X		X	X
KST01	X		X	X
KNV01	X		X	X
KVG01	X		X	X
LIRB4	X			X
LIRB5	X			X
...				
LIRB31	X			X

The dialog table above indicates which layers are visible, editable and selectable. Zoom layering should be set for all layers within KUPIS so that the zoom function will maintain the relationship between the layers. In order to be able to select items from a given layer, with the Info tool for instance, a layer must be selectable. KUPIS default setting is with all layers selectable. Layers may be made 'transparent' by removing their visibility so that although they are still an integral part of the database they will not appear in the map window. This is useful if particular features want to be viewed in isolation or if a view of the images forming the map base, in this case Tagged Image Format Files (LIRB4, LIRB5,...LIRB10, through to LIRB31) was required. Thus with only the image layers visible all that can be seen within the Map window are 18 ADP images in a line. Turn the layer KMB01 to **visible** and the map base lines will appear also, turn on the vegetation and areas of green will appear within the images etc.

Only one layer can be made editable and no changes can be made to a layer unless it is editable. Once editable additional data can be added, new objects digitised, old ones removed, labels written. This will be discussed in more detailfrom page 42 onwards.

Layer selections are made at the side of the Layer control table (see fig.28). Below the box extra layers may be added or existing layers removed. The layers may also be re-ordered and their displays altered.

The cosmetic layer is the layer which the user is most likely to utilise when labelling. As it is the topmost layer of the Map window it does not effect the other database relationships. In order to label within the cometic layer it must be made **editable** and **selectable**. Once labelled the **'Cosmetic objects'** must be saved - choose <Map> followed by <Save Cosmetic Objects>.

The ruler - This tool allows the user to measure objects and image sizes in absolute terms no matter what level of zoom currently deployed. Thus the real sizes of buildings or the actual length of tracks and roads can be calculated in kilometeres and meters. The ruler is applied by clicking at the beginning and end of a proposed path of measurement with the ruler cursor. Further clicks will continue the measurement - the result displayed in the Ruler window at the bottom right of the screen - showing a Total and a Subtotal for each subsequent click.

Legend button - The legend button simply turns the Legend window on and off. The legend window only comes into use when a thematic map is being displayed (see page 40 - Thematic Maps).

Statistics button - On clicking on this button the Statistics window will appear at the bottom right of the screen. It can be used to display the results of calculations made on selected data from the browsers. Any selected objects/records from the browsers will have their numerical fields summed and averaged. As the selection changes the results in the statistics table will be updated automatically.

The Browsers

As it is important to emphasise the relationship between the browser's objects and the digitised Map window graphics a brief description of how this system was developed is neccessary.

e.g. A building in an image requires digitising.
Choose Layer Control button - Make buildings layer KNV01 selectable and editable.
Open KNV01 browser. Using drawing tools (see page 42) digitise around building. On completion of digitising, browser will automatically create a new line for data relating to new building.
Enter data into browser. Select <File> then <Save Table>.

Thus each item within the browsers is directly connected to a digitised object. With the browsers for buildings, vegetation and infrastructure these are objects within the image frames. By selecting a particular object in the Map window using the cursor (causing it to be highlighted) the same object's data entry will be highlighted within the relevant browser. It is indicated by a black square at the left side of the record. Unselected records have a white square. This process also works in reverse, selecting a record within a browser will cause the digitised object to be highlighted too. More than one object may be highlighted at once - this is done by holding down the shift key at the same time as clicking the mouse. In this way objects can be gathered for analysis within the Statistics window or 'exported' to another browser or even a separate spreadsheet e.g. Microsoft Excel.

Other browsers are not simply digitised objects. The Image Database (KID01) browser has 18 different entries one for each image. An image can be selected within it simply by clicking on the image as the digitised area is that within the red perimeter of each image. The Map Base (KMB01) browser's items can only be selected by clicking on one of the lines of latitude or longitude. Finally the Information System (KIS01) browser's records can only be selected by clicking on the star symbol displayed at the centre of each image.
The selection of individual records from within the various browsers is crucial to the analysis of the presented data. Selected records can be used to create Thematic maps and analytical charts both within MapInfo and in other spreadsheet programs. Further more powerful (and non manual) techniques for selecting records of particular criteria will be discussed in the next section.

