Clark University Activities
Trip Report
February - May, 1998
Malawi Environmental Monitoring Programme
Department of Environmental Affairs

Submitted by: Mathilde Snel, Nicholas Haan, and Dr. Ronald Eastman
Clark University
In collaboration with the University of Arizona
May, 1998

This report will review Clark's involvement in Malawi Environmental Monitoring Programme (MEMP) II from February to May, 1998 with reference to tasks as outlined in the *Second Annual Workplan for the Components of the Malawi Environmental Monitoring Progamme* (MoREA, 1997). During this period Clark University provided technical assistance: in developing digital spatial data standards envisioned to be used as procedural guidelines for the development of digital map data by all sectors of the Government of Malawi; in investigating land cover change and soil erosion in the Shire - an investigation aimed to expose participating agencies to issues in developing a national Environmental Information System (EIS); in investigating the long term acquisition and value of 1km AVHRR data for future environmental monitoring in Malawi; and in providing general technical assistance in the use of geographic technologies for environmental monitoring as requested by line agencies.

Duties of the technical advisors
Three short term technical advisors were involved: Dr. Ronald Eastman (March 10th - March 22nd), Nicholas Haan (February 23rd - April 11th), and Mathilde Snel (February 29th - May 7th). Their duties included:

1) providing technical assistance to the Department of Surveys (DOS) in developing digital mapping standards (task ID 2.4, 2.5, and 2.6 in the *Second Annual Workplan for the Components of the Malawi Environmental Monitoring Programme*, 1997);

2) preparing and conducting a technical session in soil erosion modeling as part of the Shire investigation (task ID 2.1, 2.2, 2.3, 2,8, 6.3);

3) preparing and conducting a technical session focused on analyzing information compiled to date on land cover change and soil erosion in the Shire as a part of the Shire investigation (task ID 2.3, 2.8, and 6.3);

4) conducting social analysis in "hot spots" of significant land cover change as part of the Shire investigation (task ID 2.3);

5) investigating the application and acquisition of 1km AVHRR data for future environmental monitoring in Malawi (task ID 4.1, 4.2, and 4.3);

6) providing technical assistance in developing a GIS syllabus for an environmental sciences curriculum (task ID 6.5);and

7) providing general technical assistance in the use of geographic technologies for environmental monitoring where requested (task ID 6.3).

Accomplishments of the Technical Advisors

Assistance in the development of digital spatial data standards

The technical advisors Dr. Ronald Eastman and Mathilde Snel provided further technical assistance in developing digital spatial data standards at the Department of Surveys (DOS). While the current discussions have focused on procedures specific to the DOS, the digital spatial data standards are envisioned to be used as procedural guidelines for the development of digital map data by all sectors of the Government of Malawi. Discussions were held on March 13th with Mr. Geshan Gunda, the Chief Staff Surveyor, Mr. Emmanuel Likombola, and Mr. Geoffrey Mzembe on revisions of the digital spatial data standards draft (1997) regarding improved Molendensky constants for Malawi, digital map accuracy calculations, spatial metadata format structure, and a data transfer standard (task ID 2.4, 2.5, and 2.7). A second revision of the Malawi Digital Spatial Data Standard was drafted (see report in Appendix 1 - "Malawi Digital Spatial Data Standard, Version 0.2", Department of Surveys (1998)).

Additional technical assistance was provided by Mathilde Snel on April 29th and April 30th in developing spatial metadata for the 1:50,000 and 1:250,000 digital map sample tiles (respectively about Lisanjali and Liwonde). The digital map tiles will be used as illustrative samples of digital spatial data as they may be distributed in the future by the DOS and other line agencies in Malawi (for more details refer to Snel et al, 1997). To date, digital data for the 1:50,000 digital tile sample has been completed by the DOS. The DOS will over the next months complete the corresponding metadata for the 1:50,000 digital map tile according to the provisional data standards (Department of Surveys, 1998). Furthermore, the DOS plans to complete the digitizing of the 1:250,000 digital sample[1] and its corresponding metadata according to provisional standards over the next couple of months.

Informal discussions were held at the DOS regarding future data archiving of base digital data in developing a national EIS. The DOS is in the process of submitting a budget (to the World Bank) to request funds for additional hardware to be used specifically for digital data archiving (e.g. 1-2 computers). Furthermore, discussions were held on the possibility of scanning spatial data for the future acquisition and archiving of 1:50,000 and 1:250,000 spatial digital data . Photo plates of the 1:50,000 and 1:250,000 map series are unfortunately not separated by feature but by color. The following photo plates are available for all non-metric and some metric[2] 1:50,000 maps and non- metric 1:250,000 maps in Malawi:

1) blue photo plate: includes rivers, river names, lakes, lake names, and marsh symbols;
2) brown photo plate: includes contours (predominantly thin lines although thick lines exists for every 250m contour) and contours labels (note these labels are placed such that they separate contour lines);
3) black photo plate: includes railway track, railway track labels, district roads, district road labels, tracks, track labels, village sites, village names, peaks, and peak labels;
4) green photo plate: includes forest reserve estates, grassland, and scrub areas; and
5) pink photo plate: includes estate boundaries and estate labels

---

[1] The University of Arizona Remote Sensing Center, as part of the Shire investigation, provided digital contours and rivers for the Blantyre and Machinga ADDs off the 1:250,000 topographic series. The DOS plans to digitize the remaining contours, rivers, and roads for the 1:250,000 Liwonde topographic map sheet.

[2] The DOS is in the process of converting its 1:50,000 map tiles into metric versions (e.g. contour intervals in meters instead of feet, the use of metric tiles). In addition to converting the map units, the metric map sheets are also being used as an opportunity to revise and update mapped features (e.g. roads, forest reserves, etc). Approximately 10% of the 1:50,000 national coverage have to date been converted into metric.

Scanning may be a possibility for contour information - although contour labels between contours would need to be edited - and river information - although river labels and marsh symbols would need to be edited and removed. Scanning roads, villages, railways, forest reserves, and estates will require extensive editing and will most likely be too problematic. The DOS expressed concern in scanning the non-metric vs. the metric 1:50,000 map series considering the present revisions the DOS is undertaking in converting spatial data into metric. It was informally recommended that 1:250,000 maps and/or metric 1:50,000 maps about areas of concern and of high demand could possibly initially be scanned (e.g. areas about the Shire, the Malawi boundary, and Extension Planning Unit areas boundaries, etc.)[3]. In addition, the DOS expressed a concern of the sustainability of scanning and proposed to look into the possibility of obtaining scanning equipment at the DOS itself. Considering the long term investment of converting national spatial data into digital format these issues - whether metric vs. non-metric sheets should be scanned, which features should initially be digitized/scanned, and if scanning could be conducted at the DOS - will require further discussion.

In addition to digitizing/scanning spatial data, the DOS expressed continued interest to further archive and georeference the national coverage of Landsat 1984 and 1994 satellite images. Requests to use the data by the Department of Forestry, Ministry of Agriculture, Department of Fisheries, and UNIMA are evident. To date the DOS has archived[4] and georeferenced satellite images in southern Malawi. Arrangements with the University of Arizona Remote Sensing Center have been made to archive on CD all 1984 and 1994 Landsat images for the Government of Malawi.

Technical session on soil erosion modeling

A technical session in soil erosion modeling was conducted form March 23rd to March 27th with technical assistance from Clark University. The technical session was held as a part of the development of Shire investigation on land cover change and soil erosion in the Shire catchment (task 2.1, 2.2., 2.3, 2.8, and 6.3). As described in the EIS Design Team (1997) report the Shire investigation is aimed to expose participating agencies to issues relating to the development of a national EIS ranging from building capacity in environmental monitoring with respect to institutional mandates, to environmental analysis using a collaborative approach involving various agencies. The Soil Erosion Modeling Technical Session was hosted by the Land Resources Conservation Branch Department in Lilongwe. The technical session particularly focused on building capacity in soil erosion modeling at the Ministry of Agriculture but also included participants from other line agencies such as the Department of Forestry, Meteorology Department, and Department of Surveys. Participants of the Soil Erosion Technical Session have been listed below.

Vincent Mkandawire: Land Resources Conservation Department, Lilongwe, Ministry of Agriculture
Priska Munthali: Land Resources Conservation Branch Training Center, Zomba, Ministry of Agriculture
Matthew Manda: Lilongwe ADD, Ministry of Agriculture
Austwell Mogha: Kasungwe ADD, Ministry of Agriculture
Joel Munthali: Land Resources Conservation Branch, Lilongwe, Ministry of Agriculture
Sam Chilombe: Meteorology Department
Joseph Mlotha: Department of Forestry
Jackson Nakutepa: Department of Surveys

[3] Overlapping boundaries (e.g. the Malawi boundary) has been a recurrent issue in compiling data sets from line agencies (e.g. in the Shire investigation). Discussions need to be held between line agencies that compile spatial data to gauge which base maps are in high demand - data sets for which a standard map should be made available (e.g. this issue may be discussed during the National EIS/Mapping Programme technical session). Further discussions also need to be held with the University of Arixona Remote Sensing Center with regards to the accuracy of some select national base maps digitized off 1:250,000 maps for the Public Land Utilization Study (PLUS).

[4] Although additional equipment is needed to appropriately backup these digital files. The DOS is looking into the possibility of obtaining a CD writer to archive digital files on CD.

