Georeferencing of Scanned Spatial Data Sources & Exploring IDRISI gis

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Preface

While at work with GIS systems and multi-sourced spatial data, hardcopy materials as paper maps and aerial photographs frequently come in as additional useful information.

Such hardcopy sources can easily be scanned and even combined with other spatial layers in a GIS. However correct georeferencing of such sources often requires specific attention and skills.

This training manual will take the participant through a set of simple exercises, to demonstrate how scanned materials can be imported and georeferenced in ArcView.

Special care is given to make the participants aware of sound cartographic practices and the limitations that some spatial information sources have. This includes the geodetic differences between for example an official map publication and others sources such as a satellite images or aerial photographs.

At the end of this exercise the participant will be able to georeference scanned spatial data sources and be able to judge levels of accuracy in the obtained results, by noting possible cartographic incorrectness in the source materials.

In addition to the morning session, the afternoon session will be used to explore the functionalities of IDRISI gis. While most participants have been working in ArcView for a number of years, you may have noticed that Arcview is able to handle a larger range of spatial queries. However sometimes Arcview also reaches the limitations of it's capabilities. It is one of the aims of the project to slowly broaden the horizon on various other GIS tools that exist and which can be easily used in combination with ESRI software. This to enhance the overall understanding of universality in GIS data processing and analytical operations, while simultaneously exploring the best value for money from the GIS market place. This short exploration into IDRISI is the first in a range of alternative GIS toolkits which will be highlighted and brought to the attention of the Nile Basin participants.

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Geodetic considerations for handling scanned spatial data sources

1.1 Introduction

With the advancing revolution in information technology and digital mapping, a wide range of spatial data sources is being entered into digital computer files. Where all have in common that they serve to visualize the earth surface, we always need to be aware of fundamental cartographic characteristics belonging to three principle sources. This chapter will shortly discuss these three principle sources and their geodetic implications for integration with GIS databases.

1.2 Maps, Aerial photographs and Satellite Imagery

Both aerial photographs and maps give a two dimensional representation of the earth surface. The information that they hold can generally be subdivided in physical, object and geometric information.

The physical information is e.g. contained by variable reflection patterns in photographs or by thematic interpretations withheld in map legends. This physical information often forms the core of what a map user wants to know.

The object information is contained by shape, position, relative size and distribution of various objects, while often also holding a time dimension.

The geometric information relates to trigonometric parameters as e.g. flight altitudes and optical lens size for aerial photographs or scale and projection data for maps. Where the world is round and in many cases marked by relief, the geometric information always represents a reconstruction of a 3 dimensional physical space.

Even though aerial photographs can to some extent be used as maps, there are a few fundamental differences. Where a map is often a cartographic end product that can be constant in scale, aerial photographs and raw satellite images are never constant in scale. Both aerial photographs and satellite images are fundamentally obtained through a central projection (see figure 1).
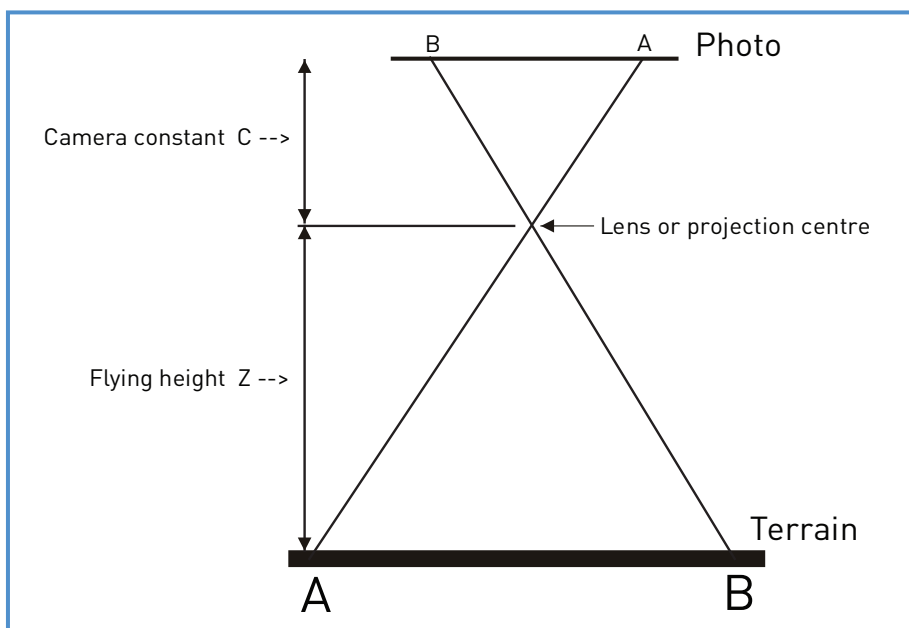

Figure 1   The principle of central projection.

The overall scale of a central recording as described in figure 1 can be represented as ab/AB which also equals c/Z. So generally a first assessment of the scale could be made from the combination of camera lens constant and flying height. These are parameters that are always recorded on the edge of aerial photographs.

The overall scale assessment can however never be more then approximate. It can easily be seen that locations not straight under the camera are recorded with a different angle. Consequently scale numbers are in effect decreasing radially away from the central point of recording.

Effects of camera tilt, where airplanes were slanting will worsen scale variability. Much relief variation in the terrain and thereby variable flying heights also causes undesirable variations in scale. For satellite recordings, that usually stretch much larger areas, even the curvature of the earth surface plays a role.

In order to use aerial photographs for cartographic purposes, correction for tilt and relief displacement are standard cartographic procedures. Similarly are satellite images geometrically corrected before usage and do mountainous areas require additional orthometric correction.