The Select Function

The select function can be accessed through <Query> on the menu bar and then <Select>. It enables the user to select records from a table (browser) that satisfy particular criteria and to then 'dump' these selected records into a new browser. A dialog box asks the user to enter the name of the browser on which Select is to work, and to enter an expression which these selected records must match. The '**assist**' button leads to a second dialog box in which the user may type their expression using the '**columns**', '**functions**', and '**operators**' in a logical sequence. The syntax may be checked using the **verify** button. The selected records will be stored in a new browser, the name of which must be entered by the user.

e.g. **Type= Str$("Unfinished")** - Would select all the records that contain the character variable "Unfinished" from the field Type.

Area<=4000 and Units<10 - Would Select all the records with both an Area less than or equal to 4000 and less than 10 Units.

Some selection results have been stored as browsers on the CD. They include:

Buildings by Type:

bcomm.tab - commercial buildings
bdom.tab - domestic buildings
bunfin.tab - unfinished buildings

Vegetation by Class:

vcomm.tab - commercial vegetation
vdom.tab - domestic vegetation
vgraz.tab - grazing vegetation
vuncult.tab - uncultivated vegetation

Vegetation by Type:

voilp.tab - oil palm
vimoilp.tab - immature oil palm
vplan.tab - plantain
vmix.tab - mixed vegetation
vgl.tab - grassland
vmixr.tab - mixed river vegetation
vrowc.tab - row crops

Vegetation by Class & Type:

vcommop.tab - commercial oil palm
vcommpl.tab - commercial plantain
vcommrc.tab - commercial row crops
vcommmi.tab - commercial mixed vegetation

(Vegetation by Class & Type cont'd)

vdomop.tab - domestic oil palm
vdompl.tab - domestic plantain
vdomrc.tab - domestic row crops
vdommix.tab - domestic mixed vegetables
vdomgl.tab - domestic grassland

vunculop.tab - uncultivated oil palm
vunculpl.tab - uncultivated plantain
vunculmi.tab - uncultivated mixed vegetation
vunculmir.tab - uncultivated mixed river vegetation
vunculgl.tab - uncultivated grassland

The SQL Function

The SQL function works in a very similar way to the select function but can be used instead to group and order records of particular expressions into new user defined browsers. SQL can also be used to examine more than one table at a time.

The Find Function

The find function will search a table or tables for particular values or expressions and mark the records position within the Map window with a user defined symbol (default is a star). This is useful for speedy location of records within the Map window.

Other Useful Functions

View: Under the <Map> menu bar are a options to change the Map window view. They give the user the option to view any one particular image, layer or data set. They are: <Previous View>, and <View Entire Layer>. <Change View> allows the user to define the map scale and zoom features of the GIS.

Layout: Maps, screens or charts may all be exported for printing. The easiest method involves selecting <Window> from the menu bar and <New Layout Window>. Windows displayed on the screen may now be selected for printing and arranged in the Layout window.

Printing: Once the Layout window has been designed the user should select <File>, <Print>.

Thematic Maps

Introduction

Some examples of thematic maps and simple bar graphs are included in the KUPIS package and are stored on the CD as workspaces in a directory labelled '**\thematic**'. To load them choose <File> from the menu bar and then <Load Workspace>. Finally select the thematic map you require from the list. Thematic maps included are:

themap01.wor
themap02.wor
themap03.wor
themap04.wor
themap05.wor
themap06.wor
themap07.wor
themap08.wor

Bar graphs included are:

bargrph01.wor
bargrph02.wor
bargrph03.wor
bargrph04.wor
bargrph05.wor

These bar graphs were made by using the <Select> function detailed in the previous chapter. It was used to remove records from the browsers that were of a partcular nature or fell within certain sets of conditions. The selected records were 'dumped' into new browsers which could be analysed later to create the graphs.

e.g. Unfinished buildings selected from the buildings browser and stored in the browser Unfin.tab

Creating Thematic Maps

Thematic maps can be created by selecting <Map> and then <Thematic Map>. Mapinfo will then display a dialog window requesting the user to select a type of thematic map from a choice of; Ranges, Bar Charts, Pie Charts, Graduated, Dot Density and Individual (see fig.29). The user is then requested to select the table (browser) and the field from which the thematic map is to draw its variables. MapInfo also provides a facility to draw records from the tables which match a particular '**expression**' and a facility to '**join**' different table (browsers) which will be explained in detail later. Thus a thematic map displaying **vegetation** by **type** and displaying the types in different colours would require the user to select <Individual> thematic map <Next> to move to the second dialog box, and then to choose <KVG01> (the vegetation browser) as the table and <Type> for the field. The subsequent dialog boxes will request the user to choose the colours and styles of the thematic map display and to design the legend that will accompany it with. This customizing ability operates with each of the six types of thematic map. Thus bar graphs will require the user to enter colours and legend but will also require bar dimensions. It is best to experiment with different combinations and and views of your thematic map and so this manual will not attempt to detail the various options.