The technical session focused on soil erosion modeling using the modified Southern Loss Estimation Model for Southern Africa (SLEMSA) for Malawi (Paris, 1991) - a soil erosion erosion model specific to Malawi that combines information on topsoil texture, soil type, slope, rainfall, and landcover[5]. The soil erosion technical session built on data sets compiled by various line agencies for the Shire investigation: land cover by the Department of Forestry; soils by the Department of Surveys, rainfall by the Meteorology Department, and slopes by the Department of Surveys[6] (task ID 2.1,2.2, 2.3, 2.8, and 6.3) (refer to Snel et al, 1997 for more detail). Technical assistance was provided by Mathilde Snel during the five day course in which participants created a soil erosion model for the Blantyre and Machinga ADDs and three select "hot spots" areas indicative of significant land cover change or soil erosion potential (the Lisanjali, Lisungwe, and Rivi-Rivi watersheds). Furthermore, soil erosion models for these areas were created for both 1994 and 1984 to indicate the effect of land cover change on soil erosion[7]. A syllabus of the Soil Erosion Technical Session has been included in Appendix 2. A summary of the steps used for the SLEMSA modeling during the technical session was drafted by Chilombe (1997) (see Appendix 3). Results of the modified SLEMSA consistently indicate an underestimation of soil loss. Additional research is needed to improve the modified SLEMSA soil loss results for Malawi. Rather than indicate actual soil loss (e.g. in tons/ha/growing season), the SLEMSA results were used to indicate soil erosion potential[8]. Results of the technical session have been included in the *Preliminary Report on the Shire Investigation* (MEMP, 1998 - see the following section on the "Shire Analysis Technical session" or Appendix 5).

Technical Session on Analysis of Land Cover Change and Soil Erosion in the Shire Catchment

A technical session was conducted from April 15th to April 16th to analyze information on land cover change and soil erosion in the Shire catchment as collected to date (task ID 2.3, 2.8, and 6.3). The technical session had two primary goals: 1) to better understand the biophysical changes with regard to land cover change and soil erosion in the Shire catchment as part of the Shire investigation and 2) to expose participating agencies to issues relating to the development of a national EIS (e.g. the need for a collaborative approach involving various line agencies in analyzing environmental data) (EIS Design Team, 1997). The technical session included presentations by line agencies on information that had been compiled to date in the Shire investigation - particularly a presentation by the Department of Forestry on land cover change and Ministry of Agriculture on soil erosion in the Shire catchment.[9] A syllabus of the technical session has been included in Appendix 4. The participants of the Shire Analysis technical session are listed below:

---

[5] IDRISI GIS was used for the soil erosion modeling during the technical session.

[6] While the DOS digitized some contours (e.g. off 1:50,000 for the Lisanjali "hot spot"), the University of Arizona Remote Sensing Center provided additional digital contours (e.g. for the Blantyre and Machinga ADDs off the 1:250,000).

[7] In creating the 1984 and 1994 soil erosion maps, all variables - soils, rainfall, and slopes - with the exception of land cover were held constant.

[8] The SLEMSA results were reclassed into soil erosion potential classes using the following soil loss ranges: 1) for the black and white soil erosion potential maps in the *Preliminary Report on the Shire Investigation* (MEMP, 1998) low soil erosion potential refers to soil loss from 0 to 2 t/ha/growing season; moderate soil erosion potential from 2 to 10 t/ha/growing season; and high soil erosion potential from 10 and above t/ha/growing season and 2) for the color soil erosion potential maps (refer to MEMP, 1998) severe low soil erosion potential refers to soil loss from 0 to 0.5 t/ha/growing season; very low soil erosion potential from 0.5 to 1 t/ha/growing season; low soil erosion potential from 1 to 2 t/has/growing sesaon; low/moderate soil erosion potential from 2 to 3 t/ha/growing season; moderate soil erosion potential from 3 to 6 t/ha/growing sesaon; moderate/high soil erosion potential from 6 to 10 t/ha/growing season; high soil erosion potential from 10 to 25 t/ha/growing season; very high soil erosion potential from 25 to 50 t/ha/growing season and severe high soil erosion potential from 25 and above t/ha/growing season.

[9] Prior to the technical session, technical assistance by Mathilde Snel was given to the Department of Forestry and Ministry of Agriculture to help prepare the land cover and soil erosion maps for the Blantyre and Machinga ADDs and three select "hot spot" micro watersheds as used during the Shire Analysis Technical Session.

Vincent Mkandawire, Land Resources Conservation Department, Lilongwe, Ministry of Agriculture
Priska Munthali, Land Resources Conservation Branch Training Center, Zomba, Ministry of Agr.
Sam Chilombe, Meteorology Department
Joseph Mlotha, Department of Forestry
Mr. Gausi, National Research Council

The session resulted in two short reports - one on land cover change and one on soil erosion in the Shire catchment - that were subsequently edited into one joint preliminary report on results collected to date in the Shire investigation (see Appendix 5) (task ID 2.3,2.8, and 6.3). While both the Shire Analysis and Soil Erosion Modeling (as described in the previous section) technical sessions proved to be useful forums for participating line agencies to collaborate and discuss information as compiled to date in the Shire investigation, it is recommended that future environmental analysis forums are more formal (e.g. a small task force of 3-4 individuals) that extend over a longer period of time (e.g. one month). It is envisioned that such a body could meet once every year/two years to write a summary statement on environmental issues of national importance (e.g. a national state of the environment report) or specific environmental issues (e.g. environmental analysis to investigate environmental changes in the Shire). It is envisioned that such a group would require a formal institutional arrangement whereby respective institutions agree to routinely subcontract staff for such annual/biannual environmental analyses.

Social analysis in the Shire Investigation
Social analysis was conducted by Nicholas Haan and two Malawian social scientists - Patrick Jambo of the Department of Forestry and Orpa Kabambe from Bunda College - from March 28th to April 10th in select villages indicative of significant land cover change in the Shire catchment (task ID 2.3). The social analysis investigations to date have been conducted in select villages within the Lisungwe watershed and Neno area. Similar social analysis to investigate the underlying causes of land cover change are required in other villages throughout the Shire catchment so that mitigation strategies may be proposed. Findings to date indicate that underlying causes of landcover change range from charcoal production to the harvesting of *nkunguni*- a bug used as an important source of protein in some villages (Haan, 1997). The social analysis will continue to rely on the biophysical results - as described in the two previous sections - to locate areas undergoing significant land cover changes and areas of significant soil erosion potential. For more detail on the social analysis results as compiled to date refer to Haan's trip report (1998) (Appendix 6).

Investigating the application and acquisition of 1km AVHRR data for future environmental monitoring
Further research and discussions were held on the application and acquisition of 1km AVHRR data for national environmental monitoring in Malawi[10] (task ID 4.1, 4.2, and 4.3). Dr. Ron Eastman and Nicholas Haan (1998) continued work on creating an algorithm to help remove cloud cover from 1km AVHRR images. Cloud removal techniques will be critical in the future use of the 1km AVHRR for national environmental monitoring. Informal discussions were held by Mathilde Snel with Harvey Boetsma at the SADC Fisheries project in Senga Bay on the future acquisition of the 1km AVHRR by the Government of Malawi. It was proposed that following the National EIS/Mapping Programme technical session (to be held approximately September/October, 1998) that discussions with the SADC fisheries project, line government ministries, and Clark University are conducted to more formally work out a strategy for the Government of Malawi to acquire, transfer, and archive the national 1km AVHRR data.

GIS syllabus for an environmental studies curriculum development
Nicholas Haan provided assistance to Yusuf Mohammed in proposing a GIS syllabus to be included in the development of an environmental sciences curriculum (task ID 6.5). For more detail with regard to the proposed GIS syllabus refer to Haan's (1998) trip report.

[10] The SADC fisheries project at Senga Bay downloads daily two 1km AVHRR (Advanced Very High Radiometer Resolution) of Malawi. Potential applications of the AVHRR data range from land cover mapping, land cover change detection, and forest fire monitoring.

General technical assistance

Continued general technical assistance was provided by Clark University as requested by agencies (task ID 6.3). This technical assistance included assistance in digitizing in ArcInfo at the Department of Forestry, assistance in ArcView at the Ministry of Agriculture, and assistance in IDRISI in interpolation methods at the Meteorology Department.

Future Activities

A National EIS/Mapping program technical session will be conducted (approximately September/October) to more formally discuss among line agencies that compile spatial data issues pertaining to the development of a national EIS. The technical session will draw on experiences of the Shire investigation to more formally discuss such issues as national digital spatial standards, routine environmental data acquisition, national data archiving, data distribution, and long range funding strategies for national environmental monitoring. More specifically with regard to the Shire investigation, Clark University will continue providing technical assistance to the Shire investigation: technical assistance for social analysis in the Shire investigation will continue to be provided, while additional assistance on biophysical assessments will be provided where requested. During the next trip Clark University will conduct the intermediate/advanced training in geographic technologies.

Bibliography

Department of Surveys, 1997. *Malawi Environmental Monitoring Programme: Technical Seminar on Environmental Information Systems. Draft Report and Recommendations*. Blantyre, June 1997.

Chilombe, 1998. Draft of Procedures used in SLEMSA (Soil Loss Estimation Model for Southern Africa, Department of Meteorology.

EIS Design Team, 1997. *Strategy for an Environmental Information System in Malawi*

Haan, 1998. *Malawi Trip Report, February - April, 1998*. Malawi Environmental Monitoring Programme; Department of Environmental Affairs, Clark Labs.

MOREA, 1997. *Second Annual Workplan for the Components of the Malawi Environmental Monitoring: Environmental Monitoring Technologies, Research, and Policy Sub-Programmes.*

Paris, 1991. *Erosion Hazard Model (modified SLEMSA).* Land Resources Evaluation Project, Malawi. Malawi Government Ministry of Agriculture, Land Husbandry Branch.

Snel, M., N. Haan, and R. Eastman, 1997. *Clark University Activities, Trip Report, October - December, 1997.* Malawi Environmental Monitoring Programme; Department of Environmental Affairs, Clark Labs.

