GRID
GLOBAL RESOURCE INFORMATION DATABASE

GRID

CASE STUDY SERIES

NO. 1

NAIROBI

JUNE 1987

Uganda Case Study: A sampler atlas of environmental resource datasets within GRID

GEMS

GLOBAL ENVIRONMENT MONITORING SYSTEM

UNITED NATIONS ENVIRONMENT PROGRAMME

GRID CASE STUDY SERIES

Foreword

The Executive Director of the United Nations Environment Programme (UNEP) has accorded the highest priority to the development of an environmental database for Uganda, both as a logical prelude to efficient and effective resource assessment and management in general, and as a useful background for many of the activities of the UNEP strategic Resource Planning in Uganda Project (SRPUP) in particular. The SRPUP was developed to facilitate action in response to the UNEP-Uganda Memorandum of Understanding of August 1986 for co-operation in matters relating to environmental protection and planning.

Responsibility for activities related to the development of a Ugandan environmental database was given to GRID, the Global Resource Information Database, which operates as an element within GEMS, the Global Environment Monitoring System.

During a five-month period (January to May 1987), GRID staff, working with sub-contractors and a team of four Ugandan sectoral experts, have built up an environmental geographical information system database which may be the most comprehensive of its kind for any developing country in the world.

The endeavour has produced:

- A digital environmental database within GRID containing basic, national datasets on land, climate, and infrastructure;

- A number of specific, problem-orientated demonstration applications which make use of GRID geographical information system (GIS) capabilities to answer questions related to land use change, degradation and capability;

- Training opportunities which will lead to a prototype national GIS capability within the Ugandan Ministry of Environmental Protection, serving as a national GRID node.

The following have contributed actively to the exercise:

- USAID/ECA Regional Office for Services in Surveying, Mapping and Remote Sensing,
- Ministry of Environmental Protection, Government of Uganda,
- Department of Geography, Birkbeck College, University of London,
- Department of Geography, University of Zurich, and
- Earth Resource Laboratory, NSTL/NASA

The Ugandan team of experts consisted of John Carvalho, Steve Kalyango, Frank Turyatunga and Julius Zake. Contributing GRID staff were Anne Burrill, Danielle Mitchell, Rhonnie Semakula, Morten Sorensen and Ron Witt. The principal investigator conducting the analysis on the data shown in this atlas was Otto Simonett.

It is difficult to express the power and usefulness of a computerized database on paper. However, this sampler atlas of Ugandan environmental datasets within GRID should give an example of its scope and the many possibilities for its use.

Efforts will now have to be made to improve the quality of the data, to fill gaps and to ensure that the capacity for data analysis and GIS application is developed within Uganda itself, in harmony with GRID and GEMS.

Harvey Croze
GRID Cordinator

UGANDA CASE STUDY:

A SAMPLER ATLAS OF ENVIRONMENTAL RESOURCE DATASETS WITHIN GRID

Table of Contents

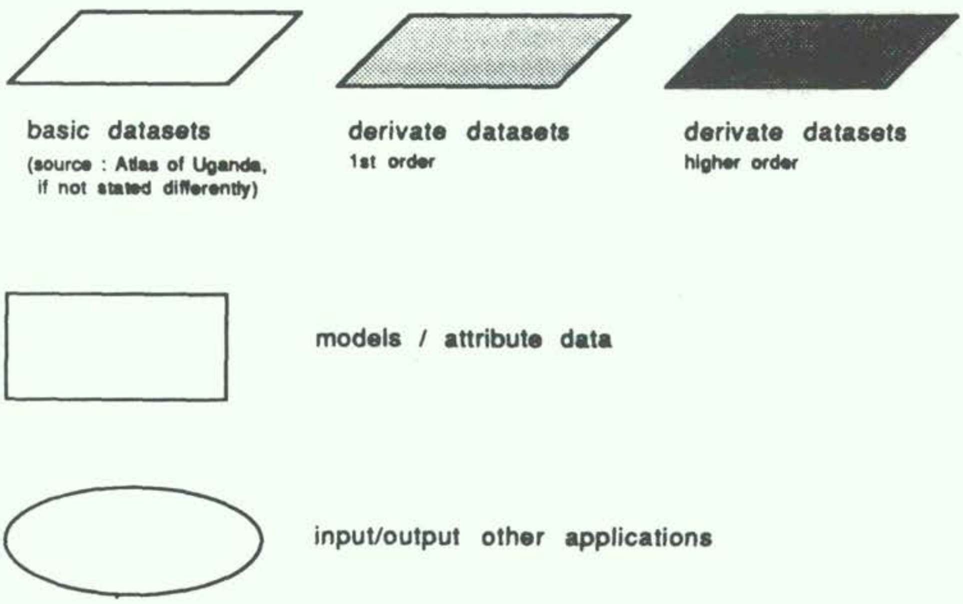
Datasets and Models

Data entry, modeling and graphical output for the Uganda case study have been carried out with the ARC/INFO Geographic Information System on a PRIME minicomputer.

Most of the basic datasets were digitized from the Atlas of Uganda (1964 and 1967 editions). More recent data for the whole country were not available; layers such as land use and forest reserves are out of date. However, the majority of data entered can be assumed unchanged (geology, terrain, soils), and some of the outdated layers were compared with more recent satellite imagery in order to map temporal changes.

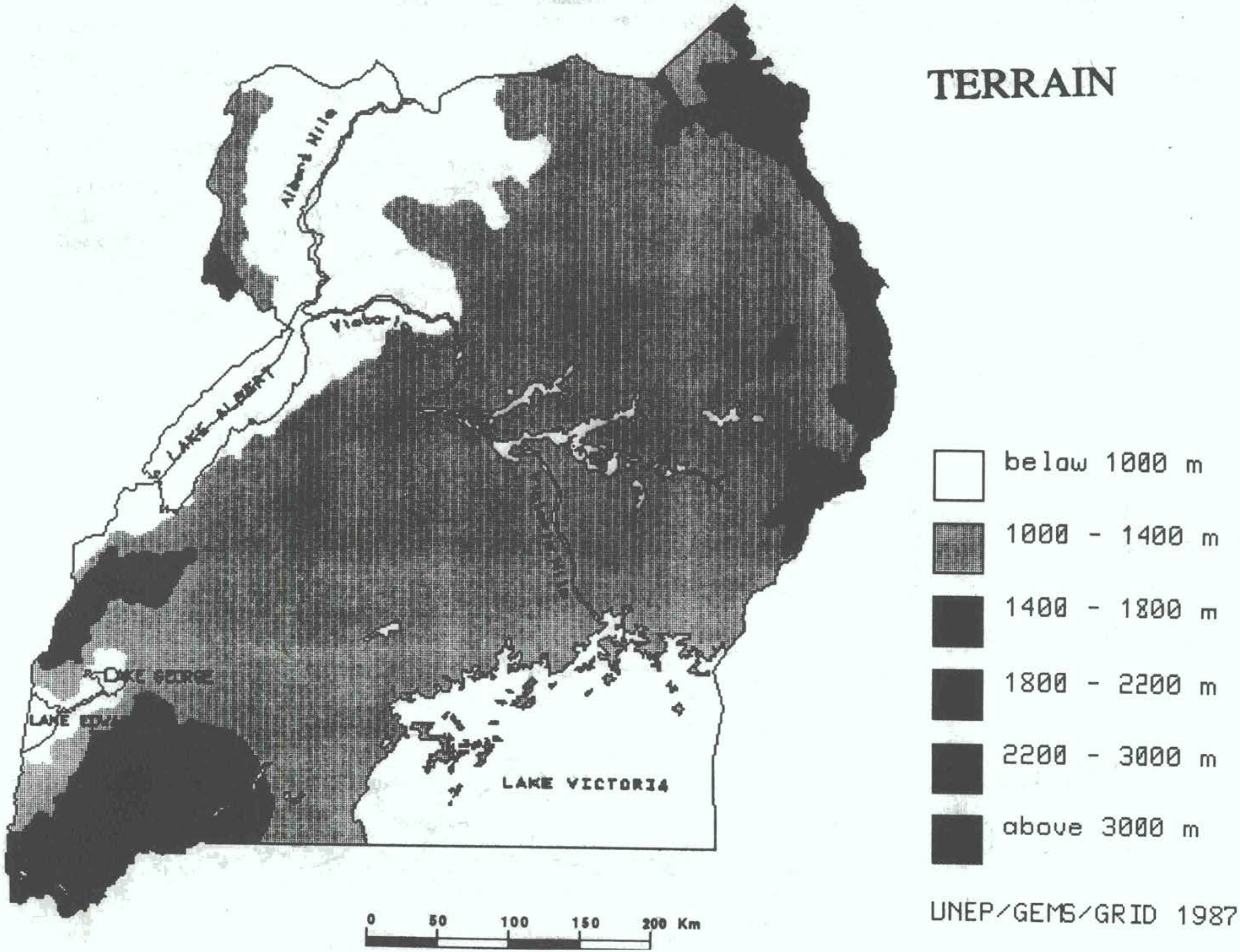
Derived datasets have been grouped into two classes: 1st and higher order. In 1st order derivations, only attribute information has been added or changed, for example the map of soil productivity. In higher order derivations, boundarties have been changed, and entirely new entities created.

Key to flowcharts:

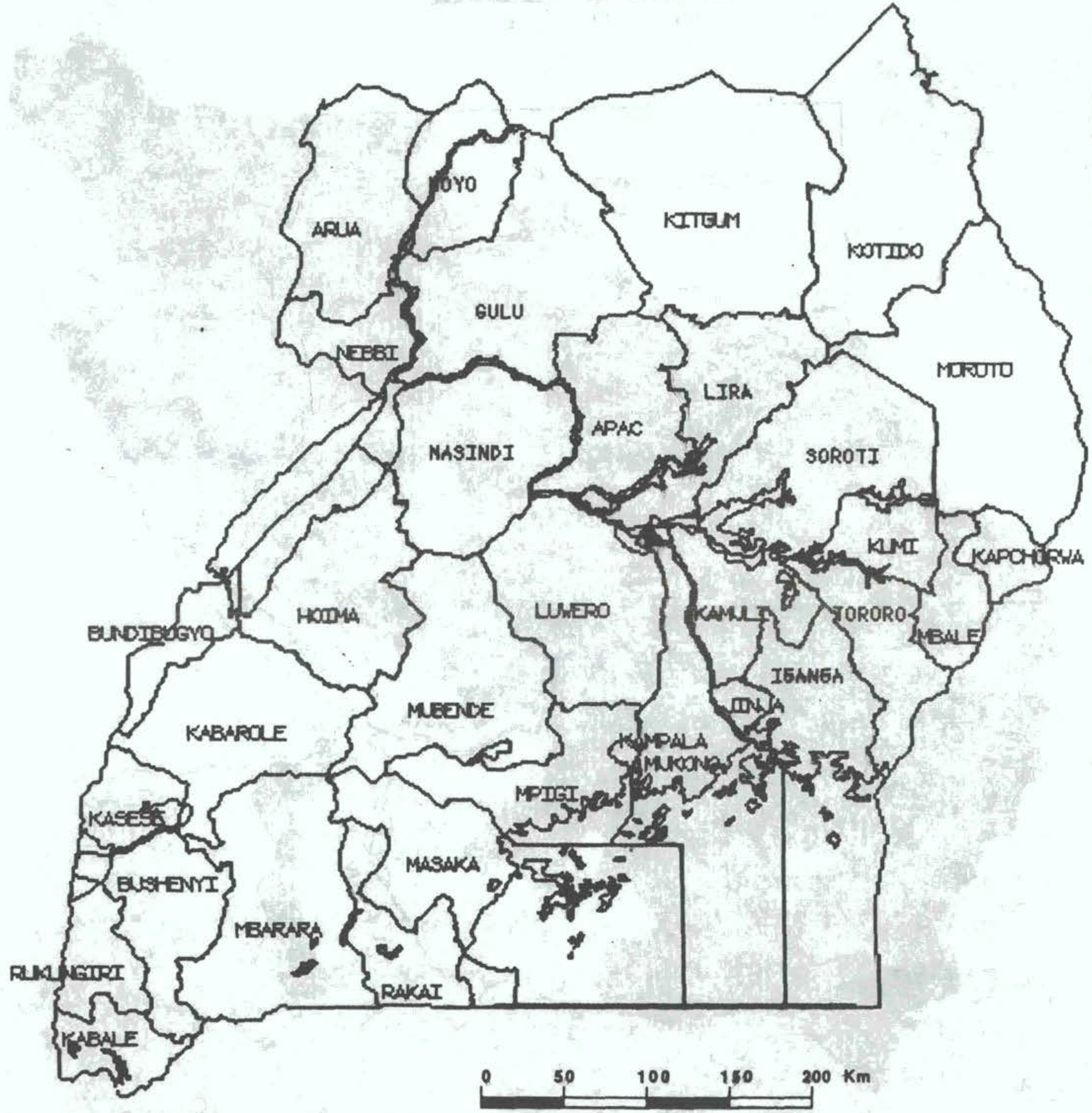


Base Maps

TERRAIN



Albert Nile
Victoria
LAKE ALBERT
LAKE GEORGE
LAKE EDW
LAKE VICTORIA
0
50
100
150
200 Km
below 1000 m
1000 - 1400 m
1400 - 1800 m
1800 - 2200 m
2200 - 3000 m
above 3000 m
UNEP/GEMS/GRID 1987



