Wildlife Conservation Society of Tanzania (WCST)

Uluguru Mountains Biodiversity Conservation Project
In collaboration with Uluguru Mountains Agriculture Development Project (UMBCP), Regional Natural Resources Office, and the Regional Catchment Project Office

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Explanatory notes on the creation of the Uluguru Mountains Biodiversity Conservation Project Geographical Information System

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Background

What is Geographic Information Systems (GIS)?

Geographic Information Systems are computer-based systems that are used to collect, store, analyze and display geographic information. The Information in a GIS is presented in two basic forms; as maps and as tables. For example, a map can show the location of forest reserves in the Uluguru Mountains. On the other hand, information on the name, area, condition, year of establishment for a particular area of forest can be given in tabular form. This data can be called up by clicking on the appropriate part of the map.

Examples of GIS applications.

a) Agriculture and land use planning. GIS is used for monitoring agricultural land use. Land use and weather data provided from field measurements and production information from previous years can be analyzed together to predict the expected yield of one or more crops. In addition to crop production GIS procedures can be used to evaluate management practices for grazing lands.
b) Forestry and Wildlife management. In forestry management GIS can be used for such analysis as timber harvesting planning, assessment of the existing forest resources, extent of forest damage etc. In wildlife management GIS can be used to analyze such factors as the availability of food and cover, protection from predators and the suitability of areas for nesting sites.

GIS applications in the activities of Uluguru Mountains Biodiversity Conservation Project.

The Uluguru Mountains Biodiversity Conservation Project focuses on the conservation of biodiversity of the Uluguru Mountains. As part of the effort to conserve biodiversity in the Ulugurus, the UMBCP is in the process of establishing a GIS based system to assist conservation activities. The main benefits will be for project planning and reporting, but also in the future the system can be used for monitoring in the Uluguru Mountains. The GIS system will support the new land laws, i.e. the Land act No.4 of 1999 and the Village act No.5 of 1999. Under these acts, lands have been classified into general lands, village lands and reserved lands. As the project proceeds these are being mapped in the GIS and this will allow improved land use planning activities.

Technical comment. The information available can be displayed using Arc View 3.0 and above. However, for the display of the information in the DEM then Arc View 3.1 or 3.2, plus Spatial Analysts 2.0 and 3D analysts will be required. If Spatial Analysts and 3D analyst are not available then the DEM will not work and many error messages will be seen. The main GIS maps are loaded on Hard Disk. However, the scanned topographical maps were so large that these are stored on CD Rom. If these maps need to be displayed then the relevant CD Rom needs to be inserted.

Creation of the Data Layers

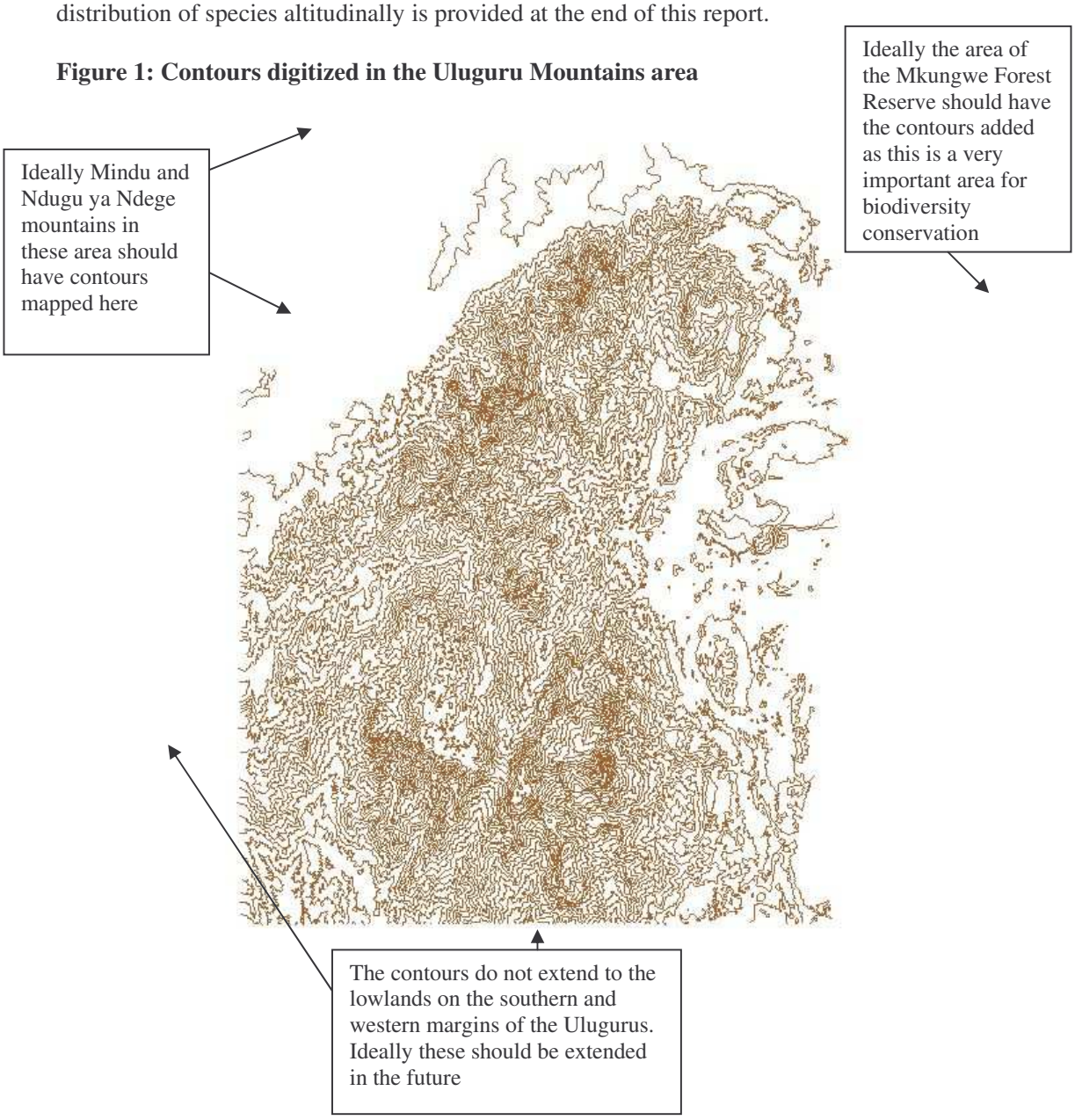
<u>Basic Map Data</u>

1) Map area. The map centers on the Uluguru Mountains in eastern Tanzania. This mountain range with its associated forests, rivers, roads and political land divisions (Divisions, Wards, Villages) is the focus of the current project. However, it was noted during the preparation of the

GIS and during the implementation of the current project that there are a number of hills close to the Ulugurus range which have some affinities to those mountains and which therefore are of some conservation importance. We have therefore extended in part the coverage of the GIS to these areas, although they have not been treated in as much detail as the main Uluguru range. The enlarged area can be termed the 'Greater Ulugurus'.

2) Contours. The contours that are mapped have been taken from the 1:50,000 topographical maps (new series) for the area. Only the 100 m contours have been mapped as digitizing the 20m contour bands would have taken too much time. The contours have been completed for the main Uluguru Mountains area, but outlying hills and lower altitude areas which are also considered as a part of the Greater Ulugurus have not had their contours mapped due to lack of time and available funds. This could be completed in the future. For the portion of the map that has contours it is possible to display the Uluguru Mountains as a digital elevation model (DEM). Further explanation of the DEM and its use as a tool for monitoring forest loss patterns and also the distribution of species altitudinally is provided at the end of this report.

Figure 1: Contours digitized in the Uluguru Mountains area



Forest Cover Layers

The forest cover layers in the GIS system were created with the aim of illustrating the current situation of the forests of the Ulugurus and also of analysing how the forests have changed over time.

1) Forest 1955. This layer illustrates the forest cover in the vicinity of the large Catchment Forest Reserves on the Uluguru Mountains (Uluguru North, Uluguru South and Bunduki).

The forest areas mapped were digitized from the 1957 Topographical Maps (sheets 183/4, 183/4, 201/1, 201/2, 201/3, 201/4), checked and updated through scrutiny on the original 1955 aerial photographs. It was these aerial photographs which were used to make the 1957 topographic maps.

183/3 (Morogoro) – original
183/4 (Kingolowira) – xerox copy
201/1 (Mgeta) – original
201/2 (Matombo) – ammonia copy (without contours)
201/3 (Kisaki) – original
201/4 (Dutumbi) – original

The layer does not show the positions or extent of forests in the lower altitudes, nor does it show forest patches not connected to the main forest blocks. The 1955 aerial photographs show that there were quite large areas of forest in the lower altitudes and many forest patches, but it was not able to geolocate these patches accurately enough to map them, despite efforts using scanned images and the latest image manipulation software. This could be attempted again in the future to show how much forest there was in 1955 at lower altitudes, and hence how this has declined through time.

2) Forest 1977. This layer illustrates the forest cover in the vicinity of the large Catchment Forest Reserves on the Uluguru Mountains (Uluguru North, Uluguru South and Bunduki). It also shows the approximate forest cover in the two largest of the lowland reserves on the eastern side of the Ulugurus, namely Kimboza and Ruvu.

The forest area was digitized from the 1978 Topographical maps, checked and updated as appropriate using 1977 and (in one part) 1982 aerial photographs of the mountains. It was the 1977 aerial photographs which were used to produce this series of topographical maps.

As with the Forest 1955 later the Forest 1977 layer does not contain forest patches, or some of the forests in smaller Forest Reserves on the slopes of the Ulugurus. These are also visible in the 1977/82 aerial photographs that the project has purchased, but it was not possible to locate these with sufficient accuracy to show them on the GIS system. It would also be value to try and do this in the future so that all forests in 1977 could be displayed.

3) Forests 2000. This layer is a modified version of the Forest 1977 cover, as it was not possible to get more recent aerial photographs covering the entire area. For the forest cover of the Uluguru North, Uluguru South and Bunduki Forest Reserves we have used the 1977 layer, with minor updating. For the forests outside these main reserves we have undertaken ground surveys and mapped as accurately as possible the remaining area of forest in reserves, and in unreserved patches. Through this process we have also been able to categorize the forest cover into natural forest, plantations, etc. These categories are shown in this layer.

In addition to the evergreen forests and plantations on the mountains, we have also mapped the distribution of woodland habitats on the slopes of the Ulgurus. This is digitized from the 1977 topographical maps and hence would require ground verification to determine if all these woodland areas still exist, or if they have expanded in any areas.

This layer therefore presents the most accurate and up-to-date assessment of the forest cover on the Uluguru Mountains, but it is also not perfect and could still be refined, in particular through an aerial survey of the entire area. However, this would be costly, and for most purposes the layer we have already created will suffice.

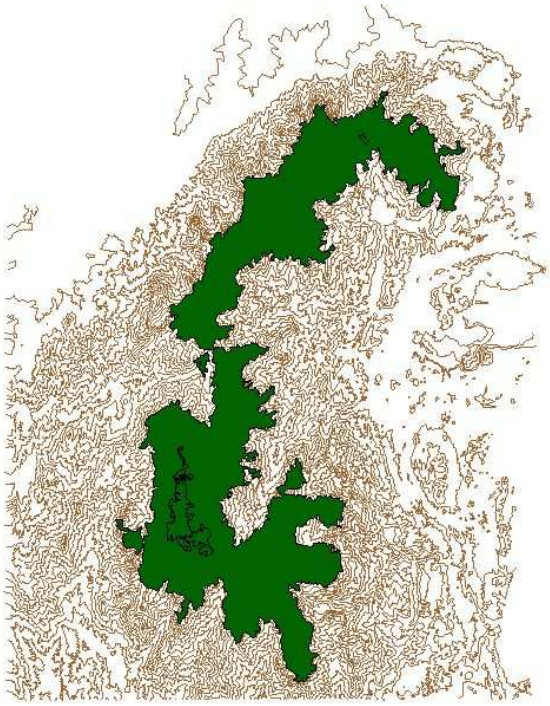
4) Forest degradation 2000. This layer shows quite generally where the most serious degradation issues are found in the Uluguru Forests at the present time. The layer has been built from Forest 2000 and then through a process of field survey the various forms of degradation have been mapped on where they are found.

In addition to this layer the project has also collected a number of other kinds of data which might in the future be mapped on the GIS system:

- Forest Boundary Survey. Catchment Forestry have competed a beacon by beacon survey of the Uluguru North Catchment Forest Reserve. This has included taking GPS readings of the beacons and also describing the condition of the boundary at each point. These data could be used to update the Forest 2000 layer, and also to update the Forest degradation 2000 layer.