List of Appendices

Appendix 1: Malawi Digital Spatial Data Standard Version 2.0 (Draft Provisional Version, Revision 2, March 1998)
Appendix 2: Syllabus for Soil Erosion Technical Session, March 23rd - 27th, 1998
Appendix 3: Draft report of Chilombe (1998) on Soil Loss Estimation Model for Southern Africa (SLEMSA)
Appendix 4: Syllabus for the Shire Analysis Technical Session, April 15th-16th, 1998

Appendix 5: Preliminary report on the Shire Investigation, April, 1998.
Appendix 6: Haan (1998) trip report

Shire Investigation files:

Blantyre and Machinga ADDs:

basic files:
bmlulc91 (landcover for 1991 for Blantyre and Machinga ADDs - based off Swede study)
bmlulc73 (landcover for 1973 for Blantyre and Machinga ADDs - based off Swede study)
bmslpoly (soil polygons for Blantyre and Machinga ADDs - based off LREP0
 - used with ihope.mdb (LREP relational database)
bmslgp (soil groups for Blantyre and Machinga ADDs - based off LREP)
bmsltx (soil topsoil texture for Blantyre and Machinga ADDs- based off LREP)
bmdem (dem for Blantyre and Machinga, based of 1:250,000 contours)
avrn8494 (average rainfall for Malawi for the 1984-85 and 1994-95 growing season - obtained from MET, Chileka)
rn9495 (rainfall for Malawi for the 1994-95 growing season - obtained from MET, Chileka)
rn8484 (rainfall for Malawi for the 1984-85 growing season - obtained from MET, Chileka)
avbmz91 (soil erosion potential for 1991 for Blantyre and Machinga ADDs - not reclassed/raw z values)
bmz73 (soil erosion potential for 1973 for Blantyre and Machinga ADDs - not reclassed/raw z values)

map composition files:
rbmlu915.map (1991 landcover for Blantyre and Machinga ADDs)
rbmlu736.map (1973 landcover for Blantyre and Machinga ADDs)
7391un.map (1973-1991 land cover change)
avbmz91m.map (color soil erosion potential for 1991for Blantyre and Machinga ADDs)
rvbmz73m.map (color soil erosion potential for 1973 for Blantyre and Machinga ADDs)
bwbmz91 (black and white soil erosion potential for 1991 for Blantyre and Machinga ADDs)
bwbmz73 (black and white soil erosion potential for 1973 for Blantyre and Machinga ADDs)

Lisungwe:

basic files:
lsnlu946 (landcover 1994, Lisungwe)
lsnlu846 (landcover 1984, Lisungwe)
lsnpoly(soil polygons, Lisungwe- based off LREP)
 - used with ihope.mdb (LREP relational database)
lsnslgp (soil group, Lisungwe)
lsnsltx (soil topsoil texture, Lisungwe)
lsndem (dem, Lisungwe, based off 1:250,000, tin model)
avrn8494 (average rainfall for Malawi for the 1984-85 and 1994-95 growing season - obtained from MET, Chileka)
rn9495 (rainfall for Malawi for the 1994-95 growing season - obtained from MET, Chileka)
rn8484 (rainfall for Malawi for the 1984-85 growing season - obtained from MET, Chileka)
avlwz94 (soil erosion potential 1994, Lisungwe - not reclassed/raw z values)
lwz84 (soil erosion potential 1984, Lisungwe - not reclassed/raw z values)

map composition files:
lsnlu94b.map (1994 landcover, Lisungwe)
lsnlu84b.map (1984 landcover, Lisungwe)
lsn8494b.map (1984 - 1994 land cover change, Lisungwe)
ralwz94b.map (color soil erosion potential for 1994, Lisungwe)

rlwz84.map (color soil erosion potential for 1984, Lisungwe)
bwlwz94b (black and white soil erosion potential, 1994, Lisungwe)
bwlwz84b (black and white soil erosion potential, 1984, Lisungwe)

Lisanjali:

basic files:
t8lu9406 (1994 landcover, Lisanjali, reclassed 6 landcover classes)
t8lu8406 (1984 landcover, Lisanjali, reclassed 6 landcover classes)
t8lu9425 (1994 landcover, Lisanjali, not reclassed/original 24 classes)
t8lu8427 (1984 landcover, Lisanjali, not reclassed/original 24 classes)
t8slpoly (soil polygons, Lisanjali)
- used with ihope.mdb (corresponding relational database)
t8sltx98 (soil topsoil texture, Lisanjali)
t8slgp98 (soil group, Lisanjali)
t8dem98 (dem, Lisanjali, based of 1:50,000 map, intercon)
avrn8494 (average rainfall for Malawi for the 1984-85 and 1994-95 growing season - obtained from MET, Chileka)
rn9495 (rainfall for Malawi for the 1994-95 growing season - obtained from MET, Chileka)
rn8484 (rainfall for Malawi for the 1984-85 growing season - obtained from MET, Chileka)
avt8z94 (1994 soil erosion potential, Lisanjali - not reclassed/ raw z values)
t8z84 (1984 soil erosion potential, Lisanjali - not reclassed/raw z values)

map composition files:
t8lu9406.map (1994 landcover, Lisanjali)
t8lu8406.map (1984 landcover, Lianjali)
rt88494.map (1984-1994 land cover change, Lisanjali)
av8z94mf.map (color soil erosion potential for 1994, Lisanjali)
av8z84mf.map (color soil erosion potential for 1984, Lisanjali)
bw8z94mf.map (black and white soil erosion potential for 1994, Lisanjali)
bw8z84mf.map (black and white soil erosion potential for 1984, Lisanjali)

Rivi-Rivi:

basic files:
rrlu944 (1994 landcover, Rivi-Rivi)
rrlu844 (1984 landcover, Rivi-Rivi)
rrslpoly (soil polygons, Rivi-Rivi)
- used with ihope.mdb (corresponding relational database)
rrslgp (soil groups, Rivi-Rivi)
rrsltx (soil topsoil texture, Rivi-Rivi)
rrdm98 (dem, Rivi-Rivi, based off 1:250,000 - intercon)
avrn8494 (average rainfall for Malawi for the 1984-85 and 1994-95 growing season - obtained from MET, Chileka)
rn9495 (rainfall for Malawi for the 1994-95 growing season - obtained from MET, Chileka)
rn8484 (rainfall for Malawi for the 1984-85 growing season - obtained from MET, Chileka)
avrrz94 (1994 soil erosion potential, Rivi-Rivi- not reclassed/raw z values)
rrz84 (1984 soil erosion potential, Rivi-Rivi - not reclassed/raw z values)

map composition:
rrlu944a.map (1994 landcover, Rivi-Rivi)

rrlu844a.map (1984 landcover, Rivi-Rivi)
rrr8494a.map (1984-1994 landcover change, Rivi-Rivi)
rrrz94ma.map (color 1994 soil erosion potential, Rivi-Rivi)
rrrz84ma.map (color 1984 soil erosion potential, Rivi-Rivi)
bwrrz94.map (black and white 1994 soil erosion potential, Rivi-Rivi)
bwrrz84.map (black and white 1984 soil erosion potential, Rivi-Rivi)

ARCVIEW projects:

hydro97.apr (color labeled Shire watershed with hdyro-electric dams)
bwhyd97.apr (black and white labeled Shire watershed with hydro-electric dams)
label97.apr (color labeled Shire watershed - no hydro-electric dam)
tob97.apr (tobacco 1997)
cas97.apr (cassava 1997)
cot97.apr (cotton 1997)
1997pop.apr (population 1997)
brick.apr (brick production, 1997)
char.apr (charcoal production, 1997)
vam_data.dbf (vulnerability database - includes population, brick, and charcoal stats)
agryld97.dbf (agricultural yield, 1997 database)

```
[VERSION]
        MALAWI DIGITAL STANDARD METADATA FORMAT PROVISIONAL VERSION 1.0
[DESCRIPTION]
Lisanjali, YU2500 (T8) Malawi 1:50,000 Metric Edition tile, Landsat TM
17/09/94, 7 bands,  true color, and false color
[STATUS]
        Provisional
[COPYRIGHT]
        (c) of original source image: CSIR (SAC), Satellite Applications
Center, Pretoria, South Africa.
        (c) of georeferenced images: Department of Surveys,1998
Government of Malawi
[FILE ORGANIZATION]
        [File Structure]
                [transfer level]
                        Level 1
                [format]
                        IDRISI Raster Image
                [version]
                        2.0
                {rows}
                        833
                {columns}
                        833
        [Number of Files]
                18
        [File List]
                T8IM94T1.img 693889 17/09/94 raster data file
                T8IM94T1.doc 2767 17/09/94 raster documentation file
                T8IM94T2.img 693889 17/09/94 raster data file
                T8IM94T2.doc 2767 17/09/94 raster documentation file
                T8IM94T3.img 693889 17/09/94 raster data file
                T8IM94T3.doc 2767 17/09/94 raster documentation file
                T8IM94T4.img 693889 17/09/94 raster data file
                T8IM94T4.doc 2767 17/09/94 raster documentation file
                T8IM94T5.img 693889 17/09/94 raster data file
                T8IM94T5.doc 2767 17/09/94 raster documentation file
                T8IM94T6.img 693889 17/09/94 raster data file
                T8IM94T6.doc 2767 17/09/94 raster documentation file
                T8IM94T7.img 693889 17/09/94 raster data file
                T8IM94T7.doc 2767 17/09/94 raster documentation file
                T8IM94TT.img 693889 17/09/94 raster data file
                T8IM94TT.doc 2767 17/09/94 raster documentation file
   T8IM94TF.img 693889 17/09/94 raster data file
                T8IM94TF.doc 2767 17/09/94 raster documentation file
 [ATTRIBUTION]
        [Authors]
                Georeferencing and tiling done by: J.A.Nakutepa.
        [Contact Information]
                Contact address: Department of Surveys, P.O.Box349,
Blantyre, Malawi. tel:621475
                 fax:630034
        [Original Creation Date]
                original image obtained on: 17/09/94
                georferenced image create on: 30/10/97
[LINEAGE]
        [Source Material]
                Landsat TM satellite images and 1:50,000 topographic
maps (for georeferencing)
       [Creation Devices]
```

```
                Gateway 2000  35-166  Pentium computer and Idrisi
software
       [Creation Details/Notes]
                The map was georeferenced according to provisional map
standards. Maps were georeferenced
                off  1:50000 topo map sheets.
[REVISIONS]
[GEOREFERENCING]
        [Reference System]
                Malawi02
        [Horizontal Datum]
                Arc 1960 (new Arc 1950)
        [Vertical Datum]
                National Datum
        [Ellipsoid]
                [name]
                        Clark 1880 (modified)
                [major semi-axis]
                        6378249.145
                [minor semi-axis]
                        6356514.870
                [flattening]
                        1/293.465000
        [Molodensky Constants]
                [delta x]
                        -160 (provisionally for ARC 1960)
                [delta y]
                        -6 (provisionally for ARC 1960)
                [delta z]
                        -73 (provisionally for ARC 1960)
        [Projection]
                [name]
                        Transverse Mercator
                [scale factor at true origin]
                        0.9996
        [True Origin: Lat/Long]
                0  33
        [False Coordinates at Origin: X/Y]
                500000   10000000
        [Measurement Units]
                meters (conformed to S.I. standards)
        [Bounding Rectangle]
                [minimum X]
                        725000
                [maximum X]
                        750000
                [minimum Y]
                        8300000
                [maximum Y]
                        8325000
[ATTRIBUTE CODING]
        DN (digital numbers) represent spectral reflectance
[ACCURACY]
        [Positional]
               54 meters (= sqrt
((0.04)^2+(0.07)^2+(8.33)^2+(4)^2+(1.5)^2+(10)^2+(5)^2+(52)^2)
               (Based on error associated with: Photo Control: 0.04m;
Aero triangulation: 0.07m; Plotting on a
               CP1: 8.33m; Cartographic production (scribing: 4m; film
distortion: 1.5m; paper map
```