POLITICAL SUBDIVISIONS

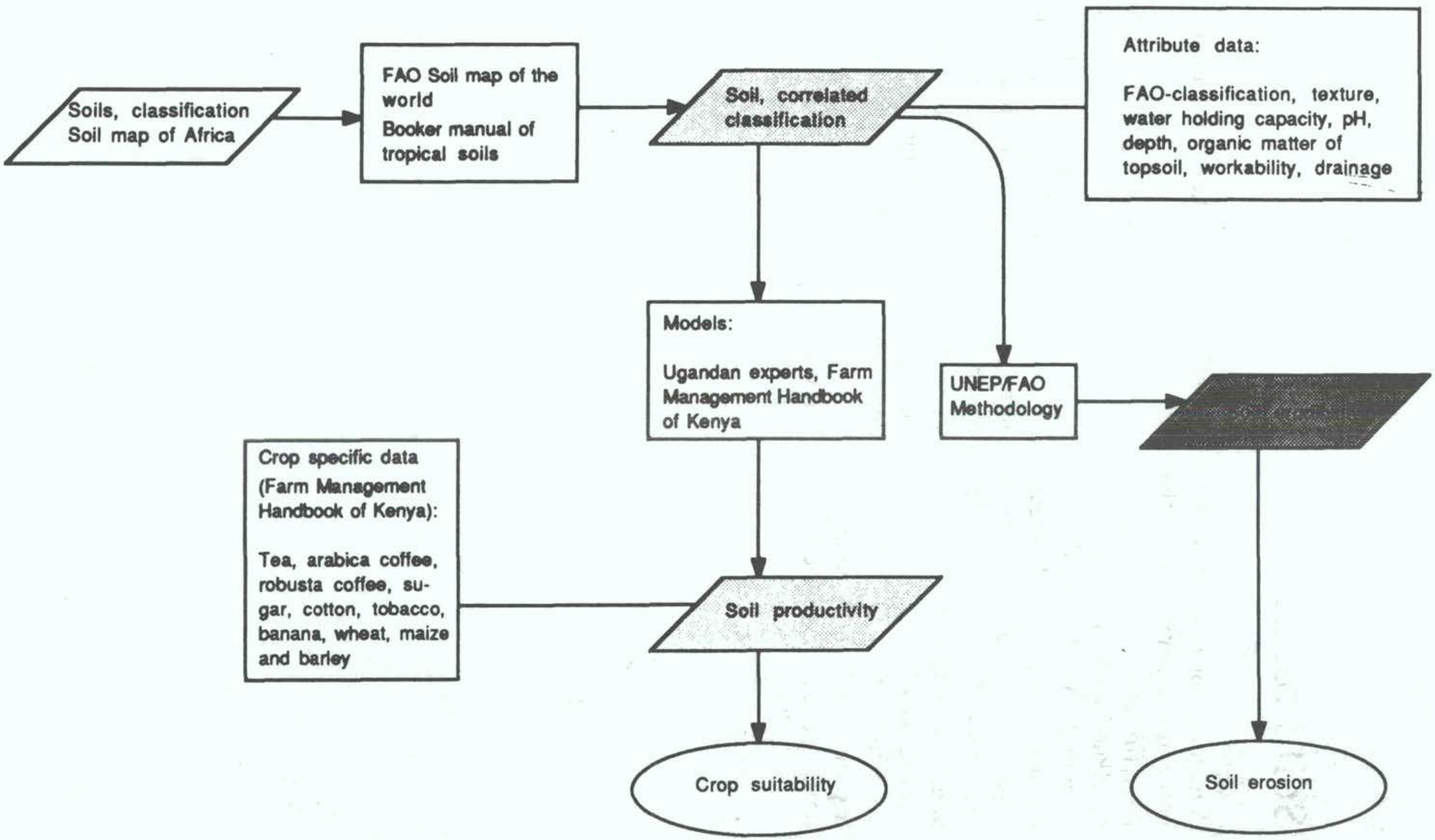
Districts 1984

UNEP/GEMS/GRID 1987

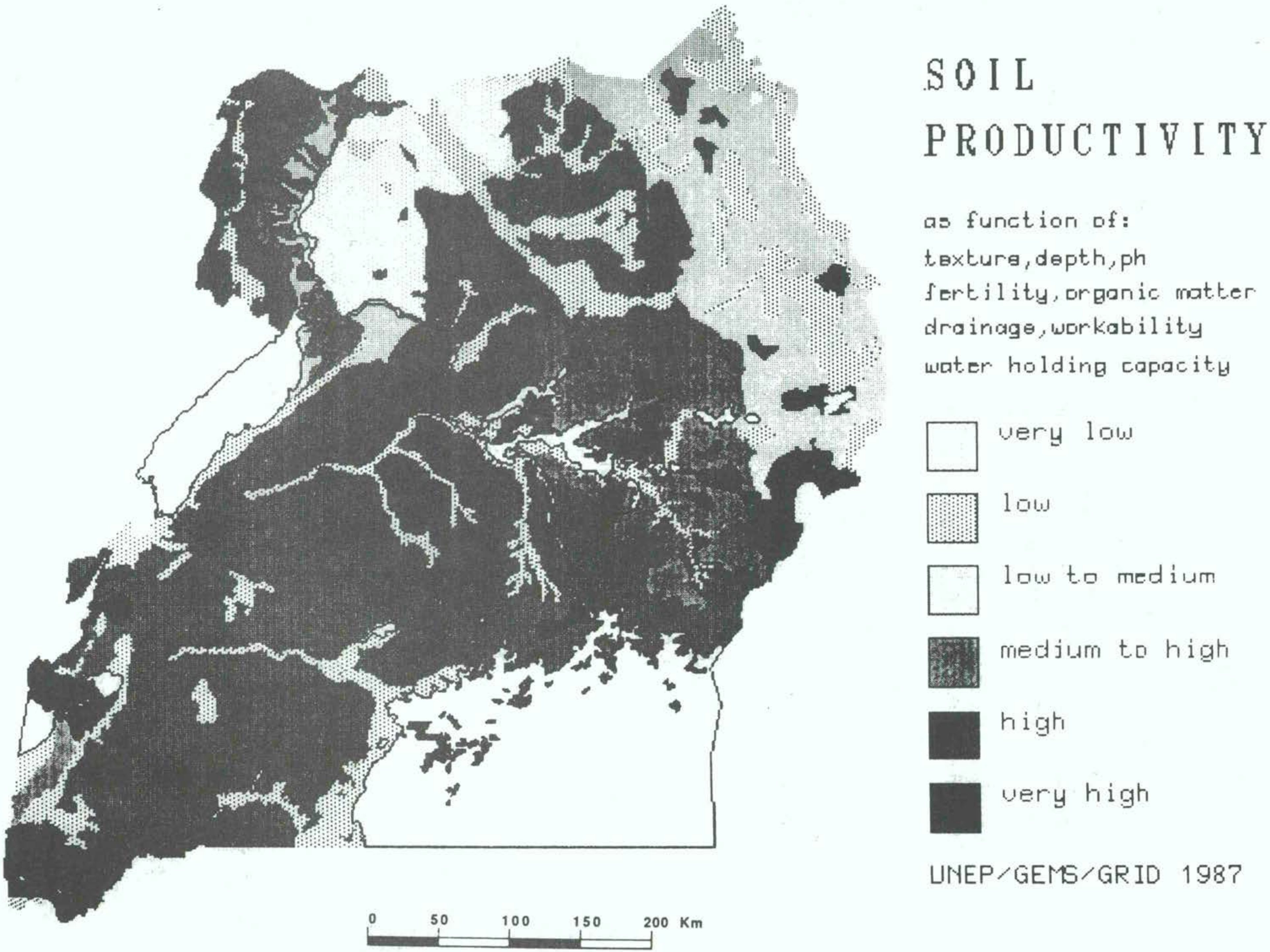
Soil Productivity

A major problem when working with soil maps is to attain correlation between the many classification systems.
As a first step, the existing soil map given in the Atlas of Uganda (1967) was corellated with the Uganda portion of the more recent FAO/UNESCO Soil Map of the World (1973). Thus they allowed additional data on, for example, texture, depth, organic matter topsoil, pH drainage, water holding capacity, workability and fertility, to be drawn from the Farm Management Handbook of Kenya (Jatzold and Schmidt 1983). This compilation, plus additional advice from Ugandan experts, was used to produce the Soil Productivity Map shown here. For its production, soil productivity was taken to be the result of a combination of the following variables: soil texture, soil depth, organic matter in topsoil, pH, drainage, soil water holding capacity, soil fertility and soil workability.

Soils



Soils, classification
Soil map of Africa
FAO Soil map of the world
Booker manual of tropical soils
Soil, correlated classification
Attribute data:
FAO-classification, texture, water holding capacity, pH, depth, organic matter of topsoil, workability, drainage
Models:
Ugandan experts, Farm Management Handbook of Kenya
UNEP/FAO Methodology
Crop specific data (Farm Management Handbook of Kenya):
Tea, arabica coffee, robusta coffee, sugar, cotton, tobacco, banana, wheat, maize and barley
Soil productivity
Crop suitability
Soil erosion



SOIL
PRODUCTIVITY
as function of:
texture,depth,ph
fertility,organic matter
drainage,workability
water holding capacity
very low
low
low to medium
medium to high
high
very high
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km

Soil Erosion

Uganda is heavily dependent on agriculture, thus soil erosion can be a threat to the nation´s economy. In this case study the problem was examined at a small scale (1:1.5 million), so detailed answers cannot be given. The resulting maps, however, identifying potential trouble spots, can be used to allocate effort and for the selection of detailed study areas.

Rainfall is the most important climatic factor contributing to soil erosion in Uganda, so the study focussed on water erosion.

There is no generally accepted model of soil erosion assessment. For this analysis, the FAO/UNEP methodology (FAO 1979) was followed. It is basically a simplification of the Universal Soil Loss Equation (USLE). Factors to be considered in the assessment of water erosion are climate, soil, topography and human impact on the land.

GIS technology allows several models to be run, once the basic data are entered, thus emphasis was given to the production of maps of single factors contributing to soil erosion:

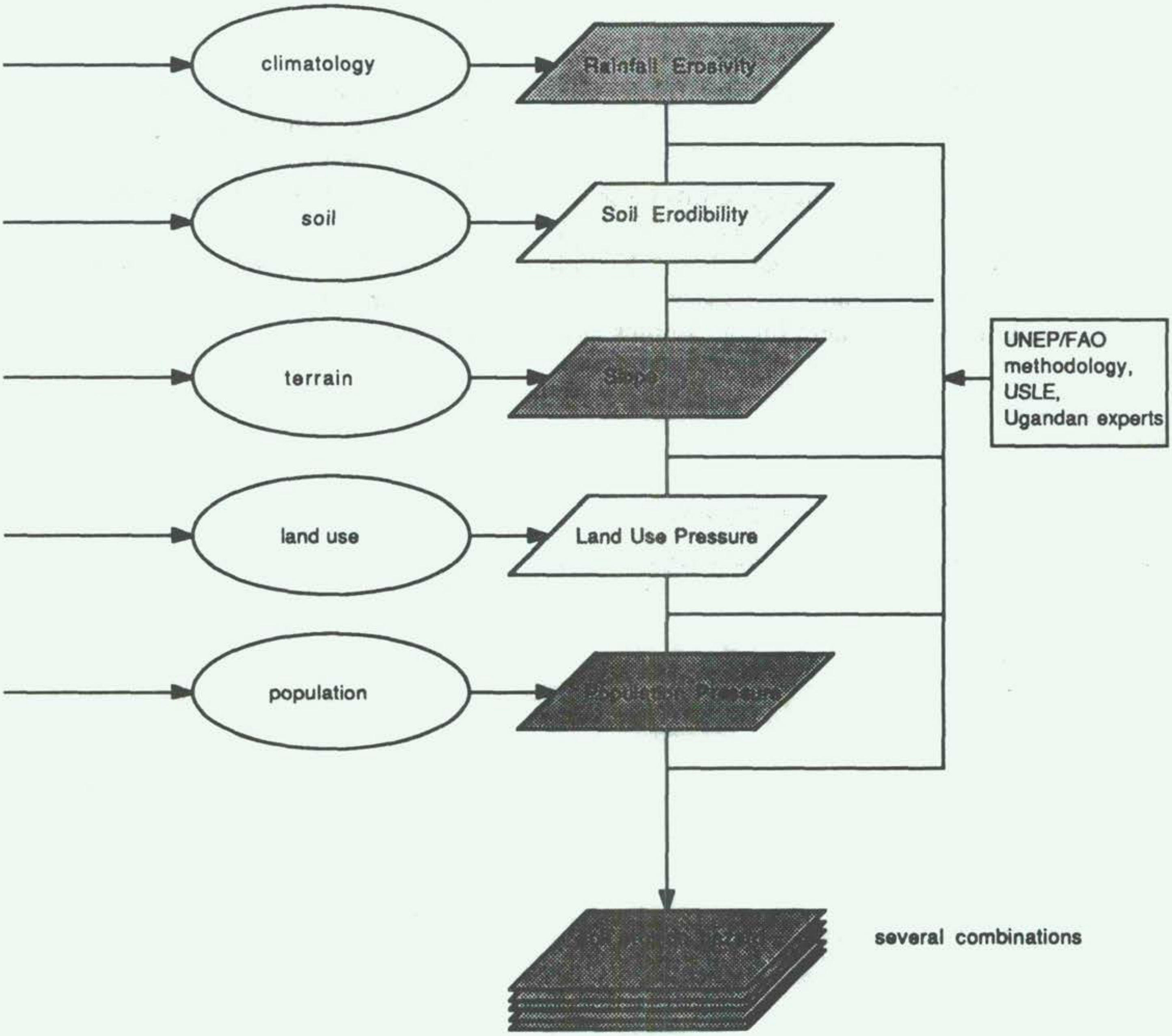
Rainfall erosivity	A simplification of Fournier´s Index was used, as described in the FAO Methodology (FAO 1979): $f[\sum_{1}^{12}(p^2 / P)]$ (p: monthly precipitation, P: annual precipitation) In Uganda, the Index map correlates very highly with the map of annual precipitation: it can be argued whether, in this case, the calculation of that particular index is useful.
Soil erodibility	This index is based on soil texture, as described in the FAO methodology (FAO 1979). Where available, organic matter of topsoil and water holding capacity were also included.
Slope	Slope was calculated from a digital terrain model

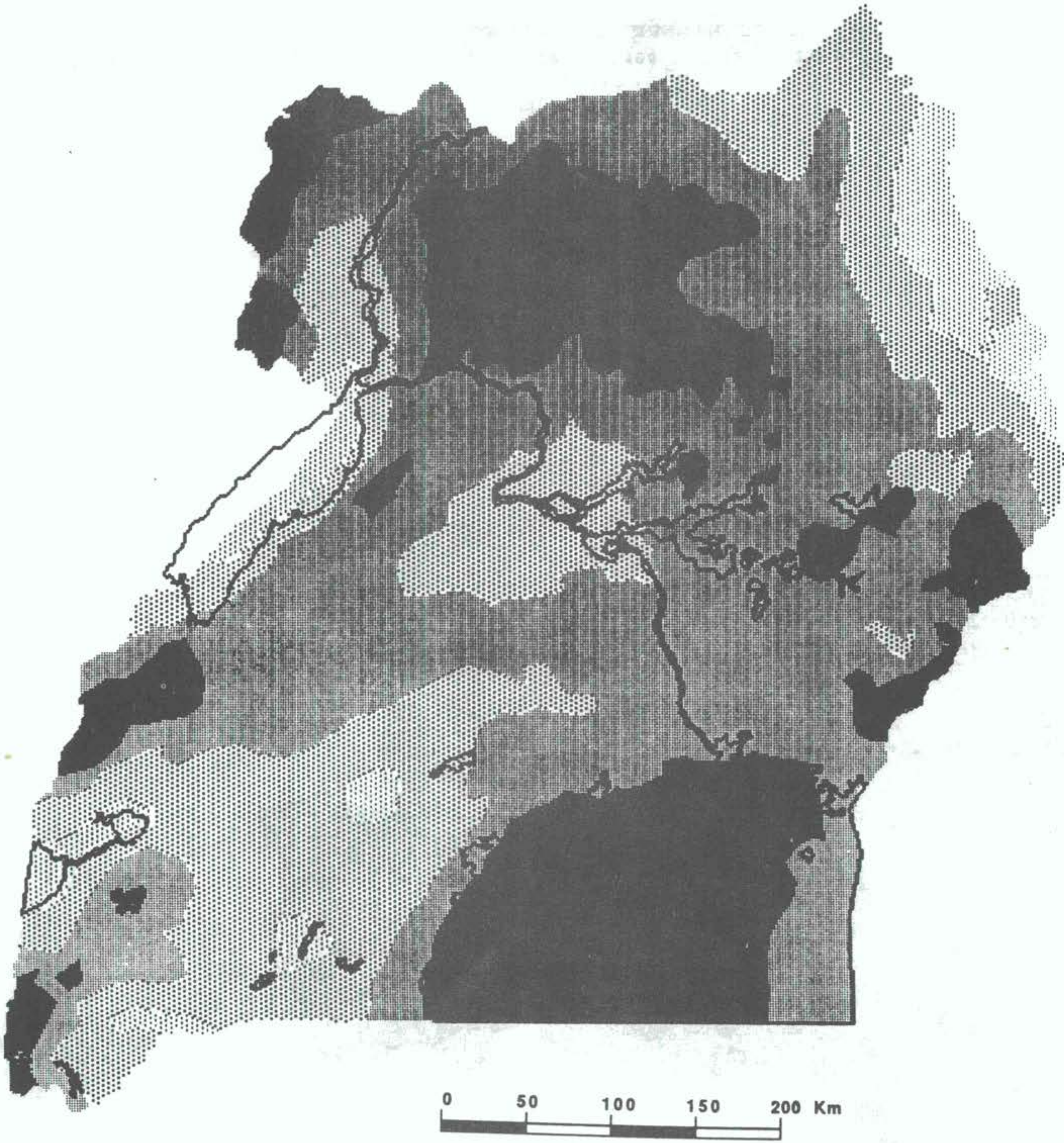
derived from a contour map. At a scale of 1:1.5 million, details in the terrain are lost; this map can therefore only point out where problem areas may lay.