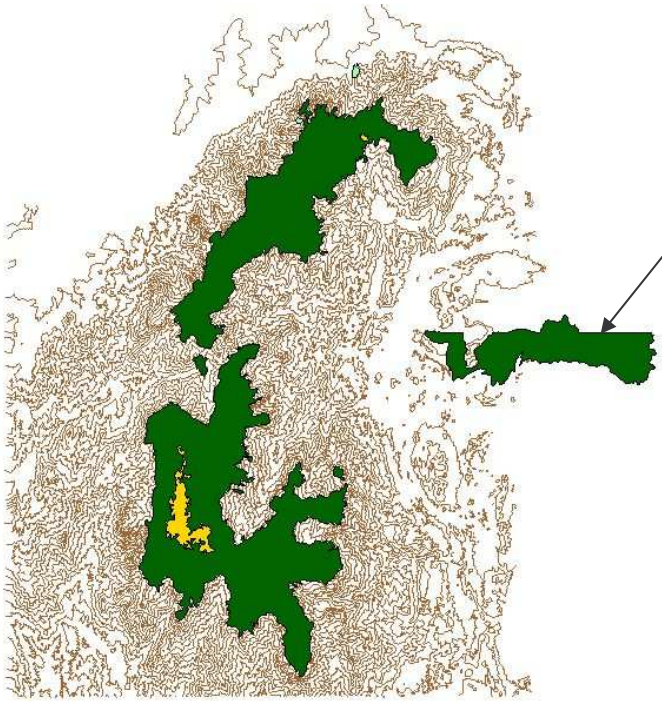
- Disturbance surveys. Transects have been undertaken in four different parts of the Ulugurus a) Kitundu/Kitumbaku Public Land forest, b) Uluguru North Catchment Forest Reserve near Tegetero, c) Uluguru South Catchment Forest Reserve near Lanzi and d) Uluguru South Catchment Forest Reserve between Bunduki and Tchenzema. Is may be possible to map these data on the GIS in future.

Figure 2: Forest Cover 1955 over the contours



Note that none of the forest patches outside the main two blocks has been mapped. The 1955 aerial photographs were scanned in, but it proved impossible to match the photos to the ground and hence no mapping was attempted. However, more lowland forest was noted around Kimboza/Ruvu than was found in 1977. On this map the Lukwangule Plateau in Uluguru South should also be marked as grassland and not forest

Figure 3: Forest Cover 1977 over the contours



Note that the lowland forest mapped for Kimboza and Ruvu forest reserves is too large on the eastern extent of Ruvu. Ideally this should be corrected to the area which is now depicted on the 2000 forest cover layer as that is more accurate and no big changes have occurred between 1977 and 2000 in this area, despite ruby mining in the area.

Figure 4: Forest Cover 2000, over contours

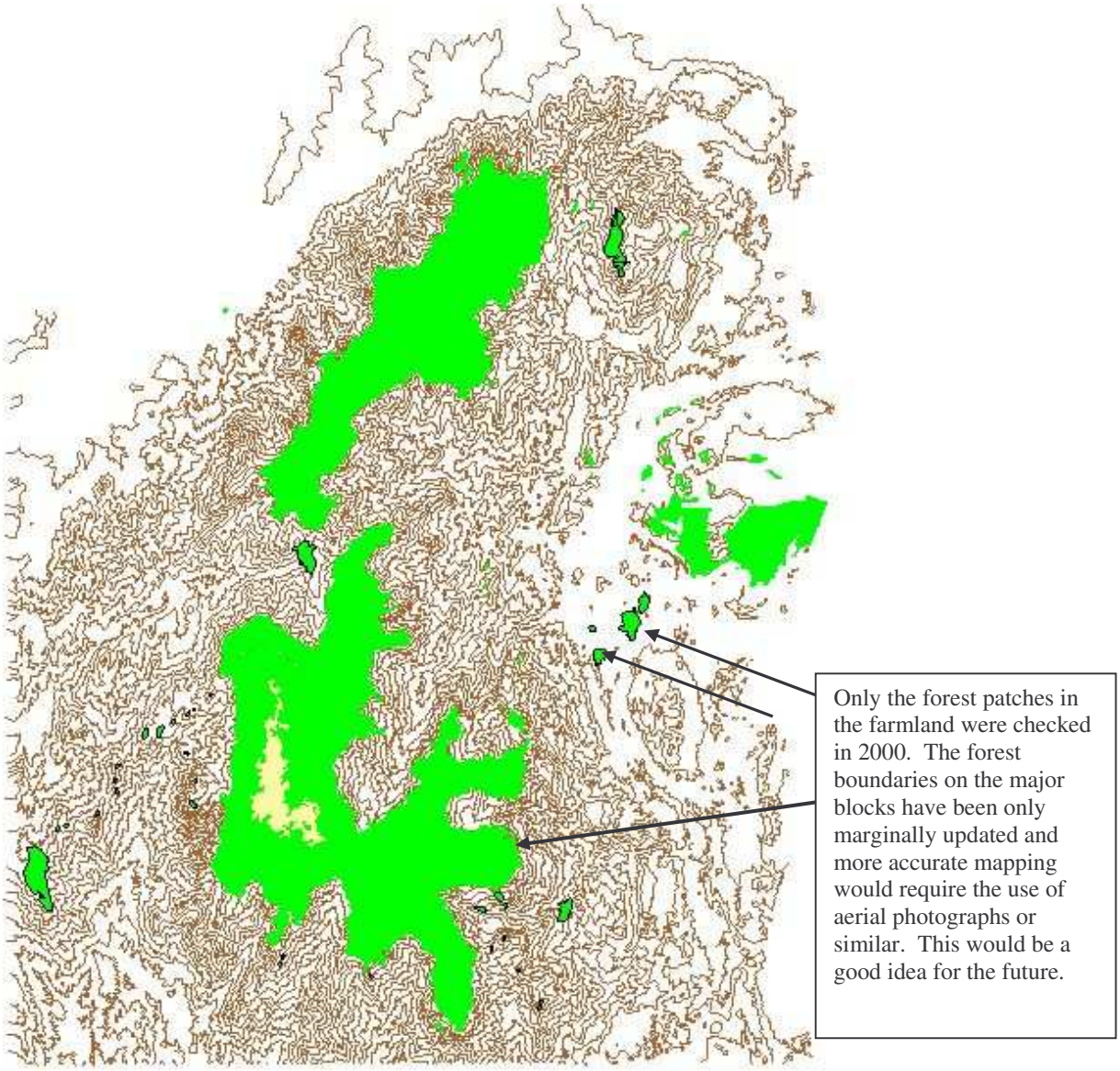
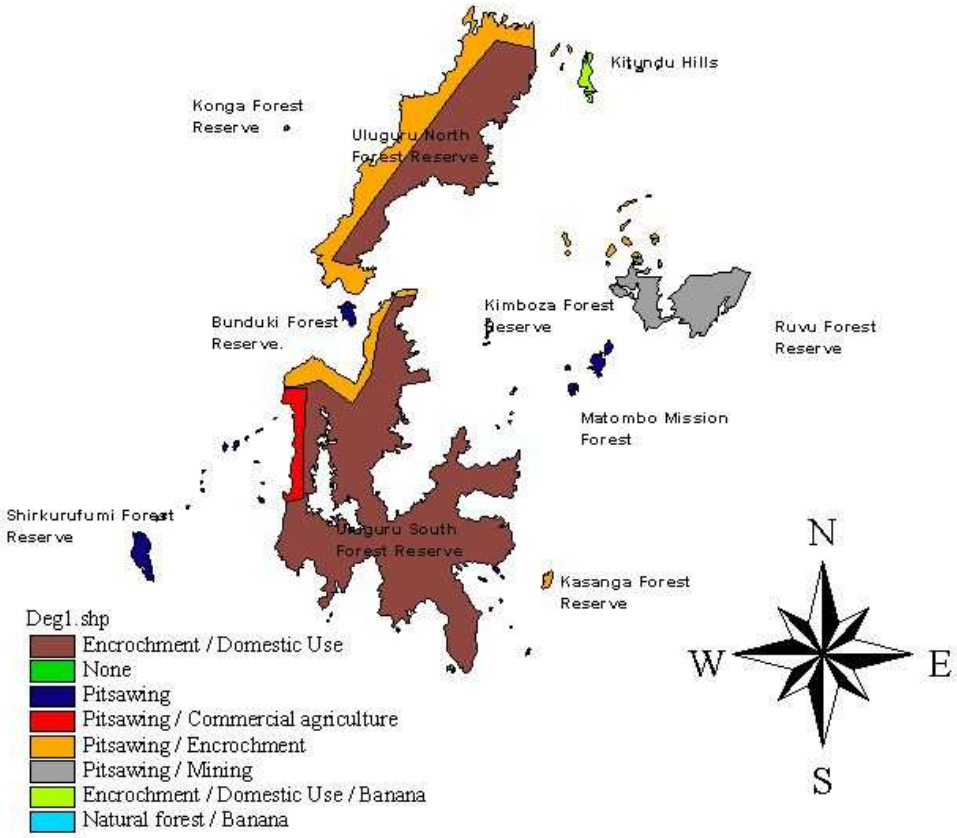


Figure 5: Forest Degradation 2000



Government Reserves

The project has digitized the forest reserves on the Uluguru Mountains using the Regional Map prepared in 1968, and the District map prepared in 1974. These show the position of all Forest Reserves that were existing at that time. Very few changes have occurred since that time although a few reserves have been degazetted, and some have been invaded and are now farmland. It has proved very difficult to accurately geolocate these maps and hence the layer does not fit very well with either the maps derived from the individual Forest Reserve Boundary maps, or with the maps of forest cover at different times. Moreover, the maps seem to show some of the reserves in the wrong positions in relation to each other (see below). With some additional time the GIS unit would be able to correct the problems to some degree, but this layer would never be 100% accurate due to a lack of adequate georeferencing on the map itself, and the errors which seem to be found in the maps themselves.

Figure 6A: Map of Forest Reserves on the Ulugurus in 1968 (from a Regional Map)