Thematic map options that have the ability to display more than one field at a time will request the user to <add> or <remove> fields from the table box to or from the thematic map box (see fig.30).

The Expression Function

Once the user has selected the desired table from which the thematic map is to draw its records the option to draw only records that match a particular expression is available. The option works in the same way as the <Select> function detailed in the previous chapter. By selecting <expression> from the second thematic map dialog window a new dialog window will appear where the user can type in the required expression (see fig.31). As with <Select> the user may choose from '**Columns**', '**Operators**', and '**Functions**' and arrange them in a logical order to extract the particular records required. The syntax may be checked using the <Verify> button. For more syntax details please see the MapInfo User's Guide.

e.g. **Type= Str$("Unfinished")** - Would select all the records that contain the character variable "Unfinished" from the field Type.

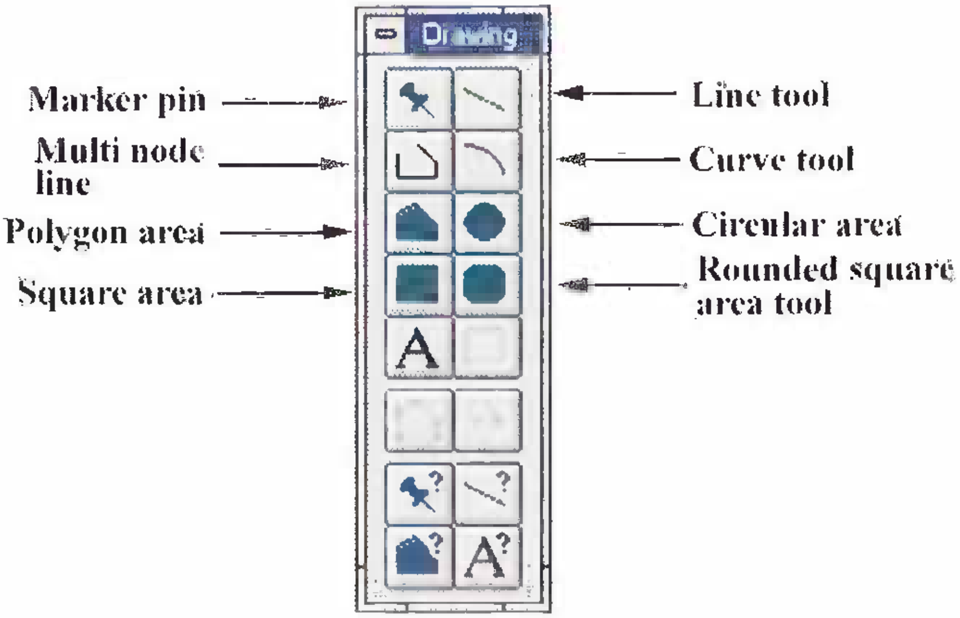
Area<=4000 and Units<10 - Would Select all the records with both an Area less than or equal to 4000 and less than 10 Units.

The Join Function

This function allows the user to '**join**' two different tables together at particular points. Thus records from more than one table can be displayed in charts at the same time. Having decided to join two tables the user must enter the name of the second table and the column from which records are to be drawn. A number of numeric functions such as 'sum_of', 'avg' and 'max' are also provided. The user must then '**join**' the two tables. This can be done either:

Where Column A from Table 1 matches Column B from Table 2
or
Object from Table 1 is within/contains/intersects with Object from Table 2

Digitising



The most useful drawing tools are labelled above and will allow the user to successfully digitise their images. For details of the other tools please refer to the MapInfo User's Guide. The drawing tools box can be made visable by selecting <Options>, <Button pads...>.

In order to digitise a layer, the user must first make that layer **Editable** using the Layer Control function. Having done this the optimum Map window view of the image area to be digitised should be achieved. For every completed digitised item an entry will be made in the currently activated browser. Thus it is important to decide on the technique to be applied in digitising any object before starting. This is best demonstrated through example:

e.g. A road is to be digitised but its area is not required.
If the road is straight choose the line tool - Click on either end of the road and a line will be drawn between the two points in the currently selected style. To cange this style choose the Pointer Arrow from the Main Toolbox and double click on the line to open the Stlye Options dialog box.
If the line is crooked or curved choose the Multinode Line or Curve tool.

e.g. An irregularly shaped building is to have its perimeter digitised and area filled.
Choose the Polygon Area tool. Digitise around the building by clicking on each of its perimeter corners finally ending at the starting point. MapInfo will complete the outline and fill the area with the currently selected style. Again to change this style double click within the shape using the Main Toolbox Pointer Arrow.

e.g. A small round bush is to have its area digitised.
Select the Circular Area tool, click on the top left corner of bush, and drag circle over bush. Style changes as above e.g.s.