Land Use Pressure	The classification of this map follows the land use map of the Atlas of Uganda. The main influencing factors are the type of cropping (annual or perennial), grazing and protected areas.
Population Pressure	Population density by subcounties (census 1969) was digitized and converted to density contours. The contour map has the advantage of continuity; there are no sharp changes at political boundaries.

The soil erosion hazard map is a combination of the single factor maps listed above. This map will be used in the field to verify the model, and also directs attention to where further studies have to be conducted.

Soil Erosion





SOIL EROSION

Rainfall erosivity
(modified Fournier-Index)

monthly and annual
precipitation from
Atlas of Uganda 1967

below 100

100 - 200

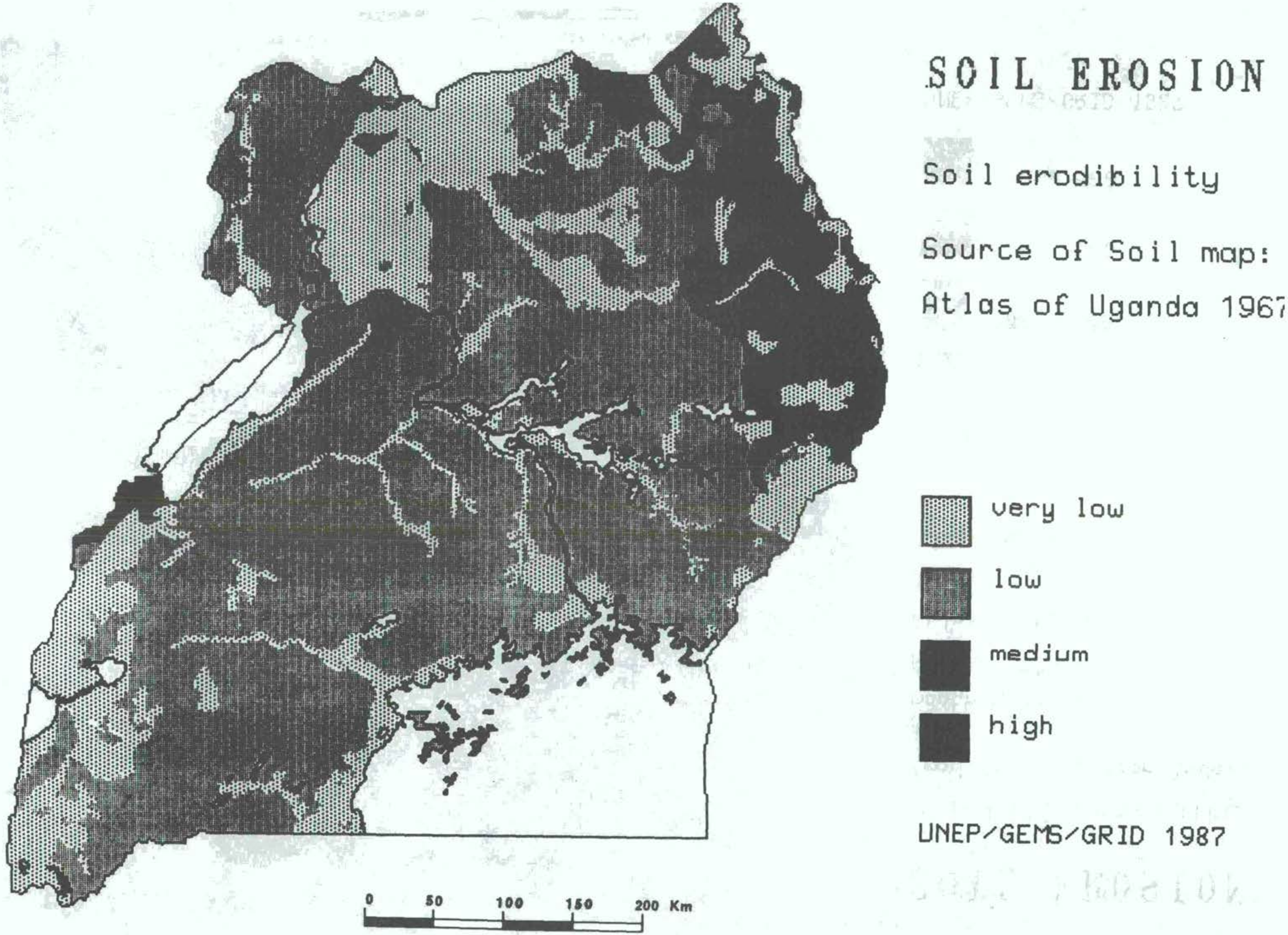
200 - 300

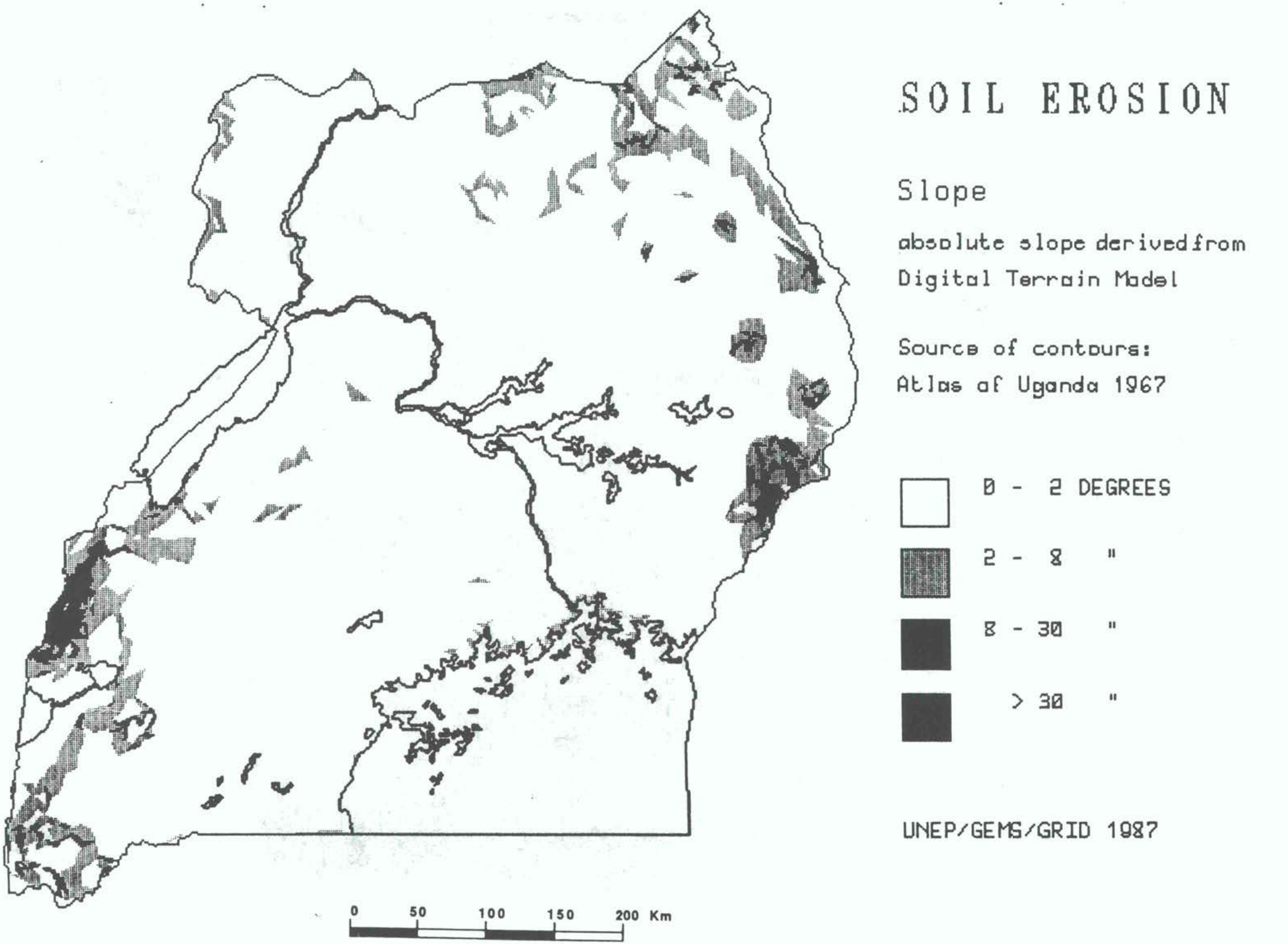
300 - 400

400 - 500

above 500

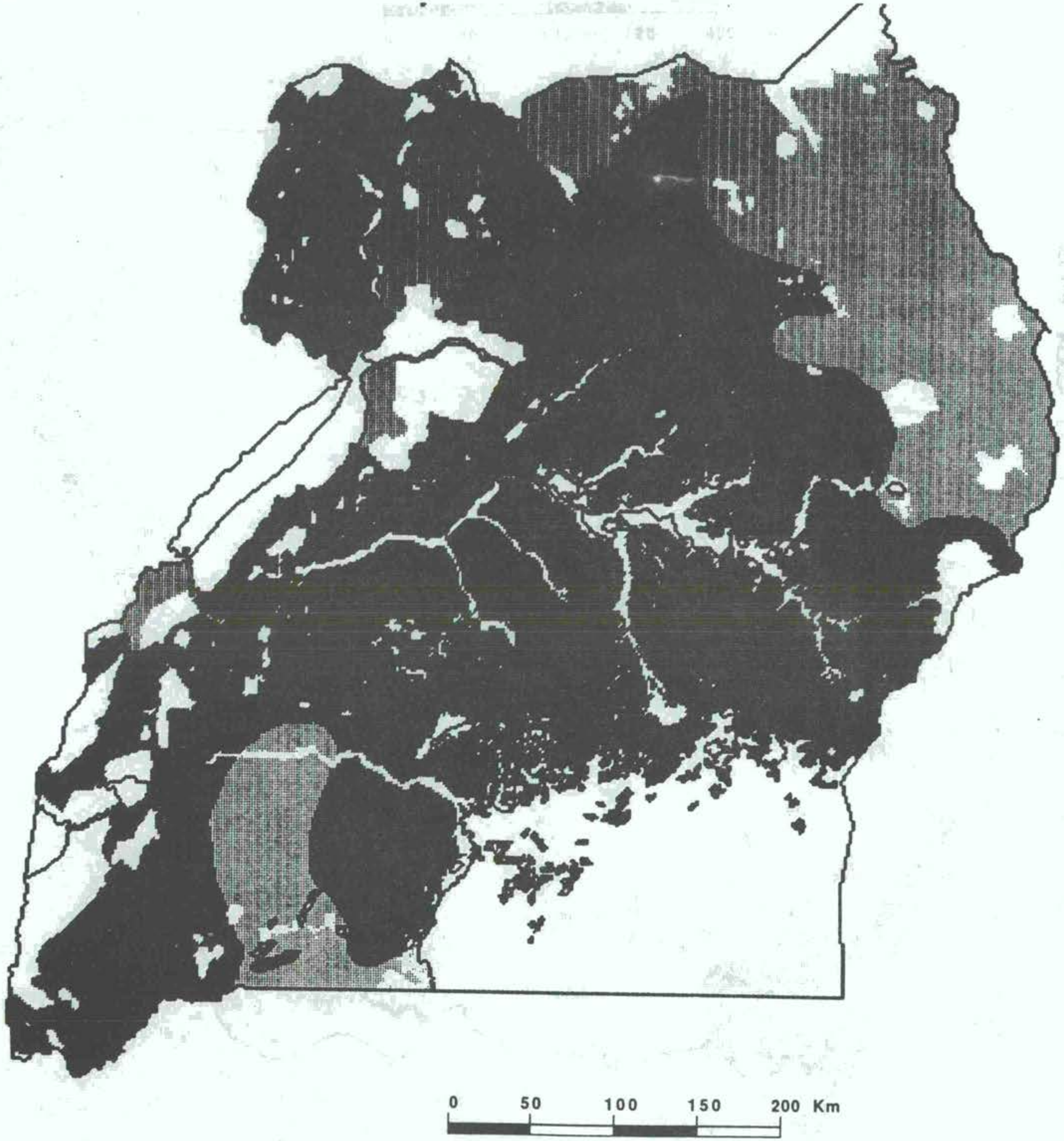
UNEP/GEMS/GRID 1987


SOIL EROSION
Soil erodibility
Source of Soil map:
Atlas of Uganda 1967
very low
low
medium
high
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km


SOIL EROSION
Slope
absolute slope derived from
Digital Terrain Model
Source of contours:
Atlas of Uganda 1967
0 - 2 DEGREES
2 - 8 "
8 - 30 "
> 30 "
UNEP/GEMS/GRID 1987
0 50 100 150 200 Km