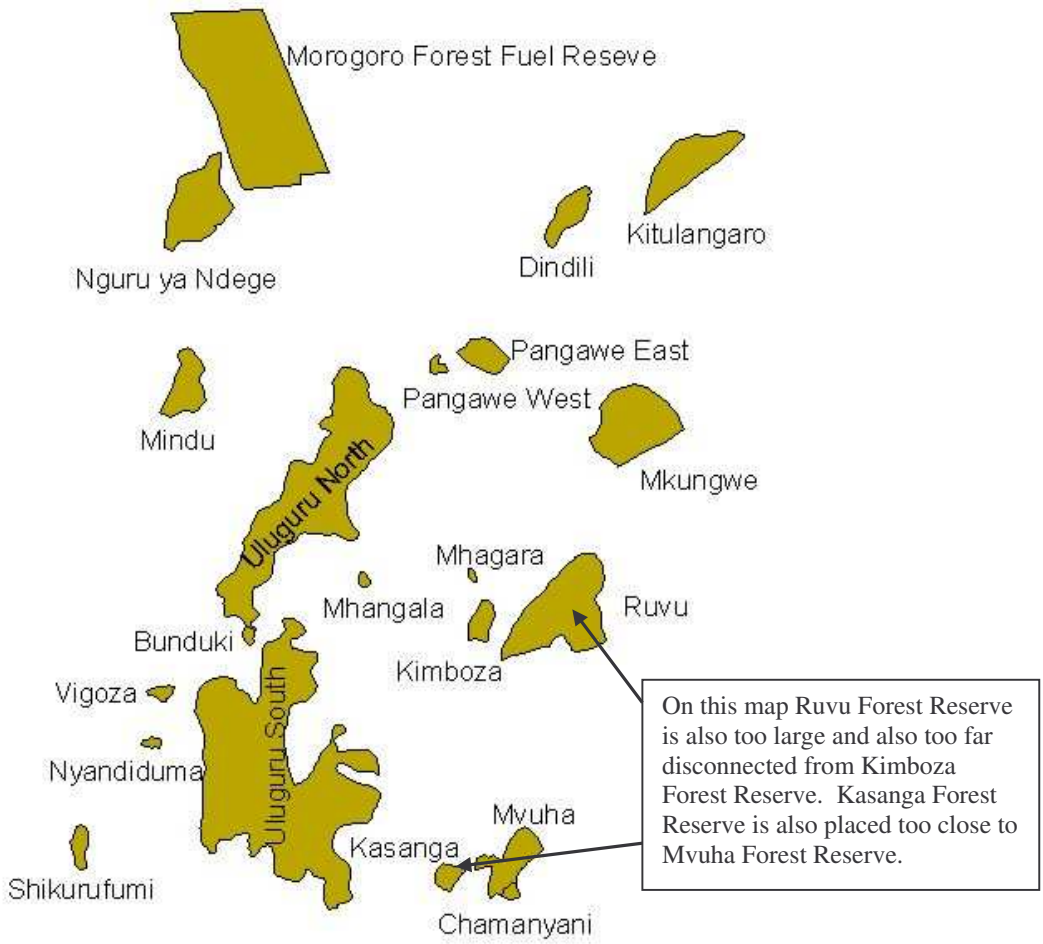
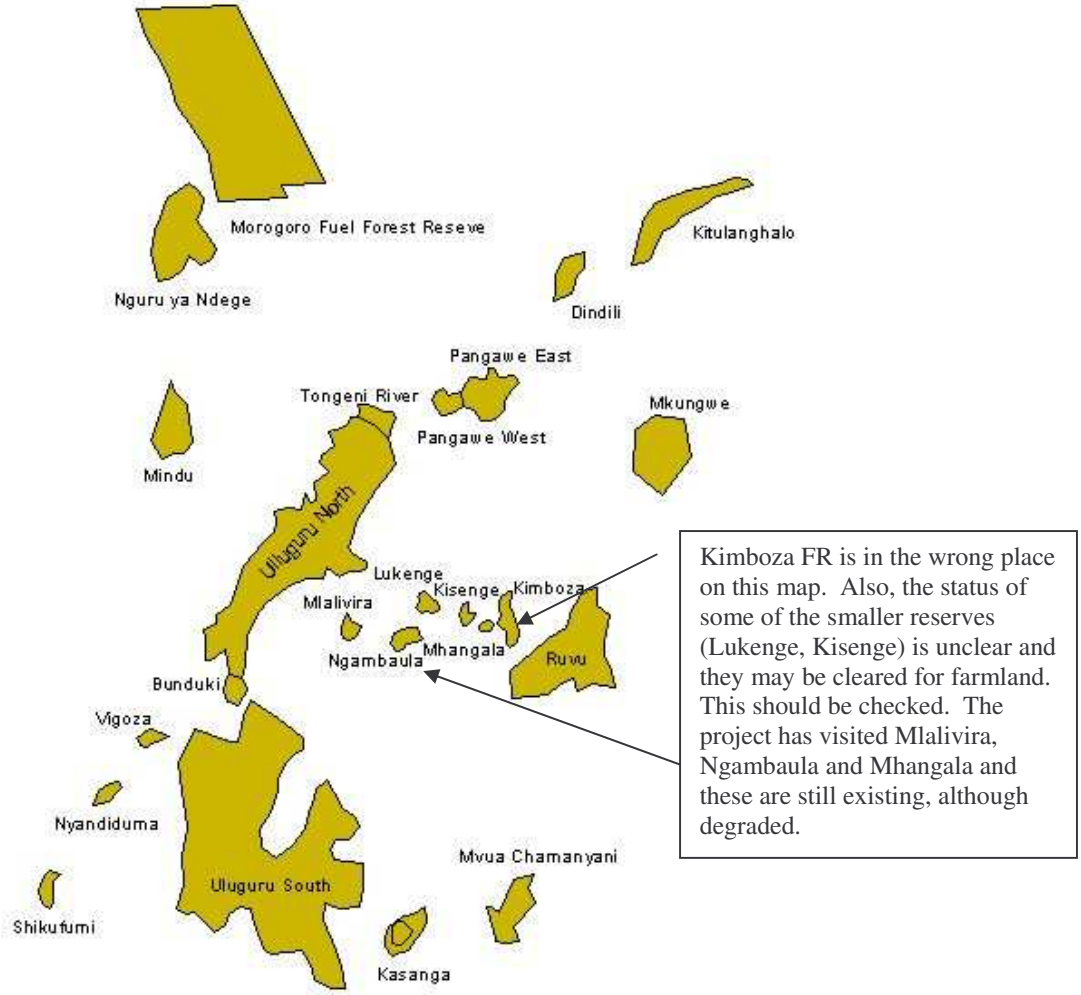
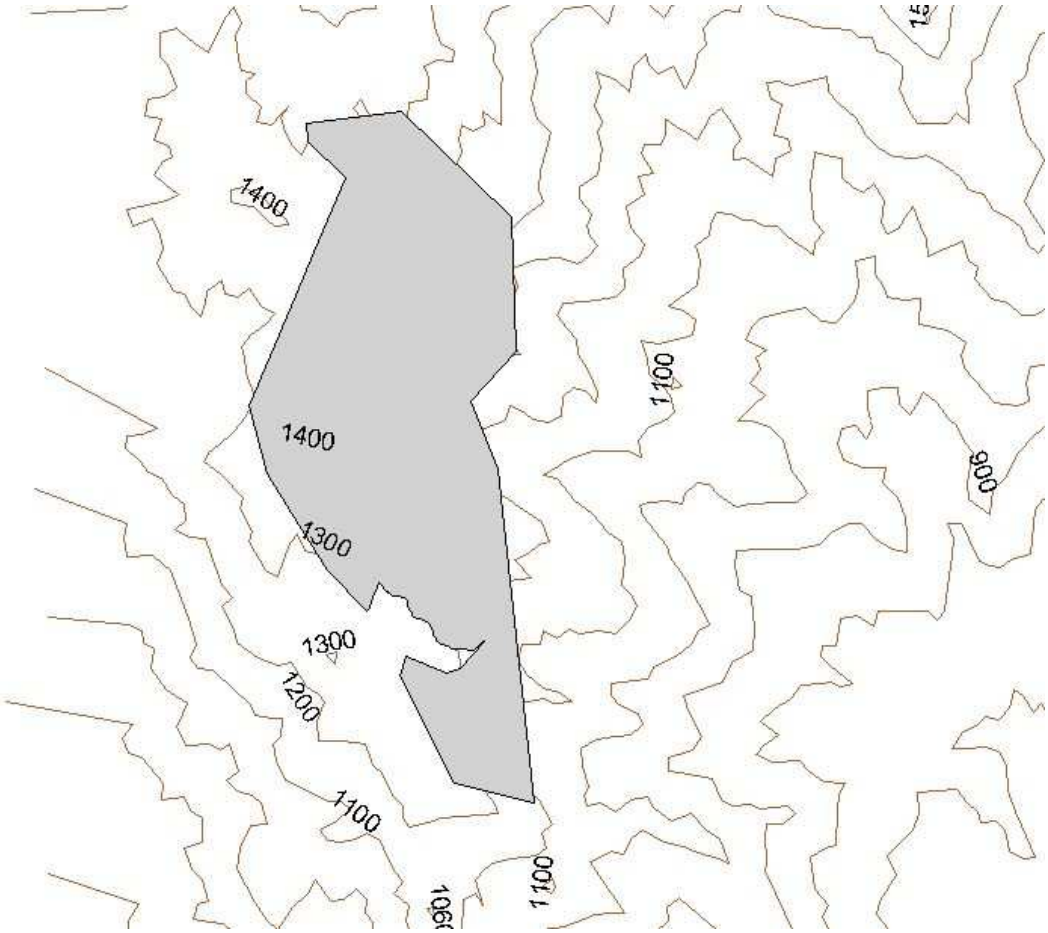


Figure 6B. Map of Forest Reserves on the Ulugurus in 1974 (from the District Map)



The project has gathered all available boundary maps for the various Forest Reserves (Catchment and District) found on the Uluguru Mountains. Those maps which have adequate geo-referencing have been digitized and can be displayed either separately as a single reserve, or mapped onto the larger base map of the Uluguru Mountains. There are some problems with these reserve boundary maps in that they appear in a different position to the forests which have also been mapped. I would be possible to correct these errors if at a later date the reserves were visited and a number of the beacons (at least 3) could be relocated and then geopositioned using a GPS. Then the boundary map could be repositioned correctly in the GIS system. The Forest Reserves which have been digitised are as follows: Uluguru North Catchment Forest Reserve, Uluguru South Catchment Forest Reserve, Kimboza Catchment Forest Reserve, Shikurufumi Catchment Forest Reserve, Vigoza Catchment Forest Reserve, Ruvu Catchment Forest Reserve,

Figure 7. Example Boundary Map for Shikurufumi Forest Reserve



Administrative Data Layers

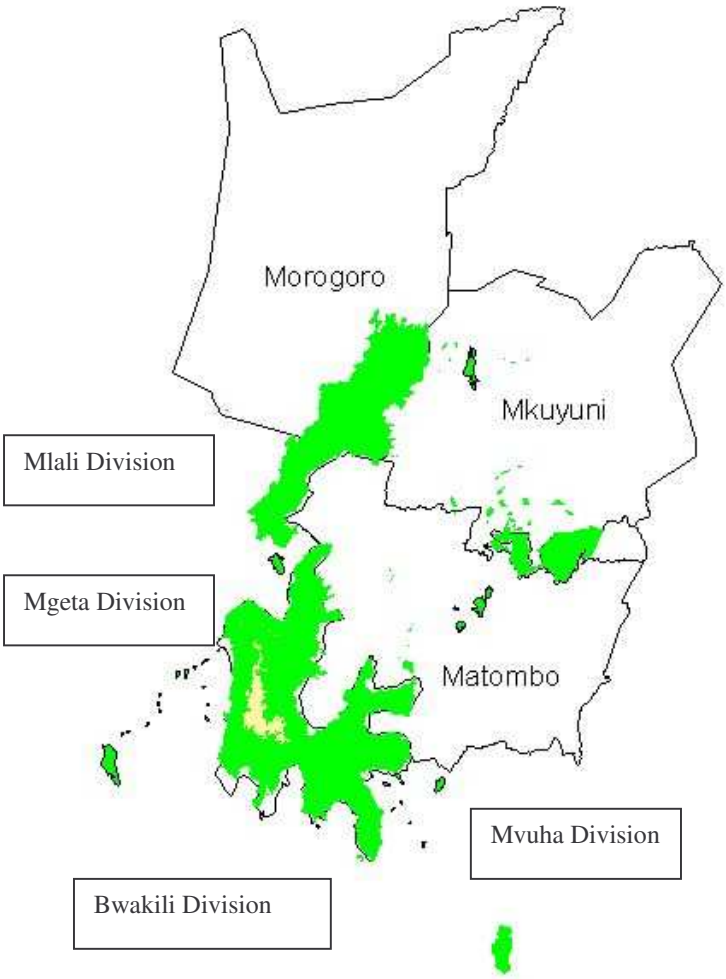
The project has also attempted to gather data on the administrative units, roads, and human populations for the Ulugurus. These layers are very useful when forest conservation is being planned and also allow the production of professional reports and articles about the project and its work.

1) Districts. The Uluguru Mountains contain a small part of Morogoro Rural District which extends north to Turiani and the Nguru Mountains. The Morogoro Municipal area, which is separate from the Morogoro Rural District is found mainly on or close to the Ulugurus and hence that has been mapped it its entirety (see Divisions below).