production: 10m); Map Storage: 5m; Georeferencing: 52meters (see {Resampling}below)

{Resampling}

Computed polynomial surface : Quadratic (based on 21 control points)

Coefficient	X	Y
b0	40890.4326844215393000	-276726.9090753770000000
b1	0.0275847734609500	0.0099660799466257
b2	-0.0094350422227762	0.0335375536128595
b3	0.0000000000847360	-0.0000000002839633
b4	0.0000000006326624	-0.0000000005109743
b5	0.0000000002213119	-0.0000000000158277

Old X	Old Y	New X	New Y	Residual
1590.828000	4785.124000	723550.000000	8307540.000000	2.518382
1925.361000	5709.501000	737850.000000	8333250.000000	2.122570
657.603300	5526.690000	699625.000000	8333925.000000	2.379595
566.278700	3069.309000	685025.000000	8261620.000000	2.555030
1031.425000	3323.710000	700090.000000	8266870.000000	1.089089
1238.911000	3354.207000	706410.000000	8266790.000000	1.504927
1128.418000	1796.343000	695600.000000	8221275.000000	1.499282
2145.345000	1533.366000	724480.000000	8208580.000000	1.449355
2271.336000	2047.821000	730690.000000	8223135.000000	1.428673
1939.360000	3117.728000	726000.000000	8256475.000000	1.614134
1932.860000	2489.783000	722785.000000	8237875.000000	0.811124
3170.271000	4640.595000	769650.000000	8295760.000000	2.438972
2715.804000	4619.097000	756125.000000	8297180.000000	1.639189
2328.332000	4313.124000	743175.000000	8290000.000000	0.178188
3065.779000	4286.626000	764875.000000	8285650.000000	1.482895
2617.811000	5403.028000	756880.000000	8320925.000000	1.133384
4340.249000	4262.504000	802500.000000	8278925.000000	1.827611
3872.220000	3251.716000	783740.000000	8251125.000000	2.365955
3386.755000	2666.267000	766625.000000	8236170.000000	1.384712
989.428000	1468.872000	689925.000000	8212175.000000	1.364893
3429.003000	2410.386000	766630.000000	8228325.000000	1.467136

Overall RMS = 1.734299 pixels = 52.028970 meters (1.734299 pixels *30 meters)

Note : RMS Error is expressed in output map units.

With low RMS errors, be careful that an adequate sample exists (eg. 2-3 times the mathematical min).

[Attribute]

n/a

[PRECISION]

[Positional Precision]

30 meters

[Attribute]

contrained within a byte range (from 0 to 255)

{RESAMPLING}

{Number of Control Points}

21

{Control Point Characteristics}

{point id / image.x / image.y / map.x / map.y /residual / confidence}

1 1590.828000 4785.124000 723550.000000 8307540.000000 1.991189 very good

2 1925.361000 5709.501000 737850.000000 8333250.000000 2.616581 very good
3 657.603300 5526.690000 699625.000000 8333925.000000 3.152203 very good
4 896.935200 4151.138000 699930.000000 8291690.000000 omitted very good
5 566.278700 3069.309000 685025.000000 8261620.000000 2.229343 very good
6 1031.425000 3323.710000 700090.000000 8266870.000000 1.427486 good
7 1238.911000 3354.207000 706410.000000 8266790.000000 2.109614 very good
8 653.952800 2712.763000 685850.000000 8250675.000000 omitted fair
9 1287.907000 1264.890000 697950.000000 8204470.000000 omitted very good
10 1128.418000 1796.343000 695600.000000 8221275.000000 2.678820 very good
11 2145.345000 1533.366000 724480.000000 8208580.000000 1.092010 very good
12 2271.336000 2047.821000 730690.000000 8223135.000000 1.861480 very good
13 2330.109000 2875.999000 736525.000000 8247420.000000 omitted very good
14 1939.360000 3117.728000 726000.000000 8256475.000000 1.793703 very good
15 1932.860000 2489.783000 722785.000000 8237875.000000 1.125278 very good
16 3170.271000 4640.595000 769650.000000 8295760.000000 2.987499 very good
17 2715.804000 4619.097000 756125.000000 8297180.000000 1.347450 very good
18 2328.332000 4313.124000 743175.000000 8290000.000000 0.179561 very good
19 3065.779000 4286.626000 764875.000000 8285650.000000 1.280796 very good
20 2617.811000 5403.028000 756880.000000 8320925.000000 2.314846 very good
21 4340.249000 4262.504000 802500.000000 8278925.000000 2.228739 good
22 3872.220000 3251.716000 783740.000000 8251125.000000 2.160111 very good
23 3386.755000 2666.267000 766625.000000 8236170.000000 0.410348 good
24 989.428000 1468.872000 689925.000000 8212175.000000 1.237137 good
25 545.614100 1662.140000 677725.000000 8219745.000000 omitted good
26 3429.003000 2410.386000 766630.000000 8228325.000000 1.859668 good

{Control Point Descriptions}

{point id / description}

1 center of railway and river crossing, sheet 1535A3
2 center of railway and river crossing, sheet 1535A1
3 road junction, sheet 1534B2
4 center of road /river crossing (at bridge) on sheet 1534B4
5 center of road /river crossing (at bridge) on sheet 1534D1
6 road junction, sheet 1534D2
7 center of road junction, sheet 1534D2 (after Chileka airport)
8 river confluence, sheet 1534D3
9 railway road crossing Sucoma estate, sheet 1634B2
10 railway road center crossing, sheet 1634B2

```
                        11   road junction (center)
                        12   road junction (center)
                        13   road junction, sheet 1535C3
                        14   road junction, sheet 1535C3
                        15   road junction, sheet 1535C3
                        16   road junction, sheet 1535B3
                        17   road junction, sheet 1535A4
                        18   road junction, sheet 1535A4
                        19   road junction, sheet 1535A4
                        20   road junction, sheet 1535A2
                        21   road junction, sheet 1535D2
                        22   road junction, sheet 1535D3
                        23   road/river crossing, sheet 1535C4
                        24   road/river crossing, sheet 1634B2
                        25   road/river crossing, sheet 1634B1
                        26   road junction, sheet 1635A2
        {Polynomial Order}
                2 (quadratic)
        {Resampling Procedure}
                nearest neighbour
        {Overall RMS}
                52.028970 meters (= 1.734299 pixels *30 meters)
[COMPLETENESS]
        {Minimum Mapping Unit}
                30 meters
[ADJOINING SHEETS]
        {NORTH}
                T4 (YU0050)
        {SOUTH}
                TC (YU0000)
        {EAST}
                T9 (YU2525)
        {WEST}
                SB (XU7525)
        {Northeast}
                T5 (YU2550)
        {Southeast}
                TD (YU2500)
        {Northwest}
                S7 (XU7550)
        {Southwest}
                SF (XU7500)
[RESTRICTIONS]
        The representations of Cadastral boundaries appearing on this
map is not taken as evidence for
location of legal bounderies.
```

Preliminary Report on the Shire Investigation

A collaborative investigation and joint report by the:
Department of Forestry:
P. Jambo
J. Mlotha
Department of Meteorology:
S. Chilombe
Department of Surveys:
G. Mzembe
J. Nakutepa
M. Chawinga
Land Resources Conservation Department:
V.A.L. Mkandawire
P.E. Mbiriyawaka-Munthali
J.G. Munthali
National Research Council/Environmental Affairs Department:
H. Gausi
with technical assistance provided by Clark University in collaboration with the University of Arizona:
M. Snel
N. Haan
R. Eastman
W.K. Burger

May, 1998. Malawi Environmental Programme, Department of Environmental Affairs. With technical assistance provided by Clark University in collaboration with the University of Arizona.