For the application of aerial photographs, each photo carries corner marks, help marks halfway, a level, clock, altimeter and camera specification on the side. A typical layout of an aerial photograph is shown in figure 2 below.
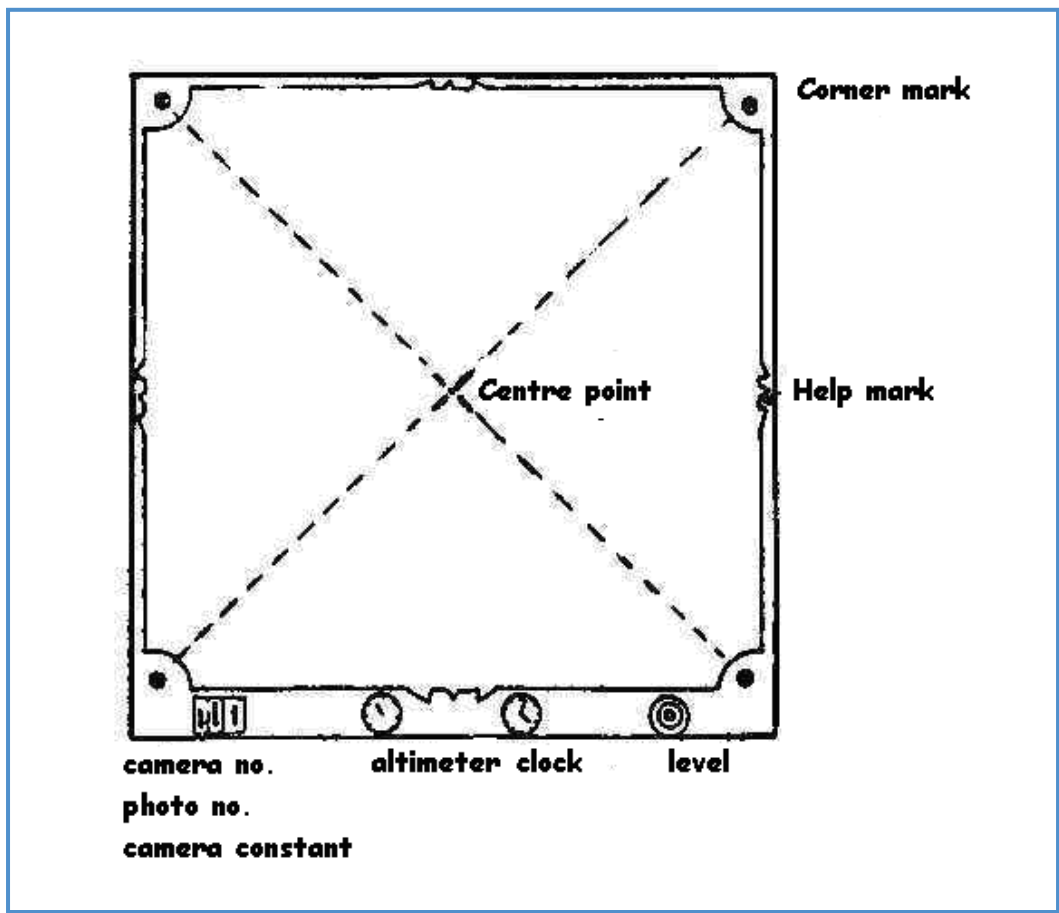

Figure 2   Typical layout of an aerial photograph.

The central point of recording in an aerial photograph is always obtained at the crossing point of opposite corner marks or alternatively the crossing of the help marks. The trigonometric center point of an aerial photograph is also represented in figure 3. The central point is sometimes also referred to as the nadir point. (only in the absence of tilt)
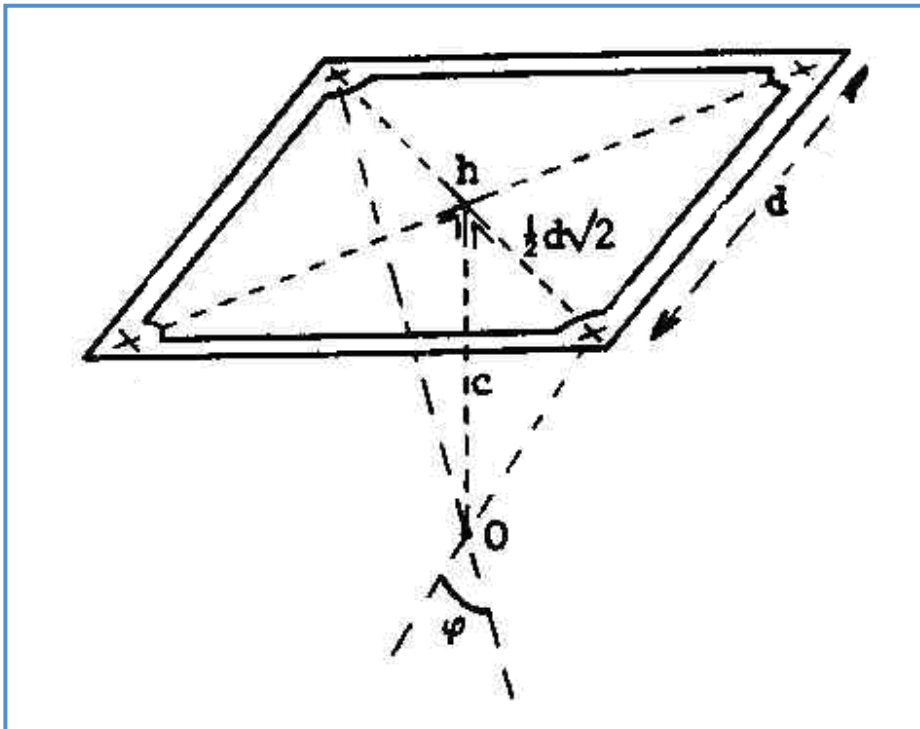
Figure 3   Position of the centre point in an aerial photograph.

Relief features already mentioned as a factor for variable scale also cause displacements of objects located away from the center point. This is easily demonstrated by the drawings in figure 4a and 4b. In figure 4a one can see that a tall vertical object with its foot and top at the same location will receive a different location for respectively the foot and top on an aerial photograph.
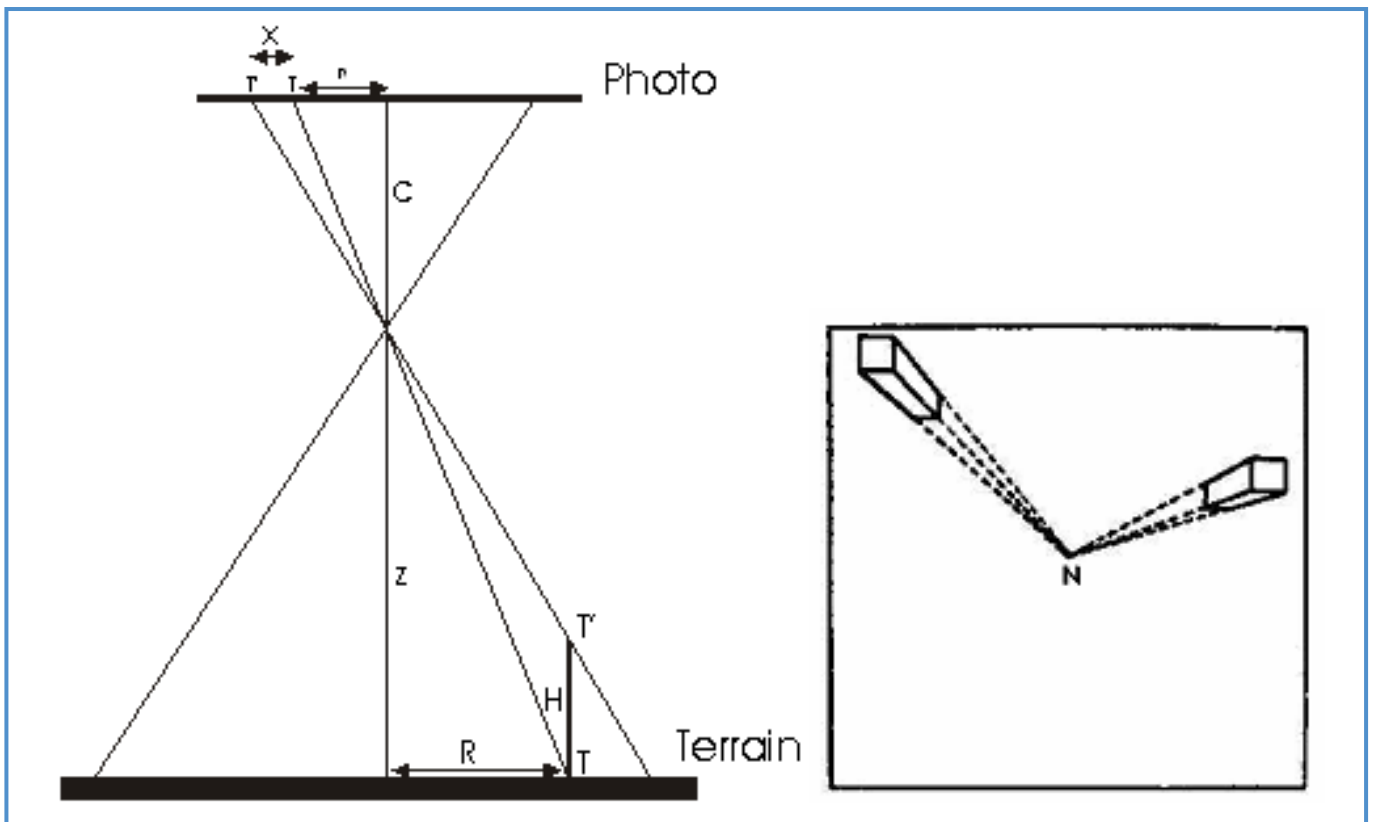

