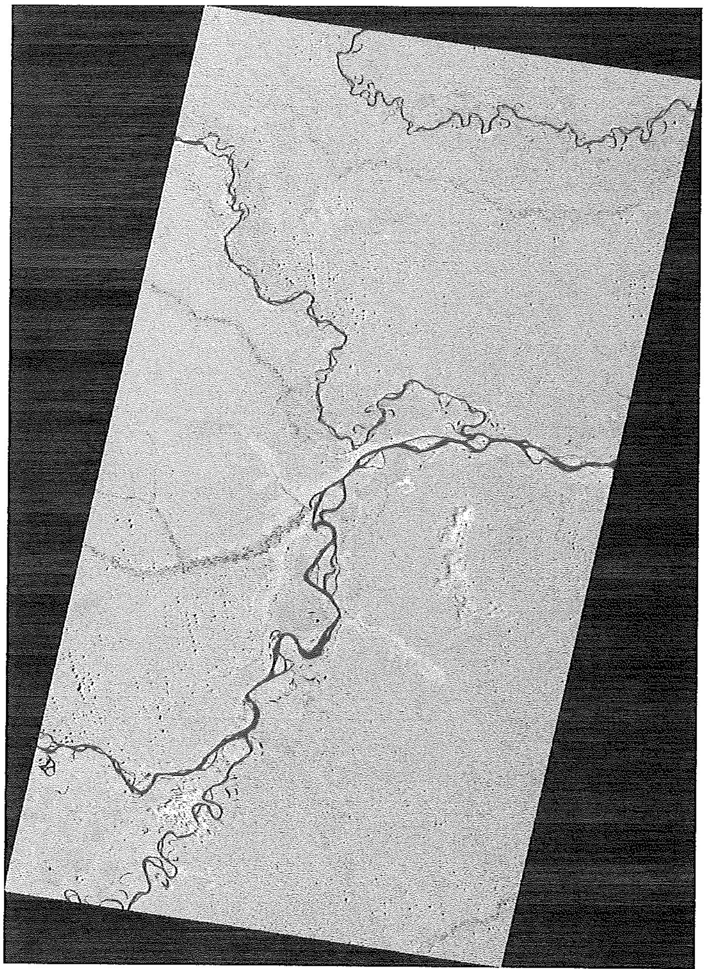
2000

Trainee Report

A summary of trainee assignments carried out at Turku University, Finland.
April-July 2000



A mosaic of two Landsat TM images, created in Erdas Imagine

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Preface

This report summarizes the tasks carried out during my trainee period at the Department of Geography of Turku University (Finland). First of all I would like to thank professor Risto Kalliola for providing me this work placement and for supporting me when having questions, or any kind of problem. I also would like to say thanks to professor Steven de Jong, who was willing to act as my co-ordinator at my home university (Utrecht University, The Netherlands). Furthermore I would like to thank Lizardo Fachín and Tuuli Toivonen for their outstanding company and fine co-operation. Finally I would like all researchers and members of the departments of Geography and Biology to know, that I am grateful for their support and for their successful attempts to make me feel comfortable in Turku.

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Introduction

Part of the fourth and final year of the studies Physical Geography, at Utrecht University in the Netherlands, consists of a so-called free study space. Students can use this space for several courses of free choice, but they can choose for carrying out a trainee post as well. Trainee posts may be of different kinds of geographical subjects and can be done at a company or university, in The Netherlands or abroad. This report describes a three months trainee period carried out at the Laboratory of Computer Cartography at the Department of Geography of Turku University (Finland). The job took place from 12/04/2000 till 14/07/2000 and has been exercised by Albert Driesprong, the author of this report.

The main goal of the trainee ship was to improve academic skills in the field of Physical Geography and to get familiar with a possible future work environment. In order to reach this goal several different assignments were completed, which together formed a highly varied job. The different tasks were provided by professor R. Kalliola, who acted as the main supervisor. A lot of the work has been done in co-operation with the Amazon Research Team of Turku University. This multidisciplinary team aims to address the evolutionary, ecological and practical consequences of the regional variability in the Amazonian Tropical Forests from many different points of view. In this research, Remote Sensing imagery plays an important role. Next to tasks in the field of Remote Sensing, work has been done on the development of a database, on the creation of a poster and on a variety of minor jobs. This report summarizes the tasks carried out during the trainee period.

1. Acquiring images from the complete Pan Amazon area

Objective

In March of the year 2000 the Amazon Research Team of the Turku University purchased 36 Landsat TM and 7 Landsat MSS images of the Peruvian rainforest. Since the team aims to create a satellite image mosaic covering the entire Pan Amazon lowland area (appendix 1A), many more images were needed, mainly from Venezuela, Colombia, Ecuador and Bolivia. Furthermore the research team was looking for images from West-Brazil and for additional, high quality, images of the Peruvian rainforest. In general, the main interest was for Landsat TM images since they contain several bands in the near infrared and infrared wavelengths.

Obtaining satellite images is easiest by browsing the on-line catalogues of different providers on Internet. In most cases these browsers provide both quicklooks and metadata of the available scenes. Orders can often be placed on-line. Prices of the images vary a lot and range from about US$ 15,00 a piece, up to a couple of thousands US$ a piece. The main objective of this assignment was to order a, high quality and low cost, image set covering the whole Pan Amazon region.

Image sources

The earlier obtained 43 scenes were ordered from EDC-DAAC (Eros Data Center), which is an institute offering satellite images for rather low prices. Landsat TM and Landsat MSS scenes only cost US$ 15,00 a piece and are provided on 8 mm, high density tapes in varying formats. Unfortunately images less than 10 years of age are for restricted distribution and therefore not available for the Amazon Research Team. Nevertheless the on-line catalogue of EDC-DAAC was a very useful source of data. The second data source was the on-line archive of the Michigan State University (TRFIC-Archive), which offers scenes of the whole Amazon area. Here scenes cost US$ 25,00 a piece and are provided on CD-ROMs in Erdas Imagine Format. Data from the TRFIC-Archive is not restricted in any way.

Strategy

Image selecting

Since EDC-DAAC and the Michigan State University are by far the cheapest known providers of satellite images, all images were purchased from these institutes. In order to find the best images both catalogues were searched systematically, according to single path-row combinations. For each location the metadata and the quicklooks of the available images were compared with each other. Then selections were made, mainly based on the amount of cloud cover, and the presence of haze, smoke and missing values. Furthermore attention has been paid to distribution restrictions and processing levels. Only systematically corrected images were considered useful, since they do not restrict the user in any way. After selecting the most appropriate scenes, a separate order proposal for each country was made, containing price information and metadata (appendix 1B). Before making a final decision, the order proposals were discussed with several members of the Amazon Research Team. In total 95 images were selected for ordering, 45 from EDC-DAAC and 55 from the Michigan State University.

Image ordering

The selected images were ordered using on-line order forms and e-mail. Both, EDC-DAAC and the Michigan State University offered good services, providing clear order receipts and payment instructions. Communication was rather frequent and took place via e-mail as well. Questions of any kind have always been answered properly, within a few days. The images were processed and sent without any extra charges, at maximum a couple of weeks after the order was made.

Conclusion

The ordering of satellite images at both, EDC-DAAC and the Michigan State University went without any major difficulties. Based on the available metadata and quicklooks a satisfying set of images could be selected. Furthermore the order procedures were rather clear.

Experiences

Doing this exercise was a useful experience since it showed in what form Remote Sensing data is available for ordering on the Internet and how the order procedure takes place. Further it was nice learning how to distinguish useful images from the less useful ones. Discussions with different researches and scientist, about the quality and practical use of the available images, increased my understanding of the role Remote Sensing plays in different researches.

2. Importing and administrating images

Objective

In spring of the year 2000, the Amazon Research Team purchased a total of 88 Landsat satellite images from EDC-DAAC (Eros Data Center). These scenes were provided on 8 mm, high density tapes, in three different formats: EOSAT, Fast Format, NLAPS and MEDIPS (MSS image format). Before any analysis could be made, the images had to be converted to a standard format, readable by at least one of the available software packages. Further it was important to administrate the data in order to make it easily accessible for all users. In close cooperation with other members of the Amazon Research Team, 47 images were imported and administrated during the trainee period.

Strategy

Importing

The tape drive available at the Laboratory of Computer Cartography is connected to the Unix system and can not be reached from the NT platform. Since Erdas Imagine at the Laboratory, runs in Unix and offers a sophisticated import tool, the Erdas Imagine (IMG.) Format was chosen as the standard. The time needed for importing an image varies between 1,5 and 2 hours, depending on the amount of bands, rows and columns the image contains. For each format the data import works slightly different. The procedure that should be followed is well described in available manuals, however. After completing the import process the quality of the images was checked in Erdas Imagine by opening all of the bands separately and checking them for lines or other areas of missing values. In case the quality was unsatisfying the import process was carried out again, which in some cases resulted in a better image.

Administrating

Since the size of the image files is too big (up to 400 MB) for storing on computer hard disks the imported scenes needed to be stored on CD-roms. For burning the CDs the software package Easy CD creator was used, which turned out to be a very well functioning and user friendly program. Next to the images the metadata and a JPEG picture of each scene was stored on a separate CD. The JPEG pictures are especially useful as quicklooks, because it normally takes quite some time to load the original images.

Further a CD cover for each scene was created in order to structure the data set and make it easily accessible. The covers contain both, a black and white picture of the image and some basic metadata. Appendix 2 shows an example of such a CD cover. Finally a duplicate of each CD was made for sharing the data with the Peruvian Amazon Research Institute (IIAP). This is an institute, located in the Peruvian region of Iquitos, which closely collaborates with the Amazon Research Team of Turku University.

Conclusion

Before any analysis of the images provided on tape could be done, they had to be imported and administrated. The importing has been done using Erdas Imagine, after which the files were burned on CD and administrated using the metadata and the quicklooks.

Experiences

By carrying out this assignment my knowledge about different image formats and my understanding of several software packages, like Erdas Imagine, improved. Further it was useful to experience what errors may occur when importing large files from tape.