Preliminary Report on the Shire Investigation

INTRODUCTION

The Shire watershed has recurrently been identified as an area of national priority (EIS Design Team, 1997; MOREA, 1997). As one of the most densely populated regions (Figure 1) the catchment has, however, undergone significant environmental degradation including the siltation of the Shire river itself which has resulted in an unstable national electricity supply. The Shire investigation was proposed to provide a situation analysis on environmental degradation in the Shire particularly with regard to land cover change and soil erosion potential (EIS Design Team, 1997; MOREA, 1997). The initial phase of the Shire investigation has focused on analyzing **where** significant land cover changes and soil erosion potential occur in the Shire catchment. This report will summarize the biophysical results on land cover change and soil erosion that have been compiled in the investigation to date. Subsequent phases of the Shire investigation will concentrate on: 1) further expanding social analysis to better understand **why** changes in land cover and soil erosion are occurring[11] and 2) disseminating information to end users ranging from government projects (e.g. reforestation and soil conservation projects such as MAFE, microprojects, and PROSCARP) to private companies (e.g. ESCOM and SUCOMA).

METHODOLOGY

A time series analysis was conducted over a thirteen year period (January 1983 to September 1996) using Advanced Very High Radiometer Resolution (AVHRR)[12] images to identify hot spots of significant land cover change in the Shire catchment[13]. The AVHRR time series results indicated that microwatersheds within the Shire catchment experiencing a present decline in vegetative cover (from 1991 to 1996 - see graph in Figure 2) are particularly Lisungwe, Mkurumadzi, and Mwanza (area codes #1 and #2 in Figure 2 – depicted as black/dark areas), while areas indicating a present relative increase in vegetative cover (from 1991 to 1996 - see graph in Figure 2) are particularly the Lisanjali microwatershed and an area to the west of mount Mulanje (areas codes #3 and #4 in Figure 2- depicted as green/light areas) (see Table 1). In the initial phase of the Shire investigation, the Lisungwe and Lisanjali microwatersheds were chosen as two "hot spot" microwatersheds for intensive investigation on land cover change and soil erosion[14]. Furthermore, a third microwatershed - the RiviRivi - was selected for intensive investigation based on Green et. al. (1996) findings that the RiviRivi watershed contributes significantly to sedimentation of the Shire River. Figure 3 indicates the location of the three microwatersheds – the Lisungwe, Lisanjali, and RiviRivi - selected in the Shire investigation for intensive environmental analysis.

In addition to conducting intensive analysis on land cover change and soil erosion potential in the three selected microwatersheds, an extensive analysis of land cover change and soil erosion potential was conducted for the entire Blantyre and Machinga ADDs. The Blantyre and Machinga ADDs were selected

---

[11] Preliminary social analysis has already been conducted in two villages: Chakhumbira - a village close to Neno - and Tiyese - a village within the Lisungwe watershed (Haan et al, 1998).

[12] Normalized Difference Vegetation Index (NDVI) AVHRR data for every ten days - of a spatial resolution of 7.5 kilometers – were used over the thirteen year period to detect land cover change.

[13] This time series analysis was conducted as a part of the Advanced training in GIS and Remote Sensing held in June, 1997 with participants from line government agencies (Department of Forestry, Surveys Department, Meteorology Department, Ministry of Agriculture) and UNIMA (University of Malawi - the Chancellor, Polytechnic, and Bunda campuses).

[14] . These two watersheds were chosen since: 1) they indicate opposite trends in vegetative cover change and 2) contribute to the siltation of the Nkula-Tedzani hydro electric dam

as appropriate administrative boundaries within which the majority of the Shire watershed is contained (EIS Design Team, 1997; MOREA, 1997) (see Figure 3 for the Blantyre and ADD boundaries).

Subsequently a summary of the Shire investigation findings to date are listed. This is followed by an index of results – namely tables, graphs, and maps - on land cover change and soil erosion potential in respectively: 1) the Blantyre and Machinga ADDs; 2) the Lisungwe microwatershed; 3) the RiviRivi microwatershed; and 4) the Lisanjali microwatershed. Note that the land cover change assessment for the Blantyre and Machinga ADDs have been based off 1973 and 1991 Swede study land cover maps, while land cover change analysis for the three selected microwatersheds have been based off 1984 and 1994 Landsat land cover results[15]. The soil erosion potential results as included in this report are based off the modified Southern Africa Loss Model for Southern Africa (SLEMSA) for Malawi (Paris, 1990)[16].

---

[15] The georeferencing of the Landsat images (of a resolution of 30m) was conducted by the Department of Surveys, while the Department of Forestry and Surveys jointly conducted ground truthing and accuracy assessment (Snel et al, 1997; Haan et al, 1997).

[16] The modified SLEMSA incorporates information on soils (soil group and topsoil texture), rainfall energy, slopes, and landcover. Most data sets used throughout this initial phase of the Shire investigation relied on line government agencies input with respect to their institutional mandates; the Meteorology department created rainfall surfaces for 1984 and 1994; the Department of Surveys digitized the LREP (Land Resources Evaluation Project) 1:250,000 soils map and georeferenced, ground truthed, and assessed accuracy of the 1984 and 1994 Landsat images; the Department of Forestry grounded, assessed accuracy, and conducted land cover change analysis for 1984 and 1994; while the Ministry of Agriculture analyzed soil erosion potential in the Shire catchment. The soil erosion analysis was conducted as a part of a technical session hosted by the Land Resources Conservation Branch (March 23 – 27, 1998) (Snel et al, 1998). SLEMSA results in this report have been indicated as soil erosion potential classes. The original SLEMSA results were, however, calculated in t/ha/growing season. Initial findings reveal that the modified SLEMSA consistently underestimates soil loss. Additional research needs to be conducted to improve SLEMSA soil loss estimates.

RESULTS

A summary of this reports results are as follows:

1) Microwatersheds – particularly within densely populated areas – indicate cultivation on marginal lands such as on steep slopes, along rivers, and on soils with a high potential for erosion (e.g. see Figure 8 depicting land cover change in the Lisanjali watershed). Afforestation and soil conversation need to focus particularly in these areas.
2) This report recommends a number of villages/EPAs about deforested areas in need of afforestation measures. These are listed in: Table 2 for the Blantyre and Machinga ADD (corresponding with the map on Figure 4) ; Table 4 for the Lisungwe microwatershed (corresponding with Figure 6); Table 9 for the Lisanjali microwatershed (corresponding with Figure 8); and Table 13 for the RiviRivi microwatershed (corresponding with Figure 10).
3) This report recommends a number of villages/EPAs in particular need of soil conservation. These are listed in: Table 3 for the Blantyre and Machinga ADD (corresponding with Figure 5); Table 8 for the Lisungwe microwatershed (corresponding with Figure 7); Table 11 for the Lisanjali microwatershed (corresponding with Figure 9); and Table 14 for the RiviRivi microwatershed (corresponding with Figure 11).
4) This report lists villages about areas which have shown afforestation – in some instances indicative of successful afforestation implementation. These villages have been listed in: Table 5 for the Lisungwe watershed (corresponding with Figure 6), Table 10 for the Lisanjali watershed (corresponding with Figure 8), and Table 13 for the RiviRivi watershed (corresponding with Figure 11).
5) The Shire investigation findings to date indicate that degradation of land cover in the Shire catchment has substantially increased soil erosion potential in the Blantyre and Machinga ADDs and the Lisungwe, RiviRivi, and Lisanjali microwatersheds.
6) Further social analysis as proposed by Haan (1997) is required to better understand the underlying causes of land cover change and soil erosion and to recommend more specific intervention strategies.

INDEX OF RESULTS OF THE SHIRE INVESTIGATION AS COMPILED TO DATE (primarily maps, tables, and graphs)

General information on the Shire watershed

Figure 1: Map on Population Density in the Shire watershed relative to the rest of Malawi.
Figure 2: Map of a time series analysis over a thirteen year highlighting areas of significant land cover change in the Shire watershed.
Figure 3: Map of the Shire watershed (with EPA, microwatershed, and ADD boundaries).
Table 1: A list of areas indicating significant relative decline (deforestation) and increase (relative afforestation) in vegetative cover over a thirteen year period in the Shire Watershed (refer to Figure 3 for geographic locations of the "Area Code").

Blantyre and Machinga ADDs

Land Cover Change Situation analysis of the Blantyre and Machinga ADDs

Figure 4: Map of land cover change in the Blantyre and Machinga ADDs from 1973 – 1991.
Table 2: Extension Planning Areas (EPAs) within which significant deforestation from 1973 to 1991 have taken place/ EPAs in need of afforestation measures in the Blantyre and Machinga ADDs. (refer to Figure 4 for geographic locations of the "Area Code").
Graph 1: Land cover change from 1973 to 1991 in the Blantyre and Machinga ADDs.

Soil Erosion Potential Situation Analysis of the Blantyre and Machinga ADDs

Figure 5: Map of Soil erosion potential in the Blantyre and Machinga ADDs.
Table 3: Extension Planning Areas (EPAs) about areas of high, moderate, and low soil erosion potential within the Blantyre and Machinga ADDs. (refer to Figure 5 for geographic locations of the "Area Code").

Lisungwe Watershed

Land Cover Change Situation Analysis of the Lisungwe microwatershed

Graph 2: Land cover change in the Lisungwe watershed from 1984 to 1994.
Figure 6: Map on Land Cover Change in the Lisungwe watershed from 1984 to 1994.
Table 4: Village areas about which deforestation have taken place from 1984 to 1994/ Villages in need of afforestation measures in the Lisungwe watershed. (refer to Figure 6 for geographic locations of the "Area Code").
Table 5: Village areas about which afforestation have taken place from 1984 to 1994 in the Lisungwe watershed (refer to Figure 6 for geographic locations of the "Area Code").

