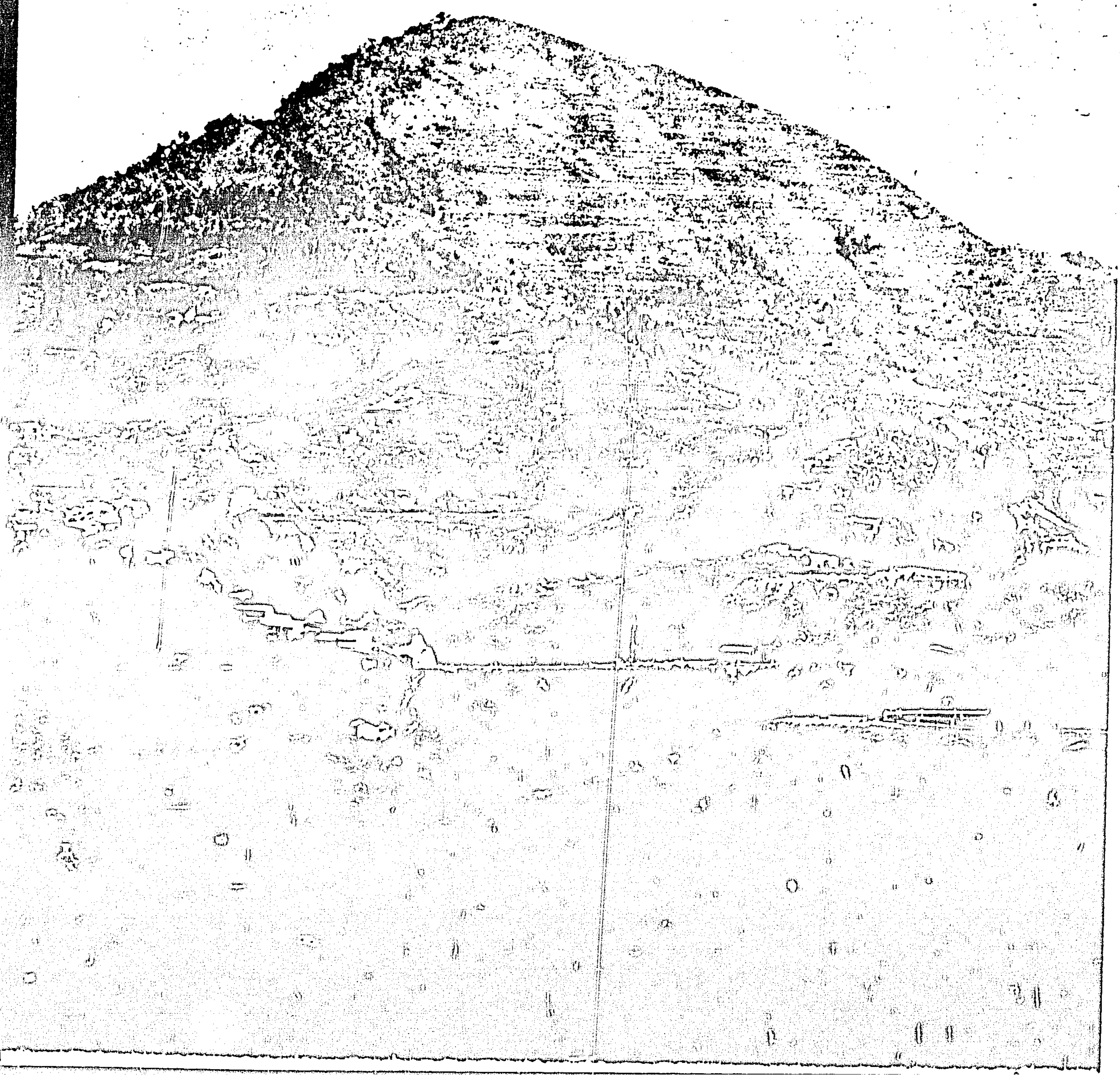
RUHENGERI AND ITS RESOURCES

An Environmental Profile of the Ruhengeri Prefecture RWANDA



RUHENGERI AND ITS RESOURCES

An Environmental Profile of the Ruhengeri Prefecture
RWANDA

Kigali, 1987

Cover: Photographic transect of Ruhengeri landscape, showing Ruhondo Commune with Mount Muhabura in background.

ACKNOWLEDGEMENTS

This study was carried out by the Ruhengeri Resource Analysis and Management (RRAM) project of the South-East Consortium for International Development in collaboration with the Government of Rwanda. Funding was provided by the United States Agency for International Development (USAID) under its Environmental Training and Management in Africa program. Additional support was provided by the Forestry Support Program and the Water and Sanitation for Health Project of USAID, and by the Winrock International Institute for Agricultural Development.

Personnel

Editor and RRAM Project Manager:	William Weber
Assistant RRAM Project Manager:	Vincent Nyamulinda
Contributors and Consultants:	Edward Backus, Geoff Chandler, Bonneau Dickson, Peter Freeman, Ernest Hardy, Zacharie Kayumba, Leslie Linn, Nicole Monfort, Innocent Muhirwa, Louis-Marie Murekezi, Tharcisse Ngerageze, Philip Roark, Vénant Rutunga, Eric Schiller, Claude Sibomana, Lucie Steinkamp-Ferrier, Amy Vedder, Patrick Wassmer, Fred Weber
GIS and Computer Specialist:	Elaine Aderhold
GIS and Computer Assistant:	Théophile Mukamayera
Cartographers:	Alpnonse Kwizera, Cyprien Sibomana, Ananias Ndikumagenge
Translation and Typing:	Dorra Jomni, Anne Joris
Printing:	Multi-Services, Kigali

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

This report presents an ecological analysis of environmental problems in the Ruhengeri Prefecture of Rwanda. The Ruhengeri environment consists of a particular combination of physical, biological and socioeconomic attributes which gives the region its unique character. Ecology is the study of these components, with particular attention to the interactions among them.

Human beings, together with their social, technological and institutional creations, are key elements in the functioning of almost any ecosystem. Humans use and transform the primary resource base of land, water, minerals, plants and animals to an unmatched degree in the course of their never-ending effort to maintain and improve their personal and collective well-being. When this process is carried out in a manner which permits resource renewal and provides continuing benefits over the long-term, it is appropriately called sustainable development. When resources are overexploited and abused, true development cannot occur and ecological imbalances result.

Today, throughout the tropics, efforts to satisfy the subsistence needs and development aspirations of rapidly growing human populations have been fueled by increasingly intensive exploitation of remnant natural resources. In many instances, the immediate benefits of this approach are positive. All too often, however, the long-term result has been an unfortunate combination of environmental degradation, diminished returns on investment and an actual increase in human suffering.

Ruhengeri

In many respects, conditions in the Ruhengeri Prefecture of Rwanda are representative of this situation, though there are three important differences. First, the regional resource base is considerably richer than the tropical average. Within its nearly 1700 km2 of rugged terrain, Ruhengeri contains a biologically unique montane forest reserve, a complex network of wetlands, lakes and rivers, and a mosaic of highly productive agroecosystems. In addition, the overall regional ecosystem has demonstrated considerable resilience in the face of stress, and continues to function and provide essential services. Finally, several initiatives have been taken in recent years to limit environmental degradation.

On the negative side, however, its rural population density of more than 380 people per km2 places Ruhengeri among the world's most densely populated areas. The efforts of this population to satisfy its basic needs have already led to considerable deforestation, wetlands modification and soil degradation on marginal farmlands. As population growth continues at a rapid rate and regional development efforts intensify, pressure to further exploit remaining resources can only increase. And conflicts between environmental conservation and development interests are inevitable.

Historical Perspectives

It is important at this point to remember that the situation in Ruhengeri, though disquieting, is not unique. Across the world, people and their governments are faced with similar conflicts. And everywhere the dual task is the same: to find the means to improve the quality of life for present populations through the development process, while also conserving a sufficient share of the common resource heritage for future generations.

The human species has shown itself to be remarkably adept in the techniques of increasingly efficient resource exploitation and the development of progressively more productive economies. Parallel success in sustaining environmental health and integrity, however, has proven to be a more elusive goal. And history teaches us the high cost of failure to balance these two essential processes.

Several ancient civilizations are remembered for their comparatively high level of development, but much less is known about their ecological failures. Whereas wars and other disasters are commonly cited as primary causes of their fall, evidence now indicates that rapid population increases followed by overexploitation of wood, water and soils were also key factors in the decline of the great river valley cultures of Mesopotamia, India and China, as well as of the Mayan kingdom of Central America.

In Europe, during the late Middle Ages, a different set of problems arose with regard to growing populations and their changing environment. Negative impacts of air pollution were first noted in 13th century London, where rapid urbanization and the uncontrolled burning of wood and charcoal combined to create a sometimes deadly hazard. By the following century, unhealthy environmental conditions in newly created towns facilitated propagation of the Black Plague epidemic, which eventually killed tens of millions across the entire continent.

In the 19th century, deforestation reappeared as a source of trouble in and around the Alps, where excessive clearing of steep slopes resulted in massive erosion and downstream flooding. Meanwhile, across the Atlantic, the uncontrolled exploitation of montane forests in North America was causing comparable damage and even threatening the water sources of major eastern cities. Fortunately, the authorities and populations of these two areas began preservation and reforestation activities in time to rectify and stabilize the rapidly deteriorating situation.

During the early part of this century, both the United States and the Soviet Union adopted policies which favored the opening of their vast semiarid prairies to mechanized agriculture. This permitted a brief increase in agricultural productivity, but the removal of the natural vegetation cover exposed already poor soils to rapid degradation and wind-born erosion. The "dustbowls" thus created caused considerable social and economic dislocations, and large areas in both countries remain nonproductive more than 50 years later.

We have learned much from past mistakes, but ecological balances remain precarious across the world. While the more industrialized nations have tended to stabilize their populations and limit certain forms of environmental degradation, hyperintensive development in these countries has created new sets of problems. Acid rain, toxic waste disposal, nuclear radiation, and even the possibility that our combined activities are changing the global climate pose management difficulties of an unprecedented nature and scale.

For the vast majority of developing countries, however, the problem set remains more traditional, though aggravated by high population growth rates. Deforestation, soil erosion, watershed degradation, and diminished biological diversity thus represent issues of pantropical importance. Examples include Nepal, where montane deforestation and inappropriate agricultural practices have resulted in catastrophic flooding on the plains below; Haiti, where population pressures have led to the clearing and degradation of much of the land resource base; and China, where all of these problems were considered quite severe until a disciplined national conservation effort began to reverse the negative trends.