3. Comparing different software packages

Objective

As mentioned before, one of the aims of the Amazon Research Team is to create a Landsat TM image mosaic of the entire Pan Amazon area (appendix 1A). When creating a mosaic two major processing steps have to be made. The first step is the georeferencing of the images and the second is the mosaicing itself. The Laboratory of Computer Cartography at the University of Turku provides several programs for processing satellite data: Erdas Imagine, PCI and ER-Mapper. In order to find out which program is most appropriate for georeferencing and mosaicing, a small survey was carried out.

Strategy

The followed strategy and the results of the survey are discussed in a separate report, which can be found in appendix 3. The report is meant to support the Amazon Research Team in choosing the right program for creating the final mosaic. The applied strategy can be summarised as follows: using two Landsat TM images of the Peruvian rainforest both, the mosaicing and the georeferencing tools of all three programs have been examined. Special attention was paid to the quality of the results, the options the different programs offer and the user friendliness of the programs.

Conclusion

The conclusions of the survey can be found in the report in appendix 3 as well. In summary: concerning the georeferencing the differences between the programs are rather small; more distinct differences were found between the mosaicing tools. Although there was a slight preference for using Erdas Imagine, non of the programs seemed to be the absolute best

Experiences

Completing this task was very useful since it gave a good idea of differences and similarities between a variety of software packages, all developed for image processing. It was interesting to notice that the idea behind basic processes is very much the same in each program, but that the user interfaces and the available extra options vary a lot. Further this assignment increased my understanding about several features like map projections, ellipsoids, coordinate systems and resolutions.

Note

The result of the mosaicing in ER-Mapper was rather poor because the background of the one scene interfered with the image of the other. Although it seemed not to be impossible to solve this problem while doing the survey, later examinations showed there is a solution (see chapter 7).

4. Acquisition of satellite images from the Finnish Archipelago

Objective

In 1996, the University of Turku started a multidisciplinary research project called: Landscapes of the Past, Present and Future. The research team aims to develop new solutions, that take use of modern information technology, to come across dynamic solutions for the interactive use of multi-source spatial data materials, like maps, remote sensing imageries and field data. One of the main areas of interest for this research is the archipelago of South-West Finland. On the moment the research team is highly interested in high quality Landsat TM images of the area. In order to find out if such images are available for a reasonable price, a query on the Internet was carried out.

Strategy

Several search engines, like Alta Vista, Yahoo and Google, were used for tracking addresses of different image providers. After a first orientating search it became clear that many companies and institutes provide satellite data, and that qualities and prices range significantly. When making the search at least one address turned out to be very helpful, since it provides a list of links to many of the available satellite image catalogues. The address and the list can be found in appendix 4. At least a couple of the listed providers offer high quality images of South-West Finland. Eurimage and GAF (Gesellschaft für Angewandte Fernerkundung) are good examples.

Unfortunately the prices of the images provided here, are quite high. A single Landsat TM image costs around US$ 1000,- which is a lot compared to the US$ 15,-, EDC-DAAC asks for their TM images of the Pan Amazon Area. Unfortunately no providers have been found who offer cheaper data. Since this search mainly was orientating however, there still is a reasonable chance that cheaper images are available. Further queries may therefore be useful.

Conclusion

After an orientating query for Landsat TM images of the archipelago of South-West Finland, it became clear that high quality scenes are available. Unfortunately, the ones found so far are fairly expensive. Since this search mainly was orientating, there still is a chance that cheaper images do exist however.

Experiences

While doing this exercise it was nice experiencing that large amounts of Remote Sensing and GIS data are available trough the Internet. It is also good to know that prices and qualities differ considerably, depending on the provider of the data. Further my skills concerning the use of different search engines on the Internet improved.

5. Creating a database

Objective

As a result of the acquisition and processing of the Landsat satellite images in spring 2000, the Amazon Research Team obtained large amounts of new data. It is expected however, that an even larger amount will be created in the near future. In order to keep an overview on the available information it was necessary to build a database, available for all members of the research team. When finished, the database should be able to store several data types, varying from text files to GIS and Remote Sensing information. Part of the database development functioned as a trainee assignment.

Strategy

It was decided to create the database in Microsoft Access, since the program is widely available at Turku University. The main task carried out during the trainee post was the development of the table structure (appendix 5), which actually forms the basis of the database. It is in this table structure where the information is stored and were the links between the different types of data are made. The development of the structure went in close co-operation with several members of the Amazon Research Team. The exact contents and the relationships were continually evaluated. After creating a satisfying set of tables some data was entered in order to test the functionality and to correct errors. Although a couple of changes were necessary, the eventual structure of the tables was rather promising.

The final part of the database development is the creation of a user interface, which will help people to find and store information in a fast and easy way. Once the interface is operational, knowledge about Microsoft Access should not be needed for running the database anymore. Unfortunately there was no time to include the creation of the interface in the trainee assignment.

Conclusion

In order to keep an overview on the data, available within the Amazon Project, a database will be needed very soon. Part of the creation of the database functioned as a trainee assignment. During the trainee ship attention has mainly been paid to the development of the main structure (see appendix 5). Although the database is not operational yet, the basic design looks promising.

Experiences

Although this assignment did probably not improve any specific geographical skills, it was really practical for increasing my knowledge about databases and their structure. Further I believe it is good to be familiar with a program like Microsoft Access, since there is a reasonable chance it will be useful when practising a future job.

6. Laboratory of Computer Cartography poster presentation

Objective

In May 2000 the third AGILE (Association of Geographic Information Laboratories in Europe) conference on geographic information science took place in Helsinki. Since the Laboratory of Computer Cartography of Turku University is a member of AGILE, professor R.Kalliola (Department of Geography) attended this conference and presented the laboratory in the form of a poster (appendix 6). Creating this poster was one of the assignments during the trainee post. The aim was to present three important aspects of the laboratory: general information and facilities, its use for education and its use for several kinds of research.

Strategy

The first step in creating the poster was the gathering, editing and writing of the texts. Internet pages of the Laboratory of Computer Cartography and individual research projects turned out to be useful information sources. The second step was the collection of pictures and figures. Photos were made by digital camera, and research-workers and lecturers were asked to provide examples of their work. The final poster was designed in A1 size, using Corel Draw and Photoshop Adobe. The three different aspects, general information, education and research, were presented in separate parts of the poster. While adding the photos, some problems with the brightness and saturation occurred, but those could be solved after all. An A3 sized copy of the poster can be found in appendix 6.

Conclusion

By using available information found on Internet and provided by research-workers and lecturers, the Laboratory of Computer Cartography of Turku University was presented in the form of a poster. Although some problems occurred during the creation, the final result is rather satisfying.

Experiences

While creating the poster it was nice discussing about the purposes of the Laboratory of Computer Cartography with different research-workers and lecturers. The available facilities and software packages support many types of research and education, exercised at Turku University. Further this assignment was useful for increasing my skills in using drawing and photo editing software packages, like Corel Draw and Photoshop Adobe.

7. Minor tasks

Objective

Next to the major assignments, provided by professor Risto Kalliola, a number of minor tasks were carried out during the trainee period. These tasks varied from helping colleagues solving their problems in the field of Remote Sensing to presenting results of the work done. In nearly all cases there was an intensive interaction between the practician and the employees of the University of Turku, which stimulated the practician's integration into the work environment. In this chapter several of the minor tasks will be summarized.

Presentation

At a meeting of the Amazon Research Team at Hirvensalo Island, the results of the program comparison (see chapter 3) were presented together with the results of another small survey, concerning the resolution of satellite images. The latter showed the influence of an increase in pixel size on the information content of satellite images. Since the research team aims to create a Landsat TM mosaic containing about 120 satellite images, it is important to know the maximum acceptable pixel size. Normal, 30 metre, pixels would create a too big file to handle with the available computers. After the presentation some discussion took place.

Checking co-ordinate information

During the trainee period, one of the researchers of the Landscapes of the Past, Present and Future project worked in Canada and georeferenced several digital aerial photographs of Ruissalo Island (SW Finland). Since the results needed to be checked, several pixel co-ordinates were taken from georefenced images, available at Turku University, and sent to Canada by e-mail.

Further checking of Georeferencing and Mosaicing Tools in ER-Mapper

When carrying out the program comparison, the result of the mosaicing tool of ER-Mapper was rather poor (see chapter/appendix 3). Since ER-Mapper is the most used Remote Sensing software package among the members of the Amazon Research Team however, it was decided that some further attempts to create a satisfying mosaic should be done. Finally the problem could be solved by setting the 0-values of the header files in the new version of ER-Mapper (6.1). In the older version this did not have any effect (6.0).

Furthermore some tests were carried out concerning the georeferencing of images, using the corner co-ordinates given in the metadata sets. Making use of these co-ordinates, instead of GCPs taken from maps, will considerably simplify the creation of the final mosaic. A series of tests showed that the use of corner co-ordinates as GCPs, in most cases leads to a satisfying result. Unfortunately some of the images do not contain sufficient metadata for using the corner co-ordinates.

Creating an ER-Mapper mosaic of the Iquitos region

In July 2000, one of the most urgent needs of the Amazon Research Team was a mosaic of the Iquitos region (Peru) in ER-Mapper format. This mosaic was created out of four Landsat TM images in a 100m resolution. Furthermore the Geodetic Projection was used in combination with the WGS84 Datum. The final document has been stored on CD-ROM in both ER Mapper and TIFF format. The TIFF image contains a 7/4/3 band combination and can easily be opened in a drawing program (appendix 7).

Conclusion

Next to the major trainee assignments, some small tasks were carried out. These tasks differed from, for example, doing a presentation to creating a Landsat TM mosaic of four separate images.