2) Divisions. The map of the Tanzanian Administrative Divisions was digitized from a base-map prepared for the project as a consultancy by Mr Duduma of the Municipal Planning Department in Dar es Salaam. He was formerly a Town Planner in Morogoro and undertook the survey of villages etc in the Uluguru Mountains when he was based in that office. Only three Divisions of

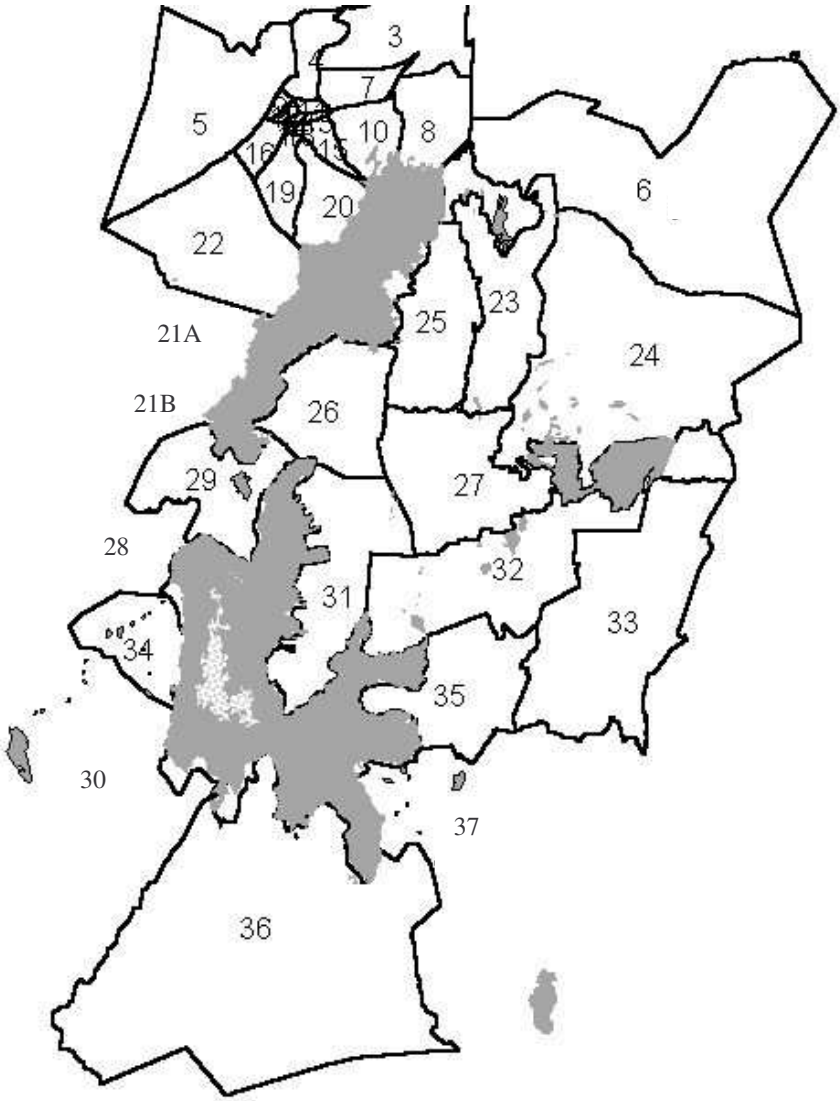
Morogoro Rural District are found entirely on the Uluguru Mountains (Mukuyuni, Matombo and Mgeta) the others all range off the Mountains. For these Divisions only the portions which are on the Uluguru Mountains have been mapped, leaving open polygons, which affects some of the analysis (e.g. area calculations and population densities etc). The Morogoro Municipality is also found on and close to the Mountains and hence that has been mapped in its entirety. In total 6 Divisions of Morogoro Rural District and the Morogoro Municipality border the forests of the Uluguru Mountains.

Figure 8: Map of the Divisions surrounding the Uluguru Mountains



3) Wards (Kata). The Wards which are found on the Uluguru Mountains have been mapped, with as many as possible being closed so that analysis of the information within their polygons is possible. For the Morogoro Rural District we used the map provided by Mr Duduma for the Ward boundaries. For the Morogoro Municipal area we used a map provided by the Morogoro Municipal Town planner.

Figure 9: Map of Wards in the Ulugurus with a list of their names



Key to Main Wards: 6=Kiroka, 8=Bigwa, 10=Kilakala, 15=Boma, 19=Mbuyuni, 20=Mlimani, 21A=Mzumbe, 21B=Mlali, 22=Mzinga, 23=Kinole, 24=Mkuyuni, 25=Tegetero, 26=Kibogwa, 27=Tawa, 28=Langali, 29=Bunduki, 30= Kikeo, 31=Kibungu, 32=Lundi, 33=Matombo, 34=Tchenzema, 35=Kolero, 36=Bwakila Juu, 37= Kasanga.

In the Morogoro Municipal area the sub-divisions are all regarded as Wards and hence Villages are not shown in this area. This is due to the different in administrative management of District and Municipal areas. This affects the ability of the GIS to display population density at Village level across the entire Uluguru area. A combination of Wards and Village maps needs to be used.

The Wards can be displayed within their Divisions, or showing their contained Villages, or alone. It is also possible to either add or remove the name labels from the Wards, and also to display the population from 1988 and the density of the population at that time (see later). If there is a possibility for updating, then increasing the number of Wards represented as closed polygons would enhance the analytical possibilities, particularly in Mgeta Division.

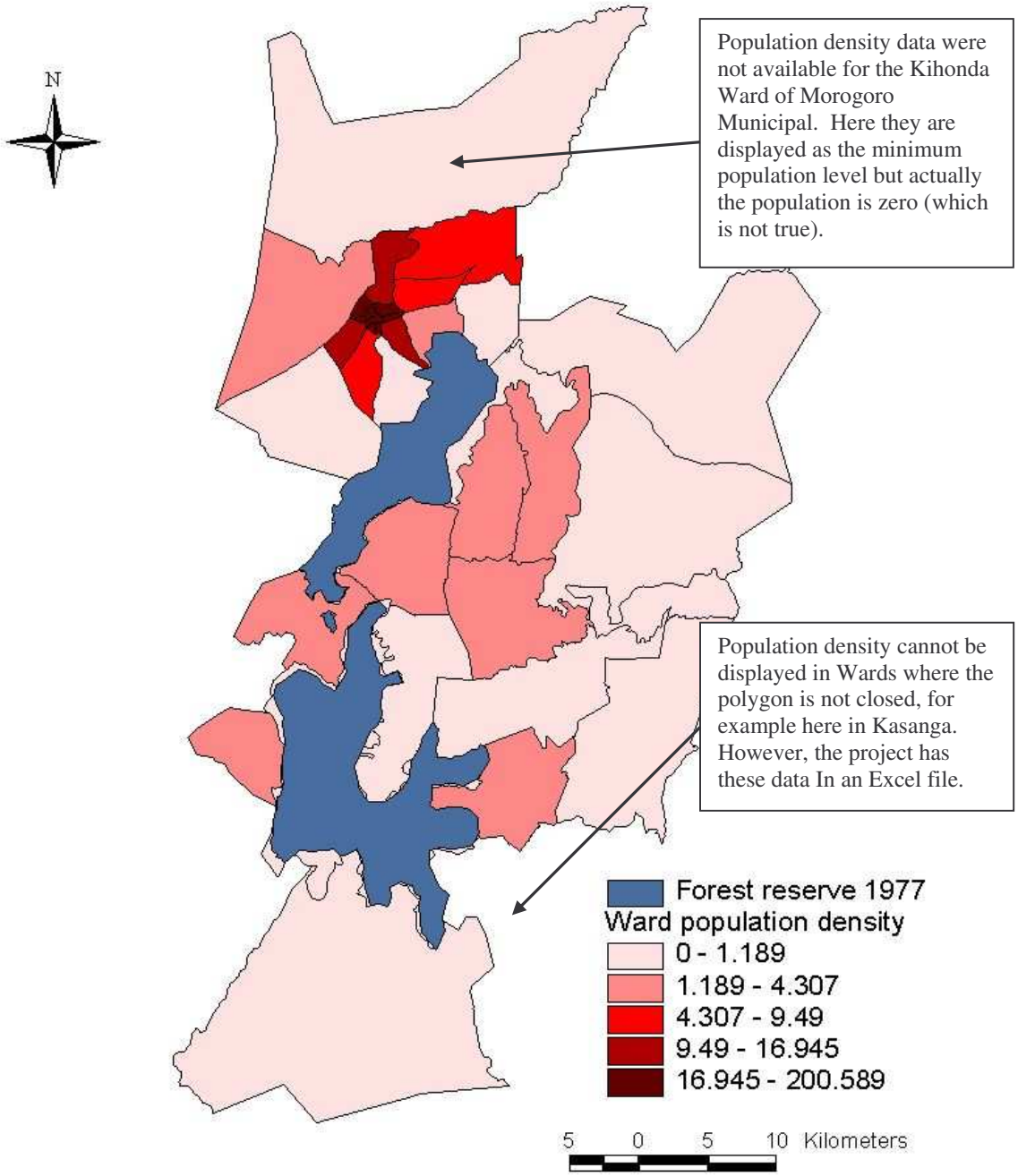
Population density of people in the Wards in 1988 has also been collected and can be displayed as numbers or in terms of shading. Here it is displayed as numbers, calculated as the number of persons per sq km of each of the Wards where the polygons are closed. If more of the Wards could be mapped so that their polygons are closed then additional population density information could be displayed.

The highest population densities are found in the Wards which are in the center of Morogoro Municipality. Here the Ward population density can reach over 200 people per sq. km. In the rural Wards on the Ulugurus the population density can be below 1 person per sq. km. In general, because of the very high population density of Morogoro town the population density of the rest of the Ulugurus appears low. This may result in a pressure on the natural resources close to the center of the highest population.

There was a difficulty in getting data for Kihonda and Bigwa Wards because they have been added to the Municipal area since 1988 when the last population census was undertaken. Hence these areas are shows as having very low population densities, which is not accurate. The planned 1998 population census was cancelled due to lack of funds and the next scheduled one is in 2008. It is not known if that will take place.

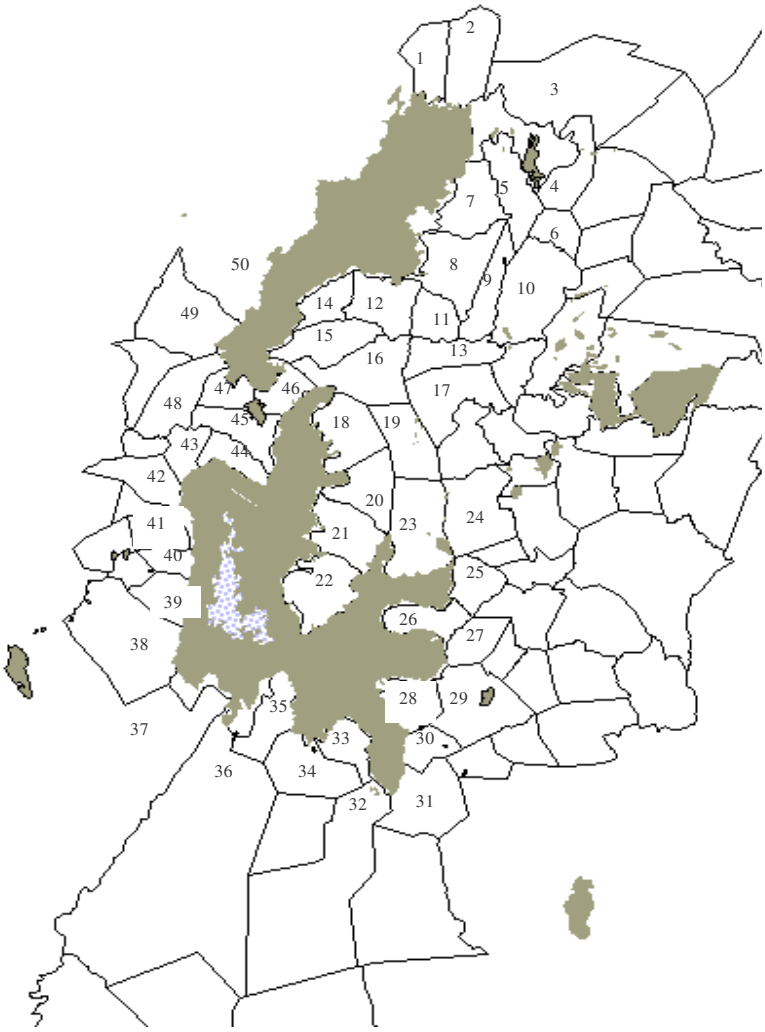
Further digging the archives of the Municipal area might uncover population data which could be used to update these figures. Moreover, it is possible that more recent census data exist for the Municipal and Rural areas. We heard about such data collected by UNICEF, but were not able to locate it for use in this project.

Figure 10: Population Density in the Wards around the Uluguru Mountains



4) Villages (Kijiji). The map produced by Mr Duduma has also been used to map the boundaries of the Villages in the Morogoro Rural District portion of the Uluguru Mountains. As mentioned above Villages are not found in the Municipal Area and hence all of the sub-divisions in the Municipal area are mapped as Wards, including areas of the Uluguru Mountains above Morogoro town. Only those villages close to the forests have been numbered and named below although the project has data on all the villages in an Excel file.