Figure 4a, 4b. A demonstration of relief displacement effects.

Where relief displacement is zero in the central nadir point, it increases as a function of the radial distance away from the nadir point. Where R is the distance to nadir and x the relief displacement we can express the relief displacement function as;

$$X= c/Z * (h*R)/(Z-h)$$

In words we can also summarize that the relief displacement is inverse to the square of the flying height. So relatively much displacement is obtained when flying too low! Reasoning further from figure 4a it can also be derived that the height of any object away from the nadir point can theoretically be calculated from measurement in the aerial photograph. For this the following equation applies;

$$h=(Z*x)/(r + x),$$ (note that r is the small r in figure 4a)

As is shortly demonstrated by the previous, many corrections either through optical instruments or through trigonometric calculations are possible. These will eventually assist to turn aerial photographs and satellite images into proper maps.

Very specific distortion, as for example due to extreme relief, always needs to be dealt with very specifically. However more general distortion or the assignment of any first coordinate system to newly entered data is always done by the use of polynomial equations. These are equations that will calculate the transfer of coordinates from one system to another. This is done through the specification of control points for which coordinates in both the old and the new system are known. Polynomial equations are equally used after table digitizing of a map, when table coordinates need to be transformed to real world coordinates. Or in other case they serve the purpose of geometric correction of satellite imagery.

Polynomials can be used for a range of fitting purposes. In their simplest form, for a single dimension, they are expressed as;
$$Z= b0 + b1X$$

For non linear fits, higher order, one dimensional functions this may expand in the form of;

$$Z=b0 + b1X+b2X2$$

Polynomial equations for two dimensional applications as maps are generally of the following form;
$$f\{(X,Y)\}= r+s \le p \sum (brs * Xr * Ys)$$

For further in depth reading on the equations, reference is hereby made to suitable literature (Burrough, 1990,page 150).

Where the theoretical backgrounds are essential for sound handling of various data sets, practically it is just important to know what the consequences are. With respect to the application of polynomial equations for simple map registration, it is important to know when to apply what? Here are some general guidelines.

- For a map or aerial photo with minor distortion, a linear polynomial with a minimum of 4 control points is sufficient to do the job.

- If minor distortion and stretching is required a quadratic polynomial with a well distributed set of control points may be used.

- Any higher order polynomial must be avoided, unless strictly for local areas and supported by a very large set of control points. You will rarely need this nor easily get good results from this for your complete scan.

- Any selection of control points needs to be done in good consideration of recognizable points and sound understanding of possible displacement effect in aerial photographs or satellite imagery. This includes for

example the selection of control points at equal altitudes. Ideally using points at similar distances from the nadir point and strict exclusion of any control points on hill tops or flat buildings!

- An equal distribution of control points is relatively less important for linear conversion, however becomes crucial for any higher order application.

- Any registration of scanned maps is much simpler because distortions are in principle strictly managed through its projection. When you photocopy a map somewhere, always look for the projection and datum information. While scanning, make sure your scanner has no distortion by itself (you can test this with a simple drawing, which you print afterwards, they should be the same). If all is OK, most maps for smaller areas and without very "exotic" projections like for example Goode, will register easily with 4 control points and linear registration. Any other is best to be converted to grid and reprojected using a proper GIS projection function for grids.

Literature

Burrough, P.A., 1990.   Principles of Geographical Information Systems for land resources assessment. Monograph on soil and resources survey no12. Oxford Science Publications.

Computer Exercises

- Georeferencing of scanned data sources
- IDRISI gis

When working with aerial photographs or maps it is always a good practice to familiarize yourself first with its geodetic properties. This involves the positioning of the north, assessing scales and verifying any projection data either written down in map corners or in case of central projection for aerial photographs, on the edge of the photo.