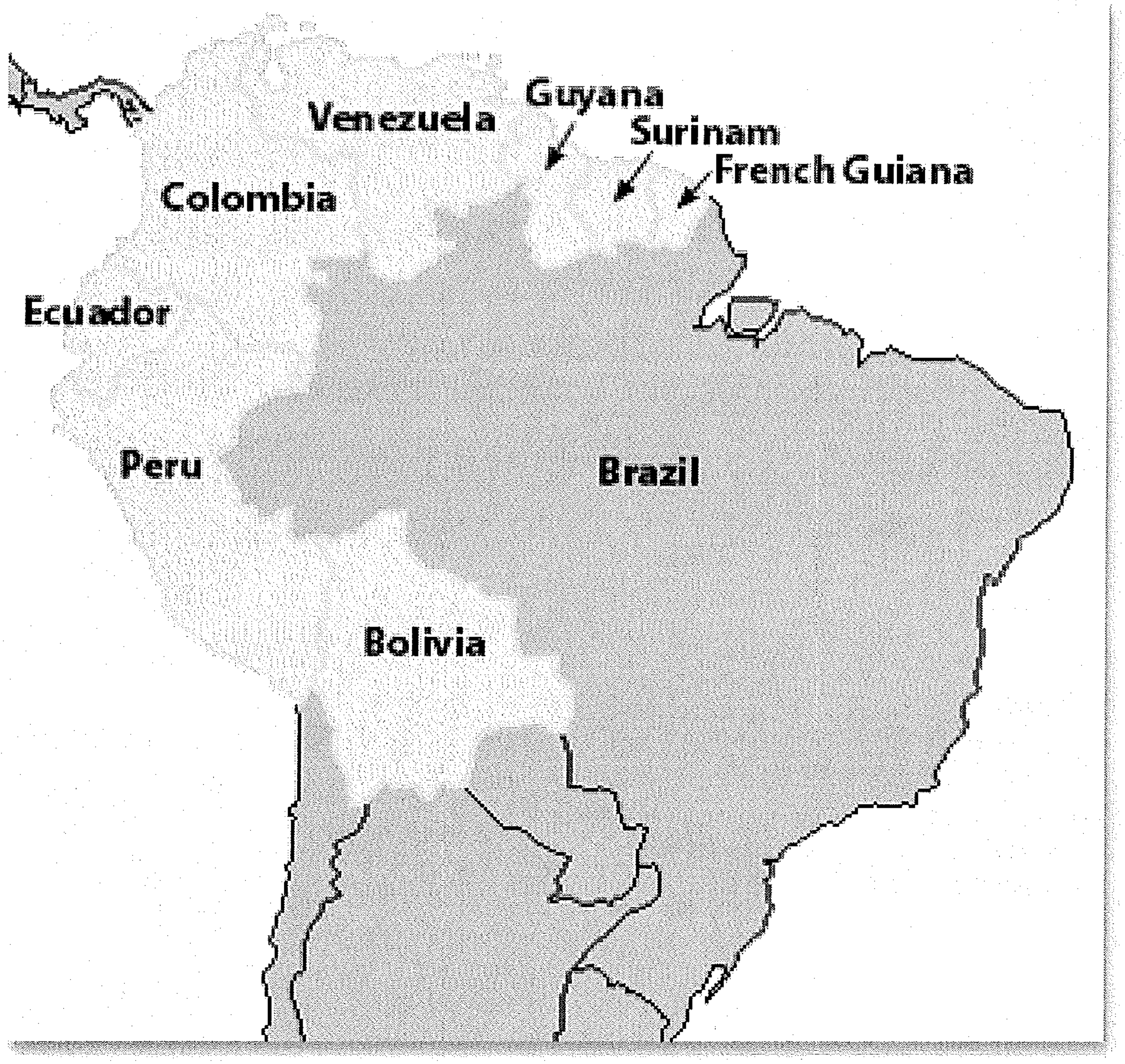
Experiences

The minor tasks during this trainee period were pleasant to carry out since they provided quite some variation in the overall job. Further it was nice to exercise work in close co-operation with the employees of Turku University. It gave me the opportunity to get integrated in the work environment, which helped to reach one of the main goals of this trainee period: getting familiar with a possible future work environment. Finally the minor tasks improved a variety of skills, like using Remote Sensing software and doing presentations in English.

Appendixes

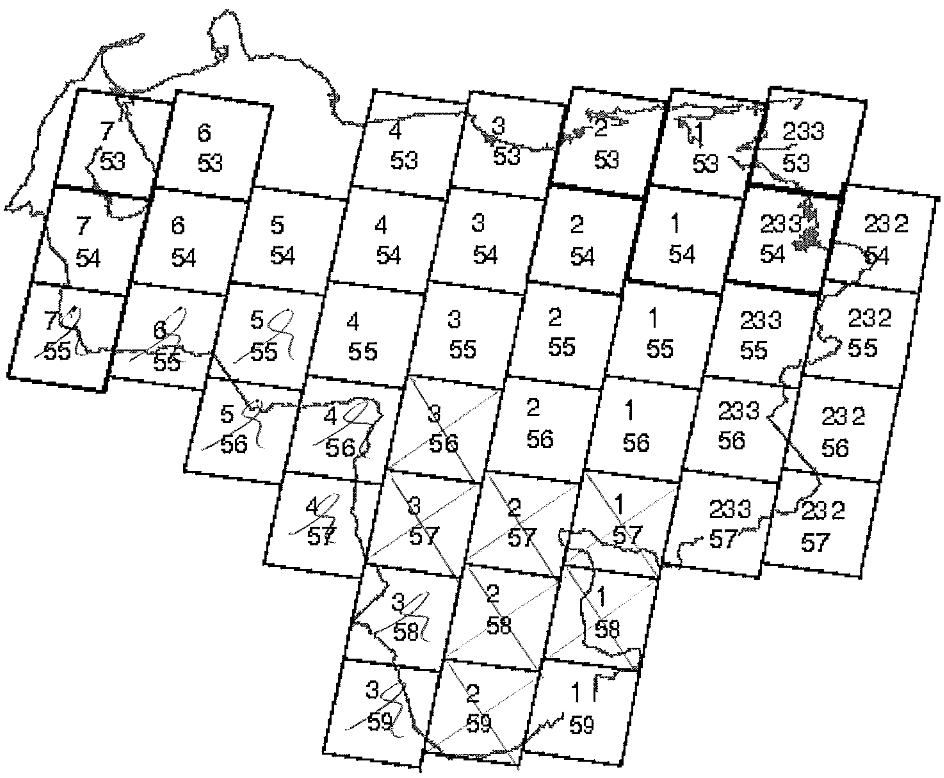
Appendix 1A

The Pan Amazon



Appendix 1B

Order proposal for images from Venezuela:



Total amount of images: 7
Amount of EDC images: 4
Cost of EDC images: $ 60,-
Amount of TRFIC images: 3
Cost of TRFIC images: $ 75,-
Total cost images from Venezuela: $ 135,-

X = images included in this report
= already purchased images or images included in other report

Venezuela Images

Image 3 / 57 / 1991

Data source: TRFIC
Date Aquired: 01/15/91
Sensor: TM
Scene ID: t0030570115912
Estimated quality: average
Path: 3
Row: 57
Percent Cloud Cover:
Top Left: 5
Top Right: 5
Lower Left: 5
Lower Right: 0

Image 3 / 56 / 1990

Data source: EDC
Sensor: Landsat TM
ID: GL5003056009010810000457
Date: 18 Apr 1990
Estimated quality: good/average
restrictions = No restrictions
project_source = Global Change Landsat Data Collection
old_scene_id = Y5223914014X0
path_nbr = 3
row_nbr = 56
wrs_type = 2
cloud_cover = 10% but less than 20%
edc_processing_level = Systematically corrected (See Guide)
map_projection = Universal Transverse Mercator
sun_azimuth = 79
sun_elevation = 54
data_format = TFASTEOSAT
condition = EOSAT nominal center coordinates
upper_left_lat = 6.65070
upper_left_lon = -67.12708
upper_right_lat = 6.41155
upper_right_lon = -65.47175
lower_right_lat = 4.91896
lower_right_lon = -65.79568
lower_left_lat = 5.15748
lower_left_lon = -67.44674

Image 2 / 59 / 1986

Data source: EDC
Sensor: Landsat TM
ID: HT5002059008631410002399
Date: 10 Nov 1986
Estimated quality: average/poor (quite some cloud cover)
Note: no better image available at TRFIC
restrictions = No restrictions
project_source = Humid Tropical Forest Project TM
old_scene_id = Y5098413550X0
path_nbr = 2
row_nbr = 59
product_size = FULL_SCENE
wrs_type = 2
cloud_cover = 10% but less than 20%
edc_processing_level = Systematically corrected (See Guide)
map_projection = Universal Transverse Mercator
sun_azimuth = 121
sun_elevation = 53
resampling_tech = cubic convolution
data_format = TTRANSFER
data_file_interleaving = band sequential
user_orientation = satellite heading
horizontal_datum = WGS84
spectral_bands_avail = 1234567
orientation_angle = 8.196093
pixel_width = 28.5000
pixel_height = 28.5000
radiometric_enhancement = No
radiometric_calibration = NASA algorithm
map_zone = 20
ellipsoid_semi_major_axis = 6378137.000
ellipsoid_semi_minor_axis = 6356752.314
upper_left_lat = 2.39895
upper_left_lon = -66.63431
upper_right_lat = 2.14712
upper_right_lon = -64.87226
lower_right_lat = 0.51406
lower_right_lon = -65.10465
lower_left_lat = 0.76820
lower_left_lon = -66.86474

Image 2 / 58 / 1986

Data source: EDC
Sensor: Landsat TM
ID: HT5002058008631410002240
Date: 10 Nov 1986
Estimated quality: average (some cloud cover)
restrictions = No restrictions
project_source = Humid Tropical Forest Project TM
old_scene_id = Y5098413544X0
path_nbr = 2
row_nbr = 58
product_size = FULL_SCENE
wrs_type = 2
cloud_cover = less than 10%

edc_processing_level = Systematically corrected (See Guide)
map_projection = Universal Transverse Mercator
sun_azimuth = 123
sun_elevation = 53
resampling_tech = cubic convolution
data_format = TTRANSFER
data_file_interleaving = band sequential
user_orientation = satellite heading
horizontal_datum = WGS84
spectral_bands_avail = 1234567
orientation_angle = 8.260463
pixel_width = 28.5000
pixel_height = 28.5000
radiometric_enhancement = No
radiometric_calibration = NASA algorithm
map_zone = 20
ellipsoid_semi_major_axis = 6378137.000
ellipsoid_semi_minor_axis = 6356752.314
upper_left_lat = 3.84341
upper_left_lon = -66.33024
upper_right_lat = 3.59110
upper_right_lon = -64.56576
lower_right_lat = 1.95791
lower_right_lon = -64.79922
lower_left_lat = 2.21208
lower_left_lon = -66.56057