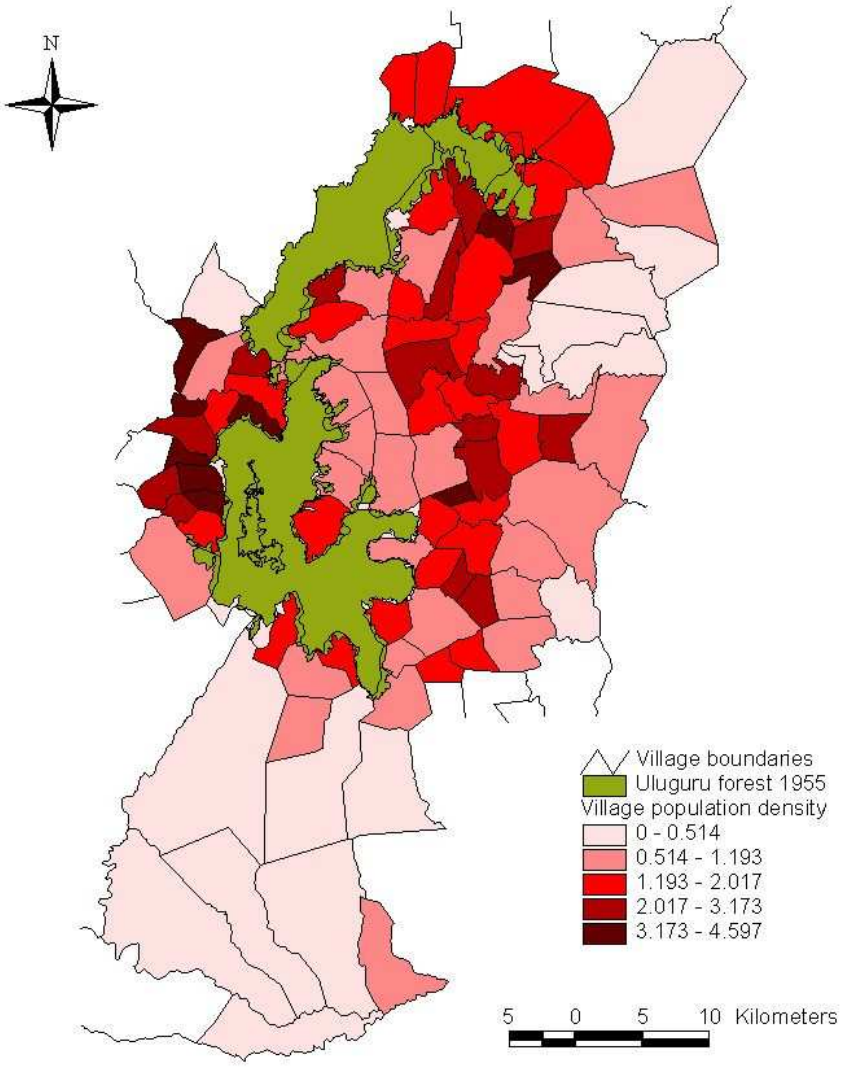
Figure 11: Map of the Villages of the Ulugurus, with a list of those closest to the forest



1=Bigwa, 2=Misogeni, 3=Kiroka, 4=Amini, 5=Tandai, 6=Kalundwa, 7=Bagilo, 8=Tegetero, 9=Mifuru, 10=Rudewa and Lun'gara, 11=Hewe, 12=Kifuru, 13= Milawilila, 14=Mambame, 15=Nyachiro, 16= Kibogwa, 17= Tawa, 18= Dimilo, 19= Lukenge, 20= Kibungo, 21= Lanzi, 22=Nyingwa, 23= Mlono, 24= Konde, 25= Lugeni, 26= Ng'weme, 27= Lusange, 28 = Ukwama, 29= Kasanga, 30= Longwe, 31= Mgata, 32= Singiza, 33= Nyamgadu A, 34=Nyamgadu B, 35= Lumba Juu, 36= Lumba Chini, 37= Kikeo, 38= Mhale, 39= Ng'ungulu, 40= Tchenzema, 41= Nyandira, 42= Langali, 43= Pinde, 44= Kibigili, 45= Bunduki, 46= Vinile, 47= Magruwe, 48 = Tandari, 49= Mongwe, 50= Tangeni.

Population data from 1988 are also available for villages, and these can also be displayed using the GIS programme (see below). As with the Ward population graphic the population density can only be displayed for those villages where the polygons have been closed. Village population density is typically higher in the lower altitude portions of the eastern part of the Ulugurus, and higher at the higher altitude portions of the western Ulugurus (especially in Mgeta). Here the population density can reach as high as 4.5 people per sq. km.

Figure 12: Population density in the villages around the Uluguru Mountains

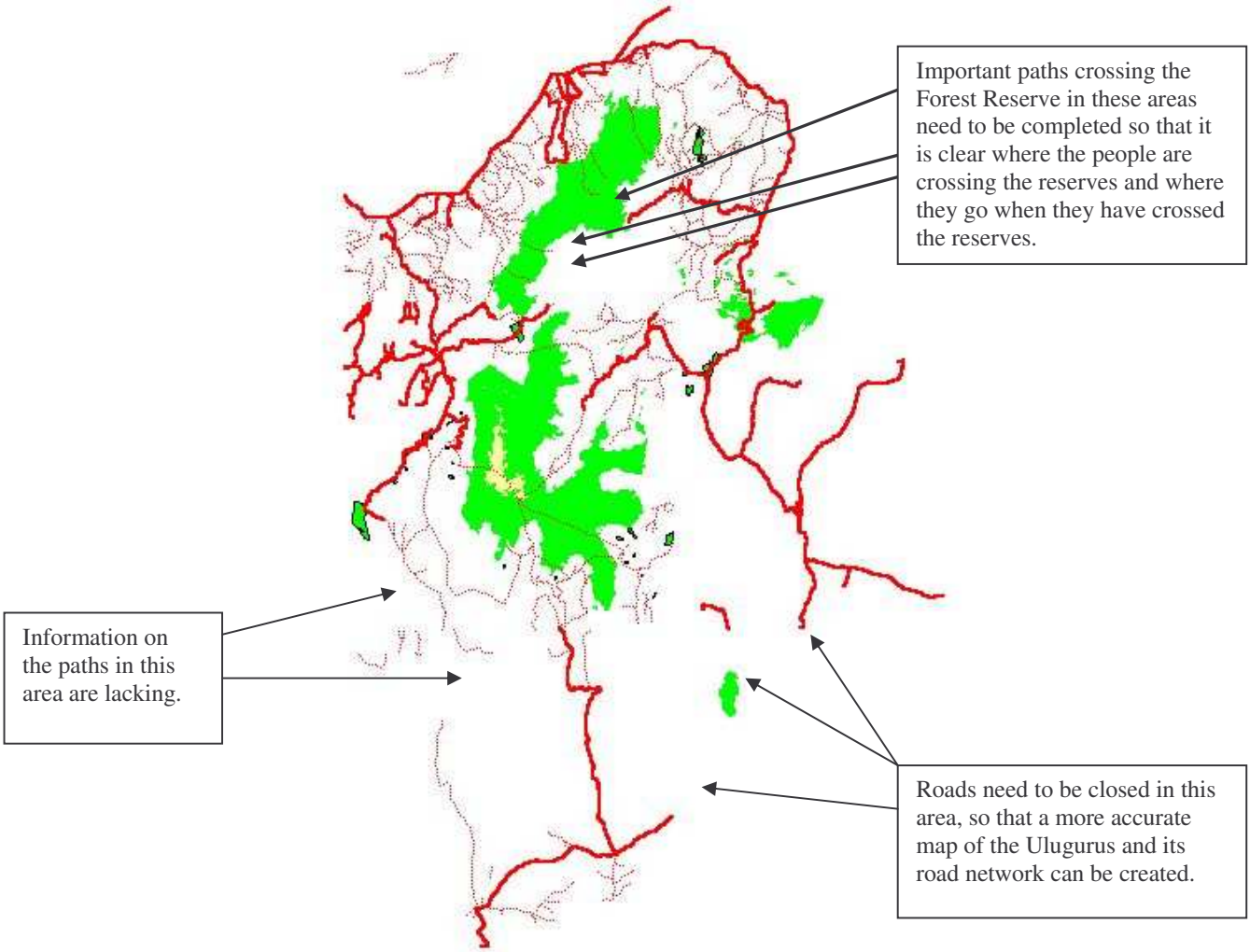


Other Data Layers

1) Roads and Paths

The layer on roads and paths has been created from the 1:50,000 topographical maps allied with local field experience on whether the roads in particular are still actively used. We have much less information on the paths. The network of roads around the Mountain has not been closed and in future this should be done to show the road network accurately. Also the path network, especially those paths which cross the Forest Reserves from one side to the other could be better located so that it is clear which are the major routes that people on the mountain are using for their trade and also to move around.

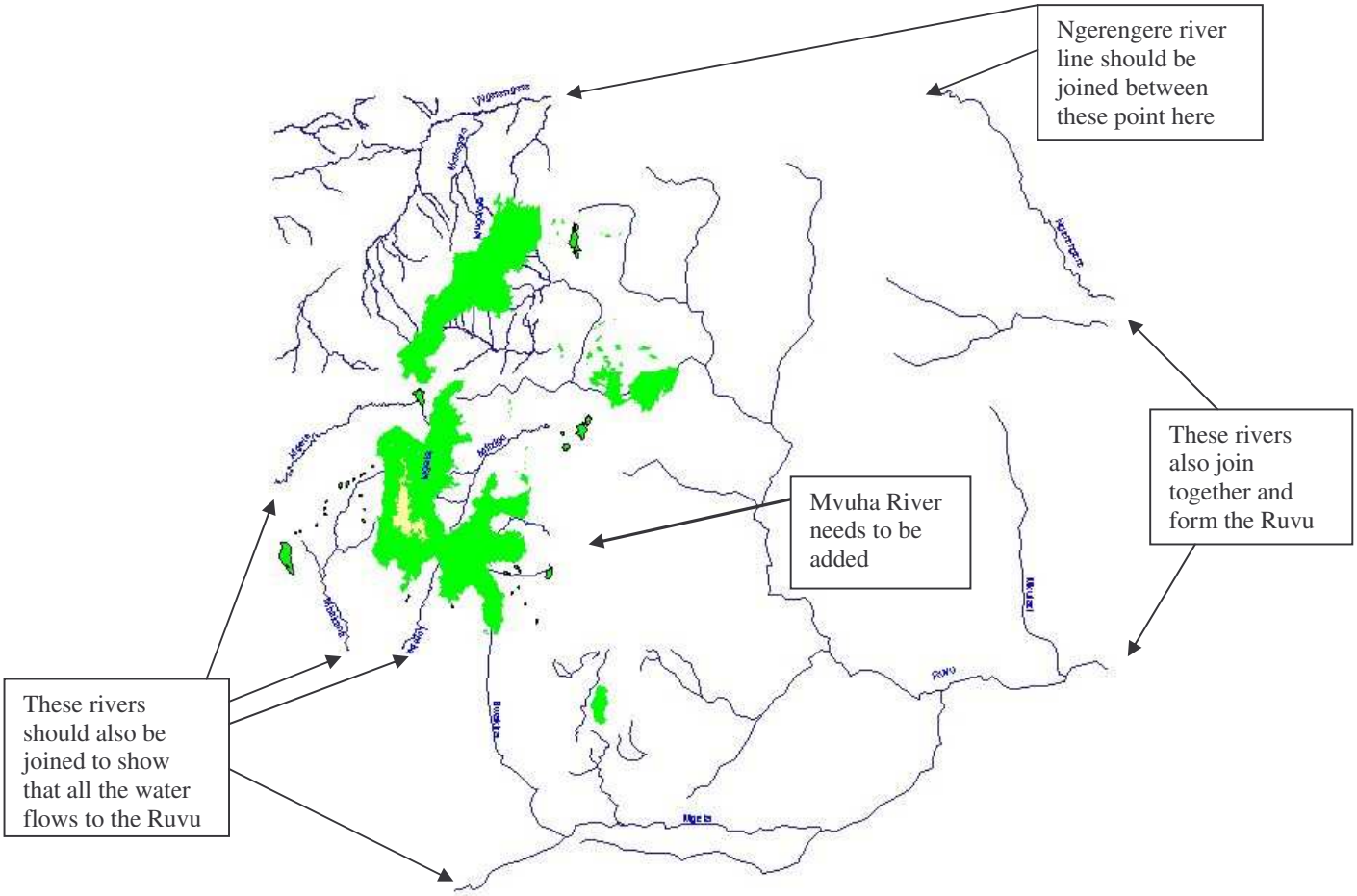
Figure 13: Main Roads and Paths on the Uluguru Mountains in relation to the remaining forest cover in 2000



2) Rivers

The major rivers flowing from the Uluguru Mountains have been digitized from the 1:50,000 topographic map sheets. However, some of the lines of the rivers have not been closed and hence it is not that clear that all these rivers eventually join to the Ruvu River and then flow to Dar es Salaam. This would be a useful graphic to have as it shows that the rivers start in the Uluguru forests and then flow to the Ruvu and from there to Dar es Salaam. The Mvuha River, which is an important river flowing east out of Uluguru South Forest Reserve is also missing from the map and should ideally be added.