Perhaps nowhere is the situation more critical today, however, than in sub-saharan Africa. The repeated droughts of the 1970s and 80s devastated vast areas of the African continent and the resultant human suffering transfixed the world's attention. Yet while cyclical climatic change was an important factor in this ecological disaster, human abuse of the natural resource base was in many ways more important.

As population pressures have grown over the past century, African farmers and herders have been forced to move onto increasingly marginal lands, where they have generally cleared existing forests. The removal of this natural vegetation cover and application of inappropriate agricultural practices has frequently resulted in rapid soil degradation and chronic hydrologic imbalances. Well before the recent ecological disaster in Ethiopia, field reports described conditions there as extremely serious, with the majority of mountains, hills and ravines denuded and susceptible to further rapid deterioration. When climatic conditions changed, the disaster occurred. But it was man who prepared the terrain through his actions; and it was man who suffered the consequences.

While the subsistance and survival activities of millions of individuals can be seen to have a destabilizing impact, national governments and the international donor community have also contributed to ecological imbalances. In their collaboration to promote development through the introduction of new technologies and more intensive means of resource exploitation, they have achieved some notable successes. Their efforts have also resulted in numerous failures, however, due to insufficient attention to both socioeconomic and ecologic aspects of development. The promotion of intensive peanut cultivation in Senegal without accompanying soil conservation measures; the drilling of wells across the Sahel without adequate knowledge of the ecology of local grazing systems; unsound wetlands drainage projects; and currently widespread efforts to convert remnant natural forest systems to "more productive" uses without sufficient prior research on forest dynamics or alternative values are all examples of the latter.

Is the situation in Ruhengeri comparable to that in Ethiopia or in other environmental crisis areas across the tropics? In general, no. Its farming population appears to take good care of the land, the resource base remains productive, serious conservation efforts have begun, and regional development activities have thus far been limited in both their scale and impact. Still, the extremely high population densities found in Ruhengeri have already exerted considerable pressure on the region's soil, water and wood resources -- pressure which can only increase with continued population growth.

The purposes of this brief historical review are multiple: to place current conditions in Ruhengeri in a larger context; to suggest that environmental problems cannot be considered as merely academic issues, but rather fundamental concerns of a very practical nature; to demonstrate that while development is essential to human wellbeing, there are nevertheless certain limits to resource exploitation; and, finally, to point out that people everywhere are confronted by comparable problems. To reduce these problems, in Ruhengeri as elsewhere, more ecologically sound approaches to development must be followed.

Toward Eco-Development

Conservation and development have historically been viewed as conflicting processes. This is largely due to the fact that the two have often focused on the same resource base with radically different objectives in mind. Proponents of development have certainly tended to see resources only in terms of their potential for exploitation, without much concern for negative impacts nor the sustainability of their actions. Conservationists, on the other hand, have too often opposed any form of development activity, especially where natural areas and their component resources are concerned. The result has been a general perception of mutual exclusiveness between the two.

Several factors have combined in recent years, however, to modify this situation. First, the individuals and institutions concerned with both development and conservation have learned some important lessons from their respective experiences in the field. While the former have seen numerous projects fail due to insufficient attention to ecological aspects of development, the latter have also become increasingly aware that conservation must be seen in a context which considers human, as well as wildlife, interests.

As a direct result of these experiences, parallel changes emerged in the theories and models which guided both fields. Then, in 1981, a unified theory of "eco-development" appeared in the form of the World Conservation Strategy. This document, prepared by representatives of national and international development and conservation agencies, laid the philosophical groundwork to recognize the two efforts as complementary and interrelated processes which share a common goal: the long-term well-being of man.

This model includes two important changes. From the development side came the recognition that while resources are there to be used, it is nevertheless difficult to maximize their exploitation without encountering serious ecological constraints. This is especially true with regard to renewable resources such as plants, animals, soil and water, which can reproduce or replenish themselves if not subjected to overexploitation. Management strategies are therefore required which optimize resource use in ways which generate sustainable benefits over the long term.

The second important element in this theory is the recognition that people must be able to satisfy their basic needs and reach a certain level of development before they can give sufficient attention to long-term conservation interests. It is difficult to expect families that do not have enough land or wood to conserve these resources for the future: as the economist Keynes once remarked, "man does not eat in the long run, he must eat today". In addition, it is clear that improvement in people's economic status reduces their dependence on traditional local resources (for example, the spread of metal roofing in the Ruhengeri Prefecture has reduced demand for the bamboo and grasses used in the past). Finally, development includes an educational component which is also of critical importance for conservation. To be supportive, people must first come to understand and appreciate that which they are expected to conserve.

The changes described above form the basis of an appealing theory of conservation and development as parallel and complementary processes. The test of any theory, however, comes with its application to real-life conditions.

The RRAM Project

The first practical applications of the new theory appeared in the form of changes in the legislation and guidelines which control the activities of development agencies. By the mid-1980s, most of the major bilateral and multilateral donors were required to carry out environmental impact assessments prior to the initiation of any development project. In addition, several agencies took the offensive in implementing policies and projects which aimed to reverse environmental degradation and restore ecological balance. For many developing countries, where ecologically unsound practices had already had a negative impact, the change was a welcome one.

In 1980, the United States Agency for International Development (USAID) took the initiative to establish the Environmental Training and Management in Africa (ETMA) program. Over the following years, dozens of subprojects were carried out across the African continent to promote improved training of personnel and strengthening of institutional capacities to conduct resource inventories and implement effective environmental management policies.

The Ruhengeri Resource Analysis and Management (RRAM) Project was conceived in 1983 as an attempt to combine and integrate the lessons of the ETMA program in a single geographical region. Ruhengeri was selected as the pilot site for this effort due to its combination of ecological diversity and problems related to high population densities and intensive land use, all within a limited administrative unit.

In June 1985, an agreement was signed between the government of Rwanda and USAID which approved implementation of the RRAM Project. Management responsibility for project execution was assigned to the South-East Consortium for International Development (SECID) as part of its overall ETMA program.

The primary objective of the RRAM Project is to assist the government of Rwanda to minimize environmental problems associated with intensified population growth and development in the Ruhengeri Prefecture. In its initial phase of 18 months, the project was to move towards this goal through two principal activities:

1. The development and assessment of an integrated data base concerning the natural resources and environmental problems of the prefecture; and

2. The provision of technical assistance to improve individual and institutional capacities within the government to deal with resource management issues.

In addition, the execution of the RRAM Project's first phase has been guided by the following series of concepts:

1. Conservation and development activities need not be in conflict and should, in fact, be mutually beneficial

2. Complex problems cannot be treated in isolation, but require an interdisciplinary, comprehensive approach.

3. A relatively complete and accurate base of information is required before effective management plans can be developed.

4. Analysis of the information base must be both quantitative and qualitative in nature: we need to know not just how much of something we have, but also its utility or effectiveness.

5. Solutions to problems should be flexible and specific to particular sites and circumstances, in accordance with the complexity of local conditions.

6. Given that environmental problems are frequently interdependent and require interdisciplinary analysis, it follows that approaches to their resolution must also require improved communication and collaboration between the ministries, agencies and individuals concerned.

Conclusion

This report is the primary product of the inventory and assessment component of the RRAM Project's initial phase. The following chapters present an overview of the Ruhengeri environment, an analysis of issues in the different resource sectors, an identification of both existing and potential problems, and options for managing these problems through either direct interventions or further research to fill critical gaps in the existing information base.

Beyond its value as a product, it is also hoped that this report will contribute to the process of increasing awareness of, and attention to, ecological aspects of development. With this in mind, information has been selected and produced -- in the form of text, tables, graphics and maps -- in a manner to help concerned authorities, advisors and technicians better understand the complex issues which they confront, and thereby assist in the formulation of effective resource management policies.

CHAPTER TWO: THE BIO-PHYSICAL ENVIRONMENT

Introduction

Ruhengeri Prefecture is situated in the northwestern highlands of Rwanda. It is one of 10 administrative units in the country and is subdivided into 16 communes and 177 sectors. The town of Ruhengeri is the political and economic center of the region (Figures 2.1 and 2.2).

Ruhengeri covers an area of roughly 1685 km2 (see note below), or 6.6% of the total national territory. The region is characterized by extremely rugged relief, with an overall altitudinal range from 1400 meters in the south to more than 4500 m in the northern mountains (Figure 2.3). The interposition of hills and valleys creates a mosaic of ecological microniches, most of which are now occupied and exploited for agricultural purposes. Despite the difficulties posed by steep slopes and high elevation, the combination of relatively productive soils and adequate rainfall has favored the settlement of this area at an average density of more than 380 persons per km2.

The principal areas not in agriculture include the Virunga chain of volcanoes, with its rainforest ecosystem protected as parkland along the northern border with Zaire and Uganda, and a complex network of lakes and wetlands to the east. Runoff from both systems flows into the Mukungwa river basin, which drains nearly 90% of the prefecture.

Numerous environmental problems stem from the fragile ecological balance which exists between the human population of Ruhengeri and the resource base on which their existence depends. To deal with these problems, however, first requires a better understanding of the environment under consideration.