Image 2 / 57 / 1995

Data source: TRFIC
Date Aquired: 01/03/95
Sensor: TM
Scene ID: t0020570103952
Estimated quality: average/poor (JPEG shows quite some cloud cover)
Path: 2
Row: 57
Percent Cloud Cover:
Top Left: 10
Top Right: 50
Lower Left: 10
Lower Right: 10

Image 1 / 58 / 1986

Data source: TRFIC
Scene ID: t0010581101912
Estimated quality: average/poor (quite some cloud cover)
Path: 001
Row: 058
Date Aquired: 11/01/91
Sensor: Thematic Mapper
Cloud Cover: 10

Image 1 / 57 / 1987

Data source: EDC
Sensor: Landsat TM
ID: HT4001057008733410002254
Date: 30 Nov 1987
Estimated quality: average/poor (quite some clouds)
Note: no better images available at TRFIC
restrictions = No restrictions
project_source = Humid Tropical Forest Project TM
old_scene_id = Y4196313510X0
path_nbr = 1
row_nbr = 57
product_size = FULL_SCENE
wrs_type = 2
cloud_cover = 20% but less than 30%
edc_processing_level = Systematically corrected (See Guide)
map_projection = Universal Transverse Mercator
sun_azimuth = 131
sun_elevation = 50
resampling_tech = cubic convolution
data_format = TTRANSFER
data_file_interleaving = band sequential
user_orientation = satellite heading
horizontal_datum = WGS84
spectral_bands_avail = 1234567
orientation_angle = 8.363895
pixel_width = 28.5000
pixel_height = 28.5000
radiometric_enhancement = No
radiometric_calibration = NASA algorithm
map_zone = 20
ellipsoid_semi_major_axis = 6378137.000
ellipsoid_semi_minor_axis = 6356752.314
upper_left_lat = 5.26260
upper_left_lon = -64.35593
upper_right_lat = 5.00424
upper_right_lon = -62.59413
lower_right_lat = 3.37356
lower_right_lon = -62.83355
lower_left_lat = 3.63189
lower_left_lon = -64.59152

Appendix 2

CD-Cover

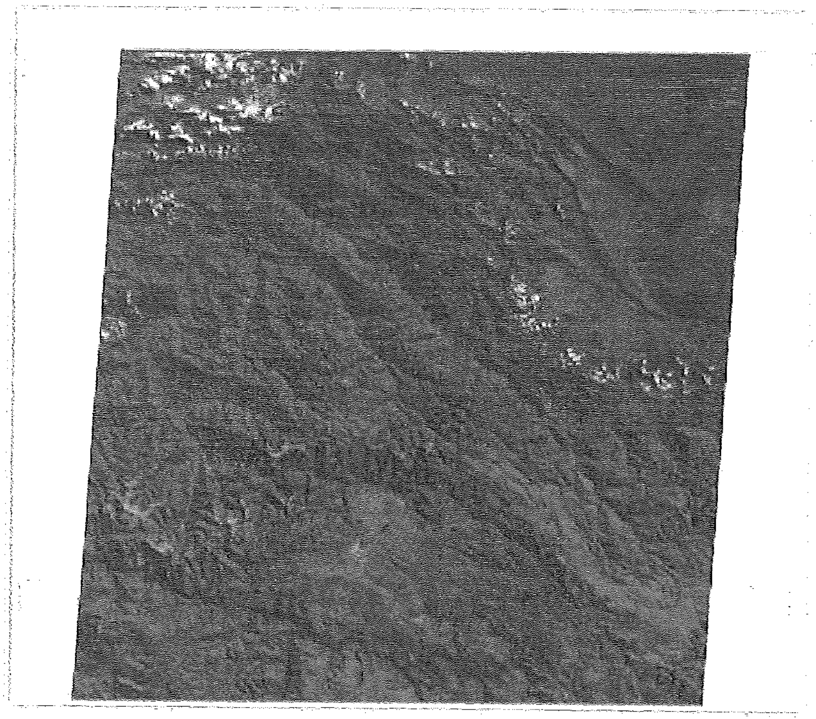
UNIVERSITY OF TURKU – AMAZON RESEARCH TEAM
Collaboration with BIODAMAZ – IIAP

CD number 56, Landsat TM image

Image name:	
Path-Row-Date:	004-069-07/08/1993
Date of arrival:	07-06-2000
Acquisition format:	Erdas Imagine IMG
Type of sensor:	LANDSAT TM
Origin of image:	TRFIC data archive (Michigan Univ.)
Date of data import in UTU:	16-04-2000
Number of bands:	6 bands
Quality evaluation:	Good/Average
Condition:	Original
Band combination:	5, 4, 3
Image code:	UTU-ART 2000 56TM_46993

Back cover

56TM_46993



Front cover

Appendix 3

Georeferencing and mosaicing Landsat TM Satellite images

A comparison between different software packages.

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Introduction

One of the main research activities at the Department of Geography of the University of Turku, is the study after the regional variability of the Amazonian tropical forests. These studies are part of a multidisciplinary research project, in which the departments of Biology, Geology and Geography co-operate. Since 1986 they perform activities under the name: The Amazon Research Team of the University of Turku (ART-UTU; also known as the Amazon project of the University of Turku). The team aims to address the evolutionary, ecological and practical consequences of the regional variability in the Amazonian tropical forests from many different points of view. Remote sensing imagery often plays an important role in the research.

Since March of the year 2000 the Amazon Research Team purchased about 150 raw satellite images from the Pan Amazon region. Before any proper analysis of the satellite images can be done they need to be georeferenced and in some cases mosaiced. Georeferencing is the process of assigning map coordinates to image data. After that the image data can be overlaid in registration with other cartographic information. The manager will then be able to make comparisons. Mosaicing, on the other hand, is the blending together of several arbitrarily shaped images to form one large image. This might be useful when a study area covers more than one satellite image (GCP Works Reference Manual, 1998).

The Laboratory of Computer Cartography at the University of Turku provides several programs for processing satellite data: Erdas Imagine, PCI and ER-Mapper. Since it was unclear which program is most appropriate for georeferencing and mosaicing, a small survey has been carried out. Using two Landsat TM images of the Peruvian rainforest (figure 1 & 2), both processes were examined in all three programs. The applied procedures will be summarised in this report and the programs are evaluated concerning the quality of their results, the options they offer and their user friendliness. When reading this document one should keep in mind that all judgements are based on a personal opinion.

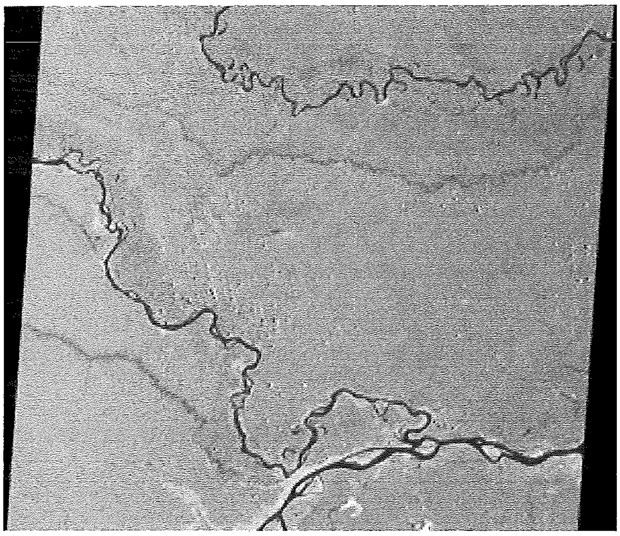

Figure 1: Uncorrected image 1

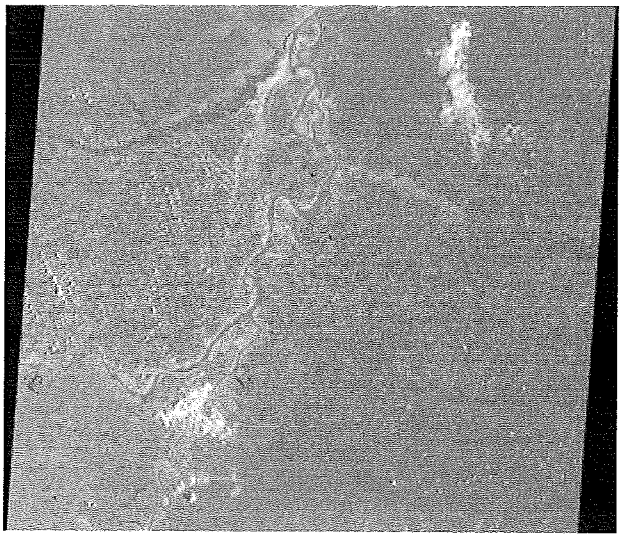

Figure 2: Uncorrected image 2

Process description and program evaluation

Georeferencing in Erdas Imagine

Erdas Imagine offers a georeferencing tool in the raster layer viewer (Raster/Geometric Correction). This tool functions a bit like a wizard, although some knowledge about the steps that should be taken is required. When opening the georeferencing tool a window appears which indicates a geometric model should be build. For this survey the polynomial first order model, with a Universal Transverse Mercator South, zone 19, projection and the Clarke 1866 ellipsoid has been used. When georeferencing images, always be careful when choosing the polynomial order. Higher orders may distort the image in a rather complicated way (see Erdas Field Guide).