Read, and note down from the aerial photograph below the following information
- Time of the day: hour   minutes
- Flying height: m   (Tororo ~1200m above sealevel)
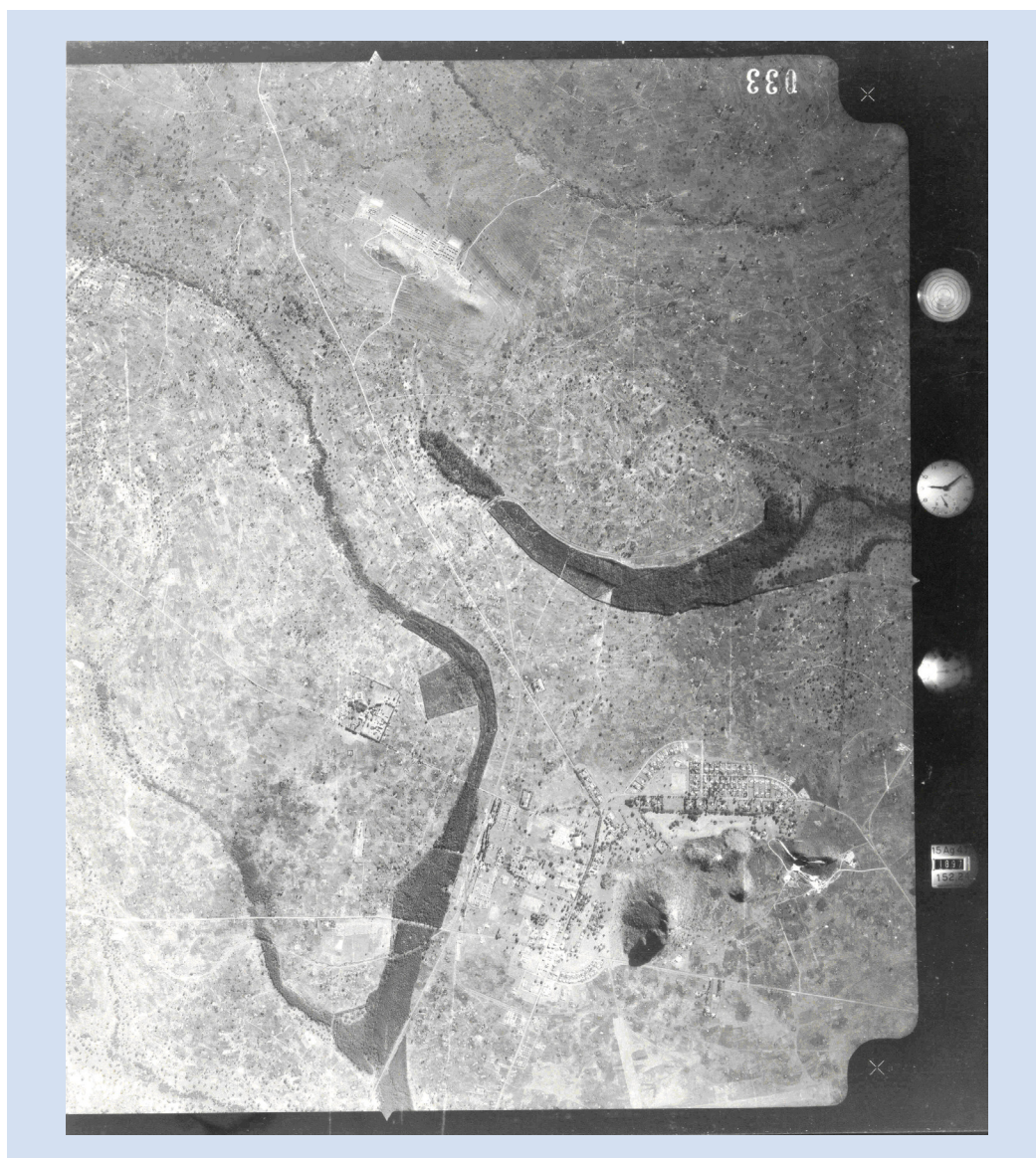- Camera constant: mm
- Try to identify the north direction

Figure 5:   An aerial photograph of Tororo town, Uganda. (source: Survey Department of Uganda)

- Open ArcView, go to "File"➔ "Extension" and switch on the "JPEG image support extension". Now open a new view and add the JPEG file called "R64-3.JPG" from the folder "C:\Scangeoref\".

- You will now see a georeferenced topographic sheet on your screen. Please zoom in to the upper left corner of the map to find Tororo town.

- Note that the map coordinates are in UTM projection and map units are in meters. We will use this map to make a first quick assessment of scale at different places in the aerial photograph. Look for clearly measurable distances, both recognizable in the toposheet and in the photograp. (eg length of roads from junction to junction or two non related intersection which come out clearly).

- Use the measure tool ▧ from the ArcView toolbar, to measure the " real world" distance in meters, between the points that you have identified. Note a minimum of 3 measured distance, representing different locations in your aerial photograph;

  -   true distance 1:   m   photo distance 1:   cm   ➔ scale 1= 1:
  -   true distance 2:   m   photo distance 2:   cm   ➔ scale 2= 1:
  -   true distance 3:   m   photo distance 3:   cm   ➔ scale 3= 1:
  -   true distance 4:   m   photo distance 4:   cm   ➔ scale 4= 1:

- Now use a ruler to measure the same distances on the aerial photograph and note them behind the true distances above. Convert all to the same units and use the systems calculator to calculate the scales.

- In comparison now use the theoretical method of derived scale from c/Z. Also calculate the scale from these photo parameters and compare! What are your conclusion with regards to the scale of the aerial photograph?

- Study the camera details in figure 5 to see whether you have signs of tilt in this photo? (Generally slight tilts occur in most photo's however no corrections are required upto tilts of 4 degrees)

- When no tilt is suspected the central point and nadir point will be the same. Now use the marks of the photo and a ruler, to locate the central point of the photo.

Now that you have successfully, read and applied various geodetic sorts of information from an aerial photograph and that you know how to work with the photo, it is now time to have a look at typical relief phenomena in your photo. Where the area covered in your aerial photographs is generally flat, there is however one clear exception. This is Tororo rock. On the southern side of the town, adjacent to it's golf course, there is a tall rock, which is formed by the remnants of an extinct volcano. All what is left of it is the volcanic pipe, which ever formed the heart of the volcano. This center core is made out of erosion resistant rock. This in sharp contrast to its surroundings. As a result the tall and steep rock typically marks the environment of the town and it is probably the first that any visitor to the town will notice. A photo of this rock is shown in figure 6 on the next page.
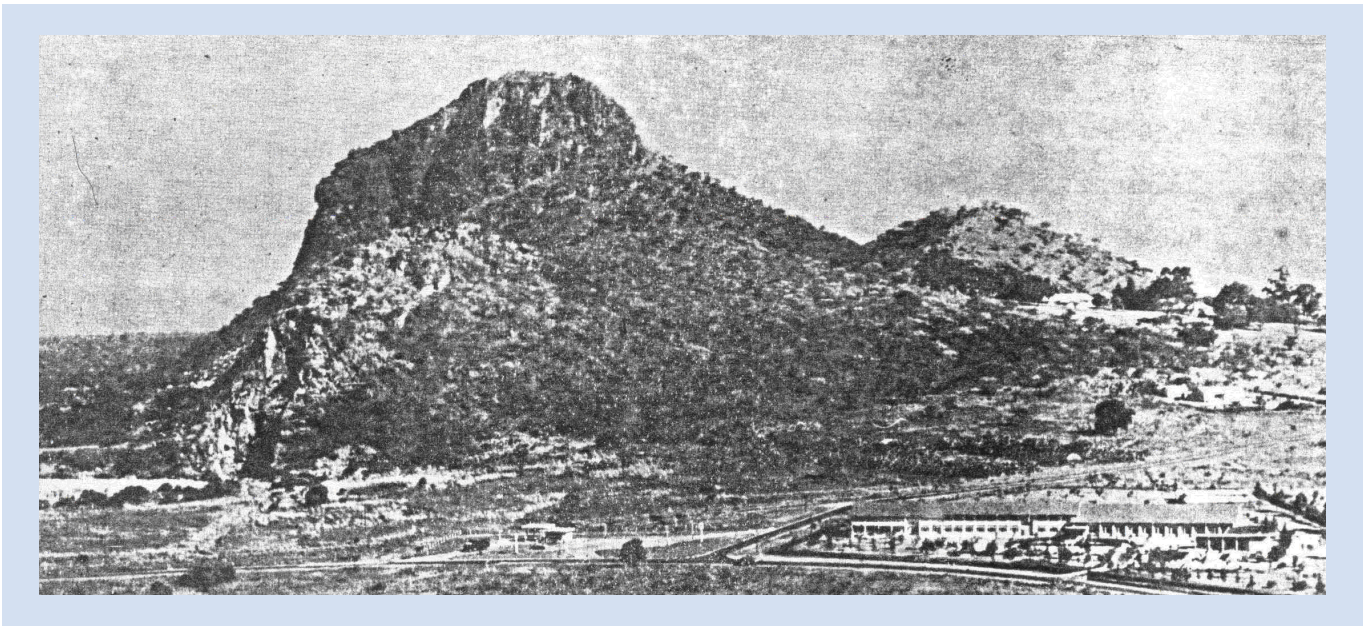
Figure 6   Tororo rock.