Soil Erosion Situation Analysis of the Lisungwe microwatershed

Table 6: Soil erosion potential in the Lisungwe watershed relative to the Lisanjali and RiviRivi watersheds.
Table 7: Soil erosion potential change from 1984 to 1994 in the Lisungwe watershed.
Figure 7: Map on Soil Erosion Potential in the Lisungwe watershed.
Table 8: Villages about areas of high soil erosion potential/Villages in needs of soil conservation in the Lisungwe watershed. (refer to Figure 7 for geographic locations of the "Area Code").

Lisanjali Watershed

Land Cover Situation Analysis of the Lisanjali microwatershed

Figure 8: Map of Land Cover Change in the Lisanjali watershed from 1984 to 1994.
Graph 3: Landcover change in the Lisanjali microwatershed from 1984 to 1994.

Table 9: Villages about areas of significant deforestation/Villages in need of afforestation measures in the Lisanjali watershed from 1984 to 1994(refer to Figure 8 for geographic locations of the “Area Code”).
Table 10: Villages about areas of significant afforestation in the Lisanjali watershed from 1984 to 1994 (refer to Figure 8 for geographic locations of the “Area Code”).

Soil Erosion Situation Analysis of the Lisanjali microwatershed

Figure 9: Map of Soil erosion potential in the Lisanjali watershed.
Table 11: Villages about areas of high soil erosion potential/Villages in need of soil conservation in the Lisanjali watershed (refer to Figure 9 for geographic locations of the “Area Code”).
Table 12: Soil erosion potential change from 1984 to 1994 in the Lisanjali watershed.

RiviRivi Watershed

Land Cover Situation Analysis of the RiviRivi microwatershed

Graph 4: Landcover change in the RiviRivi microwatershed form 1984 to 1994.
Figure 10: Map on Land Cover Change in the RiviRivi watershed from 1984 to 1994.
Table 13: Villages about areas in which deforestation have taken place from 1984 to 1994 in the Rivi-Rivi watershed (refer to Figure 10 for geographic locations of the “Area Code”).
Table 14: Village areas about which afforestation have taken place from 1984 to 1994 in the Rivi-Rivi watershed (refer to Figure 10 for geographic locations of the “Area Code”).

Soil Erosion Situation Analysis of the RiviRivi microwatershed

Figure 11: Map on Soil Erosion Potential in the RiviRivi watershed.
Table 15: Villages about areas of high soil erosion potential in the RiviRivi watershed (refer to Figure 11 for geographic locations of the “Area Code”).
Table 16: Soil erosion potential change from 1984 to 1994 in the RiviRivi watershed.

General information on the Shire watershed

Table 1: Areas indicating significant relative decline (deforestation) and increase (relative afforestation) in vegetative cover in the Shire Watershed over a thirteen year period (refer to the map on Figure 3 for geographic locations of the "Area Code").

AREA CODE	Areas indicative of relative deforestation (BLACK IN FIGURE 2)	Areas indicative of relative afforestation (GREEN/WHITE IN FIGURE 2)	AREA CODE
1	Lisungwe and Mkurumadzi microwatersheds	Lisanjali microwatershed	3
2	Mwanza microwatershed	Areas to the west of the Mulanje mountain (expansion of tea estates)	4

Blantyre and Machinga ADDs

Land Cover Change Situation analysis of the Blantyre and Machinga ADDs

Graph 1: Land cover change from 1973 to 1991 in the Blantyre and Machinga ADDs.

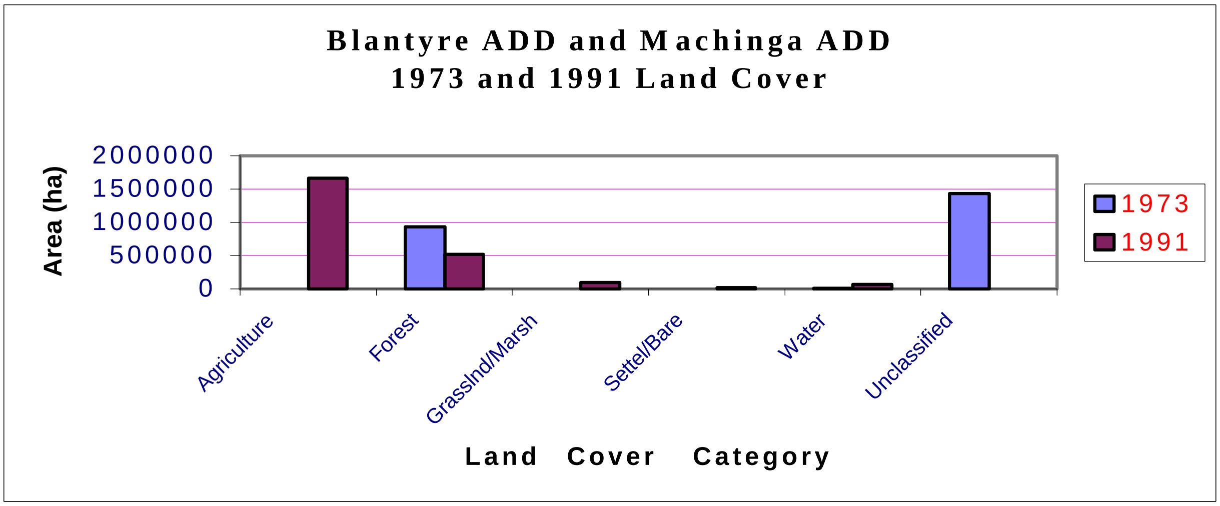


Table 2: Extension Planning Areas (EPAs) experiencing significant deforestation from 1973 to 1991/ EPAs in need of afforestation measures in the Blantyre and Machinga ADDs. (refer to the map on Figure 4 for geographic locations of the "Area Code"). (note: this only includes 45% of the entire Blantyre and Machinga ADD area that was classified in both 1973 and 1991)

AREA CODE	EXTENSION PLANNING AREA (EPA)
1	Ulongwe, Bazale
2	Lisungwe, Phalula, western Chingale, northern Lirangwe
3	Neno, Mwanza, Kalambo
4	Livunzu,Thyolo Boma
5	Nasenga, Mthiramanja, Maiwa

Blantyre and Machinga ADDs

Soil Erosion Potential Situation Analysis of the Blantyre and Machinga ADDs

Table 3: Extension Planning Areas (EPAs) indicating high, moderate, and low soil erosion potential within the Blantyre and Machinga ADDs. Those EPAs indicating a high potential for soil erosion are in particular need of soil conversation measures (refer to the map on Figure 5 for geographic locations of the "Area Code").

Area Code	Description	EPAs
1	EPAs indicating high soil erosion potential	Mulanje South, Mulanje West, Thumbwe, Thyolo Boma, Ntonda, Livunzu, Kalambo, Mwanza, Neno, Malosa, and Chingale
2	EPAs indicating moderate soil erosion potential that contribute to siltation of the Nkula-Tedzani and Kapichira dams	Ulongwe, Bazala, Mpilisi, Lisungwe, Ntubwi, Chingale, and Lirangwe
3	EPAs indicating low potential for soil erosion	Mpilipili, Lungwena, Katuli, Ntiya, Maiwa, Mbonechera, Nsama, Mbwadzulu, Mthiramanja, Nasenga, Mitole, and Phalula

Lisungwe microwatershed

Land Cover Change Situation Analysis
of the Lisungwe microwatershed

Graph 2: Land cover change in the Lisungwe watershed from 1984 to 1994.

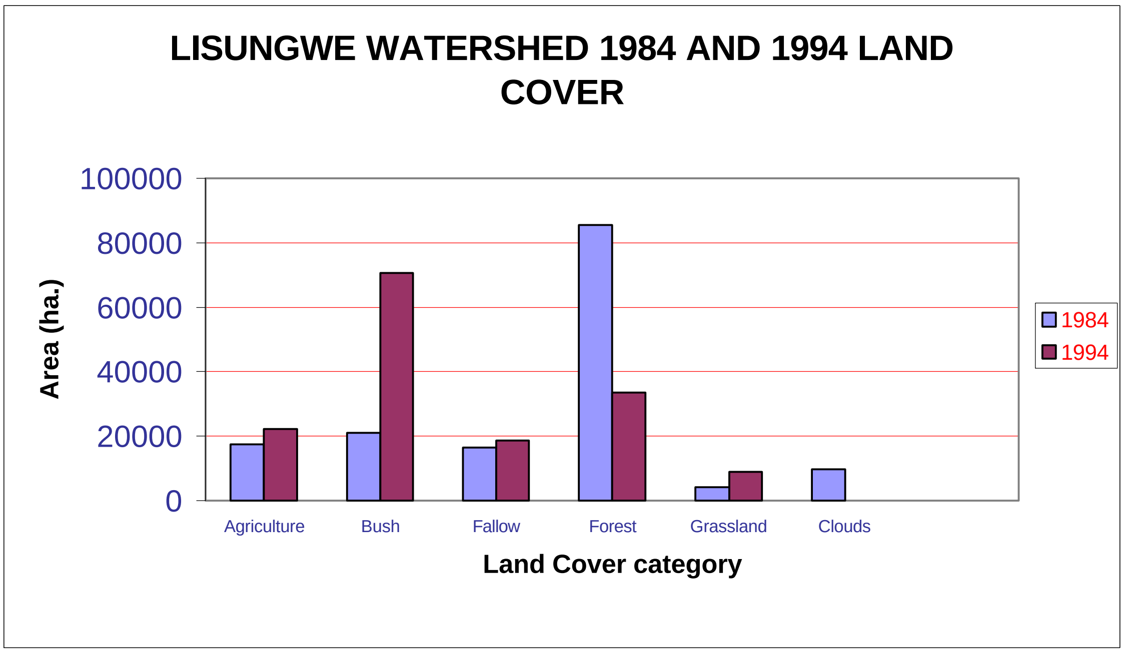


Table 4: Village areas about which deforestation have taken place from 1984 to 1994/ Villages in need of afforestation measures in the Lisungwe watershed. (refer to the map on Figure 6 for geographic locations of the "Area Code"). Pressure in these areas generally include deforestation due to population growth, agricultural expansion, and charcoal production. Responses to deforestation generally include a need of afforestation projects particularly about hills and streams, environmental education, and community participatory forest management. Social analysis (as conducted by Haan et al, 1998) is needed to more specifically recommend mitigation strategies.