Physical Characteristics

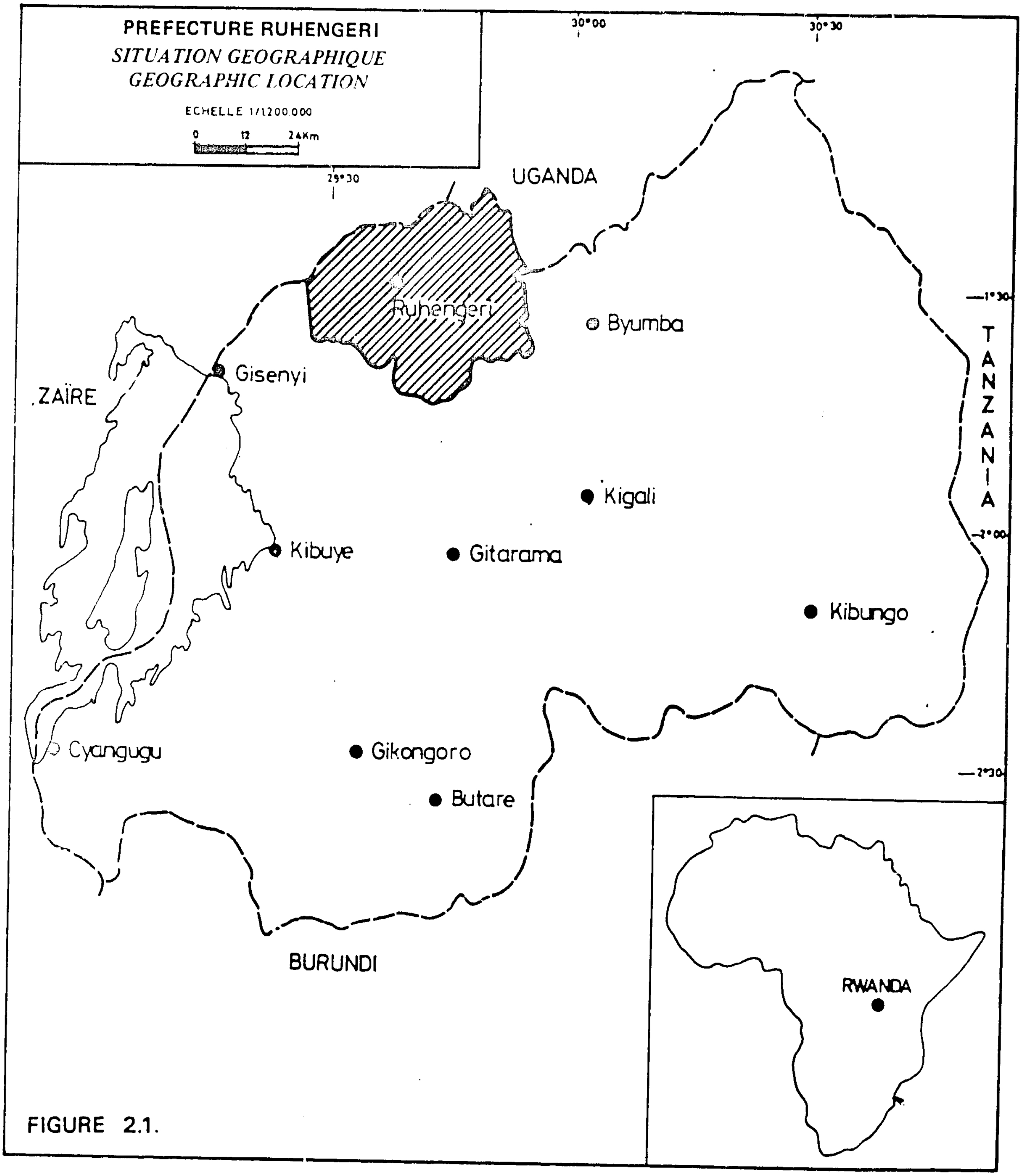
Climate. The Ruhengeri region has a generally cool, humid climate. Temperatures range from an average of 18° C in the lower Mukungwa valley (1500 m) to only 12° at the base of the Virunga volcanoes (2500 m). Frost and freezing temperatures occur at night in the park above 3000 m, and transient snow cover can be seen periodically on the summit of Mt. Karisimbi (4705 m). While it is generally true that temperatures decrease with increasing altitude across the region, it is nevertheless important to note that significant variations also occur in relation to topographic features.

Average rainfall increases from a low of roughly 1100 mm/year in the northeastern corner of the prefecture to nearly 2000 mm/yr in the northwestern mountains (Figure 2.4). Most agricultural lands receive 1200 - 1600 mm/yr, although considerable variability again appears as a function of local relief.

Rainfall is distributed bimodally, with the primary wet season occuring from March through May and a secondary season from September though December (Figure 2.5). The principal dry season lasts from two to four months between mid-May and mid-September, whereas the "short dry season" of January-February

----

Note: Several estimates exist for the actual size of the prefecture. Official statistics continue to refer to an area of 1762 km2, although planimetric studies made in 1973 by MINAGRI showed an area of 1687 km2. Planimetry done by the RRAM project supports the latter figure. In addition, major errors were detected in the official sizes of several communes. For purposes of internal consistency, RRAM totals for the prefecture (1685 km2) and communes are used in this report.



PREFECTURE RUHENGERI
SITUATION GEOGRAPHIQUE
GEOGRAPHIC LOCATION
ECHELLE 1/1200 000
0
12
24Km
30°00
30°30
29°30
UGANDA
Ruhengeri
Byumba
Gisenyi
ZAÏRE
TANZANIA
1°30
Kigali
2°00
Kibuye
Gitarama
Kibungo
Cyangugu
Gikongoro
Butare
2°30
BURUNDI
RWANDA

FIGURE 2.1.

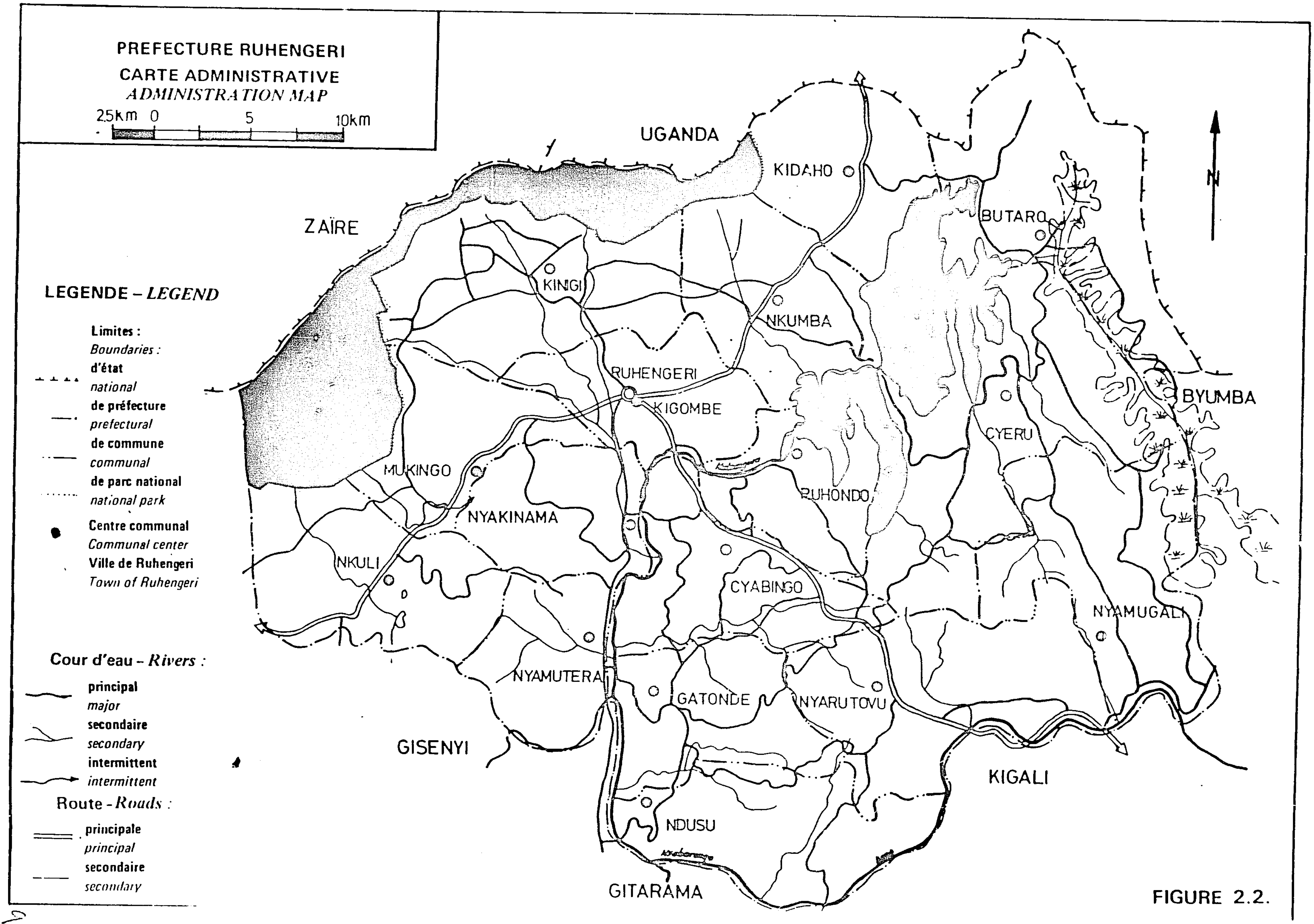

PREFECTURE RUHENGERI
CARTE ADMINISTRATIVE
ADMINISTRATION MAP
2,5km 0 5 10km
LEGENDE – LEGEND
Limites :
Boundaries :
d'état
national
de préfecture
prefectural
de commune
communal
de parc national
national park
Centre communal
Communal center
Ville de Ruhengeri
Town of Ruhengeri
Cour d'eau – Rivers :
principal
major
secondaire
secondary
intermittent
intermittent
Route – Roads :
principale
principal
secondaire
secondary
N
UGANDA
ZAÏRE
KIDAHO
BUTARO
KINIGI
NKUMBA
RUHENGERI
KIGOMBE
BYUMBA
CYERU
MUKINGO
RUHONDO
NYAKINAMA
NKULI
CYABINGO
NYAMUGALI
NYAMUTERA
GATONDE
NYARUTOVU
GISENYI
KIGALI
NDUSU
GITARAMA

FIGURE 2.2.