- Use the toposheet in ArcView and the aerial photograph to orient yourself and to find out the approximate view direction of the photo in figure 6.

- As has been described in the section on relief displacement, geodetic measurement in your aerial photograph can often be used to calculate heights of relief features. Locate the approximate location of the top on your aerial photograph. (if your copy in the manual is not sharp, ask to see the orginal)

- Measure the distance from the center point of the photo to the top of the rock and write it down below. Use figure 4a in this manual to understand what you are trying to do.

    -distance centre point to top, r+x =   cm

- Now locate where the line from the centre point to the top appears to reach the foot of the rock. Measure this distance and write it down below.

    -distance centre point to bottom of rock =   cm

    -Now calculate the value x =   cm

- Use the equation at the top of page 8 in this manual to make a quick first assessment on the maximum height of this rock, assuming that it rises vertically from the surrounding terrain. Note it down below.

    -maximum height estimate of Tororo rock =   meters

   Although at some places the rock face appears very steep, it is of course not fully vertical and some true distance must be attributed to the stretch between top and bottom of the rock.

- Use the measure tool in Arcview on the toposheet to estimate an approximate true horizontal distance from the top to the bottom of the rock and note it below

    -true horizontal distance between top and bottom of the rock =   meters

- Use the true horizontal distance above, together with your previous scale findings to calculate how much this

distance represent on the aerial photograph?

- Deduct this distance from your x value as noted on the previous page and recalculate your height estimate of the rock.

    -The corrected rock height calculation estimates an height of meters

verify this with the contours of the toposheet, does it match? Does this mean your photographs suffers from local relief displacement?

Now that you are fully conversant in using aerial photographs we will move on to the actual registration or georeferencing of scanned map sources. Find below a first example of a typical map that you may find useful in combination with other data in your GIS and therefore would wish to be georeferenced.
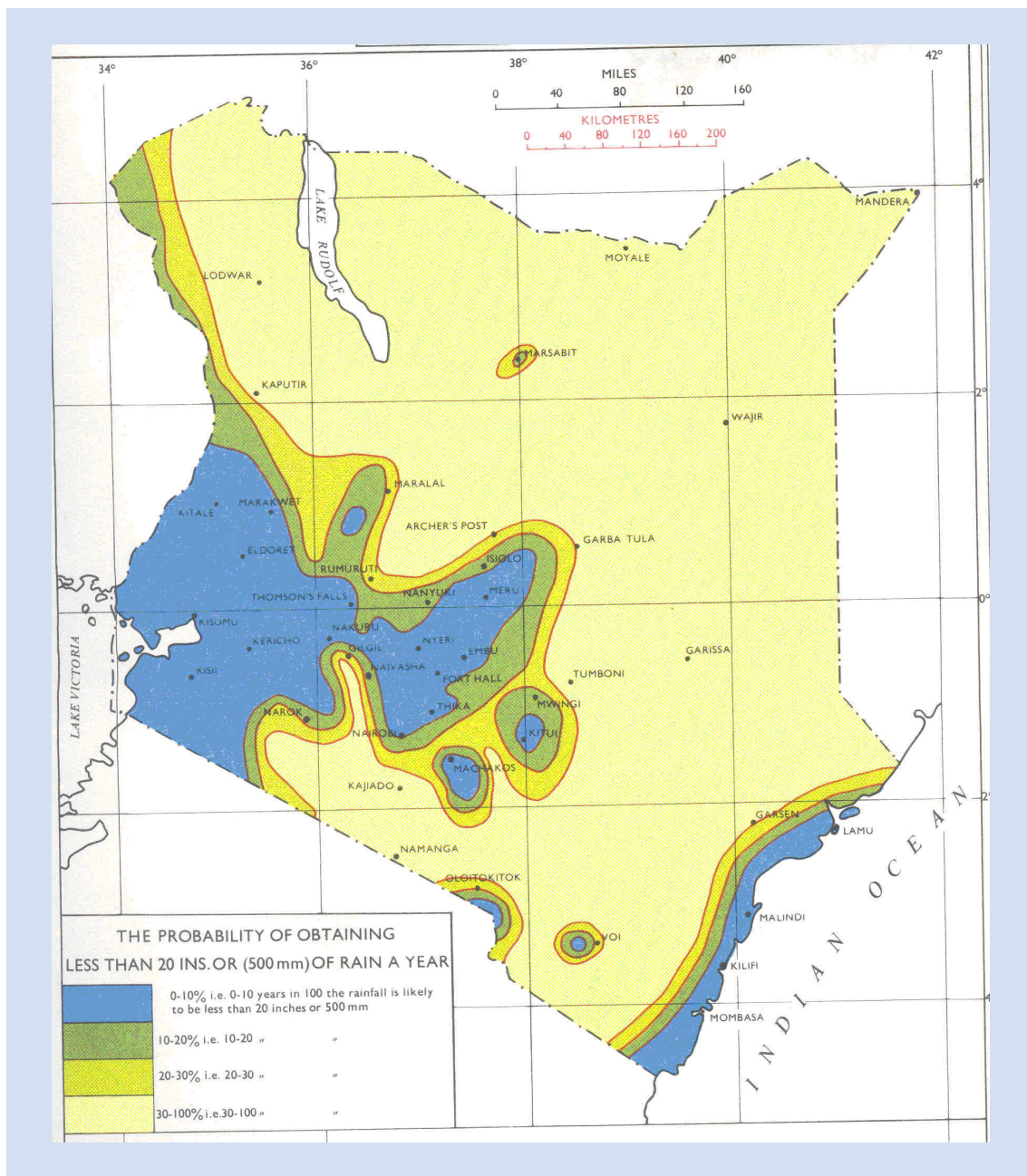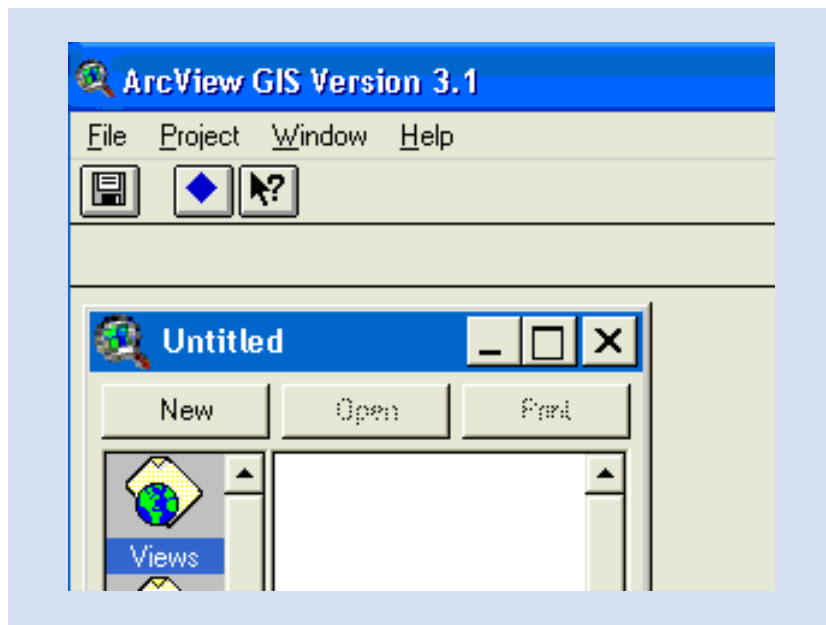

Figure 7:   A scanned rainfall probability map for Kenya.