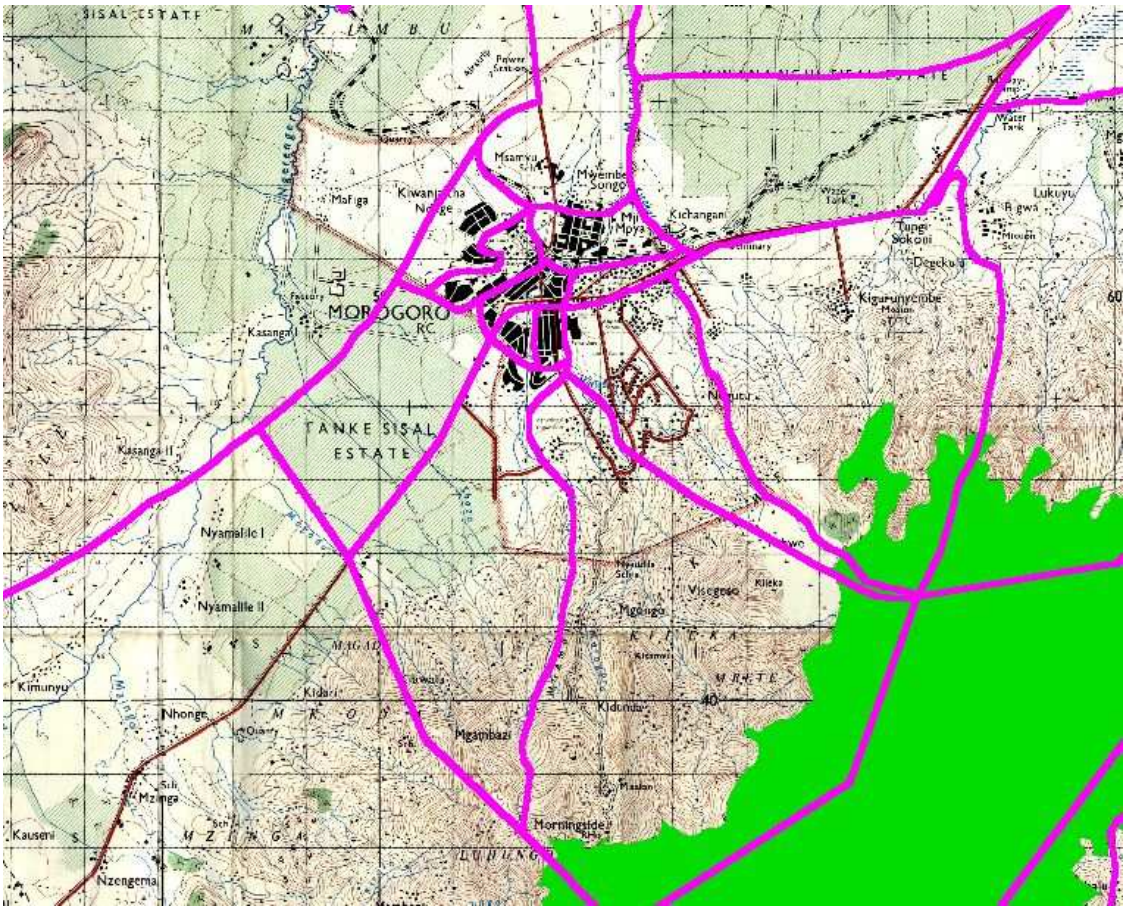
Figure 14: Major Rivers flowing from the Uluguru Mountain forests.



3) Topographic Maps

The project has also scanned in the existing topographical maps of the Uluguru Mountains. These have been georeferenced and they can thus be added as a layer in the GIS programme. When displayed they can then be overlaid any of the other layers in the GIS and hence can display a number of relevant attributes at variable scales. An example of what can be displayed is provided for the area around Morogoro, where the topographical map of the town and the slopes of the mountain is overlaid with the Ward boundaries and the forest cover in 2000. This shows how the Municipal borders are actually found within the forest and hence within the Forest Reserve boundaries, which are actually under the authority of a different management agency (Catchment Forestry). Many other things could be done with these layers, but they require quite a lot of computer power as they are very large.

Figure 15: Topographical map, Ward Boundaries and Forest Cover 2000 around Morogoro Town.



4) Aerial Photographs

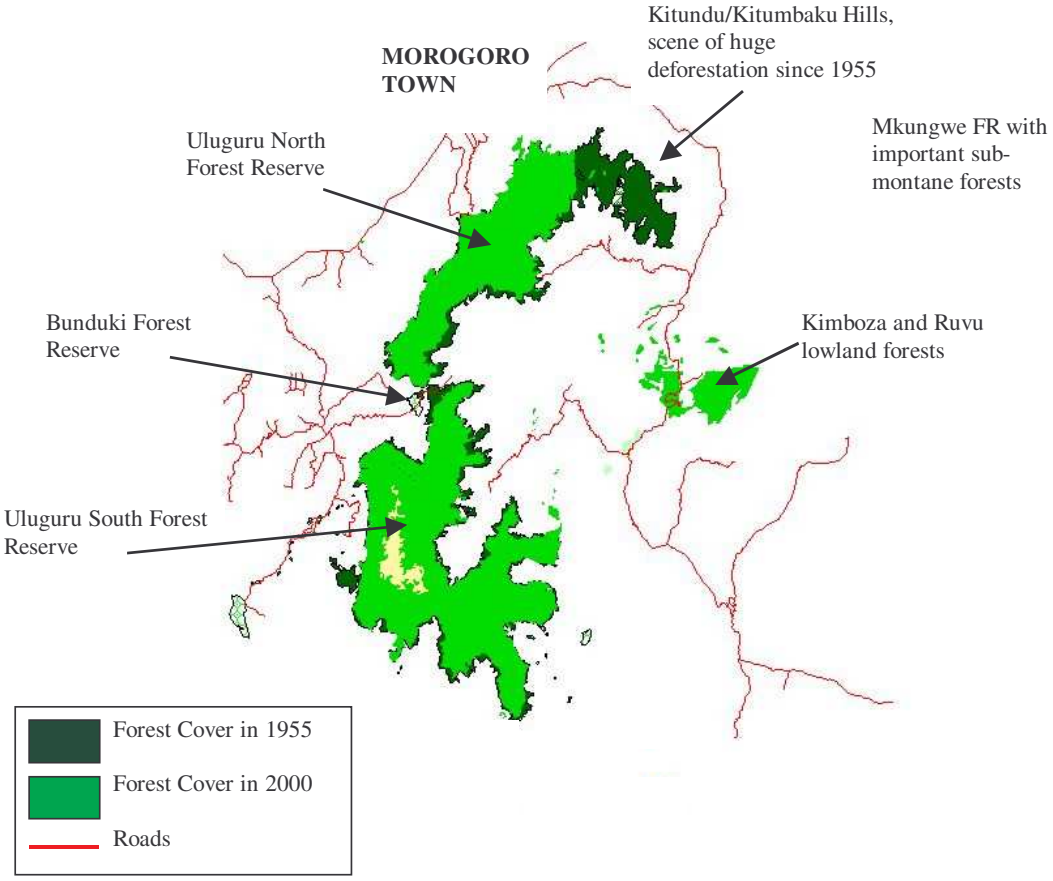
The project also purchased and digitized aerial photographs covering the Uluguru Mountains from 1955 and 1977. However, due to the different angles at which the photos had been taken, and also due to the large size of the image files and the difficulty of manipulating them, it proved impossible to add these photographs as a layer in the GIS, or to use the photographs to map the remaining forest patches outside the major forest blocks in 1955 and 1977.

Analysis Performed

Forest Area Change 1: Analysis of mapped data

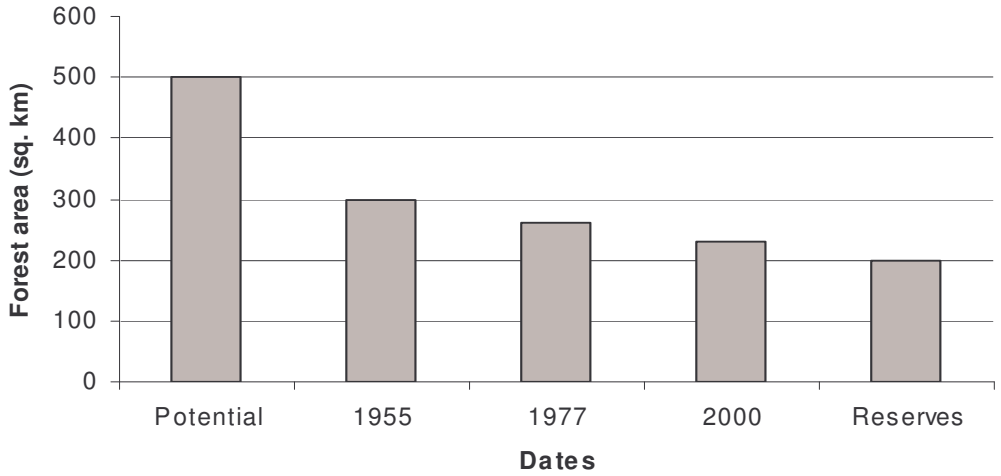
Analysis of the forest damage between the years 1955 and 1977 was performed using GIS techniques. Data were obtained from the existing topographic maps of 1955 and 1977 and converted into digital format by manual digitization. The 1977 forest cover map was then updated through field surveys undertaken in 2000, which mainly affected the forest patches outside the main reserves, and upated the remaining forests in the Kitundu/Kitunbaku Hills Public Forest area (see below).

Figure 16: Forest cover change between 1955 and 2000



As well as displaying these data as a map it is possible to extract the numerical information from the GIS and then plot graphs of the amount of forest remaining at different periods (see figure below). This provides a clear illustration of the problems with forest conservation on the Ulugurus. Almost all forest is now found within Catchment Forest Reserves, with only small areas found in Local Authority Reserves and in the village lands.

Figure 17. Changes in the area of forest on the Uluguru Mountains.



Potential is estimated from climate and the extent of lowland forest patches which are assumed to have been originally joined. Estimates for 1955 and 1977 are based on aerial photographs, and for 2000 on ground surveys. 'Reserves' is an estimate of the minimum forest area if the present reserves are maintained, with little encroachment, but all forest outside is lost (around 20 sq km of the Uluguru Forest reserves is upland grassland and some is rock).

Forest Area Change 2: Use of a Digital Elevation Model (DEM).

A Digital Elevation Model has been built of the Uluguru Mountains in the GIS programme. This model allows the Ulugurus to be looked altitudinally, and also allows various kinds of analyses based on altitudinal variation. For example forest cover in 1955 and 1977 (not updated to include the 2000 forest cover) has been draped over this DEM for the Ulugurus and this allows forest cover over the actual topography of the mountain, as well as simple plan views of forest cover to be calculated (see Table 1 below). Such methods allow the changes in forest cover at different altitudes to be assessed, which is important when (as in the Ulugurus) some of the endemic species have a narrow altitudinal range.

Apart from providing information on the extent of forest cover at different heights in the Uluguru Mountains, the DEM can also be used to display the distribution of different species of animals and trees at different heights.

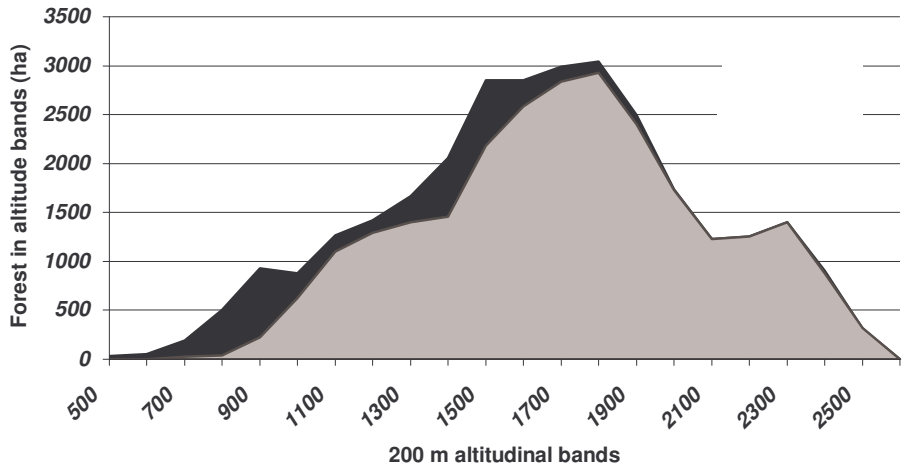
Table 1: Data on forest cover in 1955 and 1977 on plan view (flat above view) and over the topography of the Ulugurus (using the Digital Elevation Model).