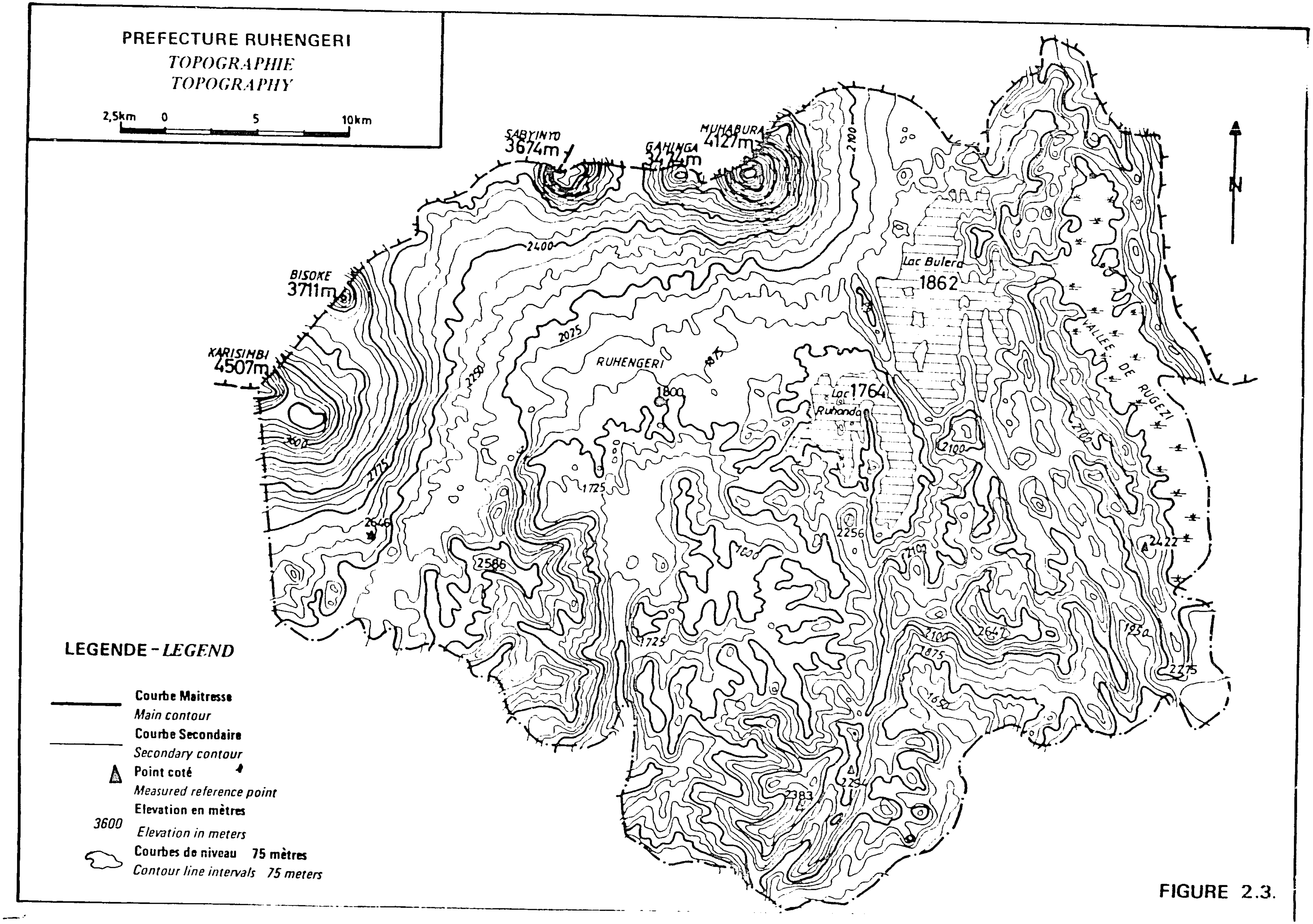

PREFECTURE RUHENGERI
TOPOGRAPHIE
TOPOGRAPHY
2,5km 0 5 10km
SABYINYO
3674m
GAHINGA
MUHABURA
4127m
BISOKE
3711m
KARISIMBI
4507m
2400
2100
2075
2250
RUHENGERI
1800
Lac Bulera
1862
Lac 1764
Ruhondo
VALLEE DE RUGEZI
N
3600
2775
1725
2646
2586
2256
2100
2422
2647
1875
1650
2275
2383
LEGENDE - LEGEND
Courbe Maitresse
Main contour
Courbe Secondaire
Secondary contour
Point coté
Measured reference point
Elevation en mètres
3600
Elevation in meters
Courbes de niveau 75 mètres
Contour line intervals 75 meters

FIGURE 2.3.

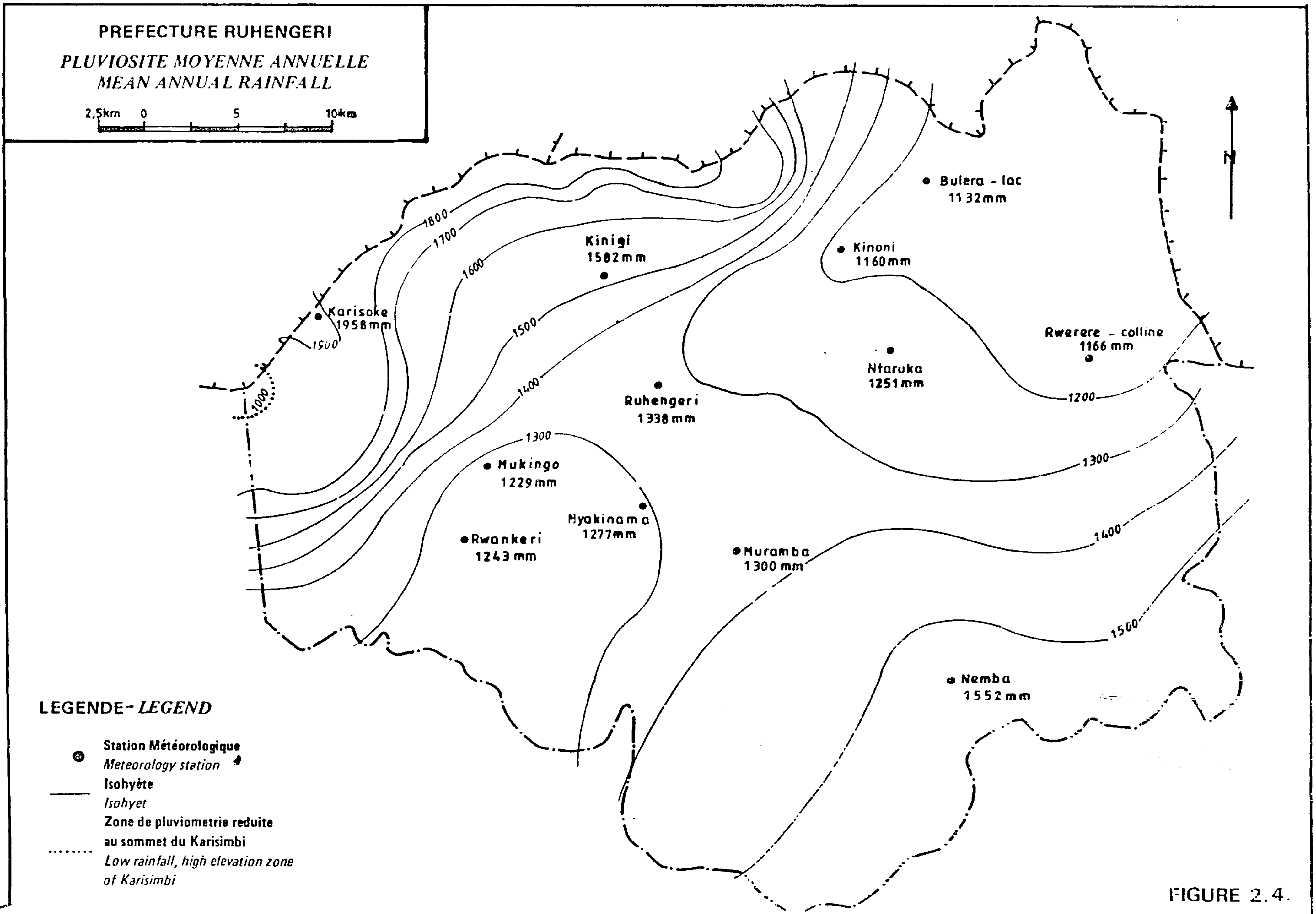
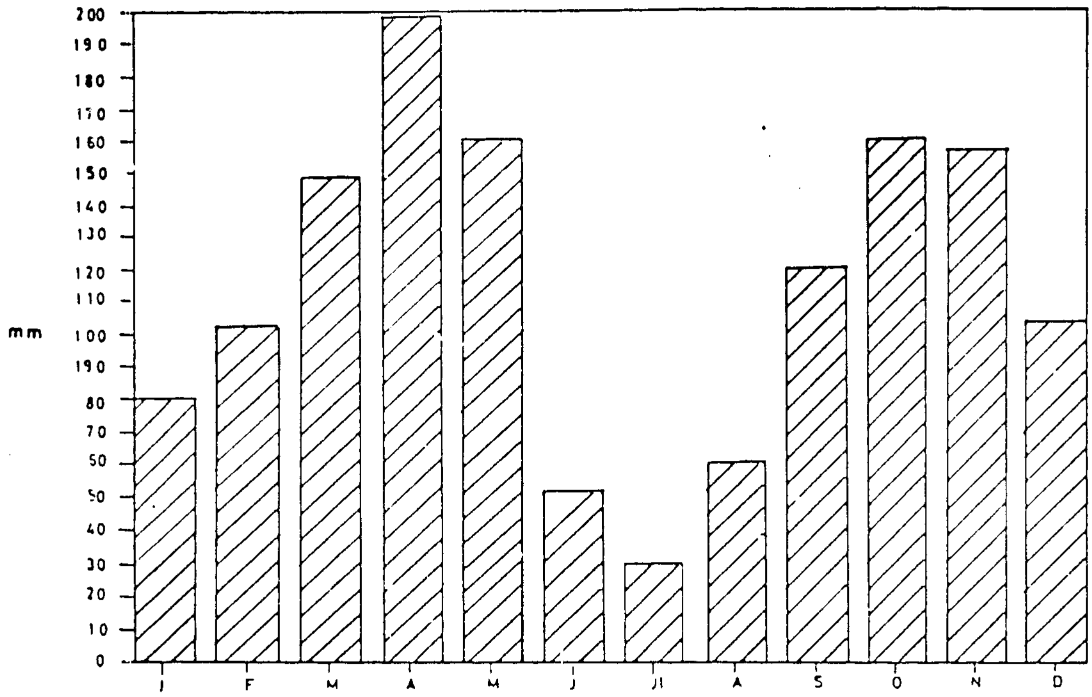
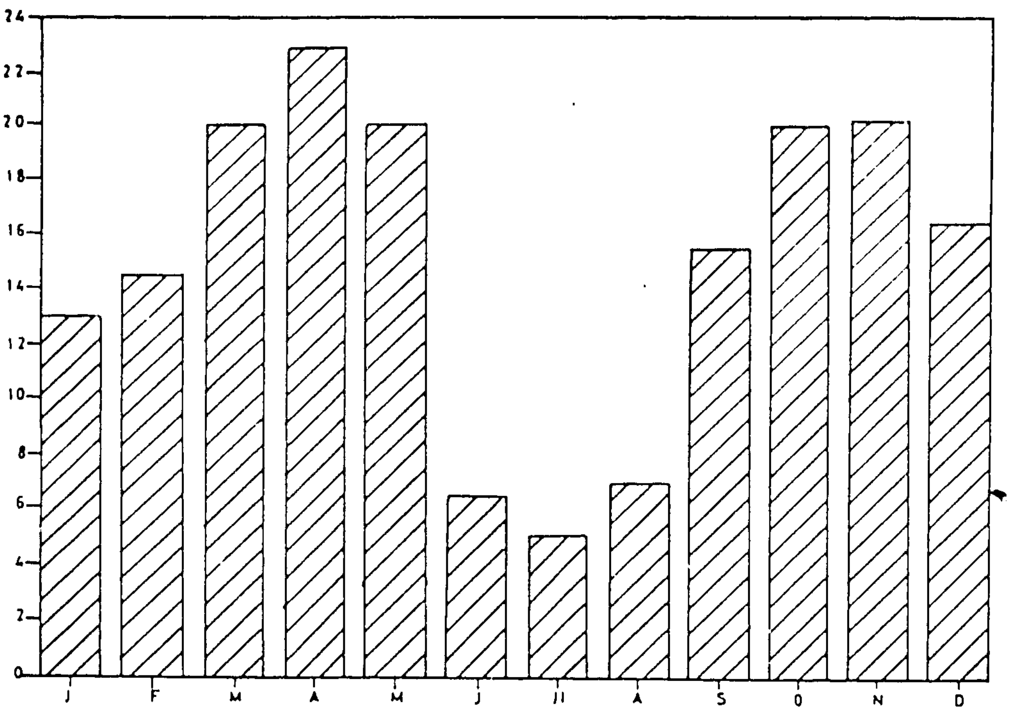