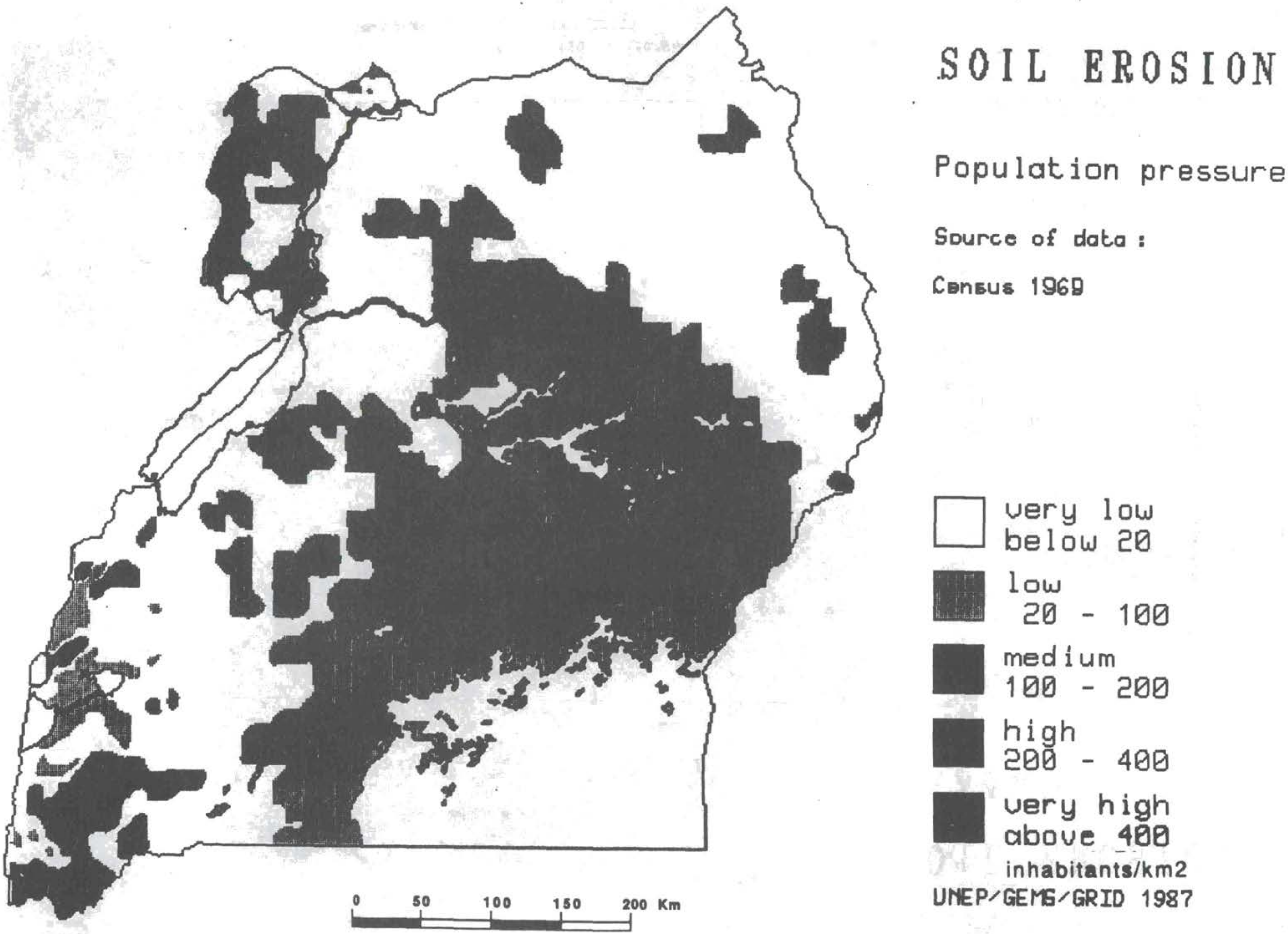
SOIL EROSION

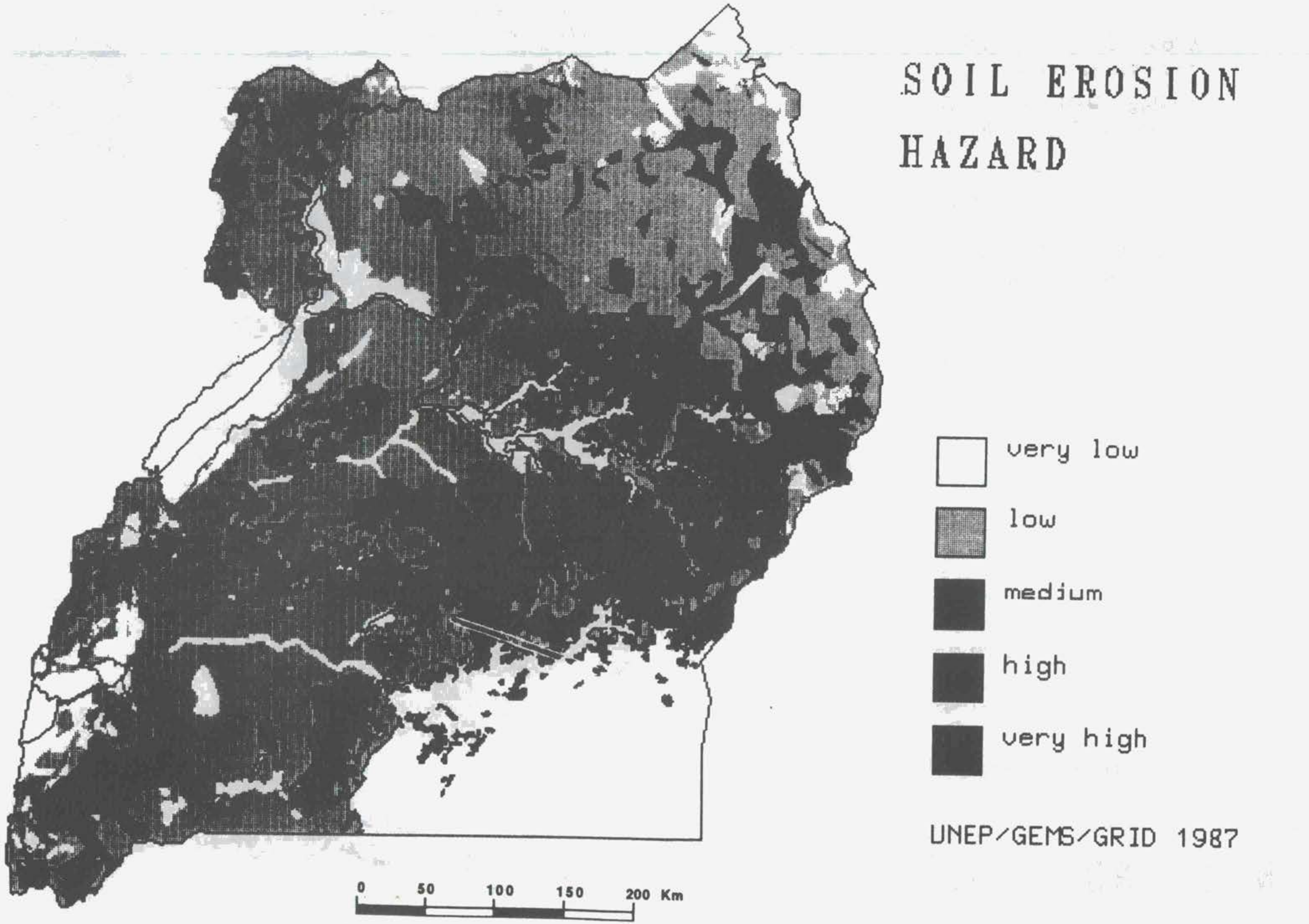
Land Use Pressure



UNEP/GEMS/GRID 1987

SOIL EROSION




SOIL EROSION
HAZARD
very low
low
medium
high
very high
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km

Agro-Ecological Modeling

Geographic Information Systems offer a great potential for Agro-Ecological modeling. For the Uganda case study , models previously applied in Kenya were automated. They are described in the **Agro-Climatic Zone Map of Kenya** (Kenya Soil Survey 1982) and in the **Farm Management Handbook of Kenya** (Jätzold and Schmidt 1983).

Agro-Ecological Zone Map

The purpose of an agro-ecological zone map is to show what areas are climatologically suitable for particular crops. Such maps can help to guide the work of planners and farmers.
Inputs for this map are temperature and moisture availability zones.
The temperature zones are derived from topography:
T mean (in °C) = 30.2-0.00650 h (meters)
Moisture Availability results from the interaction of annual rainfall and annual evaporation (Source: Atlas of Uganda 1967):
moisture availability = annual rainfall / annual evaporation
Six temperature zones and seven moisture availability zones can be distinguished and can be combined (after some merging) to produce 34 agro-ecological zones as shown in the legend to the map.

Ecological Suitability

Crop- specific data (temperature and moisture requirements) merged with the agro-ecological zone map result in ecological suitability maps for single crops. The example shows Arabica coffee, which grows best in altitudes between 1500 and 2100 meters and requires 1200 to 1800 mm of annual rainfall.

Soil Suitability

Soil requirements of particular crops have been combined with the soil map, resulting in soil suitability maps. Arabica coffee needs medium textured, deep soil, free draining, with reasonable water retention capacity and a pH between 5.3 and 6.0.

Overall Suitability

This map is a result of combining ecological and soil suitability maps. According to the models applied, the best areas for growing Arabica coffee in Uganda are Mount Elgon, Bushenyi and Mbarara District, Ruwenzori-Fort Portal and southern West Nile.

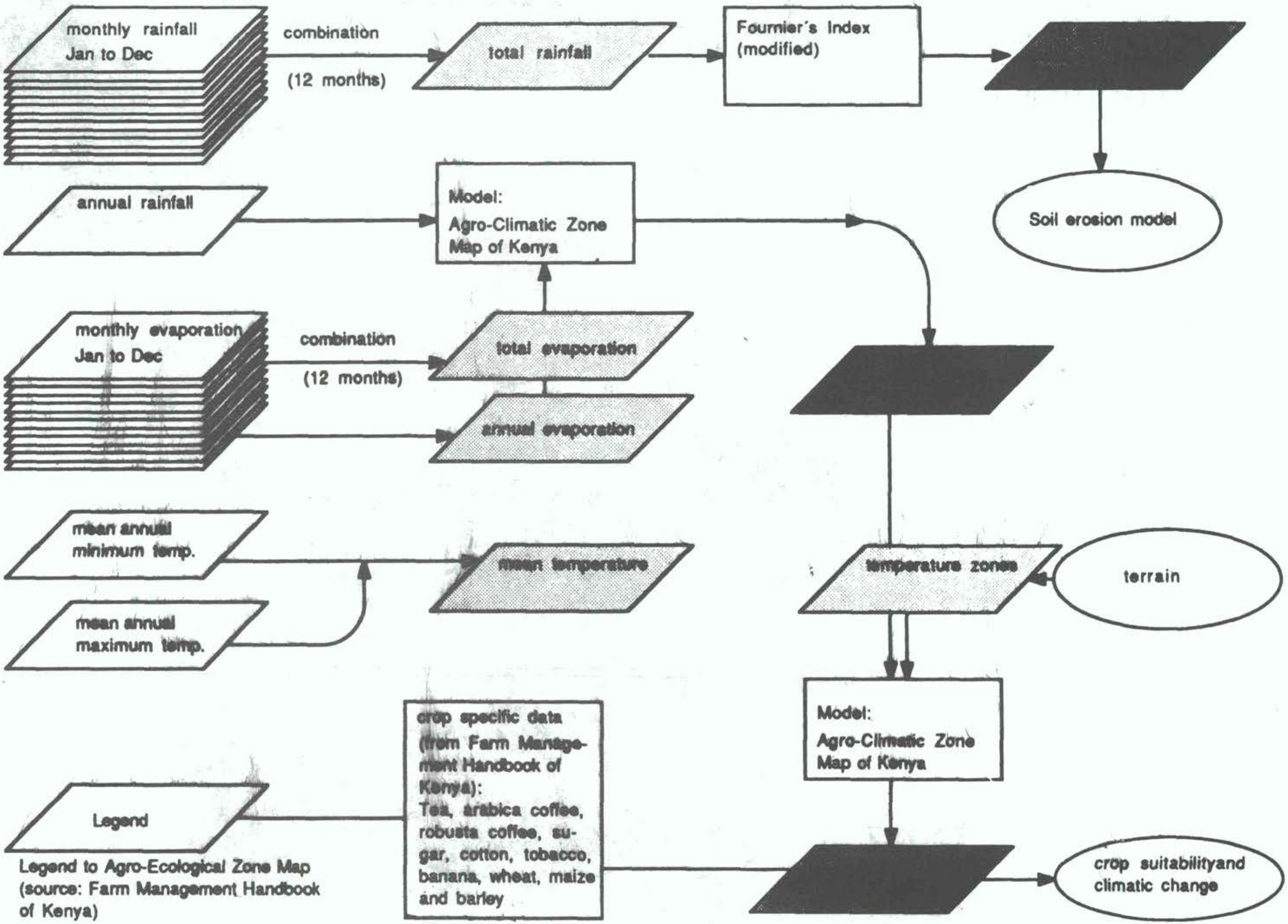
Competition of Cash Crops

The overall suitability maps for six major cash crops (tea, arabica coffee, robusta coffee, sugar, cotton and tobacco) were combined into a map showing competition between these crops. The areas with most competition are the belt around Lake Victoria, Gulu-Masindi, West Nile and Fort Portal-Mubende.

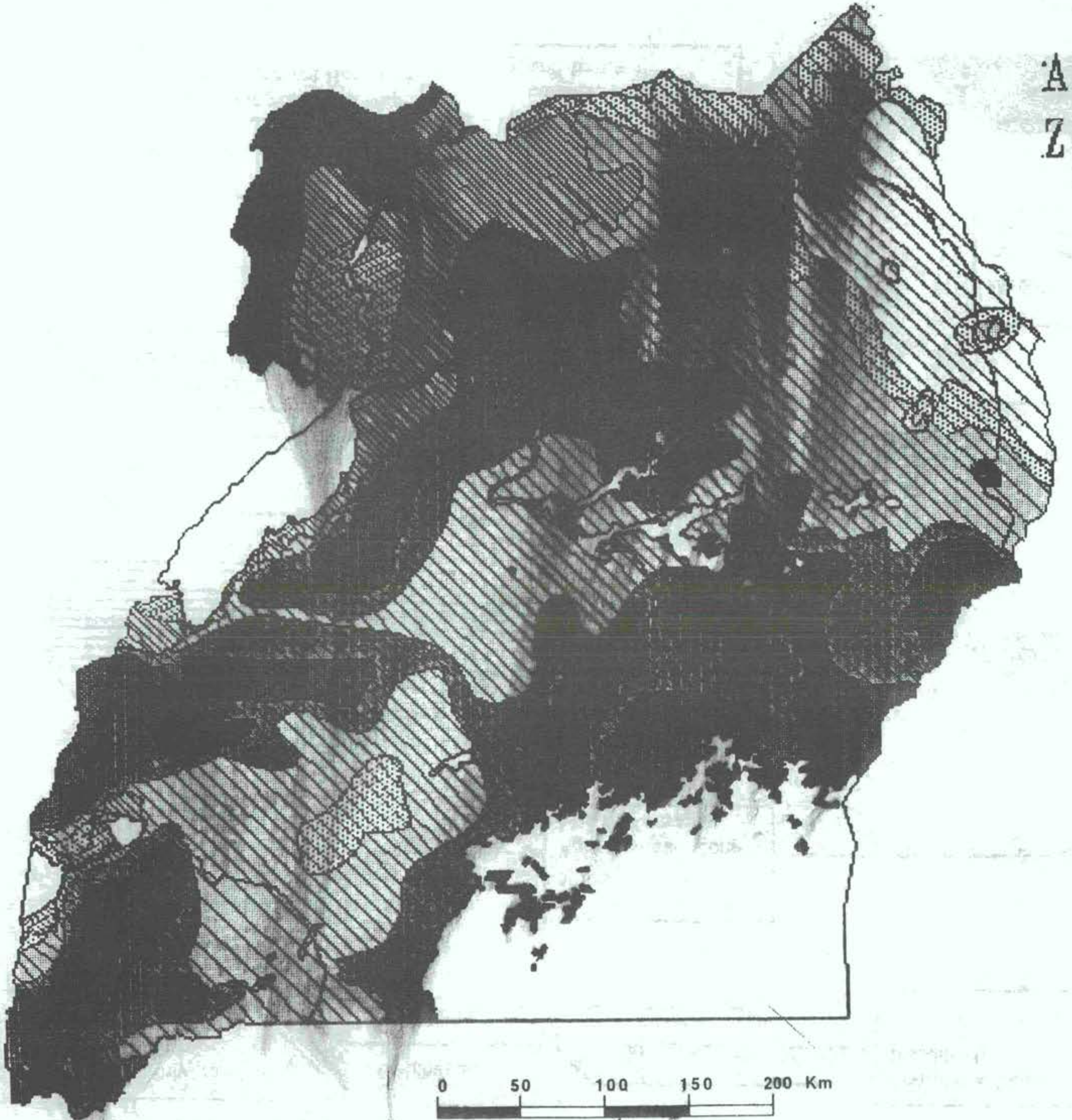
Climatic Change

The use of GIS also allows simulation of climatic change. According to experts a warming of the atmosphere may well occur over the next few decades. In this example an overall change of 2 ° C has been assumed. The potential impact of such a change on the ecological suitability for robusta coffee - Uganda´s most important cash crop - is very dramatic.