When the geometric model is set the manager can enter Ground Control Points by using the keyboard. After adding a GCP to the image, the raster coordinates will be given and the map coordinates should be entered. When four or more GCPs are added, Erdas Imagine will calculate the RMS error, which is a measure for the accuracy concerning the positions of the GCPs. In order to obtain a good result it is important to keep the RMS error as low as possible and to enter sufficient GCPs. For this survey 6 GCPs were used for each image, which probably is not enough in case a very accurately georeferenced image is needed, it is sufficient for the purpose of this project however. After placing the GCPs it is wise to save both, their position in raster coordinates and in map coordinates (these coordinates have to be saved seperatetly!). When the GCPs are defined the model can be runned and Erdas Imagine will compute the georeferenced image. Notice, however, that when defining the output file name, it is also possible to alter the cell size and set the resampling mode. Increasing the cell size will considerably decrease the size of the output file. For this reason the cell sizes were changed from about 30m to 150m during this survey. As resampling mode the Nearest Neighbour method was selected.

Mosaicing in Erdas Imagine

Erdas Imagine offers a mosaicing tool, which can be found in the Data Preparation Menu. When just a quick look of mosaiced images is needed however, it is possible to open several geocoded images in one viewer as well. At least as long as the images have the exact same geometric model, otherwise it won't work! In case the one wishes to open multiple images in one viewer: disable the 'clear display' and enable the 'fit to frame' and 'background transparent' options in the Raster options menu.

If one wishes to create a real mosaic, which means a new image that contains information from two or more base images, the mosaic tool in the Data Preparation Menu should be used. The procedure for creating the mosaic is not difficult, but requires some knowledge about the program, however. When making a mosaic for the first time, it is very useful to use the example, given in the Erdas Tour Guide. This example describes the mosaicing process for Landsat TM images very clearly. In any case, make sure the georeferenced images used do have the exact same geometric model, otherwise the mosaicing will not be succesful!

General evaluation of georeferencing and mosaicing in Erdas Imagine

Quality evaluation

The final result of both, the georeferencing and the mosaicing is presented in figure 3. The figure shows that, even though only 6 Ground Control Points were used, the two images fit each other really well. The border between both images is hardly recognisable. Although one could claim that this may partly be a result of the increased pixel size, masking small errors in the georeferenced images, there is no reason to doubt about the accuracy with which Erdas Imagine computes the corrected images and fits them together.

Options

Both, with the georeferencing and the mosaicing Erdas imagine offers quite some different options that may be useful. Concerning the georeferencing one can for example choose from a broad list of projections and ellipsoids. Ground Control Points can be collected from files, from digitizing tablets, from viewers and can be entered by keyboard. Map units can be changed from meters to kilometres to feet etc. Next to polynomial operations, images can be rotated, flipped, stretched or rubber sheeted. Further Erdas Imagine offers the opportunity to choose several resampling modes, like Nearest Neighbour, Bilinear interpolation and Cubic convolution. When mosaicing Erdas Imagine offers a range of options as well, mainly to change the order of the images, to match the images and to cut or compute the intersections. More options for both, georeferencing and mosaicing can be found in the Erdas Imagine guides.

User friendliness

Erdas Imagine may be quite a complicated program for those who did not work with it a lot. Some options are presented in a kind of wizard, but very often one has to deal with the menus by him- or herself. Fortunately the on line help and the Erdas Imagine Guides offer quite some useful information. Especially the Tour Guide is helpful since it gives rather clear examples.

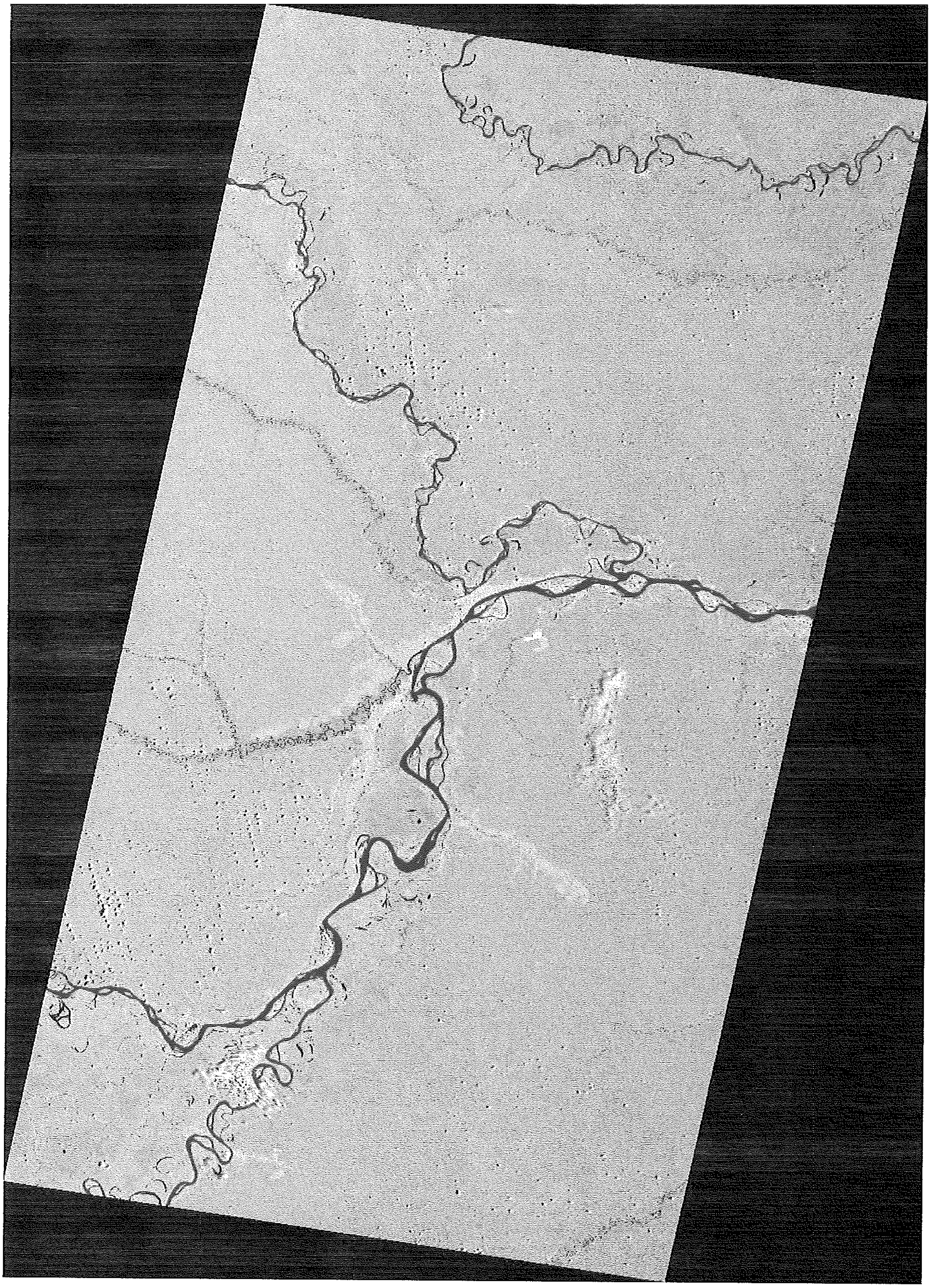

Figure 3: A mosaic of two georeferenced Landsat TM images, created in Erdas Imagine

Georeferencing in PCI

In PCI georeferencing can be done in the standalone application GCPWorks. This program has been developed to import image data from various sources, tie it down to a georeferenced source, and perform registration and mosaicing functions (Using PCI Software, 1989). PCIWorks offers the possibility to perform the registration and mosaicing operations at once, but both processes can also be performed separately, which was done during this survey. When opening PCI Works a setup menu appears from which the preferred operation options should be selected (see GCP Works Reference Manual, page 19). For this survey the full processing option with the polynomial mathematical model was used and User Entered Coordinates served as the source for the GCPs. After selecting the options, the processing steps to be taken are shown at the bottom of the window. When accepting the setup a new wizard window appears which shows, step by step, how to accomplish the georeferencing. Before the model is able to run, the uncorrected image needs to be loaded, the georeferencing units should be set and the GCPs have to be entered. For the survey the georeferencing units were chosen the same as before in Erdas Imagine, which means: a Universal Transverse Mercator South, zone 19, projection with the Clarke 1866 ellipsoid. The entering of the GCPs is very much the same as it is in Erdas Imagine. After adding a GCP to the image the raster coordinates will be given and the map coordinates should be entered. When four or more GCPs are added PCI calculates the RMS error as well. In case more than 7 GCPs are defined, PCI offers the opportunity to use a second order polynomial model. For even higher orders more GCPs are needed (see page 6, GCP Works Reference Manual). Since in this survey the same sets of 6 GCPs per image were used in all georeferencing operations only the first order model was available. After entering the GCPs it is wise to save them, so they can be used again later. Finally the 'Perform registration to disk' option should be selected to finish the operation. Before starting the computation, however, PCI offers the possibility to change the pixel size of the output image, to choose the bands the output image should contain and to define the resampling mode. For the survey the pixel size was again increased to 150m and all 7 bands of the image were selected. The resampling mode was set to Nearest Neighbour. After accepting the final settings the georeferenced image will be created and can then be opened in the application Image Works.

Mosaicing in PCI

In PCI the mosaicing of images can be done in the same GCP Works program as the georeferencing. The setup menu offers the option 'Mosaicing Only', which is just for mosaicing reoreferenced images. Several steps are now to be taken in order to create the mosaic. First a georeferenced image should be selected. GCP Works will show this image in an 'Uncorrected Image Overview' window (see GCP Works Reference Manual, page 26). Then an output file should be defined, for which the coordinates of the upper left and the lower right corner have to be entered. Make sure these coordinates are chosen such that the complete mosaic will fit in the defined frame. After creating the output file an empty Georeferenced Image Overview window is shown. Now the selected georeferenced image can be registered in the created output file, so it will appear in the Georeferenced Image Overview. In order to add the next image to the mosaic, the image should first be selected using the 'Select Image to Mosaic' button. Then with the 'Select Mosaic Area' option it is possible to define the area of the added image that will be used in the mosaic. Note that by selecting the mosaic area the manager is able to control the position of the cut line between the original image and the added image. When done, the result can be previewed, (Pre-registration Checking), or the image can be registered at once.