PREFECTURE RUHENGERI
PLUVIOSITE MOYENNE ANNUELLE
MEAN ANNUAL RAINFALL
2,5km 0 5 10km
N
Bulera - lac
1132mm
Kinoni
1160mm
Kinigi
1582mm
Karisoke
1958mm
Rwerere - colline
1166 mm
Ntaruka
1251mm
Ruhengeri
1338mm
Mukingo
1229mm
Nyakinama
1277mm
Rwankeri
1243 mm
Muramba
1300 mm
Nemba
1552mm
1800
1700
1600
1500
1400
1300
1200
1900
1000
LEGENDE- LEGEND
Station Météorologique
Meteorology station
Isohyète
Isohyet
Zone de pluviometrie reduite
au sommet du Karisimbi
Low rainfall, high elevation zone
of Karisimbi

FIGURE 2.4.

FIGURE 2.5
Seasonal Rainfall Characteristics
at Ruhengeri Town



Monthly rainfall



Number of days of rain

Table 2.1
Annual Precipitation
(in mm)

Year	Ruhengeri	Rwankeri	Ruhunde	Nemba	Kinoni	Karisoke
	Stations					
1985	1,174	1,270	1,169	1,385	1,234	--
1984	1,072	1,005	1,021*	1,416	1,034	1,673
1983	1,244	--	1,200*	1,570	--	2,000
1982	1,448*	1,194*	1,397	1,697	--	2,038
1981	1,201	1,251	1,277	1,569	1,075	2,220
1980	1,665	1,039	1,258	1,384	1,169	1,722
1979	1,619	1,373	1,287	1,643	1,152	2,096
1978	1,601	1,290	1,262	1,534	1,165	--
1977	1,579	--	1,401	1,724	1,183	--
1976	1,568	--	1,054	1,372	987	--
1975	1,895	1,388	--	1,545	1,201	--
1974	1,679	--	1,297	1,850	--	--
1973	1,495	1,104	1,424	1,734	1,110	--
1972	1,558	--	1,450	1,501	1,371	--
1971	1,764	1,537	1,30[illegible]	1,350	1,226	--
1970	1,282	--	1,255	--	1,128	--
1969	1,693	1,026	1,405	--	1,235	--
1968	1,453	--	1,734	--	1,144	--
1967	1,278	1,102	1,833	--	1,144	--
1966	1,345	1,329	1,468	--	1,148	--
1965	1,309	1,293	1,445	--	1,176	--
1964	1,399	1,342	1,398	--	--	--
1963	1,801	1,449	1,432	--	--	--
1962	1,440	1,172	1,104	--	--	--
1961	1,406	--	960	--	--	--
1960	1,120	--	797	--	--	--
1959	1,218	1,232	1,214	--	--	--
1958	1,261	1,022	1,471	--	--	--
1957	1,254	1,020	1,451	--	--	--
1956	1,320	1,409	1,191	--	--	--
1955	1,409	1,210	1,344	--	--	--
1954	1,304	1,181	1,079	--	--	--
1953	1,481	1,353	--	--	--	--
1952	1,015	1,353	--	--	--	--
1951	1,579	--	--	--	--	--
1950	1,081	1,169	--	--	--	--
1949	1,110	1,135	--	--	--	--
1948	1,009	1,040	--	--	--	--
1947	1,615	1,314	--	--	--	--
1946	1,003	1,224	--	--	--	--
1945	1,141	1,257	--	--	--	--
1944	1,077	1,083	--	--	--	--
1943	1,161	1,155	--	--	--	--
1942	1,366	1,382	--	--	--	--
1941	1,292	1,590	--	--	--	--

(continued)

Table 2.1
Annual Precipitation (cont.)
(in mm)

Year	Ruhengeri	Rwankeri	Ruhunde	Nemba	Kinoni	Karisoke
	Stations					
1940	1,200*	1,240	--	--	--	--
1939	1,081	1,218	--	--	--	--
1938	1,207	1,232	--	--	--	--
1937	1,393	1,519	--	--	--	--
1936	1,234	--	--	--	--	--
1935	1,127	--	--	--	--	--
1934	1,532	--	--	--	--	--
1933	1,136	--	--	--	--	--
1932	1,279	--	--	--	--	--
1931	1,126	--	--	--	--	--
1930	1,428	--	--	--	--	--
1929	1,222	--	--	--	--	--
1928	1,259	--	--	--	--	--
Total	77,628	48,502	40,380	23,274	20,882	11,749
Count	58	39	31	15	18	6
Average	1,338.41	1,243.64	1,302.58	1,551.60	1,160.11	1,959.17

Source: Roark and Dickson 1986.
* Extrapolated or interpolated data.

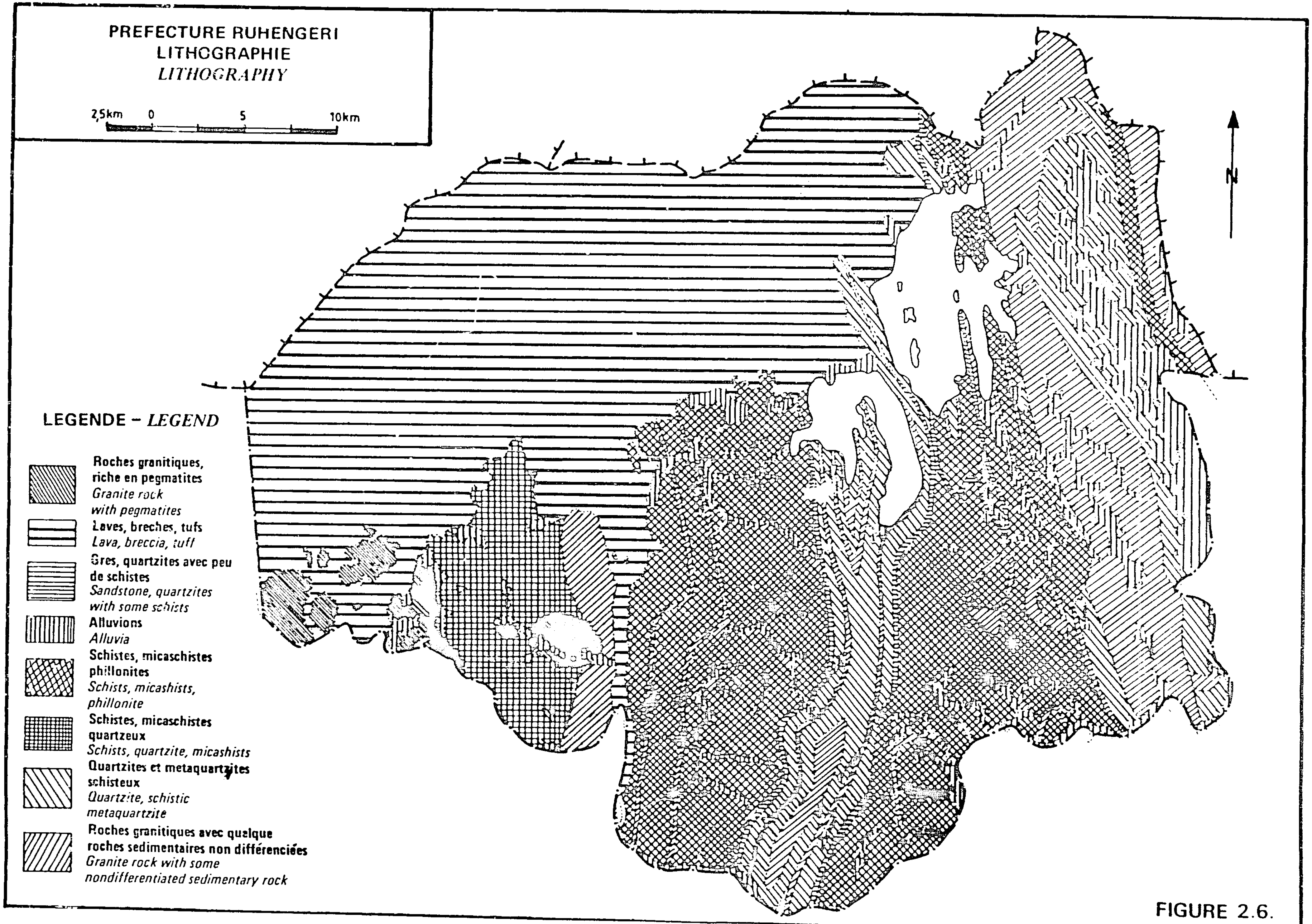

PREFECTURE RUHENGERI
LITHOGRAPHIE
LITHOGRAPHY
2,5km
0
5
10km
N
LEGENDE - LEGEND
Roches granitiques, riche en pegmatites
Granite rock with pegmatites
Laves, breches, tufs
Lava, breccia, tuff
Gres, quartzites avec peu de schistes
Sandstone, quartzites with some schists
Alluvions
Alluvia
Schistes, micaschistes phillonites
Schists, micashists, phillonite
Schistes, micaschistes quartzeux
Schists, quartzite, micashists
Quartzites et metaquartzites schisteux
Quartzite, schistic metaquartzite
Roches granitiques avec qualque roches sedimentaires non différenciées
Granite rock with some nondifferentiated sedimentary rock

FIGURE 2.6.

is more appropriately considered a time of reduced rainfall.