Agro-Ecology

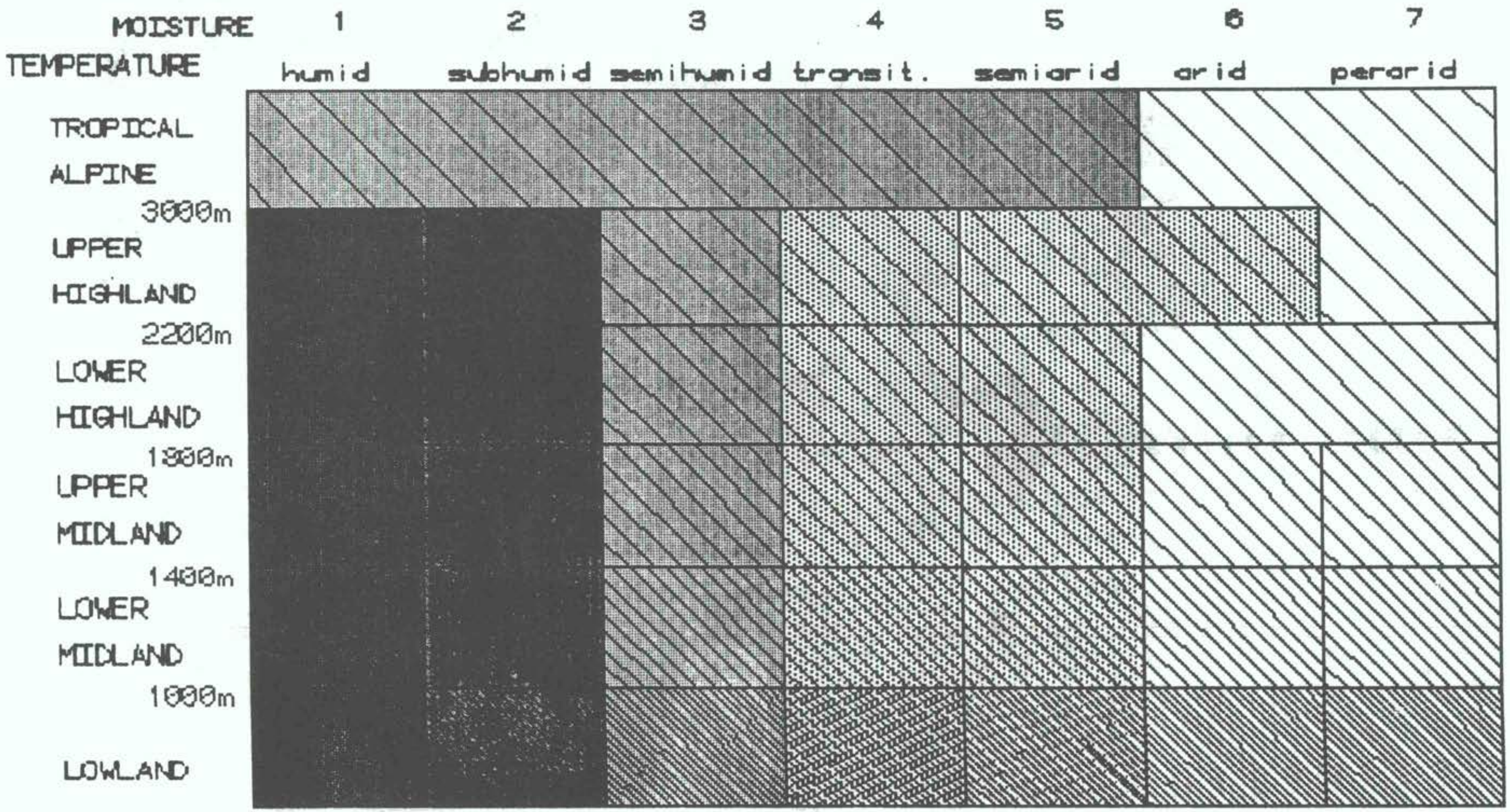


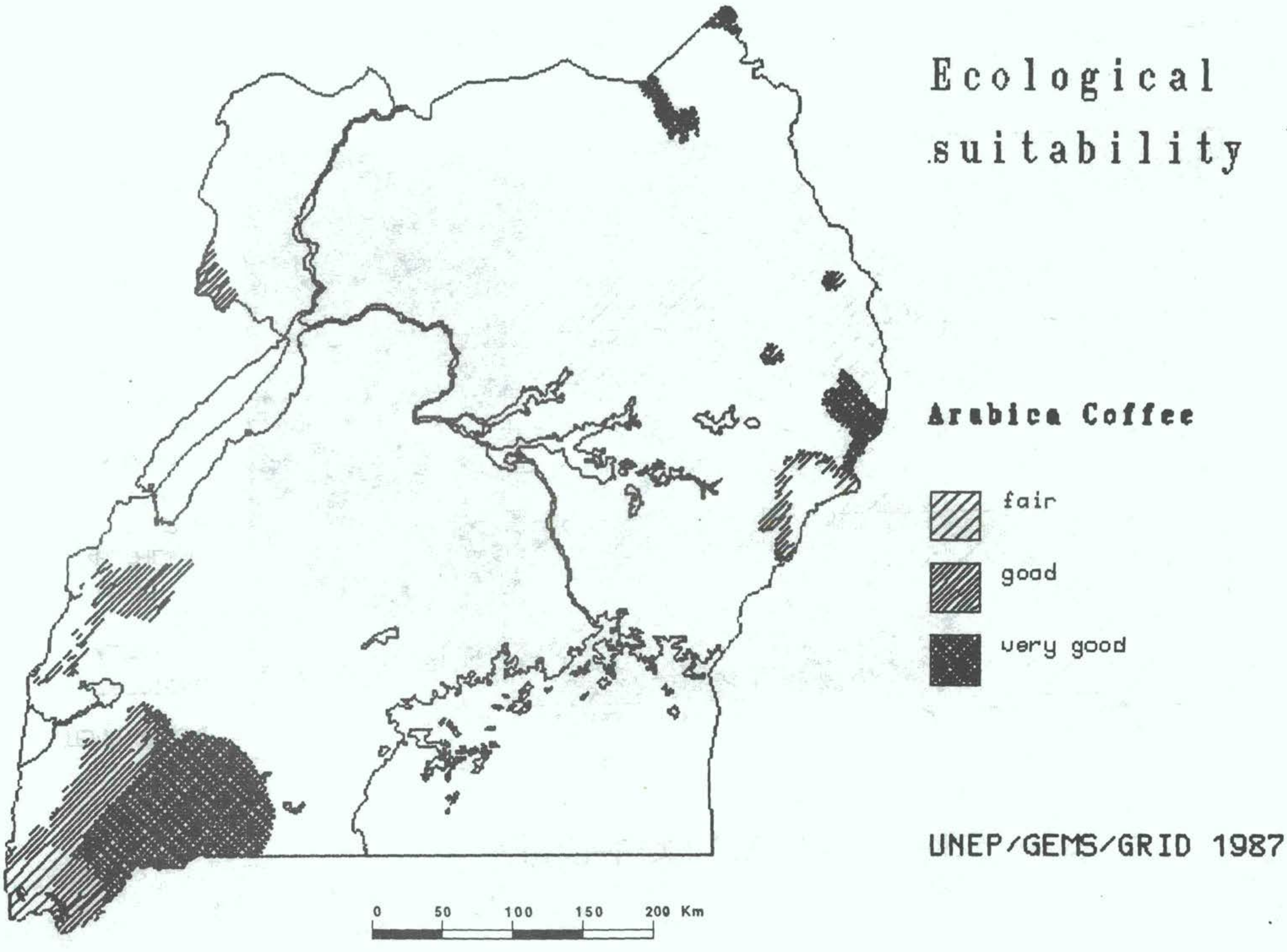
AGRO-ECOLOGICAL ZONES

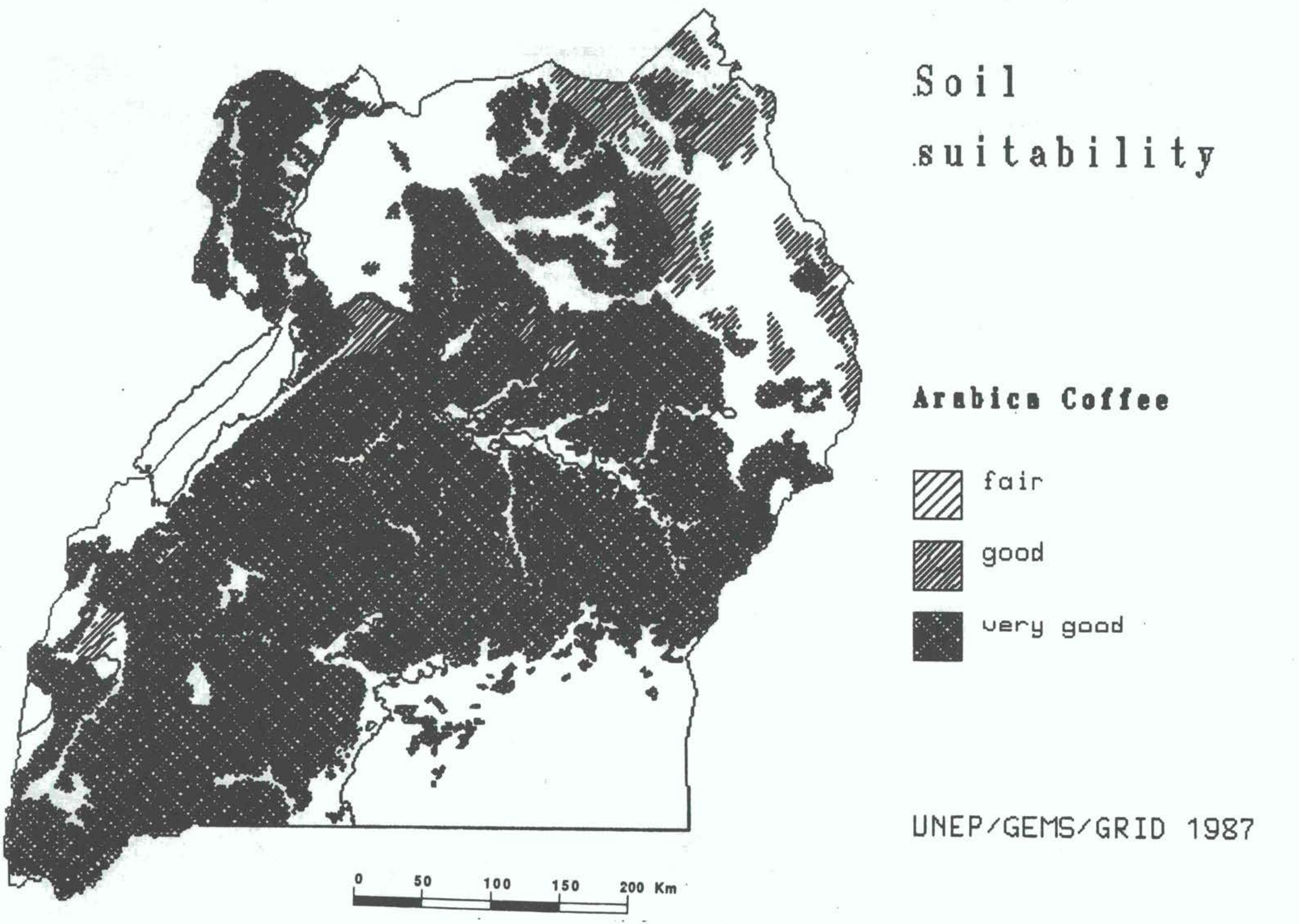


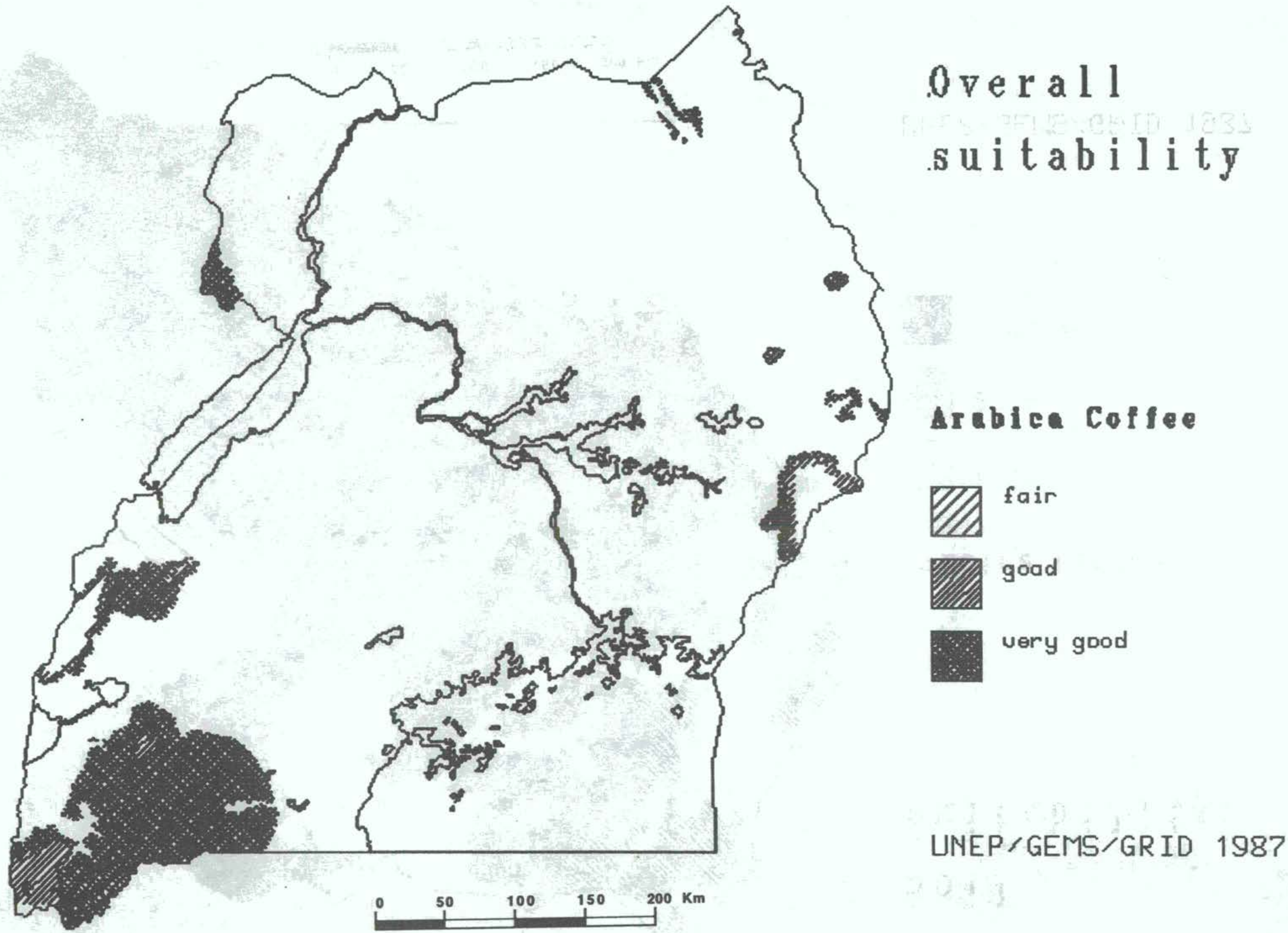
UNEP/GEMS/GRID 1987

AGRO-ECOLOGICAL ZONES

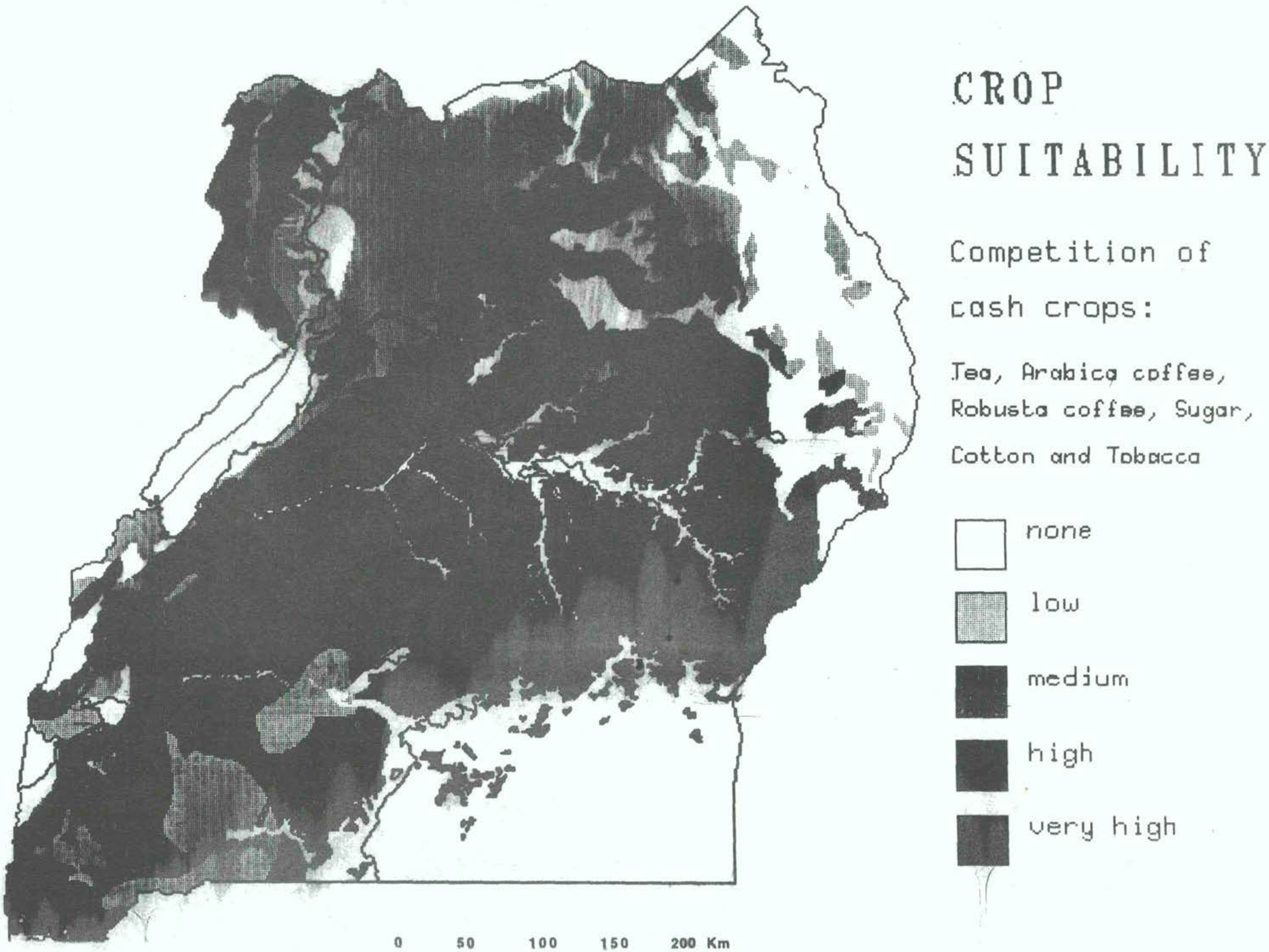


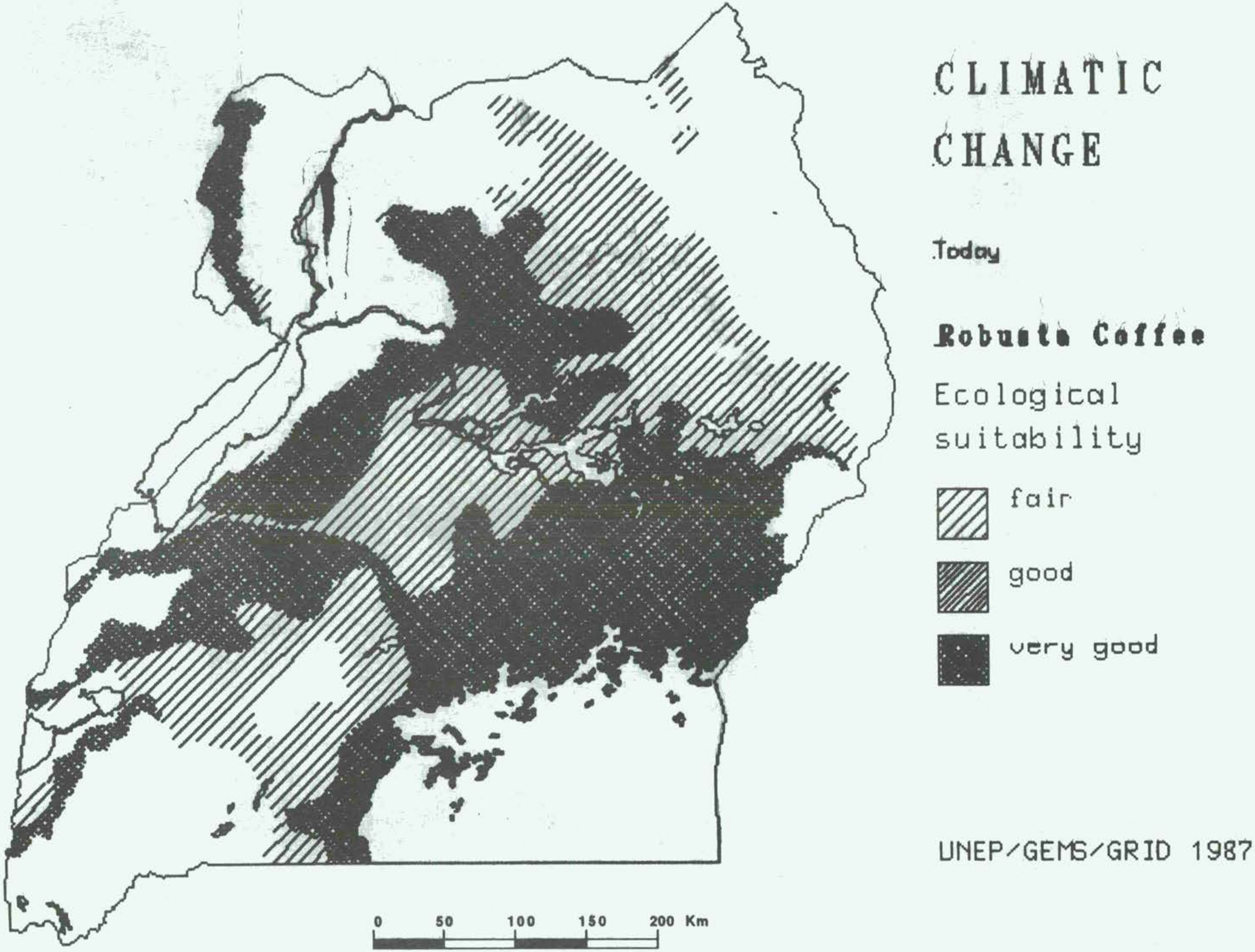

Ecological
suitability
Arabica Coffee
fair
good
very good
UNEP/GEMS/GRID 1987
0 50 100 150 200 Km