General evaluation of georeferencing and mosaicing in PCI

Quality evaluation

The final result of both, the georeferencing and the mosaicing is presented in figure 4. The figure shows that, like in Erdas Imagine, the two images in PCI fit each other really well. The border between both images is hardly recognisable, which means that the computed coordinate systems of the scenes coincide to a large extend. Of course the critics concerning the pixel size, mentioned at the evaluation of the Erdas Imagine mosaic, do as well count for this mosaic. There is no real reason, however, for doubting about the accuracy with which PCI georeferences the images and fits them together.

Options

PCI is a rather big program consisting of several different applications. Some functions can be done in more than one of them. Next to GCP Works, Xpace offers quite some options for georeferencing and mosaicing for example. According to the manual, however, GCP Works provides quicker, simpler and more accurate GCP collection and preview registration operations.
When georeferencing in GCP Works, the program offers several useful options. The manager can, for example, choose between several mathematical models. GCP coordinates can be entered by keyboard and can be collected from geocoded images, vector files, chip databases or a digitising table. Further there are options offered to choose the bands to be georeferenced, change the pixel size of the output file and to select the resampling mode. The offered resampling modes are Nearest Neighbour, Bilinear and Cubic Convolution.
Concerning the mosaicing GCP Works offers some options to choose from as well, although less than Erdas Imagine. The area for clipping the images can be selected, which actually means one can create cut lines. Then there are options for performing colour matching and blending operations, and the manager is able to choose the resampling mode, the bands of the output image and the blend width.

User friendliness

Like Erdas Imagine, PCI is a program that may be complicated for new users. The structure of the program, for example, is slightly unclear: it is not always obvious which application should be used for which purpose. Further it is not always clear how to handle the menus PCI offers. Although there is both an on line help and a manual (they are the same) available, they are not too helpful. Somehow the information provided does very often not lead to real answers on your questions. At least not when you have problems succeeding a certain process. The theoretic background description is rather clear.

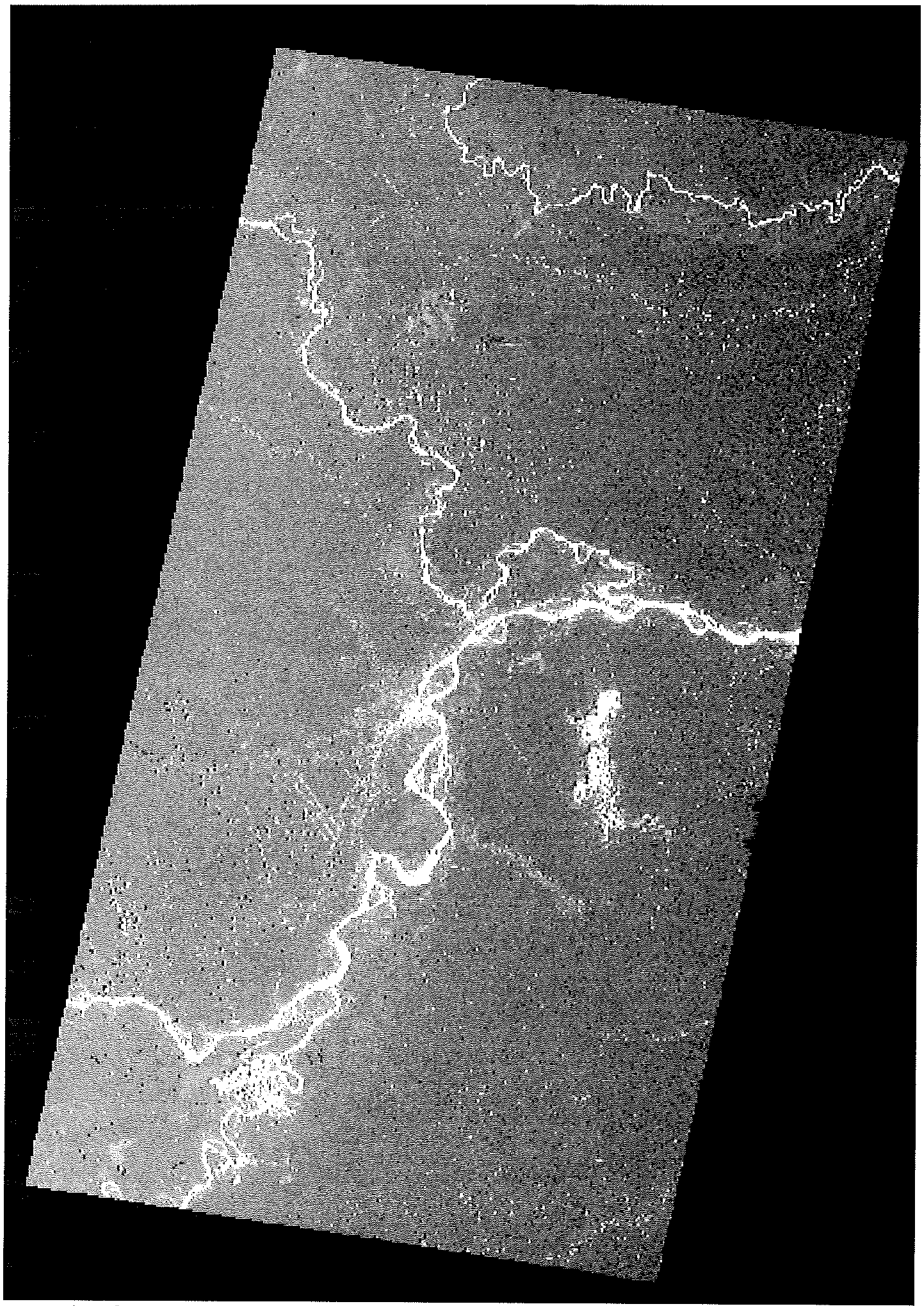

Figure 4: A mosaic of two georeferenced Landsat TM images, created in PCI

Georeferencing in ER Mapper

ER Mapper offers a wizard for georeferencing images in the process menu on top of the screen. When opening the wizard a window appears showing the steps that should be taken. Although these steps differ a little, depending on the options the manager chooses, the basic process is very much the same as in Erdas Imagine and PCI. First the mathematical model should be selected, then the geometric model needs to be set and finally the GCPs have to be entered. For the survey the first order polynomial model was used as the mathematical input again and the same GCP sets used in Erdas Imagine and PCI served as the reference points. Since ER Mapper only requires 6 GCPs for calculating a second order polynomial model, this option could be selected, but the first order model was considered more convenient. The geometric model was chosen the same as before as well, which means the UTM, zone 19 for the Southern Hemisphere, projection together with the Clarke 1866 Ellipsoid. When defining the name of the output file ER Mapper also offers the possibility to change the cell size and choose the resampling mode. In order to reduce the size of the files and increase the computation speed a pixel size of 150m was used again. The Nearest Neighbour method has been selected for resampling. After accepting the final settings the georeferenced image will be created and is shown on the screen.

Mosaicing in ER Mapper

For mosaicing ER Mapper offers a wizard as well, it can be found as a button on the program's 'common functions' toolbar. When opening this wizard a window opens which gives the manager several basic options to choose from. After selecting one or more options, one proceeds to a next window in which again some choices should be made. In this way all options are to be set and ER Mapper will create a mosaic of the selected images. It should be noted however that the protocol used by ER Mapper is rather different from that of Erdas Imagine and PCI. ER Mapper does not make an output file containing a new mosaiced image. It just shows several images, or parts of them, in one window. This means that the program does not create huge new files, but just uses the already existing scenes.

Although the wizard offers quite some different options to choose from, many of them are inferior, making the process of mosaic creation in ER Mapper rather fixed. The manager therefore is not able to influence the final result to a big extend, which may be problematic. When overlaying the images for this survey, the background of the one scene interfered with the image of the other (see figure 5). Since it seems not to be possible to define a cut line, make the background transparent or perform any cutting operation in order to take away the background, the problem could not be solved.

General evaluation of georeferencing and mosaicing in ER Mapper

Quality evaluation

Concerning the georeferencing of the images ER Mapper seems to give the same satisfying results as Erdas Imagine and PCI. The fact that the images fit very well suggests that ER Mapper references the images rather accurately. Unfortunately the mosaicing process itself was not completely successful because of the backgrounds interfering with the final image. It seems not to be possible to prevent this, at least not in an easy way.

Options

When it comes to the georeferencing of images ER Mapper has more or less the same basic options as Erdas Imagine and PCI. The manager can choose between several mathematical models like triangulation, orthorectification, 3 orders of polynomial georeferencing, and rotation. GCP coordinates can be entered by keyboard and can be collected from geocoded images, vector files, algorithms or from a digitising table. Then the pixel size of the output file and the resampling mode can be selected. Also ER Mapper offers the Nearest Neighbour, Bilinear and Cubic Convolution resampling modes.

User friendliness

ER Mapper seems to be more accessible for the user than both Erdas Imagine and PCI, at least in the way that the wizards and menus are easier to use. In case of problems or questions the manual and the on line help may be rather useful, although it may happen that the information is just not right. Both the manual and on the line help, for example, promise that a function for cutting a portion out of an existing image is available, but in reality it is not. Then concerning the mosaicing: the wizard is very clear and simple, but does not provide too many options, which in the case of this research lead to a disturbing problem.