Weather systems generally move from east to west across the prefecture, although ridges and valleys have obvious effects on circulation. In the Virungas, transpiration from the natural vegetation combines with orographic factors to maintain that area's particularly humid microclimate.

Prolonged drought has not posed a serious threat in Ruhengeri during recent times. Evidence from numerous studies, however, indicates that the regional climate has undergone repeated radical change over the past 30,000 years. According to these studies, most of tropical Africa experienced significantly colder and drier conditions during the period 21,000 - 12,000 years ago, followed by a prolonged period of increased rainfall and higher temperatures. Precipitation began to decline again after 4000 B.P., but not to previous levels.

Current trends are more difficult to discern, although there is considerable speculation that conditions in Africa continue to get drier. Yet while it is certain that parts of the continent have recently experienced serious and prolonged droughts, records from the past 58 years in Ruhengeri are ambivalent with regard to this theory (Table 2.1). The period from 1928 to 1960 was characterized by generally lower than average rainfall, while more humid conditions predominated during the 1960s and '70s. The first half of the present decade has again been drier, with a particularly bad year for farming in 1984, coincident with the generalized African drought of that year. Current data indicate that 1986, however, will be wetter than average.

Geology. The entire basement formation of the region consists of Precambrian rocks from which harder lithologies have obtruded and softer ones eroded. In addition, this underlying structure has been significantly altered over the millenia by faulting, vulcanism, tectonic movements and alluvial deposition.

The vast majority of the prefecture is underlain by the Burundian series of schist, micaschist and quartz formations (Figure 2.6). The quartz veins tend to be harder than the others and are evident in the major north-south ridges of the eastern half of the region. Schists and associated rock structures are more commonly found on side-slopes and valley bottoms, where they are covered by alluvial deposits. Rock formations of the Burundian series around lakes Bulera and Ruhondo provide the principal sites of mining interest in the prefecture.

The late Tertiary and Quaternary eruptions of the Virunga volcanoes spread successive layers of lava over the Precambrian bedrock of northwestern Ruhengeri. One-third of the prefecture is covered by this relatively uniform rock of recent volcanic origin. Continual weathering of the soft parent material has produced extremely fertile soils across most of this zone, although its high porosity has also precluded the presence of significant surface water resources.

The southwestern corner of the prefecture is comprised of Ruzizian series metamorphic rock. This ancient formation was uplifted during the Tertiary period to form the horst of the western Rift Valley, along which it extends for the full length of Rwanda, forming the divide between the Zaire and Nile watersheds. The northern terminus of this mountain range occupies only a small portion (9.5%) of the Ruhengeri region, and consists primarily of schists and quartzites mixed with significant outcroppings of granitic rock.

Ruhengeri's tortured topography is a function of multiple factors. Initial lithologic contrasts were compounded by the violent actions of tectonic movement and vulcanism. Erosion and the subsequent formation of a dense hydrologic network served to further modify the landscape into its present form. These same factors have also largely determined the nature of the regional soil resource base (with biotic factors of vegetative cover and human activity to be considered in later sections).

Soils. The major soil types of Ruhengeri generally derive from their underlying parent rock material, with boundaries which follow the pattern of geologic zonation described above. The four principal source materials are thus lava, schists, granite and quartz. The alluvial and colluvial soils, which are also widespread across the prefecture, represent the compound products of erosion from these primary sources and/or accumulated organic matter.

Soils of volcanic origin (andepts) cover roughly 55,000 ha, or 33% of the region. They are concentrated on the extensive lava flows of northwestern Ruhengeri. Soil profiles are not well developed due to the relatively young age of the underlying rock structure. Accelerated decomposition of the lava has combined with humus formation under forest cover, however, to create a relatively deep A horizon in many areas. Eutrophic soils of volcanic ash are mixed with more shallow lithosols on the most recent lava flows.

High concentrations of organic matter and high pH make the andepts of Ruhengeri very fertile. Characteristics of these soils include high natural moisture, low bulk density, high cation exchange capacity and high phosphorus sorption. On the negative side, there are risks of magnesium deficiencies, low acidity retention, and excessive phosphorus-fixation capacity. Erosion is not a serious problem in most of the lava zone, however, due to its generally moderate slopes and the excellent physical properties of the volcanic soil itself.

Soils of schist origin occupy approximately 51,000 ha (29%) of Ruhengeri. They occur primarily in the eastern half of the prefecture, although they are also found in the southwestern sector in combination with quartzitic elements. Oxisols are the dominant soil order across this broad region, interspersed with more shallow lithic entisols on quartzite ridges.

Oxisols tend to be well-drained and acidic, with excellent physical characteristics. At the same time, their chemical properties are poor. They are thus considered to be good for cultivation, provided that nutrient and organic matter levels are maintained. They are also highly susceptible to erosion of the A horizon, however, which results in significant reduction of both water retention and fertility.

Quartz-derived soils cover nearly 25,000 ha, or 14% of the prefecture. They are concentrated along the north-south ridges of eastern Ruhengeri, where they are classified as lithic entisols. These soils are generally characterized by their poor texture, shallow profile, limited agricultural potential and high erosion risk. On surrounding slopes, quartzites mix with schists to form oxisols with properties similar to those described above.

Granitic soils are limited to about 8,000 ha in isolated pockets of southwestern Ruhengeri. Enriched by volcanic ash deposits and humus development under recent forest cover, these oxisols tend to have good agricultural potential when first put into cultivation. The combination of relatively shallow profiles, low saturation levels due to high clay content, and steep slopes, however, creates high erosion risks and resultant declines in productivity across this region.

Alluvial and colluvial soils cover the thousands of hectares of marshes and bottomlands spread throughout the non-volcanic parts of the prefecture. Most of these young mineral soils, formed by the actions of hillside erosion and subsequent deposition in valley bottoms, are classed as fluvents within the order of entisols. They are generally characterized by their high fertility and excellent agricultural potential, provided that proper management techniques are applied.

Histosols represent a much smaller class of alluvial soils in the prefecture. They are found primarily in the extensive peat formations of the Rugezi marsh, with smaller bogs dispersed across the landscape. These organic soils are difficult to manage in their natural state because of nutrient deficiencies and waterlogging. They are also highly susceptible to problems of subsidence and excessive drying following inappropriate drainage and exploitation practices.

In summary, the soils of Ruhengeri derive from a variety of sources and have generally good agricultural potential. Serious problems of erosion control and fertility maintenance, however, are widespread and require careful attention. A detailed treatment of these issues is presented in Chapter 4.

Water. Ruhengeri as a whole is rich in water resources. Abundant rainfall feeds a diverse and well-developed hydrologic system of rivers, lakes and wetlands in most areas of the prefecture. There are nevertheless problems with regard to the management of these water resources; and improved understanding of this system is essential to stable regional development.

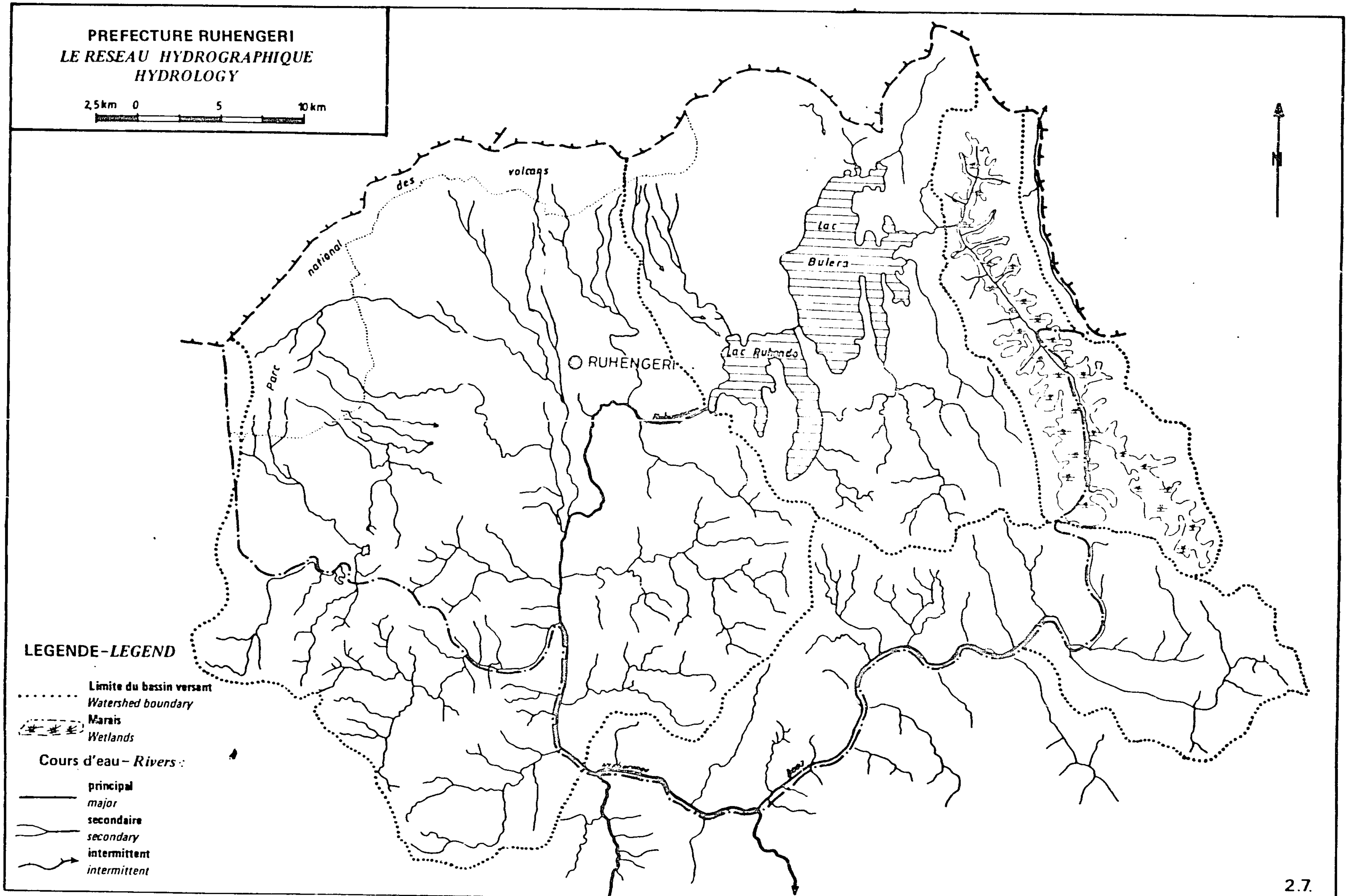
The vast majority of the prefecture lies within the Mukungwa watershed (Figure 2.7). Another 12% is comprised by the Base-Nyabarongo system in the south, while a miniscule portion drains northeast into Byumba. The Mukungwa is not only the largest, but also the most complex of these watersheds. In fact, it is best understood as four sub-units of the same system.