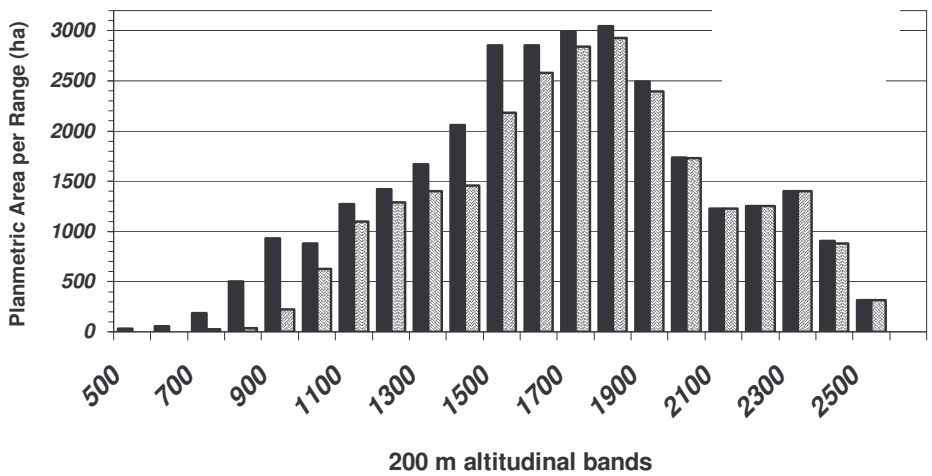
Altitudinal Range (m)	Plan View of Uluguru Mountains used to calculate forest cover			Topographical View of the Uluguru Mountains used to calculate forest cover		
	Plan forest area in 1955 (ha)	Plan forest area in 1977 (ha)	Change in Plan forest area from 1977-1955	DEM forest area in 1955 (ha)	DEM forest area in 1977 (ha)	Change in topographical forest area from 1977-1955
500	28.73		-28.73	31.39		-31.39
600	53.54		-53.54	60.89		-60.89
700	188.56	25.87	-162.69	205.43	29.53	-175.9
800	504.86	38.85	-466.01	540.45	40.73	-499.72
900	927.88	224.03	-703.85	975.61	235.66	-739.95
1000	877.85	625.29	-252.56	957.47	685.64	-271.83
1100	1269.12	1099.73	-169.39	1395.75	1776.92	381.17
1200	1417.18	1291.74	-125.44	1581.09	1447.11	-133.98
1300	1666.21	1401.81	-264.4	1877.46	1576.39	-301.07
1400	2056.14	1458.32	-597.82	2381.27	1697.79	-683.48
1500	2850.29	2183.02	-667.27	3246.52	2484.61	-761.91
1600	2850.89	2580.56	-270.33	3321.09	3008.49	-312.6
1700	2988.17	2839.06	-149.11	3454.06	3274.76	-179.3
1800	3042.75	2930.15	-112.6	3520.6	3374.69	-145.91
1900	2492.24	2396.2	-96.04	2879.49	2764.74	-114.75
2000	1738.98	1730.8	-8.18	2029.47	2021.37	-8.1
2100	1227.24	1227.24	0	1434.26	1434.26	0
2200	1251.34	1254.85	3.51	1420	1423.5	3.5
2300	1402.39	1400.91	-1.48	1541.53	1540.15	-1.38
2400	906.26	878.36	-27.9	986.48	957.26	-29.22
2500	314.34	316.51	2.17	341.07	343.1	2.03
2600						
Totals	**30054.96**	**25903.3**	**-4151.66**	**34181.38**	**30116.7**	**-4064.68**

Analysis of these data by altidudinal range (see figure below) shows the area of forest at different altitudes. Most forest in 1955 was already found above 1000 m on the Ulugurus. By 1977 an area of forest had been lost at the lower to medium parts of this altitude range. Above 1900 m there has been very little loss of forest, mainly because at this altitude the forest is all found within the Catchment Forest Reserves where it is quite well protected.

Although the analyses have not been done, the mapped data presented above show that further forest loss has occurred outside the Forest Reserves between 1977 and 2000. This forest loss is concentrated in the altitudes 700-1200m and hence will continue the trend seen the below graphs, that of forest being lost preferentially in the low to medium altitudes, but surviving well in the higher altitudes.

Figure 18. Altitudinal distribution of montane forests in the Uluguru Mountains, 1955 and 1977, illustrating the greatest forest loss between 700 and 1700 m, and very little forest loss above this altitude.





TECHNICAL NOTES

Phase I GIS work.

Phase I of the GIS development involved the creation of the Digital Elevation Model and the mapping of forest cover in 1955, 1977, the forest reserve in 1977 and some of the Roads, Divisons, Wards and Villages, around the Ulugurus. The data created at this time can be found on a CD (Uluguru data) in the project office and is also found in the following directory:

C:My Documents/Uluguru
The operational file here is c:My Documents/Uluguru/admin2.apr

If the data are installed onto other computers then they have to be placed in the same files on the new computer otherwise it will not work.

Within this project there are a number of views which can be changed. Within the project there are also a number of completed layouts which are final products with titles, legends, scales etc. The layouts can be printed as posters, or as large scale maps.

Phase I of the GIS development used the following programmes: ArcView 3.1, Spatial Analyist 2.0 and 3D-Analyist. Currently the project only has a copy of ArcView 3.1 and hence the topographical information and the DEM which was built during Phase I of the project cannot be displayed. It would be advised to purchase the full package of ArcView, Spatial Analyist and 3D-Analyist so that the full potential of this project can be exploited. This will also allow further analysis of the data (for example 2000 forest cover by altitude, population density by altitude, area of land protected by altitude etc.).

Phase II GIS work.

In Phase II of the projects GIS work, the existing files created during Phase I, with the exception of the DEM portion were updated. This involved creating forest cover layers for 2000, forest degradation layers for 2000, and updating all the other layers to cover the entire Uluguru Mountains, and to incorporate other data such as human population densities. The data created during this phase can be found in 6 CDs in the office and also on the computers at the following location:

C:wcst/umbcp
The operational file here is C:wcst/umbcp/moro_nv.apr

Again, if the files are to be installed onto new computers then it has to follow this file structure in order to work.

Within the project there are lot of views which can be changed, and also a lot of data which can be accessed if the correct part of the map is clicked on. This includes names, populations, population densities, areas of reserves and villages etc etc. Layouts can also be created which include scale bars, legends etc.

The topographical maps of the Ulugurus can also be displayed in the GIS. These can be added in Arc View by using view/add themes. Then go to c:\wcst\gis\mosaics. The georeferenced **image** files for each of the 6 topographical maps covering the Ulugurus can be found in the relevant folders, and can be added to the GIS by clicking on them. Opening a map from the GIS will take some time as they are very large files.

For the full use of this project a copy of ArcView 3.1 or 3.2 is required. There are no spatial or 3D features here and hence the project will work well, but it is not possible to display the Ulugurus in relief, or to undertake any altitudinal analyses of these data. The files created under Phase II of the GIS work and those which are on the 6 CDs are outlined below.

APPENDIX 1: PHASE II GIS WORK FILES CREATED

Phase II GIS work involved the update the previous GIS Database of the Project Area (Uluguru Mountains Forest) and also involved the extension of GIS Database.

The following is the list of the coverages or layers, updated, analyzed or collected and built as new GIS database:

KIJIJI3 <DIR> KIJIJI3 is the village coverage updated from KIJIJI2 in former Database. These are village boundaries and polygons for those having closed boundaries. For polygons, they have names as well as population data.

KATA1 <DIR> KATA1 is Ward coverage. This was updated from KATA coverage in the former Database. It contains ward boundaries and polygons for those having closed boundaries. For polygons, they have names as well as population data.

F2000 <DIR F2000 is forest coverage for the forest area existed year of 2000 but not existing on 1 : 50 000 Topographic maps of 1977.

M_RESE <DIR> M_RESE is a forest reserve boundaries coverage, extracted from Morogoro District map, with grid coordinate system in Degree Decimal (DD)

M_RESE1 <DIR> M_RESE1 is forest reserve boundaries coverage, extracted from Morogoro Region map, with grid coordinate system in DD.

ROAD2 <DIR> ROAD2 is coverage containing roads and footpaths.

RUVU <DIR> RUVU is forest coverage containing Ruvu Forest Reserve.

MKUNGWE <DIR> MKUNGWE is forest coverage containing Mkungwe Forest Reserve

PANGA_E <DIR> PANGA_E is forest coverage containing Pangawe East Forest Reserve

PANGA_W <DIR> PANGA_W is a forest coverage containing Pangawe West Forest Reserve

VIGOZA <DIR> VIGOZA is forest coverage containing Vigoza Forest Reserve

S_ULUG <DIR> S_ULUG is forest coverage containing Uluguru South Forest Reserve (1963)

NYANDI <DIR> NYANDI is forest coverage containing Nyandiduma Forest Reserve

NYANDI_N <DIR> NYANDI_N is coverage containing location areas in the Nyandiduma Forest Reserve

KIMBOZA <DIR> KIMBOZA is forest coverage containing Kimboza Forest Reserve

BUNDUKI <DIR> BUNDUKI is forest coverage containing Bunduki Forest Reserve

ULUGU61 <DIR> ULUGU61 is forest coverage containing Uluguru North Forest Reserve (1961)

SHIKU58 <DIR> SHIKU58 is forest coverage containing Shikurumi Forest Reserve

TARAFA <DIR> TARAFA is Division coverage updated from DIVI coverage in the former Database.

RIVERS <DIR> RIVERS is coverage of major rivers in the project area.

FOREST2 <DIR> FOREST2 is a forest coverage made by combining forest2000.shp and Deg1.shp ArcView layers.

F_DEGRA <DIR> F_DEGRA is a forest coverage made by combining for2000.shp and Deg1.shp ArcView layers.

Note: For2000.shp is the same as F2000 coverage

M_RESE1 SHP file M_RESE1.SHP is ArcView layer in (UTM) generated from M_seve1 coverage.

M_RESE SHP file M_RESE.SHP is ArcView layer in (UTM) generated from M_seve coverage.