- In Arcview activate the extension "Image to world file creator". In the main menu of Arcview you will now find a new blue diamond shaped button that can help you to register images. (see for example screen below)


Principally georeferencing of scanned images in ArcView deals with the creation of a "world file", that needs to be located in the same folder as the scanned image and have the same name. The contents of this world file is calculated through a fitting procedure with control points and it is exactly this that the "Image to world file creator" in the register.avx file will help to do.

- Click on the blue diamond button as shown above. You will first be asked to select the image name that you want to register. Please select the file Kenrain.bmp in the folder C:\scangeoref\.

- Next you will be asked to specify a shapefile that holds the coordinate system that you want to use for your image. Please select the file Keadmin.shp from the folder C:\scangeoref\.

- Finally you will asked to give a location and table name, for the control point table in dbf format. After specifying the table details, your screen looks as shown below.
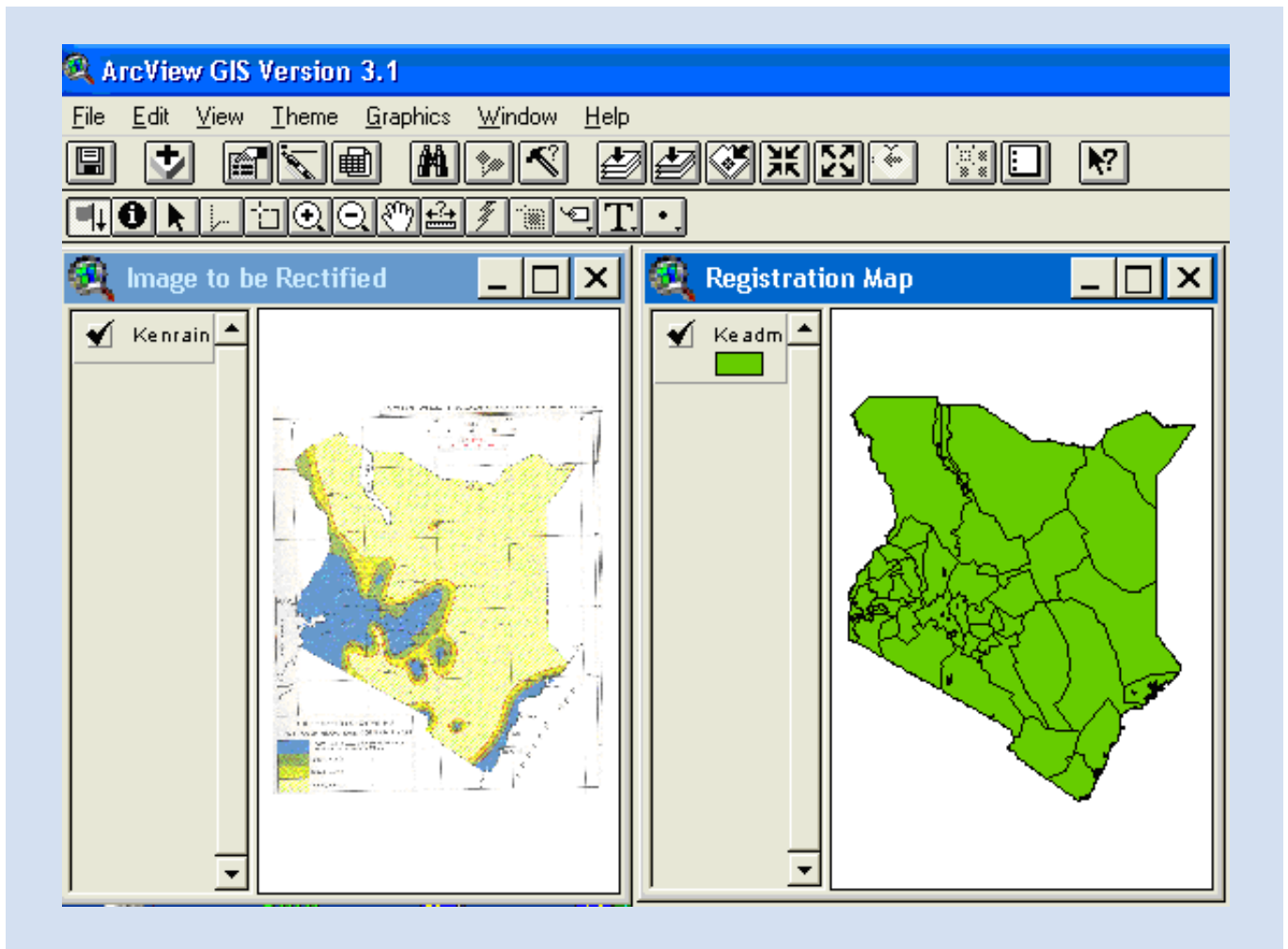
- Now click on the control point button ⬛↓ to start selecting control points.

- You need to select a minimum of 6 control points in this extension. First select a point on one of the known coordinate lines of the scanned map, the systems asks you if you want to keep this point, only click "no" if you clicked in the wrong place, otherwise click "yes".

- Now continue to click on the corresponding point in the "Keadmin.shp" file. Use the coordinate indicator to navigate to the correct point.

- Repeat this procedure for a minimum of 6 points. Always make sure you first select the point in the left screen and then the corresponding in the right screen. You can zoom and pan around in any of the two maps at any time, it will only require to reselect the control point button to continue selecting points.