To the northeast of the prefecture lies the Rugezi marsh at an elevation above 2100 m. This wetlands complex fills an eliptical basin nearly 30 km long, surrounded by quartzite ridges. The marsh itself covers 6294 ha and drains an area nearly triple its size, including a small portion of the prefecture of Byumba.

Although the entire Kamiranzovu branch in the north and most of its extensive border areas have been cultivated, more than half of the Rugezi remains in a natural state. This central portion of the marsh contains a major water reserve, covered by a permanently-saturated peat formation and associated vegetation. In terms of its hydro-ecological role, the Rugezi is best considered to be a large lake with a giant sponge floating in it: both serve to hold considerable amounts of water and to regulate its release throughout the year to downstream systems.

The Rugezi complex has only one natural outlet, at Rusomo. From there, water flows at an average rate of 1.3 cubic meters/second down a series of falls and cascades to lakes Bulera and Ruhondo. This lakes basin represents the second major sub-unit of the Mukungwa watershed.

Lakes Bulera and Ruhondo were formed as a result of the Virunga uplifting and subsequent lava flows. These actions served to block the formerly northern flow of most river systems in



PREFECTURE RUHENGERI
LE RESEAU HYDROGRAPHIQUE
HYDROLOGY
2,5km 0 5 10km
N
Parc national des volcans
Lac Bulera
Lac Ruhondo
RUHENGERI
LEGENDE-LEGEND
Limite du bassin versant
Watershed boundary
Marais
Wetlands
Cours d'eau - Rivers :
principal
major
secondaire
secondary
intermittent
intermittent
2.7.

Ruhengeri, forcing them to seek outlets to the south. In the case of Bulera, entire valley systems were flooded to a depth of 173 m, creating Rwanda's largest internal lake with a surface area of 5,184 ha. A fracture in the quartz ridge which forms its western edge provides an outlet to Lake Ruhondo (2,598 ha), 100 meters below. Ruhondo, in turn, gives rise to the Mukungwa River via a similar breach along its southwestern rim.

The combined lakes cover 4.6% of the prefecture and drain an area of nearly 500 km2. In addition to rainfall and in-flow from the Rugezi marsh, they are fed by subterranean infiltration from the Lava zone and runoff from surrounding hills. This surface tributary network is not very dense and consists primarily of seasonal watercourses. Several permanent rivers do exist, however, which replenish broad bottomlands with their sediment loads before emptying into the lakes.

Approximately one-fourth of the total water volume flowing through the lower Mukungwa River comes from the lakes basin system. The regular release of this water not only serves to regulate downstream flow, but also drives turbines at the outlet of each lake which generate the major share of Rwanda's entire electrical energy production.

The two remaining sub-units of the Mukungwa watershed lie to the west of the lakes basin and feed directly into the Mukungwa river. In the northwest, the rain-drenched Virunga forest serves as the water tower of the region. More than 220 million cubic meters of rain fall annually on the 125 km2 of parkland, with much of this amount being held by the soil and vegetation for slow release throughout the year.

Unfortunately, the water tower analogy falls apart when one considers that there are almost no permanent water sources on the lava plain outside the park. This anomaly is due to the fact that the volcanic soil and underlying rock structures are highly permeable, permitting rapid infiltration. What water does flow through the region's many stream beds tends to come in the form of brief but destructive torrents following periods of heavy rainfall.

While the lack of surface water and torrential runoff patterns pose serious problems for the local population (see Chapter 6), the water from the lava zone is not lost to the rest of the prefecture. Rather, it flows underground to reappear as base flow in the Munkungwa River itself, or else rises to the surface in the form of multiple springs along the contact line between the lava zone and the harder bedrock strata to the south. In the southwestern corner of the prefecture, several small lakes (Karago, Bihinga, Nyirakigugu and Cyunyu) have formed in depressions along this contact zone.

The fourth and final sub-unit of the Mukungwa watershed is characterized by a dense network of permanent streams and rivers which drain the steep hills of southwestern Ruhengeri and parts of neighboring Gisenyi. To the west, sources high along the Zaire-Nile Divide give rise to numerous streams which cascade nearly 1000 meters down abrupt slopes to the lower Mukungwa valley. The drop is less severe (400 m) from eastern quartzite ridges, down a series of step-like valleys, then passing through extensive alluvial plains before joining the Mukungwa. In addition to its streams, this region is also rich in perennial springs.

The Mukungwa system terminates at its confluence with the Nyabarongo River at Ngaru. From there the Nyabarongo flows east until it is joined by the Base, at which point it turns south. The combined Base-Nyabarongo system not only forms the prefecture's southern border, but also drains its second major watershed.

The Base-Nyabarongo basin covers an area of roughly 200 km2 within the prefecture, with an even larger drainage area outside of its borders. Its line of separation from the Mukungwa system follows a series of quartzite ridges from the southeastern end of the Rugezi marsh, through Mt. Kabuye and Ngaru to the west.

The tributary network of the Base-Nyabarongo is characterized by a higher density of streams in the east, versus steeper slopes in the west. Although there are no lakes in this region, most of the watercourses flow year-around and springs are relatively abundant. In addition, the broad wetlands of the central Base provide excellent conditions for raised bed agriculture.

In sum, Ruhengeri is particularly well-endowed with surface water resources in the form of its lakes and marshes. Most areas of the prefecture also contain a relatively dense network of perennial streams and springs. Problems remain, however, with regard to water supply in the lava zone, water quality in several areas, and water control (flooding, irrigation) across the region's extensive wetlands. These issues are discussed in more detail in Chapter 6.

Biological Resources

Historical. Just as the physical landscape of Ruhengeri has undergone considerable change over time, so too has its biological environment. The major difference has been that plant and animal communities have changed more frequently and rapidly in the past -- and that humans have played a much more important role in their recent modification and transformation. Long before there was any significant human presence in Ruhengeri, however, there was a fully functioning and dynamic natural ecosystem. And all evidence indicates that this environment was predominantly forested.

Under current climatic conditions, Ruhengeri's altitudinal range of 1500 to 4500 meters corresponds almost perfectly to the established limits of the afromontane vegetation zone. Under this zonation scheme, true montane forest in Africa begins at around 1600 m and continues up to 2600 m. This dense forest then gives way to an altitudinal succession of bamboo thickets, more open woodland and, finally, a limited mix of afroalpine associations at the highest elevations.

In pre-historic times, Ruhengeri's natural vegetation cover changed drastically in relation to the longer-term climatic cycles described above. During periods of colder and drier conditions, forest limits contracted at both altitudinal extremes, to be replaced by more open vegetational communities. When warmer and more humid conditions prevailed, the forest expanded to cover the entire region, except where edaphic conditions favored the establishment of marsh vegetation.

Natural areas. Today, less than 10% of the prefecture remains in primarily natural condition. The biologically diverse lower montane forest zone, between 1600 and 2600 m has been systematically eliminated by human settlement and clearing, leaving behind only its contribution of organic matter to enrich the soil capital of the region. Wetlands, too, have undergone extensive conversion and drainage for agricultural purposes. As these areas have been transformed, most of the plant and animal species which they harbored have also disappeared.

The principal remaining natural area in Ruhengeri is the Volcanoes National Park, which occupies 7.4% of the prefecture. Its 12,500 ha within the Virunga range contain the upper stages of the afromontane vegetation sequence described above: bamboo, open woodland, sub-alpine and alpine associations. These plant communities in turn provide habitat to a surprising variety of animal species. In addition to more than 100 species of birds, the park contains elephant, buffalo, bushbuck, duiker, giant forest hog, leopard and four types of primate. Among the latter are the rare golden monkey and the highly endangered mountain gorilla.

A second major natural area is comprised of the non-cultivated core of the Rugezi marsh. There, remnant vegetation communities, dominated by Miscanthidium, Papyrus and Cyperus species, cover roughly 3000 ha, or less than 2% of the entire prefecture. Despite occasional impacts of burning, grazing and harvesting, these grassland associations continue to function as wetlands habitat for resident populations of mammals and birds.

No other large areas in Ruhengeri remain in essentially natural condition. Small patches of undeveloped marsh vegetation and riverine forest still exist in certain valleys, and a number of native tree species still dot the countryside. These are generally in regression, though, as man continues to modify the regional landscape.