AREAS INDICATIVE OF DEFORESTATION IN LISUNGWE WATERSHED.

AREA CODE	VILLAGES	EPA	NOTES
1	Senzani, Njunga, Phingo, Kankao, Ntonda,Matale	Manjawira	Area along and around M1 Zalewa Road
2	Villages along Mwetang`ombe River and in a Proposed forest Reserve-Mwanza (mostly new villages such as Tiese not presently indicated on the 1:50,000 topo map series)	Neno	settlements and agricultural estate expansion
3	Hilly areas along Namitani, adjacent Zalewa	Manjawira	
4	Nkhanya-Lisungwe confluence	Lisungwe	Southern part of Nkhanya river
5	Chakulembera, Matandani, Kundembo, Msambe, Dzinjiriza, Kabango, Kabvalankwinda – villages in the Tsamba Forest Reserve	Lisungwe /Manjawira	

Table 5: Village areas about which afforestation have taken place from 1984 to 1994 in the Lisungwe watershed (refer to the map on Figure 6 for geographic locations of the "Area Code").

AREAS INDICATIVE OF AFFORESTATION IN LISUNGWE WATERSHED.

AREA CODE	VILLAGES	EPA	NOTES
6	Kasamba, Kang`ombe, Ngwenyama, Funsani	Lisungwe	Area surrounds Lisungwe river

Lisungwe microwatershed

Soil Erosion Situation Analysis of the Lisungwe microwatershed

Table 6: Soil erosion potential in the Lisungwe watershed as compared to the Lisanjali and RiviRivi watersheds (soil erosion potential rates for 1994 expressed as a percentage of the watershed).

Soil Erosion Potential Class	LISUNGWE	RIVIRIVI	LISANJALI
Low soil erosion potential	76.3%	38.6%	34.9%
Moderate soil erosion potential	19.5%	46.5%	53.1%
High soil erosion potential	3%	11.1%	11.6%
Unclassified (n/a)	1.2%	3.8%	0.4%

Table 7: Soil erosion potential change from 1984 to 1994 in the Lisungwe watershed.

Soil Erosion Potential Class	1984 Soil Erosion Potential	1994 Soil Erosion Potential	% change in soil erosion potential from 1984 to 1994
Low soil erosion potential	122447 ha. (79.3%)	117617 ha. (76.3%)	- 3%
Moderate soil erosion potential	18724 ha. (12.2%)	30075 ha. (19.5%)	+ 7.3%
High soil erosion potential	1978 ha. (1.2%)	4793 ha. (3%)	+ 1.8%
Unclassified (n/a)	11135 ha. (7.2%)	1803 ha. (1.2%)	N/a

Table 8: Villages about areas of high soil erosion potential/Villages in needs of soil conservation in the Lisungwe watershed. (refer to the map on Figure 7 for geographic locations of the "Area Code"). Soil erosion pressure in these areas are generally due to agricultural expansion, particularly on marginal lands (e.g on steep slopes and along rivers) and population growth. Responses to the soil erosion generally include a need for soil erosion conservation practices (e.g. contour ridging, vetiver grass, and agroforestry) and environmental education. Social analysis (as conducted by Haan et al, 1998) is needed to more specifically recommend mitigation strategies. Areas of high soil erosion potential in which significant deforestation has taken place (from 1984 to 1994) have been indicated in *italic* font.

AREAS INDICATIVE OF HIGH SOIL EROSION POENTIAL IN THE LISUNGWE WATERSHED

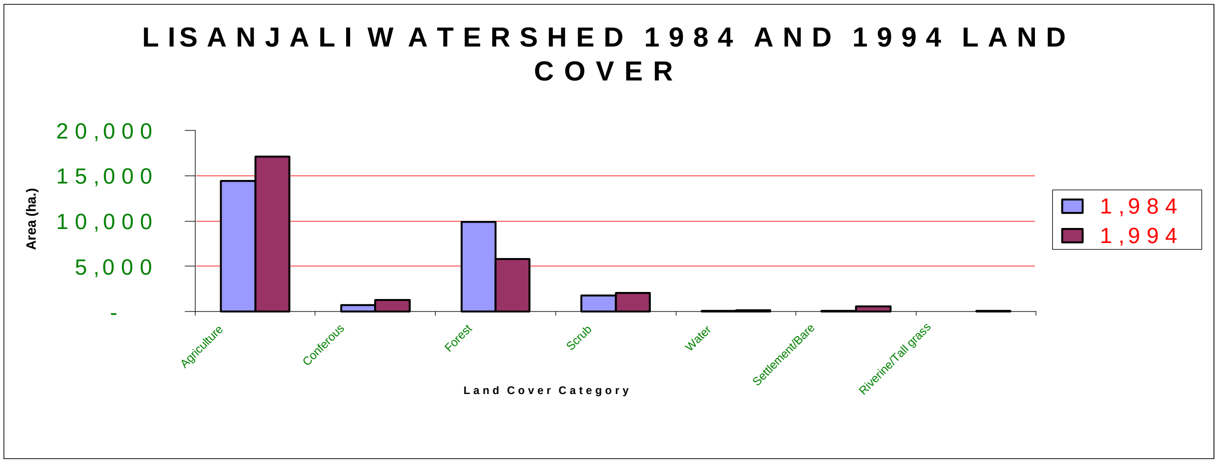
AREA CODE	VILLAGES	EPA
1	*Katloeza, Selemani, Chinchembere, Samusoni*	*Lisungwe*
2	Chiembekeza, Moffatti, Tsamba, Kumbwani	Neno
3	*no villages within area*	*Manjawira*

4	*Dzonze, Cabwera, Kandoma*	*Tsangano*

Lisanjali microwatershed

Land Cover Situation Analysis of the Lisanjali microwatershed

Graph 3: Landcover change in the Lisanjali microwatershed form 1984 to 1994.



Lisanjali microwatershed

Table 9: Villages about areas of significant deforestation from 1984 to 1994/Villages in need of afforestation measures in the Lisanjali watershed (refer to the map on Figure 8 for locations of "Area Code"). Pressure in these areas generally include deforestation due to population growth, agricultural expansion, and charcoal production. Responses to the deforestation generally include a need of afforestation projects particularly about hills and streams, environmental education, and community participatory forest management. Social analysis (as conducted by Haan et al, 1998) is needed to more specifically recommend mitigation strategies.

AREAS INDICATIVE OF DEFORESTATION IN LISANJALI WATERSHED

AREA CODE	VILLAGES	EPA	NOTES
1	Chisinkha , Matipani, Pimbi, Mchela, Chathinachinga	Phalula /Mpilisi	Area around Rivi-Rivi / Shire river confluence
2	Masula, Kazembe, Kandionanji, Chikonde, Mitawa2, Basikolo, Mtambo, Whisky, Bwanausi, Chibwana	Chingale	Along Linthipe dambo
3	Mthumba, Wilson	Ntubwi	Along M1 road and in Chnduzi hill part of Liwonde Forest Reserve
4	Ndaje Nkula, Machinga Boma, Lipongo, Mkalawire.	Ntubwi	Around Machinga Boma
5	Kwilapo, M`dele, Chinkwenzule, Michongwe, Mdoka, Kwiteuka, Mikundi, Matola, Moto, Mchisa, Makunganya, Matandika, Salimu, Katuli2, Mkasala, Mkawa2, aachimatiro	Malosa	Along Malosa Mtn slopes
6	Kasonga, Mbuliwa, Malonga, M`bawa, Chilasanje, Domasi	Malosa	Along Domasi dambo

Lisanjali microwatershed

Table 10: Village areas about areas of significant afforestation in the Lisanjali watershed from 1984 to 1994 (refer to the map on Figure 8 for geographic locations of the "Area Code").

AREAS INDICATIVE OF AFFORESTATION IN LISANJALI WATERSHED

AREA CODE	VILLAGES	EPA	NOTES
7	North west part of Malosa F.R.	Malosa	Indication of successful implementation of Wood Energy project (ZCGP)
8	Around Mberekezi hills in Liwonde F.R.	Ntubwi	Indication of successful implementation of Wood Energy project (ZCGP)
9	Tobacco Estate Ltd, Kalambo	Mpilisi	Tobacco farming seized some years ago

Lisanjali microwatershed

Soil Erosion Situation Analysis of the Lisanjali microwatershed

Table 11: Villages about areas of high soil erosion potential/Villages in need of soil conservation in the Lisanjali watershed (refer to the map on Figure 9 for geographic locations of the "Area Code"). Soil erosion pressure in these areas are generally due to agricultural expansion, particularly on marginal lands (e.g on steep slopes and along rivers) and population growth. Responses to the soil erosion generally include a need for soil erosion conservation practices (e.g. contour ridging, vetiver grass, and agroforestry) and environmental education. Social analysis (as conducted by Haan et al, 1998) is needed to more specifically recommend mitigation strategies. Areas of high soil erosion potential in which significant deforestation has taken place (from 1984 to 1994) have been indicated in *italic* font.