Data Editing, Addition and Updating

The structure of the GIS has been designed to facilitate the easy addition of extra data to existing tables and maps, or the addition of new tables and maps that can be fully integrated with the existing data. Detailed below are several ways in which this data can be added.

Updating

New features may be added to the exisiting tables and maps by setting the appropriate layer to **editable** digitising around the new feature and entering information into the relevant browser in the new lines provided. Fields such as **Area** which must be calculated by MapInfo can be updated b selecting <Table> from the menu bar, and then <Update Column>. More complex calculations are provided for by the '**Assist**' button which enables the user to enter a desired expression or numeric calculation. Table columns can be updated from other tables using the '**Join**' button (see Expression and Join functions, page 40). MapInfo will then automatically update all the records in the selected columns. It is important to remember that some browser records depend upon the contents of other browsers and so in adding new data to one browser it becomes neccessary to update any dependant browsers.

e.g. The user digitises around a previously undigitised building and enters information regarding this into the buildings browser (KNV01). Using <Update Column> the user updates the area column to calculate the area of the new building. The user must now update the values of any other browser that draws results from KNV01. In this case the Information System browser (KIS01) must be updated as it calculates number of buildings per image, area of buildings per image and building percentage area. This is also done using the <Update Column>, by entering a correct numerical expression and joining the browsers where there filenames are the same.

<Append Rows> also under the menu header <Table> allows the user to add rows from one table to the bottom of another.

Eroneous digitising or records may be removed by selectingthe appropriate record within its browser (highlight the white box to the left of the record) and pressing the delete key. The line will loose its text and turn grey, the digitised graphics will disappear from the Map window. The table will then have to be re-packed to remove this empty record - Select <Table>, <Maintenance>, and then <Pack Table>.

Editing Existing Tables

New columns or alterations to existing column structures may be made by selecting <Table>, <Maintenance>, <Table Structure>. Having choosen the rquired table the user may add or remove fields and change their name,size and structure.

New Raster Images

As the database grows it may be neccessary to add more and more Raster Images (ADP images) to the Map Base so that they can be digitised and their data added to the existing browsers. Once the raster image has been prepared it may be 'imported' into MapInfo by selecting <File>, <Open Table>, and then selecting Raster Image as the file format. Now choose the filename of the image required, which MapInfo will load ready for geocoding. This involves selecting four points (usually the four corners) on the image with the provided cursor and entering Latitude/Longitude co-ordinates for each. It is important that the Map Projection remains constant (KUPIS uses WGS'84). Once geocoded MapInfo will place the image in its correct position within the Map window and on top of the Map Base.

Although the image is now visible, it has not been entered into the Image Database (KID01). To do this make the KID01 layer **Editable** (using **Layer Control**) and draw a box around the image perimeter using the Square Area tool from the Drawing Toolbox, by clicking on the top left hand corner of the image and dragging the square to the bottom right corner. A new line will automatically appear in the KID01 browser ready to be updated. The style of the box around the image, and its filling pattern (which is best off) can be set by double clicking within the box with the Main Toolbox Pointer Arrow to open the Style Options dialog window.

Having updated the KID01 browser, a space must now be made for the image within the KIS01 browser. This is done by making the KIS01 layer **Editable**, choosing the Pin Marker tool from the Drawing Toolbox, and clicking in the centre of the image.Again the style of the Marker can be changed (a star is default) by double clicking on the symbol with the Main Toolbox Pointer Arrow. The new line within the KIS01 browser may now be updated as far as possible.

New Tables and Data Sets

Extra data sets can easily be added to KUPIS as extra columns in existing browsers (see above) - e.g. Population figures per household could be added to the buildings browser as an extra column - or may be added as completely new browsers with their own digitised map layers. The browsers and maps may be added by selecting <File> from the menu bar, and then <New Table>. The user will be shown a dialog screen with the following options:

X **Open New Browser**
Open New Mapper
X **Add To Current Mapper**

In cases where new data is being added to KUPIS the options should be set as above - i.e. Open a new browser and add a map layer to the current Map window. By selecting Open New Mapper a new unrelated Map window will be opened for the new data.The next stage involves the user defining the details of the new browser and its structure requiring inputs for field names, sizes and structures. Clicking on the '**Create**' button will produce a new empty browser and a new mappable layer added to the **Layer Control**.