R. A. Ludovic
Monday, April 02, 2001

APPENDIX 2: PHASE II GIS WORK - DATA ON CDs

CD# 1
CD name: wcst-umbcp1
Directory of D:\wcst\gis

```
F2000          <DIR>        12-12-00  3:02p F2000
M-RESEVE       <DIR>        12-12-00  5:20p M-RESEVE
F_DEGRA        <DIR>        03-04-01 11:27a F_DEGRA
FOREST~2       <DIR>        02-22-01 10:02a forestdeg
FOREST2        <DIR>        03-04-01 11:28a FOREST2
MKUNGWE        <DIR>        12-12-00  4:30p MKUNGWE
ROAD1          <DIR>        12-12-00  4:30p ROAD1
DEGRAD~1       <DIR>        12-12-00  4:57p Degradation
MAPPED~1       <DIR>        12-12-00  4:57p Mapped forests
FOREST~1       <DIR>        12-12-00  4:57p Forest 2000

README   TXT        1,281  12-12-00  5:22p README.txt
RESERVE  XLS       24,064  11-28-00  1:22p RESERVE.XLS
POP2     XLS       71,680  12-02-00  9:00a POP2.XLS
MGETA    AP~       15,706  02-13-01 12:53p mgeta.ap~
MGETA    A~~       15,706  02-13-01 12:53p mgeta.a~~
MGETA    APR       15,628  03-14-01  9:28a mgeta.apr

Directory of D:\wcst\UMBCP

BEACON77       <DIR>        02-17-01  1:58p BEACON77
C_77TIN        <DIR>        02-17-01  1:58p C_77TIN
C_F55TIN       <DIR>        02-17-01  1:58p C_F55TIN
C_RESE~1       <DIR>        02-17-01  2:00p C_RESE~1
CONT           <DIR>        02-17-01  2:00p CONT
CONTROL        <DIR>        02-17-01  2:01p CONTROL
DIVI           <DIR>        02-17-01  2:01p DIVI
FORN2          <DIR>        02-17-01  2:01p FORN2
FORN55         <DIR>        02-17-01  2:01p FORN55
INFO           <DIR>        02-17-01  2:01p INFO
LOGO           <DIR>        02-17-01  2:01p LOGO
MAP            <DIR>        02-17-01  2:01p MAP
MAP2           <DIR>        02-17-01  2:01p MAP2
NOF55TIN       <DIR>        02-17-01  2:01p NOF55TIN
NOF77TIN       <DIR>        02-17-01  2:03p NOF77TIN
RESERV77       <DIR>        02-17-01  2:03p RESERV77
ROADS          <DIR>        02-17-01  2:03p ROADS
SPOT           <DIR>        02-17-01  2:03p SPOT
ULUGUR~1       <DIR>        02-17-01  2:03p ULUGUR~1
ULUGUR~2       <DIR>        02-17-01  2:05p ULUGUR~2
VE             <DIR>        02-17-01  2:07p VE
WARD           <DIR>        02-17-01  2:08p WARD
ANALYSIS       <DIR>        02-17-01  2:08p ANALYSIS
KIJIJI2        <DIR>        02-17-01  2:08p KIJIJI2
KATA           <DIR>        02-17-01  2:08p KATA
KATA1          <DIR>        02-17-01  2:08p KATA1
KIJIJI3        <DIR>        02-17-01  3:08p KIJIJI3
```

```
F2000          <DIR>        02-17-01  2:08p F2000
ROAD1          <DIR>        02-17-01  2:08p ROAD1
MKUNGWE        <DIR>        02-17-01  2:08p MKUNGWE
RUVU           <DIR>        02-17-01  2:08p RUVU
M_RESE         <DIR>        02-17-01  2:08p M_RESE
M_RESE1        <DIR>        02-17-01  2:08p M_RESE1
FRESEV         <DIR>        02-17-01  2:08p FRESEV
S_ULUG         <DIR>        02-17-01  2:08p S_ULUG
PANGA_W        <DIR>        02-17-01  2:08p PANGA_W
VIGOZA         <DIR>        02-17-01  2:08p VIGOZA
PANGA_E        <DIR>        02-17-01  2:08p PANGA_E
BUNDUKI        <DIR>        02-17-01  2:08p BUNDUKI
ULUG61         <DIR>        02-17-01  2:08p ULUG61
KIMBOZA        <DIR>        02-17-01  2:08p KIMBOZA
NYANDI         <DIR>        02-17-01  2:08p NYANDI
NYANDI_N       <DIR>        02-17-01  2:08p NYANDI_N
ULUGU61        <DIR>        02-17-01  2:08p ULUGU61
SHIKU58        <DIR>        02-17-01  2:08p SHIKU58
TARAFA         <DIR>        02-17-01  2:08p TARAFA
RIVERS         <DIR>        02-17-01  2:08p RIVERS
ROAD2          <DIR>        02-17-01  2:08p ROAD2

FOREST~1 AIH          280  12-12-00  3:08p forest2000.aih
FOREST~1 AIN       21,504  12-12-00  3:19p forest2000.ain
FOREST~1 DBF        5,639  12-12-00  3:19p forest2000.dbf
FOREST~1 SBN          892  12-12-00  3:08p forest2000.sbn
FOREST~1 SBX          220  12-12-00  3:08p forest2000.sbx
FOREST~1 SHP      111,216  12-12-00  3:08p forest2000.shp
FOREST~1 SHX          460  12-12-00  3:08p forest2000.shx

C_F77    DBF       54,578  05-29-00  9:52a C_F77.DBF
C_F77    SHP      368,956  05-29-00  9:52a C_F77.SHP
C_F77    SHX        5,532  05-29-00  9:52a C_F77.SHX
C_RESE~1 DBF       43,698  05-29-00  9:58a C_RESE~1.DBF
C_RESE~1 SHP      333,276  05-29-00  9:58a C_RESE~1.SHP
C_RESE~1 SHX        4,444  05-29-00  9:58a C_RESE~1.SHX

CONTOUR1 DBF      101,858  05-25-00  9:05a CONTOUR1.DBF
CONTOUR1 SBN       19,716  05-25-00  9:01a CONTOUR1.SBN
CONTOUR1 SBX        2,116  05-25-00  9:01a CONTOUR1.SBX
CONTOUR1 SHP    1,385,144  05-25-00  9:01a CONTOUR1.SHP
CONTOUR1 SHX       10,260  05-25-00  9:01a CONTOUR1.SHX

DIVI1    DBF        6,434  05-30-00 10:00a DIVI1.DBF
DIVI1    SBN        1,252  05-30-00 10:00a DIVI1.SBN
DIVI1    SBX          268  05-30-00 10:00a DIVI1.SBX
DIVI1    SHP       22,660  05-30-00 10:00a DIVI1.SHP
DIVI1    SHX          612  05-30-00 10:00a DIVI1.SHX

DIVISION DBF          386  05-30-00  9:50a DIVISION.DBF
DIVISION SBN          132  05-30-00  9:50a DIVISION.SBN
DIVISION SBX          116  05-30-00  9:50a DIVISION.SBX
DIVISION SHP          188  05-30-00  9:50a DIVISION.SHP
DIVISION SHX          108  05-30-00  9:50a DIVISION.SHX
ELEVAT   PS     2,271,457  06-06-00  6:05a ELEVAT.PS
```

```
F55      DBF       64,498  05-29-00  9:40a F55.DBF
F55      SHP      421,484  05-29-00  9:40a F55.SHP
F55      SHX        6,524  05-29-00  9:40a F55.SHX

F77      DBF        1,351  05-29-00  9:43a F77.DBF
F77      SBN          308  05-29-00  9:43a F77.SBN
F77      SBX          148  05-29-00  9:43a F77.SBX
F77      SHP       59,900  05-29-00  9:43a F77.SHP
F77      SHX          204  05-29-00  9:43a F77.SHX

FOR-CON  PS      1,689,402  06-06-00  6:13a FOR-CON.PS
FORE55   DBF           583  05-29-00  2:18p FORE55.DBF
FOR-EL   PS      1,261,686  06-06-00  6:09a FOR-EL.PS
FOREST   PS        684,319  06-06-00  6:16a FOREST.PS
H-SHADE  PS        569,135  06-06-00  6:21a H-SHADE.PS
ND       DBG            43  05-23-00  9:38a ND.DBG

THEME1   DBF           747  05-29-00  9:36a THEME1.DBF
THEME1   SBN           212  05-29-00  9:36a THEME1.SBN
THEME1   SBX           132  05-29-00  9:36a THEME1.SBX
THEME1   SHP        78,860  05-29-00  9:36a THEME1.SHP
THEME1   SHX           156  05-29-00  9:36a THEME1.SHX

M_RESE1  DBF         2,327  12-12-00  4:27p M_RESE1.DBF
M_RESE1  SHP         9,072  12-12-00  4:27p M_RESE1.SHP
M_RESE1  SHX           316  12-12-00  4:27p M_RESE1.SHX
M_RESE1  SBN           468  12-12-00  4:27p M_RESE1.SBN
M_RESE1  SBX           180  12-12-00  4:27p M_RESE1.SBX

M_RESE   DBF         2,011  12-12-00  4:28p M_RESE.DBF
M_RESE   SHP        20,396  12-12-00  4:28p M_RESE.SHP
M_RESE   SHX           284  12-12-00  4:28p M_RESE.SHX
M_RESE   SBN           396  12-12-00  4:28p M_RESE.SBN
M_RESE   SBX           156  12-12-00  4:28p M_RESE.SBX

VILLAGE  JPG        80,151  01-22-01 12:39p VILLAGE.JPG
ULU-VI~1 JPG        88,981  05-04-00  1:33p ULU-VI~1.JPG
ADMIN    PS        358,886  06-06-00  6:01a ADMIN.PS
REV-77   PS      1,454,034  06-06-00  6:20a REV-77.PS

MORO_NV  APR        255,316  03-14-01  9:34a moro_nv.apr
ADMIN    APR      1,298,255  03-14-01 10:04a ADMIN.APR
ULUG     APR        276,702  03-14-01 10:07a ULUG.APR
MORO     APR        318,052  03-14-01  9:32a MORO.APR

Directory of D:\wcst\gis\mosaics

DUTUMI        <DIR>        03-19-01 11:01a dutumi
KISAKI        <DIR>        03-19-01 11:06a kisaki

DUTUMI   JPG    11,501,799  12-12-00  4:37p dutumi.jpg
KISAKI   JPG     9,181,494  12-12-00  4:22p kisaki.jpg
```

CD# 2
CD name: wcst-umbcp2
Directory of D:\wcst\gis\mosaics

```
KINGOL~1       <DIR>       03-19-01 11:03a kingolwira
MOROGORO       <DIR>       03-19-01 11:13a morogoro

MOROG1-6 JPG     9,344,723  12-12-00  4:12p morog1-6.jpg
KINGOL~1 JPG     8,835,730  12-12-00  4:27p kingolwira.jpg
```

CD# 3
CD name: wcst-umbcp3
Directory of D:\wcst\gis\mosaics

```
DUTUMI         <DIR>       03-19-01 11:01a dutumi
KISAKI         <DIR>       03-19-01 11:06a kisaki

DUTUMI   JPG    11,501,799  12-12-00  4:37p dutumi.jpg
KISAKI   JPG     9,181,494  12-12-00  4:22p kisaki.jpg
```

CD# 4
CD name: wcst-umbcp4
Directory of D:\wcst\gis\mosaics

```
MATOMBO        <DIR>       03-19-01 11:08a matombo
MGETA          <DIR>       03-19-01 11:10a mgeta

MATOMBO  JPG     7,806,822  12-12-00  4:17p matombo.jpg
```

CD# 5
CD name: wcst-umbcp5
Directory of D:\wcst\gis\Toposheets\zip

```
MGETA    JPG    11,391,251  12-12-00  3:29p mgeta.jpg

MOROGO~3 ZIP    23,068,804  12-09-00  3:27p morogoro3.zip
MOROGO~1 ZIP    24,517,934  12-09-00  3:01p morogoro1.zip
MOROGO~2 ZIP    30,789,161  12-09-00  3:18p morogoro2.zip
MOROGO~4 ZIP    39,822,730  12-09-00  3:48p morogoro4.zip
MOROGO~5 ZIP    28,491,312  12-09-00  3:53p morogoro5.zip
MOROGO~6 ZIP    36,335,641  12-09-00  4:49p morogoro6.zip

KINGOL~1 ZIP    28,314,045  12-10-00  3:02p kingolwira1.zip
KINGOL~2 ZIP    26,437,557  12-10-00  2:56p kingolwira2.zip
KINGOL~3 ZIP    32,359,304  12-10-00  2:51p kingolwira3.zip
KINGOL~4 ZIP    29,216,578  12-10-00  2:48p kingolwira4.zip
KINGOL~5 ZIP    30,351,256  12-10-00 11:26a kingolwira5.zip
KINGOL~6 ZIP    28,498,938  12-10-00 11:22a kingolwira6.zip

MATOMBO1 ZIP    29,459,299  12-10-00 10:01a matombo1.zip
MATOMBO2 ZIP    22,826,401  12-10-00  9:46a matombo2.zip
MATOMBO3 ZIP    29,294,029  12-10-00  9:18a matombo3.zip
MATOMBO4 ZIP    12,406,131  12-10-00  8:53a matombo4.zip
MATOMBO5 ZIP    29,066,345  12-10-00  8:43a matombo5.zip
MATOMBO6 ZIP    15,447,083  12-09-00  5:33p matombo6.zip
```

CD# 6
CD name: wcst-umbcp6
Directory of D:\wcst\gis\Toposheets\zip

```
MGETA2   ZIP    35,217,494  12-09-00  2:34p mgeta2.zip
MGETA1   ZIP    34,210,344  12-09-00  2:30p mgeta1.zip
MGETA3   ZIP    35,932,750  12-09-00  2:57p mgeta3.zip
MGETA4   ZIP    37,830,665  12-09-00  2:50p mgeta4.zip
MGETA5   ZIP    32,096,518  12-09-00  2:44p mgeta5.zip
MGETA6   ZIP    35,724,893  12-09-00  2:47p mgeta6.zip
MGETA2B  ZIP    31,969,706  12-09-00  2:53p mgeta2b.zip

DUTUMI1  ZIP    24,896,148  12-12-00  4:45p dutumi1.zip
DUTUMI2  ZIP    21,723,611  12-12-00  4:50p dutumi2.zip
DUTUMI3  ZIP    19,026,438  12-12-00  4:56p dutumi3.zip
DUTUMI4  ZIP    23,083,431  12-12-00  5:02p dutumi4.zip
DUTUMI5  ZIP    18,427,622  12-12-00  5:08p dutumi5.zip
DUTUMI6  ZIP    21,729,174  12-10-00  3:22p dutumi6.zip

KISAKI1  ZIP    30,261,340  12-10-00 11:17a kisaki1.zip
KISAKI2  ZIP    31,459,416  12-10-00 11:10a kisaki2.zip
KISAKI3  ZIP    28,073,906  12-10-00 10:44a kisaki3.zip
KISAKI4  ZIP    23,338,480  12-10-00 10:36a kisaki4.zip
KISAKI5  ZIP    17,080,225  12-10-00 10:28a kisaki5.zip
KISAKI6  ZIP    13,726,052  12-10-00 10:08a kisaki6.zip
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