AREAS INDICATIVE OF HIGH SOIL EROSION POENTIAL IN THE LISUNGWE WATERSHED

AREA CODE	VILLAGES	NOTES
1	*Kwilapo, M'dele, Chinkwenzule, Michongwe, Chisanje, Moloka, Dwiteuda, Mikundi, Matola, Moto, Mchisa Makunganya, Matandika, Salimu Katuli2, Mkasala, Majambe, Chingenga, Makasala, Chiunda2*	*Between the road running north-south through the Lisanjali watershed and Zomba/Malosa mountain western slopes.*
2	*Mthumba*	*Between Liwonde Forest Reserve and Mangolwe hills*
3	Mkwanba, Makwangwala, Bifa Salifu, Sabuni, Matunda	North-west of the Piemonpe and Namitembo Estates
4	*Mbewe, Pimbi, Matipani, Chisinkha, Thundu, Namweta II, Jiya*	*Outside the Lisanjali watershed, at the confluence of the Rivi-Rivi and Shire rivers*

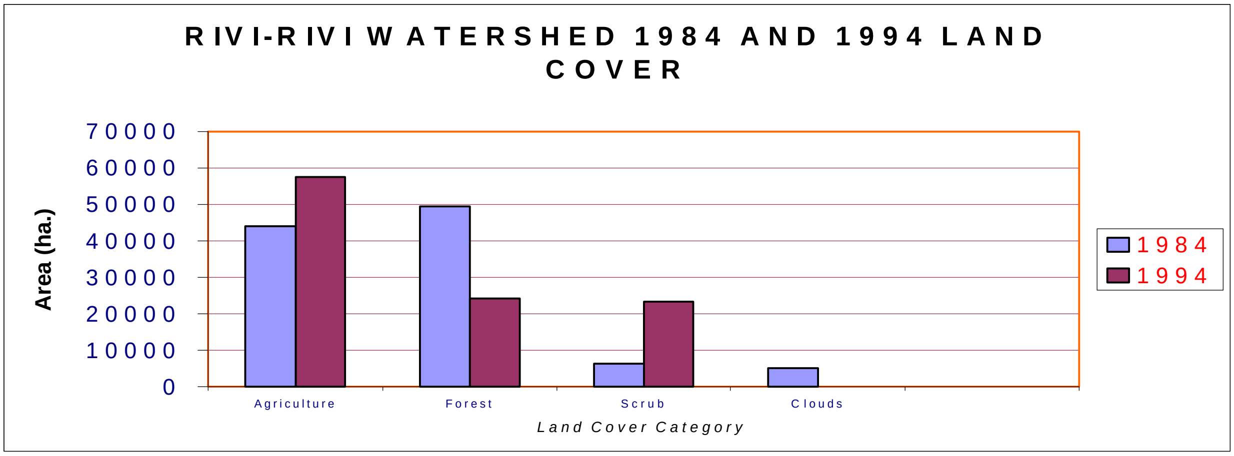
Table 12: Soil erosion potential change from 1984 to 1994 in the Lisanjali watershed.

Soil Erosion Potential Class	**1984 Soil Erosion Potential**	**1994 Soil Erosion Potential**	**% change in soil erosion potential from 1973 to 1991**
Low soil erosion potential	9498ha. (34.9%)	6579 ha. (24.1%)	- 10.8%
Moderate soil erosion potential	14432 ha. (53.1%)	16194 ha. (59.5%)	+ 6.4%
High soil erosion potential	3162 ha. (11.6%)	4320 ha. (15.8%)	+4.2%
Unclassified (n/a)	114 ha. (0.4%)	114 ha. (0.4%)	N/a

Rivi-Rivi microwatershed

Land Cover Situation Analysis of the
Rivi-Rivi microwatershed

Graph 4: Landcover change in the Rivi-Rivi microwatershed form 1984 to 1994.



Rivi-Rivi microwatershed

Table 13: Village areas about which deforestation have taken place from 1984 to 1994/ Villages in need of afforestation measures in the Rivi-Rivi watershed (refer to the map on Figure 10 for geographic locations of the “Area Code”). Pressure in these areas generally include deforestation due to population growth, agricultural expansion, and charcoal production. Responses to the deforestation generally include a need of afforestation projects particularly about hills and streams, environmental education, and community participatory forest management. Social analysis (as conducted by Haan et al, 1998) is needed to more specifically recommend mitigation strategies.

AREAS INDICATIVE OF DEFORESTATION IN RIVIRIVI WATERSHED.

AREA CODE	**VILLAGES**	**EPA**	**NOTES**
1	Magombo, Nambuya,Ositeni , Bilira, Mkutumula, Chindazi, Pulumuka, Chiwisa, Binoni, Balaka Market, Msiyaludzu	Bilira/ Bazale	All the villages are to the north of M1 Zalewa Road
2	Chamthunya, Phingo, Manjawira	Bazale	South west of Kamzati market, & School
3	Joni, Mwansambe, Zidana, Mpalale, Malota, Hauya, Faiti, Nsenjere, Kamwamba, Seselu, Wandawanda, Kainga, Chisamba	Manjawira	
4	Chinyamula	Nsipe	South west of Ntcheu boma
5	Dzunje, Njolinjo, Chanya, Zidana, Mkwezalamba, Njuya, Kawele	Nsipe	

Rivi-Rivi microwatershed

Table 14: Village areas about which afforestation have taken place from 1984 to 1994 in the Rivi-Rivi watershed (refer to the map on Figure 10 for geographic locations of the "Area Code").

AREAS INDICATIVE OF AFFORESTATION IN RIVIRIVI WATERSHED.

AREA CODE	VILLAGES	NOTES
6	Chikuse, Kasale, Kafetula, Jalasi, Chinkuluchira, Chinkanda, Visenti, Chikondanji, Howa, Chibondo	This area surrounds Mvai Forest Reserve
7	Chakudza, Nenani, Ntendele, Mbirintengerenji, Jenya, Kamuze, Beni-Ngolombe, Kalonga and Kambilonjo	This area is arround Nzama Mission

Rivi-Rivi microwatershed

Soil Erosion Situation Analysis of the
Rivi-Rivi microwatershed

Table 15: Villages about areas of high soil erosion potential in the Rivi-Rivi watershed (refer to the map on Figure 11 for geographic locations of the "Area Code"). Soil erosion pressure in these areas are generally due to agricultural expansion, particularly on marginal lands (e.g on steep slopes and along rivers) and population growth. Responses to the soil erosion generally include a need for soil erosion conservation practices (e.g. contour ridging, vetiver grass, and agroforestry) and environmental education. Social analysis (as conducted by Haan et al, 1998) is needed to more specifically recommend mitigation strategies. Areas of high soil erosion potential in which significant deforestation has taken place (from 1984 to 1994) have been indicated in *italic* font.

AREAS INDICATIVE OF HIGH SOIL EROSION POENTIAL IN THE LISUNGWE WATERSHED

AREA CODE	VILLAGES	NOTES
1	*Balaka, Chamathunya, Zamminba, Kapalamula, Amonistute, Matola, Gande, Silivia, Gunde, Jemusi, Alasala, Mberongwa, Balaka Market, Matole, Jemusi, Sabwera, Mpezeni, Sosola, Mponda, Kapalamula, Chinjeni, Chimutu, Gumbi, Njopilo, Kadondo, Lupanga, Kabuthu, Madyelatu, Balaka*	*West of Balaka*
2	*Sande, Muyenda, Kalimeryira, Machenga*	*North of Balaka market*
3	Madeya, Londalonda, Kam'mwamba, Tsikulamowa,	South of Kumwnji/ Livilidzi estate, west of RiviRivi estate
4	Chinkutuchina, Kabwane, Chinkondenii, ChinkandaIII, Chinkandai, Jalasi, Kufetula	South-east of Ntcheu, north of Mwai forest reserve
5	Chipusile, Kamuzeni, Kaisa, KamuzeniII,	South-east of Ntcheu

Rivi-Rivi microwatershed

Table 16: Soil erosion potential change from 1984 to 1994 in the Rivi-Rivi watershed.

Soil Erosion Potential Class	**1984 Soil Erosion Potential**	**1994 Soil Erosion Potential**	**% change in soil erosion potential from 1973 to 1991**
Low soil erosion potential	52533 ha. (50%)	40499 ha. (38.6%)	- 11.4%
Moderate soil erosion potential	34448 ha. (32.9%)	48764 ha. (46.5%)	+ 13.6
High soil erosion potential	9708 ha. (5.9%)	11665 ha. (11.1%)	+ 5.2%
Unclassified (n/a)	8236 ha. (7.8%)	3994 ha. (3.8%)	

BIBLIOGRAPHY

EIS Design Team, 1997. *Strategy for an Environmental Information System in Malawi*. Ministry of Research and Environmental Affairs.

Haan et al, 1997, *Trip Report, November – December, 1997*. Clark University.

Haan et al, 1998, *Trip Report, March – April, 1998*. Clark University.

Green, R.I., V. Mkandawire, H. Kandaya, and M. Kapila, 1996. *Study to Identify Sources of Siltation in the Middle Shire River Catchment Area*. Ministry of Research and Environmental Affairs.

MOREA, 1997. *The Second Annual Workplan for the Components of the Malawi Environmental Monitoring Programme: Environmental Monitoring Technologies, Research, And Policy Sub-Programmes.*

Paris, S., 1990. *Erosion Hazard model (modified SLEMSA). Field Document No. 13 (Second Version).* Land Resources Evaluation Project, Malawi.. Malawi Government Ministry of Agriculture Land Husbandry Branch, United National Development Programme, and Food and Agriculture Organization of the United Nations.

Snel, M, N. Haan, and R. Eastman, 1997, *Trip report, November – December, 1997*. Clark University.

Snel, M, N. Haan and R. Eastman, 1998, *Trip report, March – April, 1988*. Clark University.