- When ready move the small map views on the side or minimize them. Then open under tables the "ground control point" table. (see below)
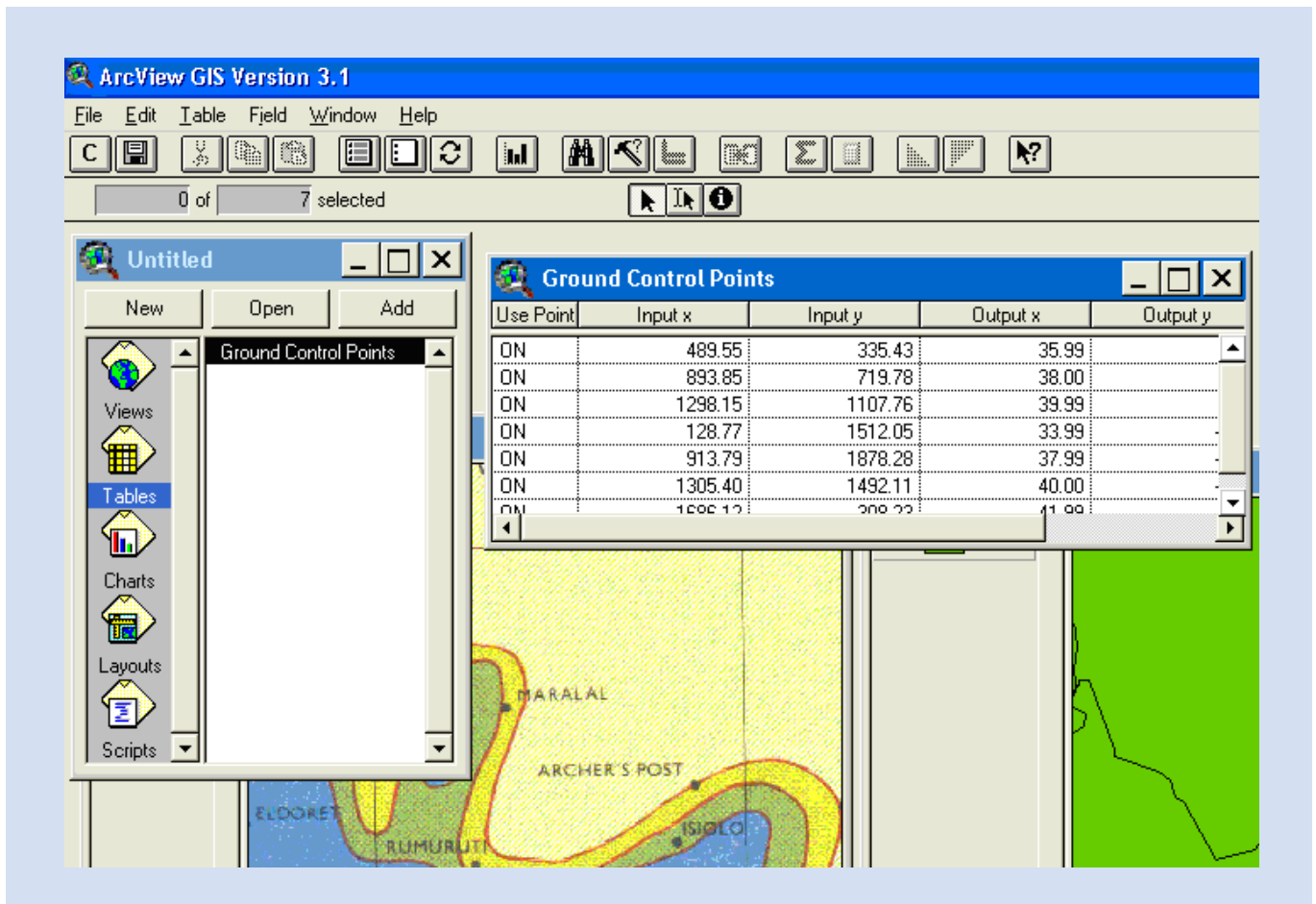
In the "ground control point table" you will find 6 fields that will help you make your registration to fit. These fields respectively contain;

Field 1 -> Use Pnts	You will notice every record has this field ON
Field 2-> Input x	For the image x coordinate
Field 3-> Input y	For the image y coordinate
Field 4-> Output x	For the output x coordinate
Field 5-> Output y	Fort he output y cordinate
Field 6-> rms	Displays the Root Mean Square for the image/feature per record

- In order to calculate the RMS and to activate the fitting press the fit button. [C]

- You can now switch off coordinate pairs with high RMS values to improve your fit, by typing "OFF" instead of on in this table. Press the button [C] again to refit. Please note that you always need a minimum of 6 points for the calculation. If you have only 6 points selected , you can not switch off any in case RMS values are higher!

- Once you are satisfied about the fitting results press the write button to write the world file. Save the world file in the same folder and same name as the image and you have completed the georefencing of a scanned image.

- The extension will automatically close and you will have to open a new view to load and verify your results. So open a new view, again load the "kenrain.bmp" file and this time overlay the keadmin.shp as a transparent layer on top. Congratulations with successfully georefenrencing this scanned bitmap file. You can now use it further, but please don't forget that it remains an image. For more analytical purposes you may have to do some additional screen digitizing.

In a similar way you can now georeference the scanned aerial photograph, which is available as a JPEG file called "Tororo033.jpg" in the folder C:\scangeoref\. There is a small difference in this next example as here you would be using two JPEG files, one unregistered and one already georeferenced in UTM. Even though the "Register module" initially insists you should strictly be using a shapefile as the registration map, you can modify this in a later stage.

- Start with opening a new project file in ArcView. Then load both the extensions for "JPEG image support" and "Image to map world file creator".

- Press the blue diamond icon to start georeferencing process.

- Load the JPEG file "Tororo033.jpg".

- Next it will ask for the shapefile to be used as the registration map. However you don't have a shapefile but another JPEG file called "R64-3.jpg" in UTM. Where the system insists on loading a shapefile, just load the previous file "Keadm.shp", as soon as it is loaded, you delete it and replace it by the correct JPEG file "R64-3.jpg" that you want to use instead.