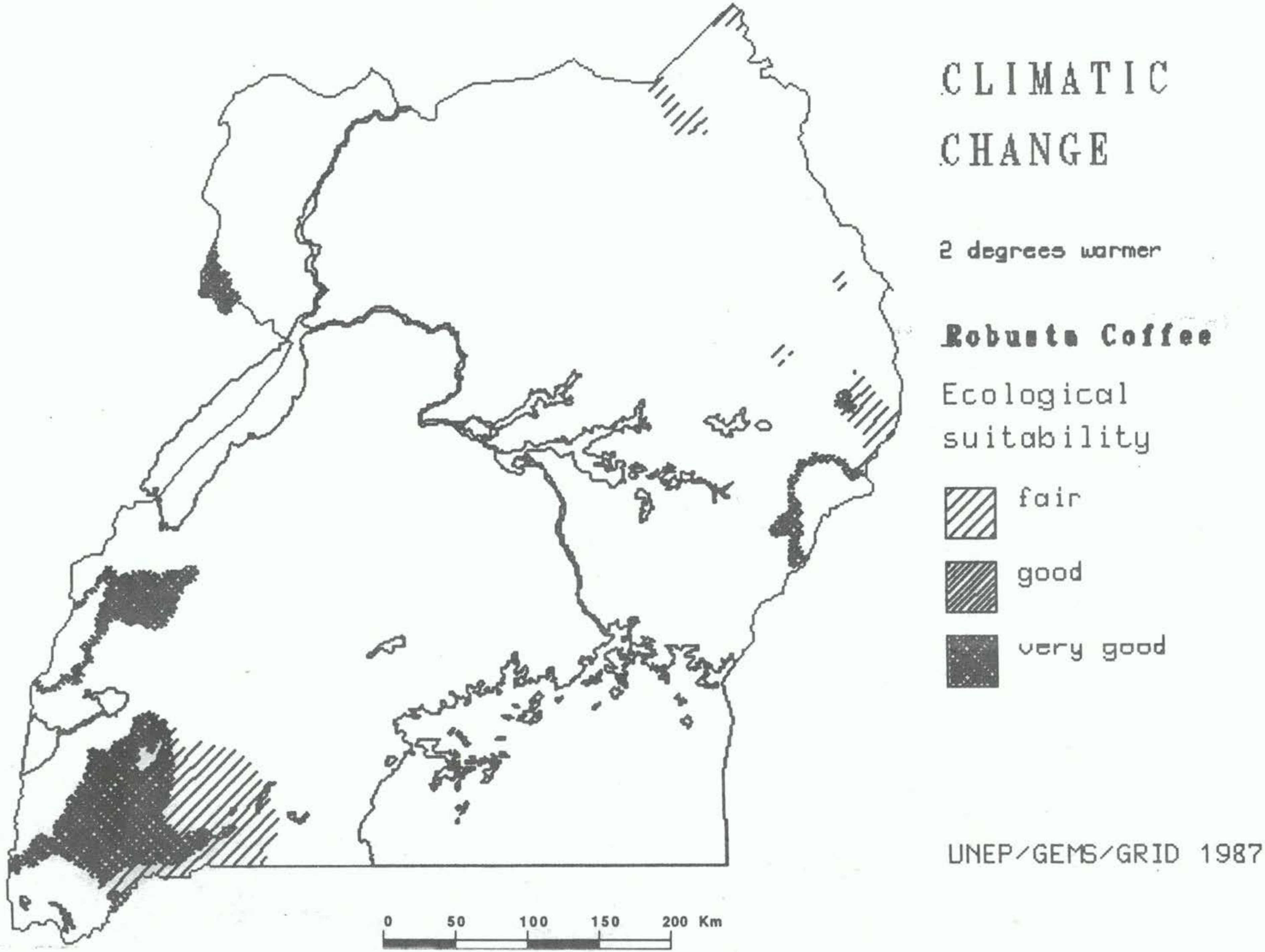

Soil
suitability
Arabica Coffee
fair
good
very good
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km



Overall
suitability
Arabica Coffee
fair
good
very good
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km

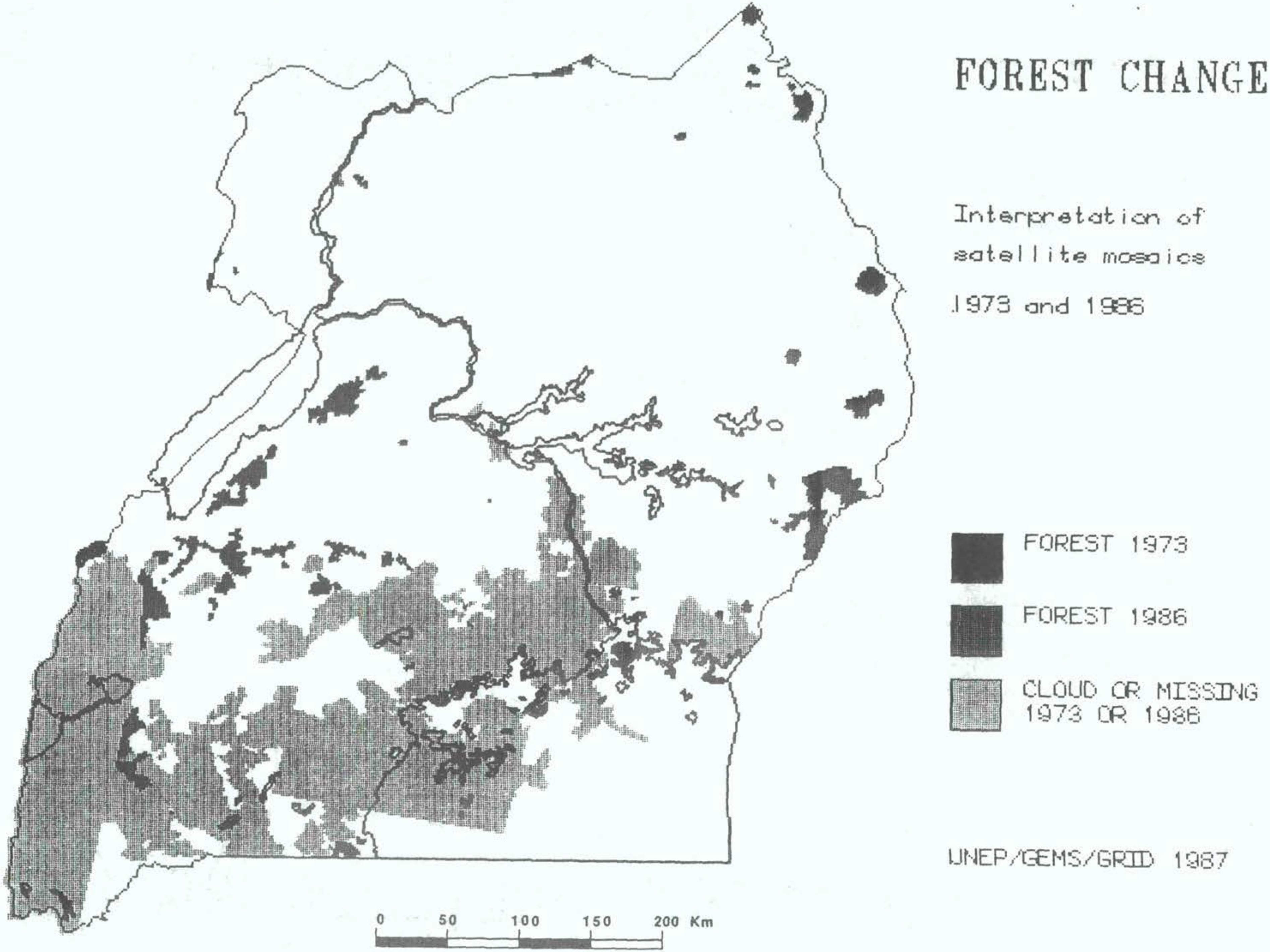

CROP
SUITABILITY
Competition of
cash crops:
Tea, Arabica coffee,
Robusta coffee, Sugar,
Cotton and Tobacco
none
low
medium
high
very high
0 50 100 150 200 Km