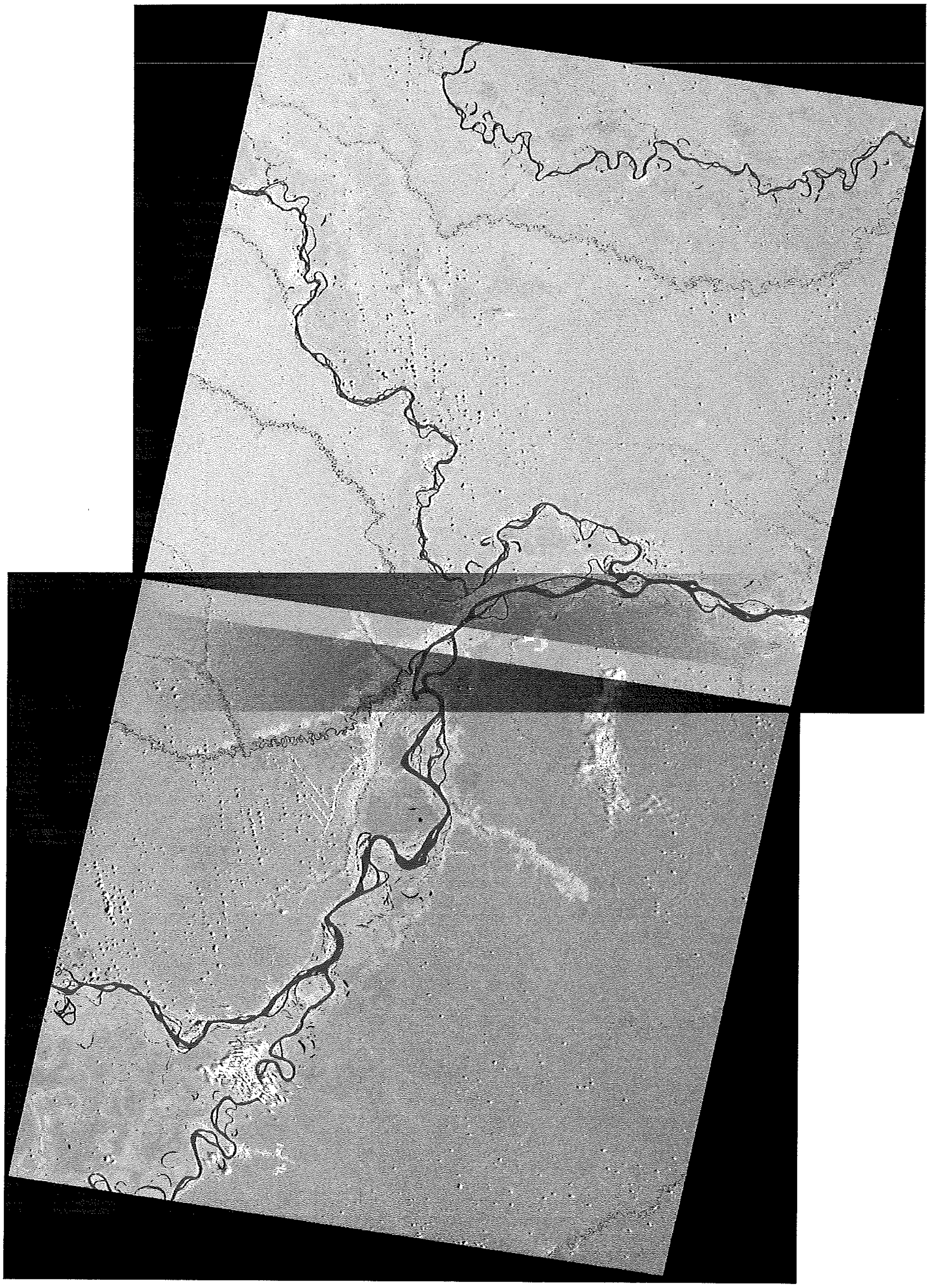

Figure 5: A mosaic of two georeferenced Landsat TM images, created in ER Mapper

Summary & Conclusions

The Laboratory of Computer Cartography at the University of Turku offers several software packages for processing satellite images, Erdas Imagine, PCI and ER Mapper. In order to find out which of these packages is most convenient for georeferencing and mosaicing Landsat TM and Landsat MSS images, a small survey has been carried out. Using two Landsat TM images of the Peruvian rainforest (figure 1), the processes of georeferencing and mosaicing were examined in all three programs.

Concerning the georeferencing of images it seems that all three packages offer more or less the same options and compute quite identical georeferenced images of good quality. For mosaicing images, however, the differences between the programs are much bigger. It seems that Erdas Imagine offers the most sophisticated tool, presenting a large amount of different options, resulting in a good mosaic. PCI, on the other hand, offers a simpler tool, containing less options, but the final result is of quite a high quality as well. The mosaicing tool of ER Mapper is the least sophisticated and unfortunately resulted in a rather disappointing mosaic.

Concerning the user friendliness of the programs there are some differences as well. ER Mapper is the most user-friendly program when it comes to the clearness of menus and wizards. The manual and online help are clear, but provide some incorrect information about the cutting of image, however. Erdas Imagine may be less accessible than ER Mapper when it comes to the structure of the program, but the manual and on line help are of a good quality and really help solving problems. PCI probably is the least user-friendly program. The structure of the program is rather complicated and the manuals and on line help functions seldom offer satisfying answers to questions.

Summary table

	Erdas Imagine	PCI	ER Mapper
Quality georeferencing	good	good	good
Quality mosaicing	good	good	poor
Options georeferencing	many	many	many
Options mosaicing	many	average	few
User friendliness program	average/poor	average/poor	good
User friendliness manual/help	good	poor	average/poor

References

-Erdas Field Guide, fourth edition. ERDAS Inc. 1997.

-Erdas Imagine Tour Guides, version 8.3. ERDAS Inc.1997.

-ER Mapper User Guide. Earth Resource Mapping Pty Ltd 1998.

-GCP Works Reference Manual, version 6.3. PCI Geomatics 1998.

-Using PCI Software, version 6.3. PCI Geomatics 1998.

Appendix 4

Data and metadata services

Address:

http://www.geog.nottingham.ac.uk/~mather/useful/data-and-metadata.html

1 Digital Catalogues
2 Spectral Libraries
3 General Sources of Information and Data
4 Other information and data services
5 Return to Main Page

Also check out the GIS page (look under Data)

Digital catalogues

Australian (ACRES) Digital Catalogue
Alaska SAR facility
Amazon Basin image browser from JPL - SAR data coverage
Arcdata online -GIS data from ESRI
Arctic Environmental Metadata Centre (NERC)
Arizona Regional Data Archive - free Landsat 7 ETM+ imagery of Arizona, plus DEMS etc
Atmospheric Data Centre, Rutherford-Appleton Laboratory (RAL), UK
AVHRR 1km Dataset Project
AVHRR Global 10-day composites (ftp access)
AVHRR Pathfinder AVHRR Land (PAL) ftp site
AVHRR archive at Dundee University, Scotland
AVIRIS Data Facility at JPL
AVIRIS ftp site - quicklooks, calibration data etc.
Canadian National Atlas Information Service
Carterra data search system (Space Imaging Co) - Landsat TM and IRS LISS and pan imagery
CEOS Search Engine - access to data providers, etc. etc.
CERSAT - French Processing and Archive Facility for ERS-1 and -2 products/software
CIESIN: Consortium for International Earth Science Information Network
CIESIN (see above) New WWW Gateway for free text search
DALI - Spot Image catalogue
Earth Observing System (EOS) Data Gateway
EOSDIS V0 WWW Gateway - links to 9 NASA Data Centres
EOSDIS V0 Earth Science Information Management System
EOSDIS Version 0 IMS Home Page
EROS Data Center
EROS Data Center DAAC - for SIR-C, Landsat 7, ASTER, MODIS, AVHRR, etc
Eurimage catalogue/browser

Gateway to Antarctica - Home Page
GCDIS home page
GLIS - USGS Global Land Information System - includes declassified intelligence images
Global Change Data Center, NASA Goddard Spaceflight Center
GLOBAL CHANGE MASTER DIRECTORY (NASA)
Global Environmental Information Locator Service (GELOS)
Global Land Biosphere Data and Resources (NASA Goddard SFC)
Global Observation of Forest Cover: CEOS initiative - provision of forum, datasets, methods
Goddard Institute for Space Studies (GISS): datasets and images (mainly climate)
Hyperlens HyperDAAC demo: browsing global data from USGS/EDC DAAC (landdaac)
Imagenet: Graphical interface to satellite imagery, air photos and other geospatial data
INFEO - INFormation on Earth Observation, from the JRC CEO
International Arctic Environmental Data Directory
Ionia 1 km AVHRR Global Land Data Set Net-Browser
ISIS - the DLR Intelligent Satellite Information System
Japanese (NASDA) Earth Observation Center - TRMM and ADEOS data (EOIS)
JPL Physical Oceanography DAAC (Distributed Active Archive Centre)
Knowledge-based Interface to National Data Sets (Spatial Data about the United Kingdom)
Lakes - the MSSL-WCMC-UNEP Global Lake and Catchment Conservation Database (Mullard Space Science Laboratory)
Landsat-7 data ordering tutorial (from EOS Data Gateway)
Modern Average Global Sea-Surface Temperature
NASA-NOAA Pathfinder Data Sets
NASA JSC Office of Earth Sciences: searchable database of Shuttle photographs
National Snow and Ice Data Center, Colorado
NOAA Satellite Active Archive (SAA): NOAA AVHRR data
NOAA/NASA AVHRR Oceans Pathfinder Home Page
NOAA National Geophysical Data Center - Global Sea Floor Topography from Satellite Altimetry
National Remote Sensing Centre (UK)-Satellite images and orthophotos etc.
Oceanography Distributed Active Archive Center (JPL) (Sea Surface Temperature data sets)
Oak Ridge DAAC for Biogeochemical Dynamics
Scanex - a Russian company offering RESURS-01 and MOMS-P2 data (mirror site at Cambridge)
SIRIUS on-line catalogue (SPOT Image products)
SPIN-2 (SPace Information - High Resolution imagery, mainly from Russian sources (?))
Terraserver (Microsoft)
Topozone - digital maps of the USA (scales from 1:100,000 to 1:24,000)
TRFC - cheap Landsat MSS, TM and ETM+ imagery of rainforest areas of the world
Tropical Forest Information Centre & other forestry stuff, Michigan State University
UK Standard Geographic Base (UKSGB): Details of data sets for Great Britain and Northern Ireland
UNEP GRID - Global Resource Information Database
US Bureau of Land Management Metadata Service
West Freugh Data Centre - ERS SAR data for Europe (Matra Marconi)
World Data Center A for Remote Sensing Land Data
World Data Center C (Glaciology)
World Data Center A: Atmospheric Trace Gases (Oak Ridge Nat. Lab.)
Yale University Center for Earth Observation - data set archive (TM, MSS, AVHRR etc.)