- Zoom in to identical areas with recognizable points in both screen and start the process of specifying control points. Your screen now looks as is shown below.
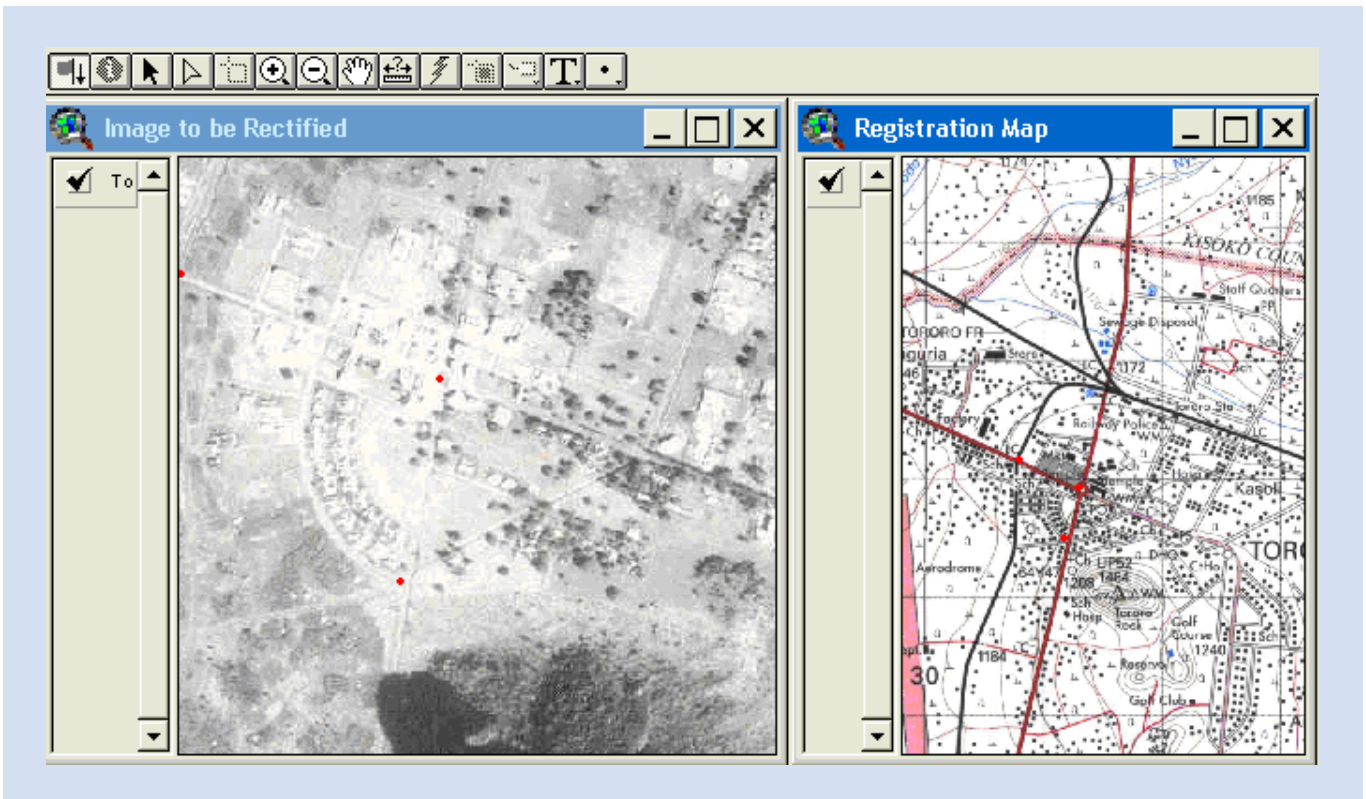
- Complete a number of control points well distributed over the aerial photo. Add more than six pairs so that you have some options in the RMS to remove some bad points. Do not select any point on or nearby Tororo rock as effects of relief displacement will automatically give you poor RMS results for such points.

- Complete the registration and writing of the world.

- Open a new project and check whether you have successfully registered and georeferenced this aerial photograph?

- Based on the RMS levels that you achieved, what are the absolute levels of accuracy associated with your georeferenced aerial photograph? Would you use your results for any cadastral mapping in Tororo town?

- You have so far used simple first order polynomial fairly successfully, however in case you feel you might need to use an higher order polynomial functions to shape and stretch your scanned image please look on the internet at the following site to download a different type of extension; http://home.earthlink.net/~rcreed/rift.html

As is written in the preface of this manual the next exercise on "exploring IDRISI gis" intends to broaden the participants knowledge on useful GIS toolkits besides ArcView and ArcInfo. IDRISI is one of such software options that allows full exchange from one system to another and which adds much in terms of analytical capacities.

IDRISI is a user friendly and easy to learn GIS, which is very strong on the analytical functions and tools. IDRISI handles both vector and raster formats and is fully compatible with MsAccess relational database files. The strongest side of IDRISI lies however in the raster analysis and you will find much added value besides what is already possible in the Spatial Analyst of ArcView.

While being more raster oriented, IDRISI features many advanced image processing and remote sensing tools. Time series processing and spatial modeling are well supported by useful toolboxes. Even though some of the functionalities are complex by nature, explanations and operations remain always simple and well explained. This is supported by a well structured help system, and a large set of tutorial exercises, that allows an easy entry way of learning.

Lastly it may be of value to know that IDRISI licenses are moderately priced at only a few hundred dollars. Especially in cases where you may seek to strengthen your internal GIS capacities with stronger analytical tools at a very affordable cost.

Please have a look at the system and explore the value of this rich GIS toolbox and what it may have to offer in addition to your current GIS systems setup.

- Open IDRISI from the shortcut on your desktop and select "Run" from the temporary installation window. Now go "Help" on the main menu and select "IDRISI Tutorial".
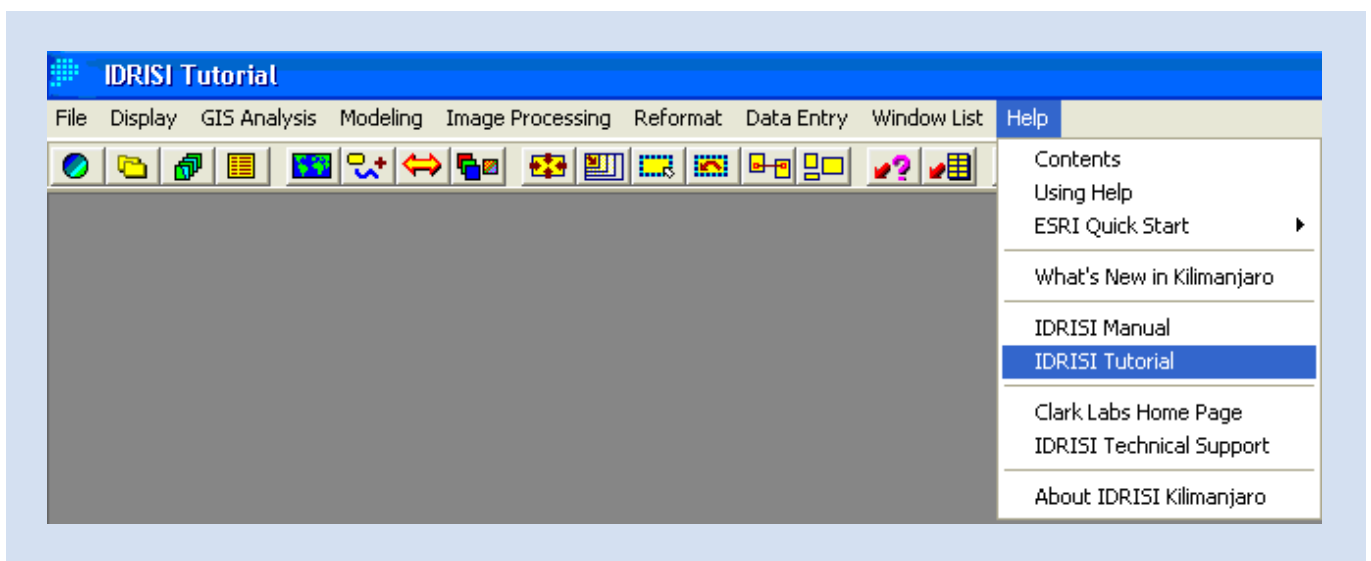
- You will find that a large PDF file will open, showing all the different tutorial exercises that the system contains. Please try to start with exercises 1.1 until 1.3. After that pick any other exercise from 1.4 to 1-10 that has your interest. In the coming days will slowly learn how to use more of the system.