CLIMATIC
CHANGE
Today
Robusta Coffee
Ecological
suitability
fair
good
very good
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km

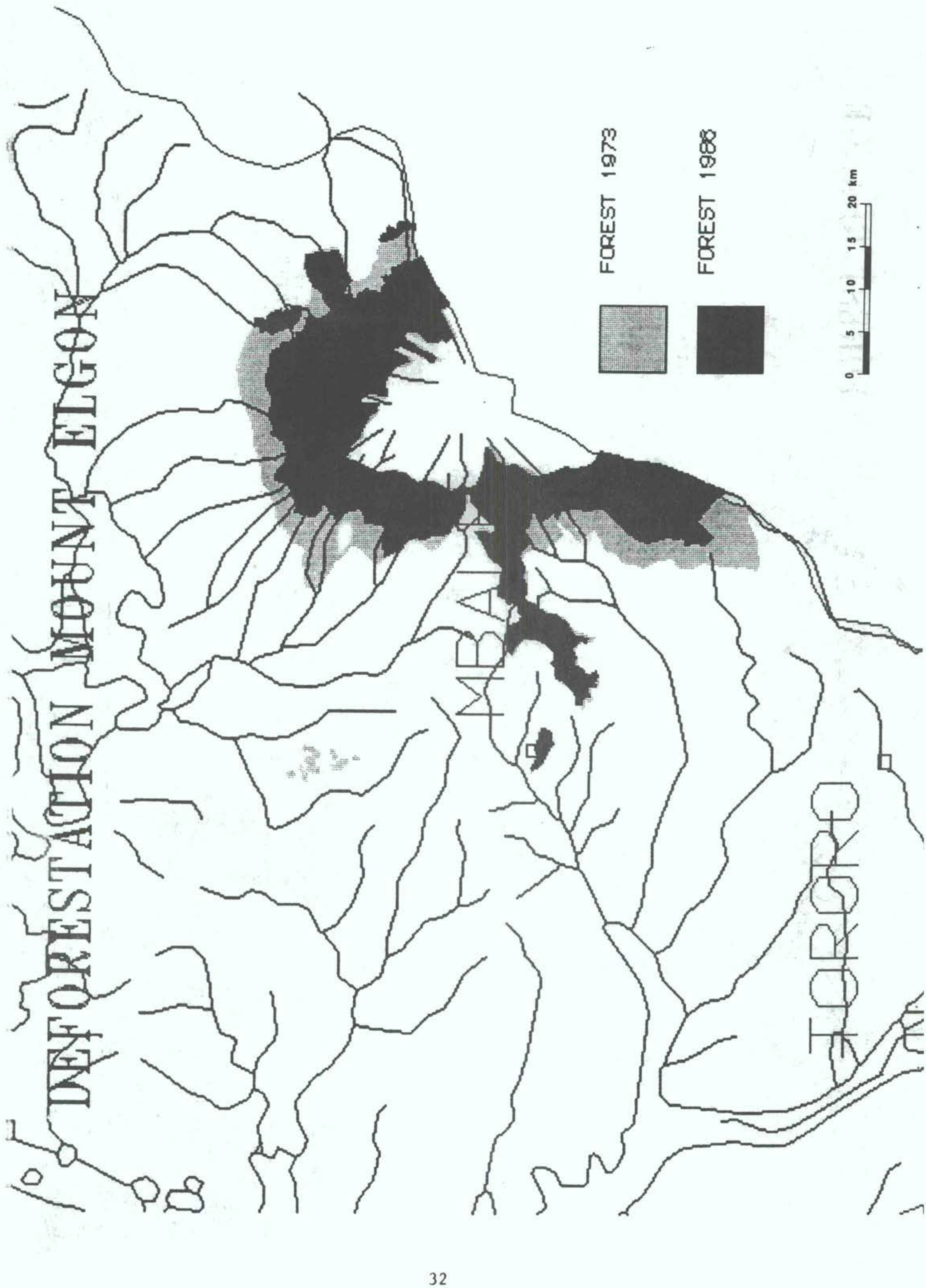

CLIMATIC
CHANGE
2 degrees warmer
Robusta Coffee
Ecological
suitability
fair
good
very good
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km

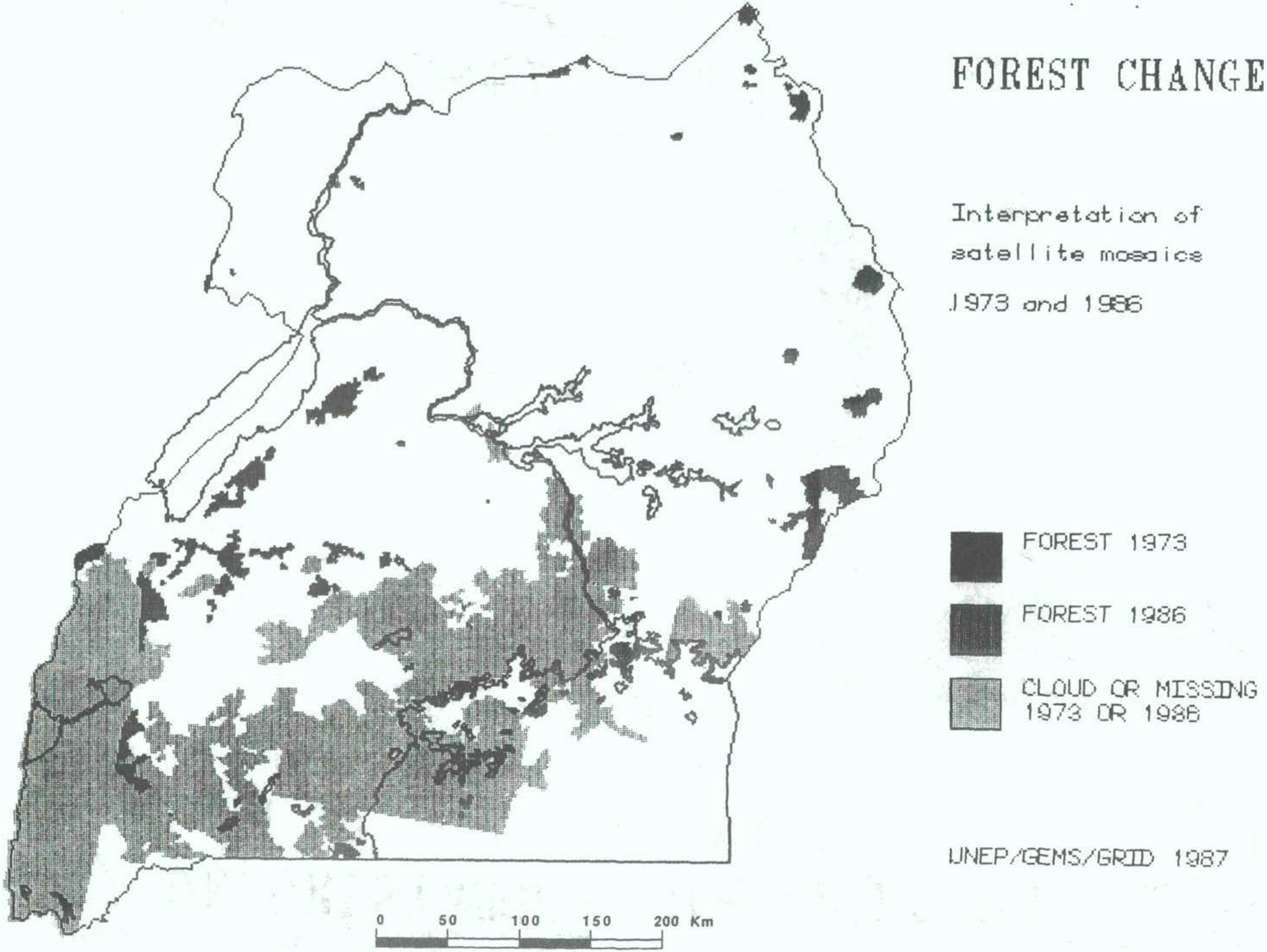
Forest Change

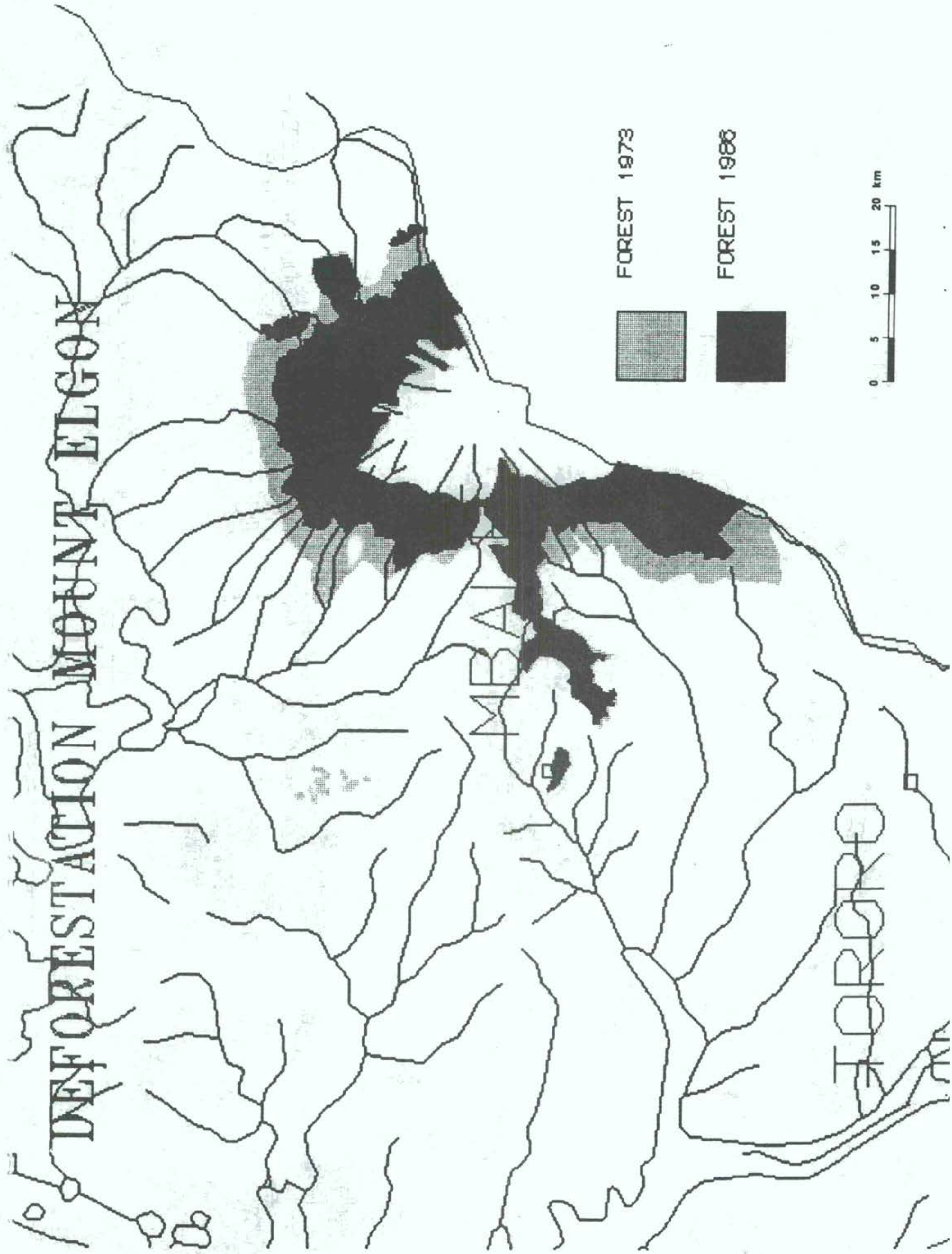
An Ugandan team of experts interpreted two satellite mosaics, one from 1973 the other from 1986. The comparison of the two stages allows the detection of changes in forest cover. The map for Uganda as a whole has limitations, because due to cloud cover or missing imagery important areas in the south could not be compared.
Zooming in on Mount Elgon however, reveals a dramatic decline of the forest cover in only 13 years. Areas like this should be subject of further studies.