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Spectral Libraries

JPL's ASTER Digital Spectral Library (JPL/Johns Hopkins University)
FIGOS/EGO Hyperspectral BDRF Database
LILIAN: Spectral library for Antarctic rock types
LILIT: Spectral library for Italian lithologies
USGS Imaging Spectroscopy Lab, including Digital Spectral Library

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General sources of information and data

Centre for Earth Observation, CEO, JRC, Ispra, Italy
CEOS Information Locator Service
CEOS WGISS World-wide on-line services directory Information Infrastructure
Committee on Earth Observation Satellites, CEOS
DaimlerChrysler Aerospace (Dornier): Geographical Data Warehouse (Images of Germany, Switzerland and Austria
EDUSPOT - educational service giving access to SPOT quicklooks etc
EOSDIS/ESDIS Home Page
EUMETSAT's home page
Finnish National Land Survey
French Meteorological service (Meteo France) - European weather forecasts
French Meteorological Service - Meteosat images
INFEO - Information on Earth Observation (CEO, JRC, Ispra, Italy)
Iraq ("Desert Storm") imagery from FAS - links to US Intelligence imagery e.g. Corona
Japanese Geographical Survey Institute
Kuwait Data Archive
MIMAS (UK) Landsat & SPOT images, digital maps of UK
Mojave Server: TM images, topo, hydrological datasets and bibliography for Mojave Desert area
MIMAS (UK data centre - from socioeconomic to spatial)
NEONET (Netherlands Earth Observation Network)
USGS-- Earth Science Information Center

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Other information and data services

AERONET (AErosol RObotic NETwork): atmospheric aerosol monitoring network and data archive (NASA)
Agro-ecological Information System, Technical Univ. of Munich
Australia Survey & Land Information Group
Canadian land cover digital map from AVHRR
NASA Earth Pages

NASA Spacelink
NASA's Observatorium FREE Landsat TM data sets
NASA Technical Reports Server - NTRS -searches NASA database for technical reports, conference proceedings etc.
Ordnance Survey of Great Britain
Ordnance Survey CampusWorld
SPOT Image
TOPEX/Poseidon: Oceans and Climate from Space
Tromsø Satellite Receiving Station, Norway
US Geological Survey
US Global Change Research Office - lots of interesting links
USGS Earthshots - useful data sets for teaching

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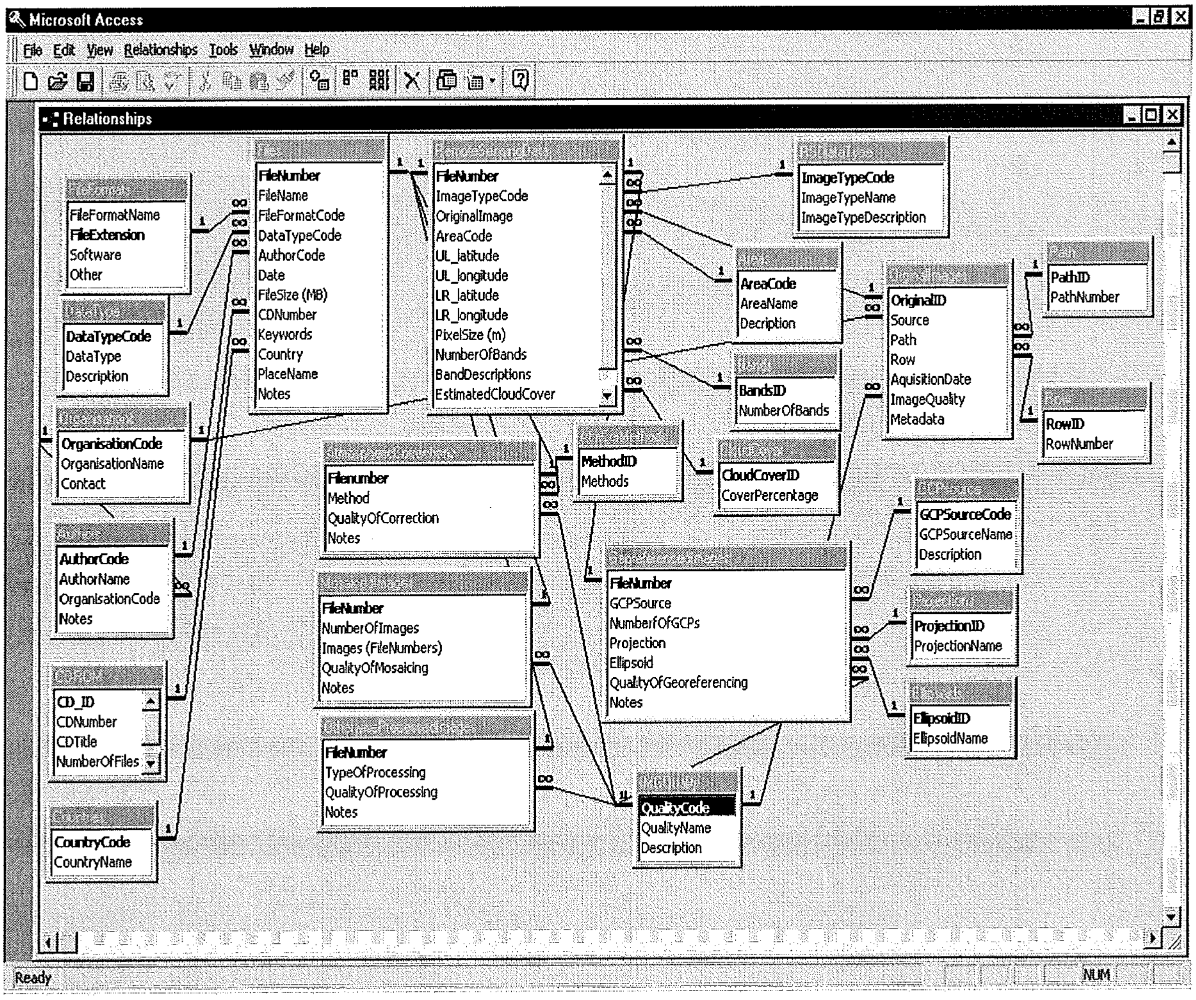
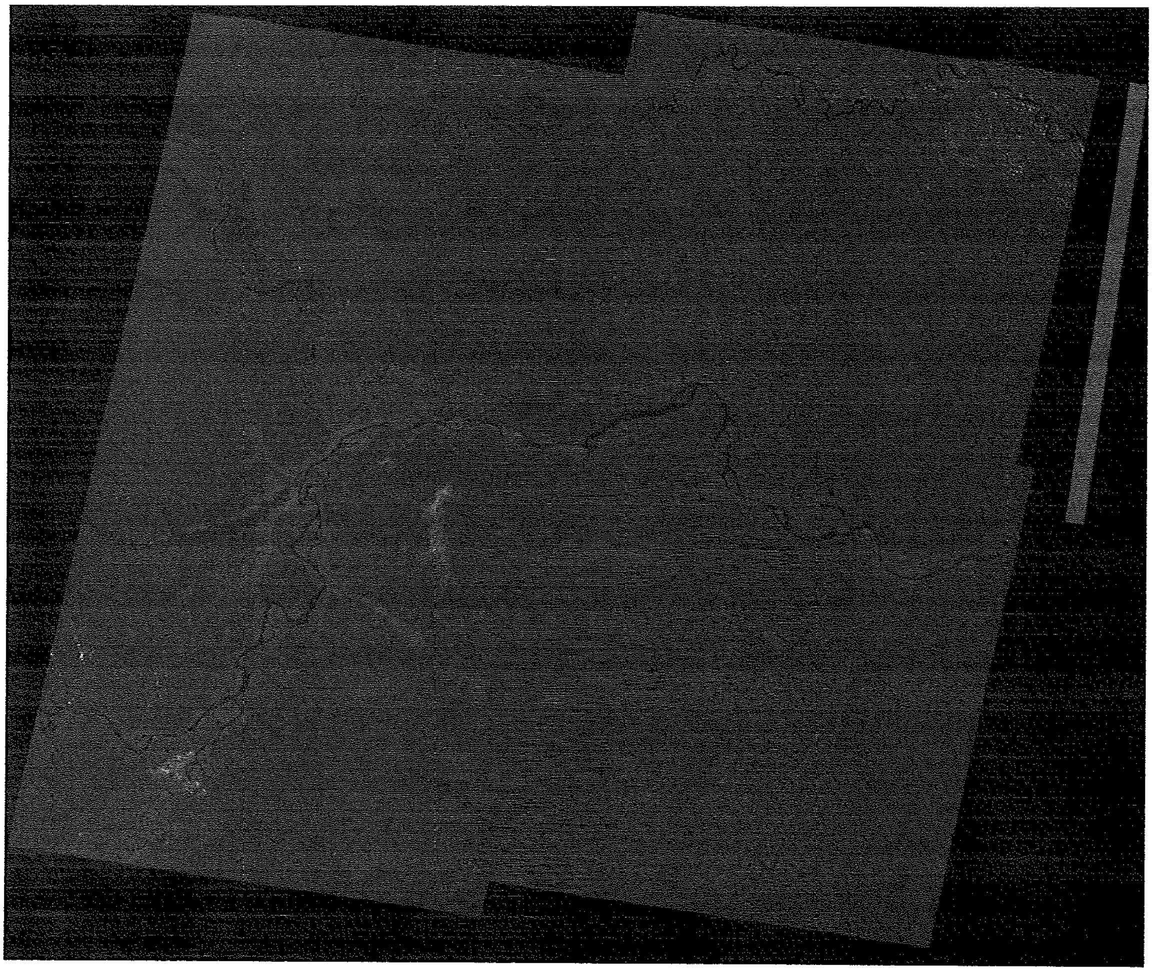
Appendix 5

Microsoft Access table structure



Appendix 7

Landsat TM image mosaic



A mosaic of the Iquitos region in Peru.