FOREST CHANGE
Interpretation of
satellite mosaics
1973 and 1986
FOREST 1973
FOREST 1986
CLOUD OR MISSING
1973 OR 1986
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km


DEFORESTATION MOUNT ELGON
MBALE
TORORO
FOREST 1973
FOREST 1988
0 5 10 15 20 km


FOREST CHANGE
Interpretation of
satellite mosaics
1973 and 1986
FOREST 1973
FOREST 1986
CLOUD OR MISSING
1973 OR 1986
UNEP/GEMS/GRID 1987
0
50
100
150
200 Km


DEFORESTATION MOUNT ELGON
FOREST 1973
FOREST 1988
0 5 10 15 20 km
MBALE
TORORO

Population Density

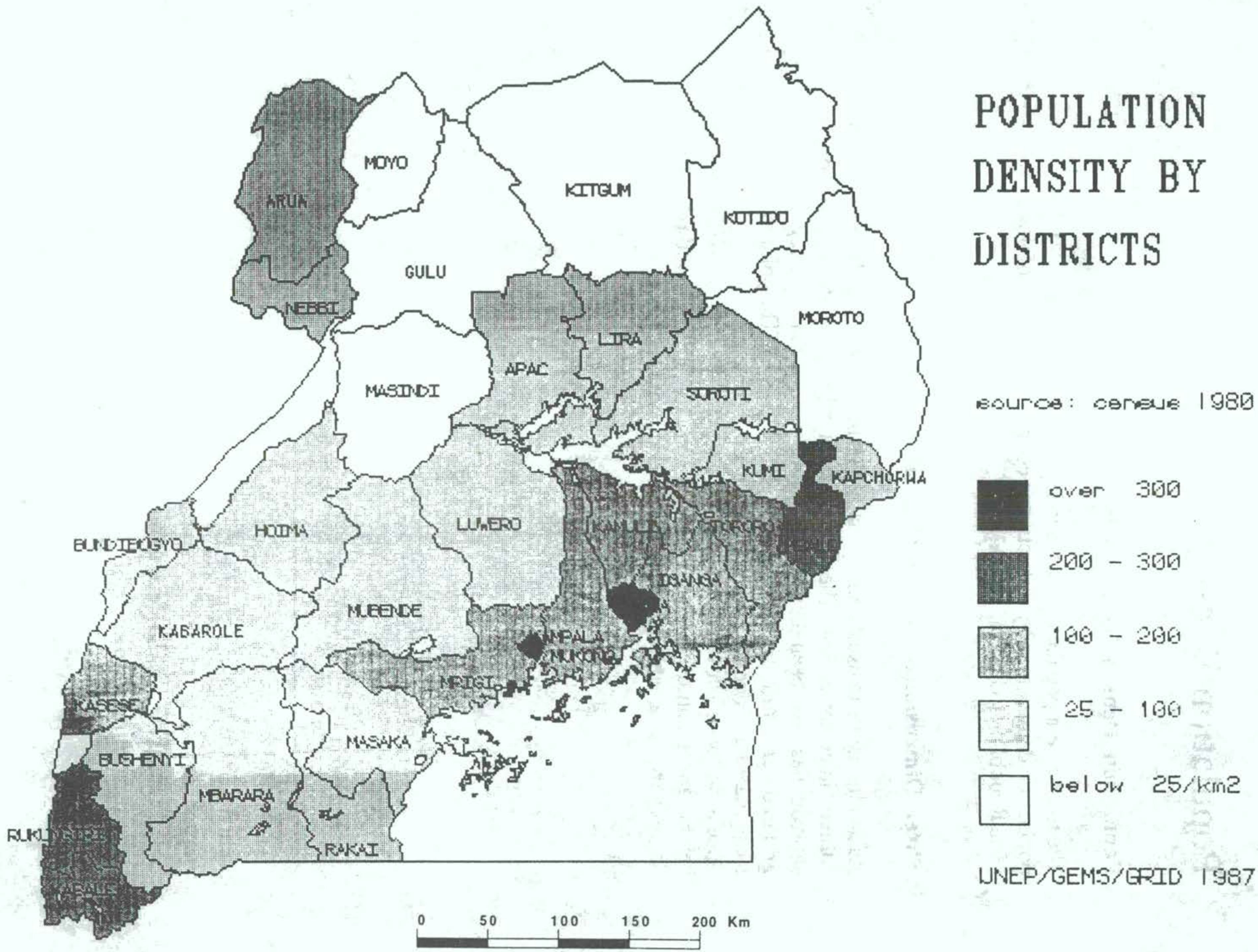
Population Density by Districts

The most recent population census in Uganda took place in 1980. The population density map by districts was compiled from data of this census (The Republic of Uganda, 1982).

Three Dimensional View of Population Density

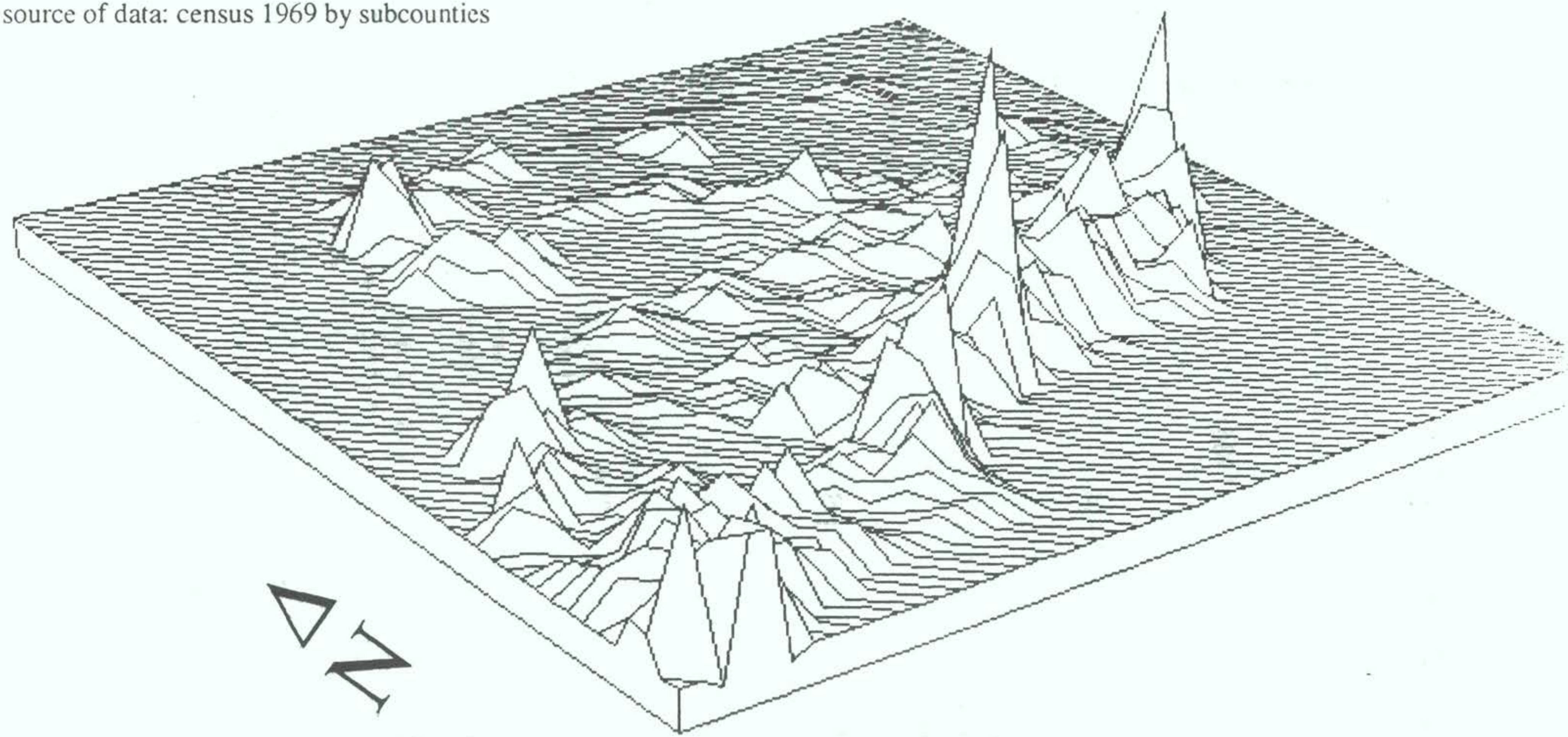
As an alternative to usual density maps, this map shows population density as a three dimensional view. The original input map - population density by sub-counties - has been digitized. This map was overlaid by a regular point grid in order to calculate densities for point locations. The point map was triangulated and density contours then interpolated.
Special software allows the viewing of continuous surfaces from different heights and azimuths. In the map shown here, Uganda is viewed from 40 degress above the surface.

POPULATION DENSITY BY DISTRICTS



Population Density
Three Dimensional View from Southwest

source of data: census 1969 by subcounties



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Woodhead, T. (1970) A Classification of East African Rangeland II. The Water Balance as a Guide to Site Potential. in: Journal of Applied Ecology 7: 647-652.

Zachar, D. (1982) Soil Erosion. Elsevier, Amsterdam, 547 pp.

Uganda Case Study: ARC/INFO Datasets

("Atlas" = Atlas of Uganda; TIN = Triangular Irregular Network datastructure)

TOPOGRAPHY

Basic Datasets

Dataset Attributes	Source	Scale
Political Boundary	Atlas 1967	1:1.5m
Latitude/Longitude Grid	Tabular Data	
Relief Contours altitude in feet (1000 ft intervals)	Atlas 1967	1:1.5m
Hydrology: Lakes water/land	Atlas 1967	1:1.5m
Hydrology: Rivers stream order	Atlas 1967	1:1.5m
Hydrology: Watersheds classification Atlas	Atlas 1967	1:1.5m
Geology: Lithology classification Atlas	Atlas 1967	1:1.5m
Geology: Faults major/minor	Atlas 1967	1:1.5m

Geomorphology classification atlas	Atlas 1967	1:1.5m

Derived Datasets

Dataset Attributes	Source/Model
Digital Terrain Model (TIN)	Derived from Relief Contours
Metric Relief Contours altitude in meters (200m intervals)	Contouring of TIN Dataset
Slope slope class water/land	Derived from TIN Datastructure

Climatology

Basic Datasets

Dataset Attributes	Source	Scale
Mean Annual Rainfall rainfall in mm (polygon and line)	Atlas 1967	1:1.5m
Mean Monthly Rainfall **January to December (12 datasets)** rainfall in mm (polygon and line)	Atlas 1967	1:6m

Mean Monthly Evaporation **January to December (12 datasets)** evaporation in mm (polygon and line)	Atlas 1967	1:6m
Number of Days of Rain	Atlas 1967	1:3m
Mean Annual Minimum Temperature temperature code (polygon and line)	Atlas 1967	1:3m
Mean Annual Maximum Temperature temperature code (polygon and line)	Atlas 1967	1:3m
Mean Annual Windspeed windspeed in mm/s	Point Data (FAO)	
Mean Annual Sunshine sunshine in % of potential	Point Data (FAO)	

Derivate Datasets

Dataset Attributes	Source/Model
Rainfall Erosivity Fournier´s Index	Calculated from annual and 12 monthly datasets
Mean Annual Evaporation annual total in mm (polygon and line) 12 monthly means (polygon and line)	Combination of 12 monthly datasets
Sunshine (TIN Datastructure)	Interpolated from Point Data
Sunshine (Polygons) annual mean in %	Contouring of TIN Datastructure
Windspeed (TIN Datastructure)	Interpolated from Point Data

Windspeed (Polygons) windspeed class	Contouring of TIN Datastructure
Mean Annual Temperature annual temperature in °C mean minimum temperature in °C mean maximum temperature in °C	Combination of Mean Minimum and Mean Maximum Temperature
Moisture Availability moisture availability code	Combination of Annual Rainfall and Annual Evaporation
Agro-Ecological Zones moisture availability temperature area in km2 ecological suitability code for tea, arabica coffee, robusta coffee, sugar, cotton, tobacco, banana, barley, wheat, maize	Combination of Moisture Availability and Temperature Zones
Climatic Change: + 2° Celsius see Agro-Ecological zones	Modification of Agro-Ecological Zones
Climatic Change: - 2° Celsius see Agro-Ecological zones	Modification of Agro-Ecological Zones
Climatic Change: 200mm less Rainfall see Agro-Ecological zones	Modification of Agro-Ecological Zones
Climatic Change: - 2° Celsius and 200mm less Rainfall see Agro-Ecological zones	Modification of Agro-Ecological Zones
Number of Growing Days growing days	Modification of Agro-Ecological Zones

Land Cover

Basic Datasets

Dataset Attributes	Source	Scale
Soils classification Atlas FAO-Code (number and text) soil productivity soil erodibility	Atlas 1964	1:1.5m
Land Use classification Atlas land use pressure (soil erosion model)	Atlas 1964	1:1.5m
Land Cover 1973 interpretation	Landsat Interpretation	1:500,000
Land Cover 1986 interpretation	Landsat Interpretation	1:500,000
Vegetation detailed classification (numbers and text) coarse classification	Map 1964	1:500,000
Seasonal Vegetation Burning classification	Remote Sensing 1971	1:3m
Sawmills	Atlas 1967	1:1.5m
Fuelwood Plantations	Atlas 1964	1:1.5m

Derived Datasets

Dataset Attributes	Source/Model
Forest Reserves classification	reclassified Land Use dataset
Overall Suitability of Crops soil moisture temperature ecological suitability code for tea, arabica coffee, robusta coffee, sugar, cotton, tobacco, banana, barley, wheat, maize soil suitability code for tea, arabica coffee, robusta coffee, sugar, cotton, tobacco, banana, barley, wheat, maize overall suitability code for tea, arabica coffee, robusta coffee, sugar, cotton, tobacco, banana, barley, wheat, maize	Combination of Agro-Ecological Zones and Soils
Competition of Cash Crops competition code	Derived from Overall Suitability dataset
Soil Erosion Hazard rainfall erosivity soil erodibility slope factor land use pressure population pressure overall erosion hazard	Combination of single factor maps

Population

Basic Datasets

Dataset Attributes	Source	Scale
Cattle Distribution	Atlas 1967	1:1.5m
Population Density by Subcounties population density subcounty-ID county-ID district-ID	Census map 1969	1:1.5m
Population Density by Counties population density annotation (district and county names)	Census map 1980	
Administrative subdivisions county-ID district-ID annotation (district and county names)	Map 1984	1:1.5m
Distribution of Electrical Power Supply	Atlas 1967	1:1.5m
Towns (Top 40) Annotation population 1969 population 1980 population Change 1969 - 1980	Map 1984	1:1.5m
Railroads	UNEP/FAO African Database	

Roads surface: tarmac or dirt	UNEP/FAO African Database

Derived Datasets

Dataset Attributes	Source/Model
Cattle Density (TIN Datastructure)	Interpolated from Point Data
Cattle Density (Contours) cattle density (line)	Contouring of TIN Datastructure
Cattle Density (Polygons) cattle density (polygon)	Point data resampled in grid cells
Population Density (TIN)	Interpoltated from Point Data derived from density map by Subcounties
Population Density (Polygons) population pressure (soil erosion model) water/land	Contouring of TIN datastructure, conversion to polygons
3 Dimensional Views of Population Density (9 datasets)	Derived from TIN Datastructure
Distance to Roads (10km) inside/outside	Buffer of Roads
Distance to Roads (20km) inside/outside	Buffer of Roads
Population of Towns 1969	Circles proportional to population 1969
Population of Towns 1980	Circles proportional to population 1980

Lake Level Simulation

Basic Datasets

Dataset Attributes	Source	Scale
Land/Water Boundary	topographic map 1962	1:250,000
Relief Contours altitude in feet (200 ft interval) metric conversion	topographic map 1962	1:250,000
Spot Heights on Land altitude in feet and meters	topographic map 1962	1:250,000
Land Use land use	topographic map 1962	1:250,000
Infrastructure Line road classification	topographic map 1962	1:250,000
Infrastructure Point human settlements	topographic map 1962	1:250,000

Derived Datasets

Dataset Attributes	Source/Model
Lake Surface (Point Data) altitude in feet and meters	Generated from Tabular Data
TIN Datastructure of Relief	Derived from Contours and Points
Interpolated Relief Contours altitude in meters (10m interval)	Contouring of TIN Datastructure
Slope Triangles shading factor	Derived from TIN Datastructure
Lake Level 1150 m above sea level **Lake Level 1160** m above sea level **Lake Level 1170** m above sea level **Lake Level 1180** m above sea level **Lake Level 1190** m above sea level **Lake Level 1200** m above sea level	Derived from Interpolated Relief Contours
Three Dimensional View	Derived from TIN Datastructure
Loss: Land Use loss at every 10m lake level rise total loss after each rise	Combination of Land Use with different Lake Levels
Loss: Infrastructure (Line) see Loss: Land Use	Combination of Infrastructure with different Lake Levels
Loss: Infrastructure (Point) see Loss: Land Use	Combination of Infrastructure with different Lake Levels