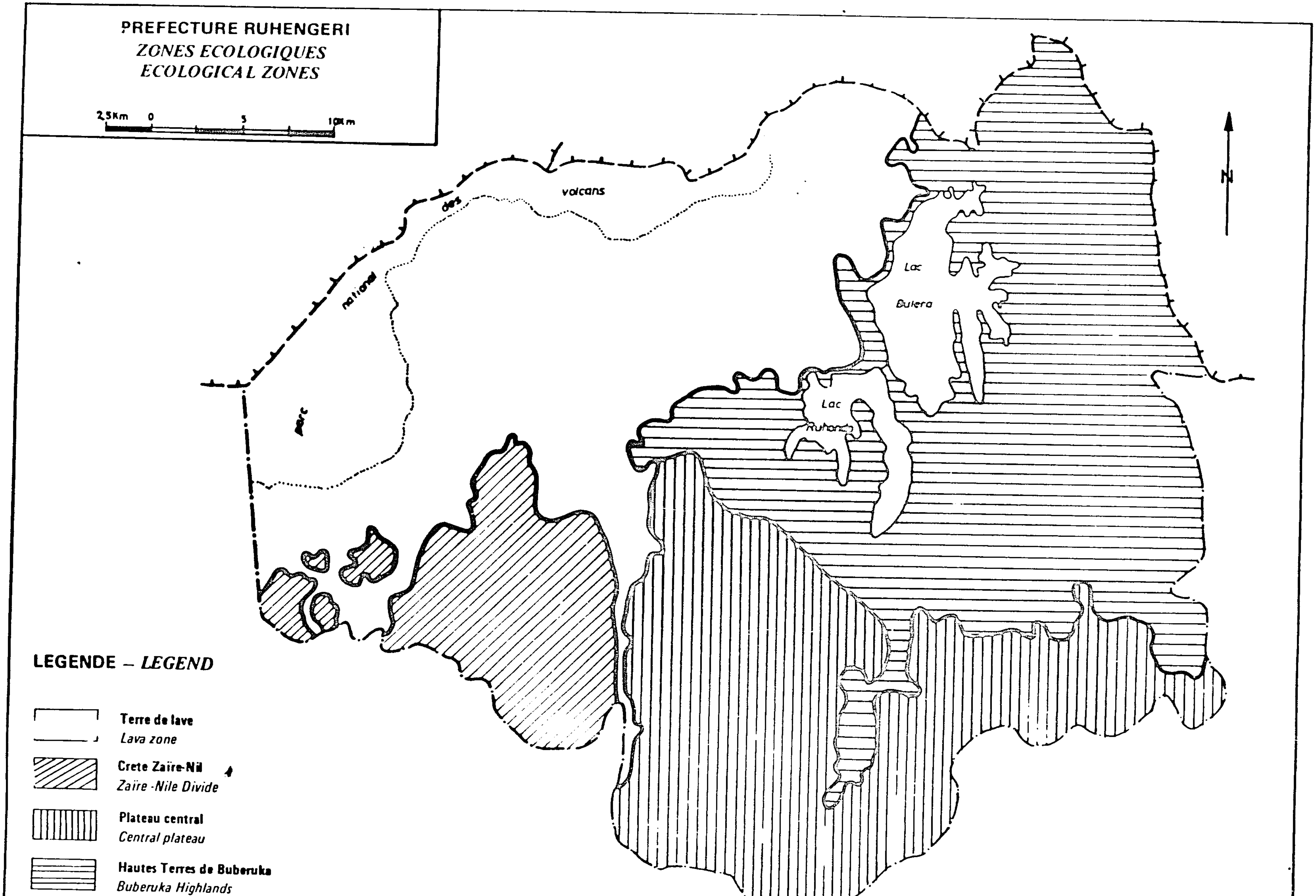
Ecological Zones

The concept of ecological zones has proven to be a useful tool for resource planners and managers in many parts of the world. In brief, it requires that divisions and groupings be made on the basis of bio-physical differences and similarities among regions. This in turn permits research and development activities to be focused on relatively distinct geographic units, from which results can then be extrapolated to other areas with shared characteristics. In Ruhengeri, at least five general ecological zones can be distinguished in this manner (Figure 2.8).

Virunga parkland. Its combination of steep mountains, high elevation and natural vegetation cover sets the Virunga ecosystem off from the rest of the Ruhengeri prefecture. In addition, its status as both a national park and an international biosphere reserve places this 125 km2 area under a radically different management regime. No direct exploitation of any kind (farming, grazing, hunting, wood-cutting) is permitted within the park limits, and all other human activities (tourism, research) are strictly regulated. The agricultural potential of this harsh ecosystem is considered to be minimal, especially in comparison with the significant revenues and employment generated by tourism and the overall biological value of the park (see Chapter 7 for more detailed information).

Lava Zone. The volcanic plain which completely surrounds the Virungas and extends more than 30 km down the Mukungwa valley to the south constitutes the lava zone. Excluding the parklands, it covers 426 km2, or 25% of the prefecture. It includes the entire commune of Kinigi, most of Mukingo, Nkumba and Kidaho, and major parts of Kigombe, Nyakinama and Nkuli.

The lava zone has several distinctive attributes. It has the highest average rainfall and the richest soils (due to their volcanic origin and high organic input from recent forest cover) in the prefecture. In addition, the geomorphology of the region is significantly different from any other part of Rwanda. It can generally be characterized as a broad piedmont, with relatively moderate slopes. These factors combine to make farming in the lava zone extremely attractive. At the same time, however, reduced temperatures serve to



PREFECTURE RUHENGERI
ZONES ECOLOGIQUES
ECOLOGICAL ZONES
2,5Km 0 5 10Km
N
Parc national des volcans
Lac Bulera
Lac Ruhondo
LEGENDE – LEGEND
Terre de lave
Lava zone
Crete Zaïre-Nil
Zaïre -Nile Divide
Plateau central
Central plateau
Hautes Terres de Buberuka
Buberuka Highlands

FIGURE 2.8.

limit the productive potential of many staple crops at higher elevations, and surface water shortages constrain human settlement.

Zaire-Nile Divide. The largest ecological zone in Rwanda, the Zaire-Nile Divide (ZND) covers only 9.5% of Ruhengeri. Its 159 km2 consist of highly mountainous terrain in the southwest corner of the prefecture, plus several isolated granite domes within the lava zone. The ZND includes most of the commune of Nyamutera and major parts of Nyakinama and Nkuli.

Elevation ranges from below 1600 m along the Mukungwa valley to more than 2500 m in the central highlands of the ZND. While extremely steep (often more than 60%) slopes are characteristic of this entire region, there is an important geomorphological difference between the abrupt eastern escarpment and the more moderate western sector. Yet even in the latter, differences of 300 to 400 meters between valley bottoms and surrounding ridges are common. When factors of relatively high rainfall (1200 - 1500 mm/yr) and unstable soil formations are added, high erosion risk is the inevitable result.

Additional problems across the ZND include an uneven distribution of water sources and an entirely inadequate road network. The region is nevertheless settled at an extremely high human population density.

Central Plateau. This northern terminus of a more extensive national ecological zone covers 372 km2, or 22% of Ruhengeri. It includes virtually all of the communes of Cyabingo, Gatonde and Ndusu, most of Nyarutovu and a small part of Nyamugali. Divided into almost equal parts by the Kivuruga ridge, the northwestern half of the Plateau region lies within the Mukungwa watershed, while the southeastern section feeds into the Base-Nyabarongo system.

Although the label "plateau" is a definite misnomer for a region of numerous hills and valleys, it helps to distinguish this zone from the more rugged ZND. Elevation differences across the plateau range from below 1500 m at the confluence of the Base and Nyabarongo rivers to an upper limit of only 1900 m (except for a few quartz summits of 2300 - 2600 m which mark the northern boundary of the zone). Distances from valley bottoms to ridgetops are thus reduced, averaging roughly 200 meters; yet slopes of 40 - 60% are not uncommon.

The valleys of the Central Plateau have particular geomorphological characteristics. Formed by quartzite barriers which tend to block sediments and organic matter behind them, they often descend in step-like fashion before joining larger river systems below. These steps range in size from a few hectares to dozens of square kilometers in major valleys such as the Mukinga. The latter are generally distinguished by their concave edges tapering to broad, flat and fertile bottomlands.

Although the plateau soils are of good quality, and relief factors are less important than in some other areas, erosion is still a considerable threat under conditions of high rainfall (1300 -1600 mm) and intensive land use. Similarly, though the lack of water sources and access roads is less of a problem than in the ZND, both serve to inhibit settlement and development of the plateau region.

Buberuka Highlands. The last of Ruhengeri's major ecological zones is the Buberuka highlands region in the northeast, which extends over 600 km2, or more than one-third of the prefecture. If the combined surface areas of lakes Bulera and Ruhondo and undrained parts of the Rugezi Marsh are subtracted from this figure, however, a more accurate land base total of 492 km2 (29.4%) emerges. This still makes Buberuka the largest zone, covering most of eastern Ruhengeri including the entire communes of Cyeru, Butaro and Ruhondo, almost all of Nyamugali, and parts of Nyarutovu, Ndusu, Kidaho, Nkumba and Kigombe.

The most striking feature of the Buberuka landscape is unquestionably its plentiful surface water resources in the form of lakes and marshes. Its total hydrographic network is less well developed than that of the Plateau region; but what permanent rivers there are tend to flow through extensive valleys which contain more than half of the agricultural bottomlands of the prefecture.

The long, rectilinear valleys of Buberuka are formed by the parallel quartz crests which represent a second distinctive characteristic of the region. The sides of these valleys are generally steep, with slopes of 60 to 70% quite common. Although mean annual rainfall is lower (1300 mm) than in other parts of the prefecture, it is nevertheless high enough to combine with relief factors to create conditions of high erosion risk. This, plus the danger of wetlands mismanagement, represent the major ecological constraints on regional development in Buberuka.

Ecological microniches. The five regions described above represent the principal ecological zones of the Ruhengeri prefecture. However, just as any natural ecosystem contains numerous niches -- localized combinations of biophysical attributes which favor certain kinds of exploitation by different species -- so, too, does the Ruhengeri environment present a variety of microniches for human exploitation. A further refinement and subdivision of this regional zonation scheme therefore seems essential from a management perspective.

The overall distinguishing feature of the Ruhengeri region is its extremely rugged relief. Outside of the lava zone, all parts of the prefecture are characterized by an endless succession of hills and valleys. In prehistoric times, the natural vegetation which covered the prefecture would have differentially colonized the microzones available in this landscape: marsh communities in the bottomlands, dense forest on the lower and more moderate slopes, and more open communities on the upper slopes and ridges. Although the former natural vegetation no longer exists, these zonal microniches along an altitudinal transect remain. And humans -- as the modern agents of colonization -- continue to exploit them in a systematic and consistent manner.

Land use patterns in the prefecture can thus be differentiated within five distinct micro-zones: bottomland, lower (concave) slope, middle slope, upper (convex) slope, and ridgetop. These represent significant subdivisions of the major ecological zones described above, excepting the parklands and lava zones, and their particular attributes must be considered in any effort to better understand and manage resource problems in these areas.

CHAPTER THREE: HUMAN ECOLOGY AND LAND USE

Human beings, through their complex interrelationships with other elements of the environment, are key factors in the functioning of any ecosystem. This is certainly the case in Ruhengeri, given their major role in transforming the regional landscape and their intensive use of virtually all available resources. The following sections describe the evolution of human settlement of the region, demographic trends, current land use patterns, health issues, and people's perceptions of the environment.

Settlement and Land Tenure.

The unquestioned first settlers of Ruhengeri were the Twa pygmies. The wild animals and plants of the predominantly forested region provided ample resources for their hunting and gathering lifestyle. In addition, their low numbers and high mobility precluded any serious problems of resource overexploitation. Today, however, there are barely 1000 Twa continue to live in the region, and no trace of their former predominance remains.

The next wave of immigrants to arrive in northern Rwanda not only displaced the Twa, but also left a more definite and permanent mark. More than 2000 years ago, ancestors of the modern Hutu introduced the iron-age tools and the agricultural technology necessary to transform the Rwandan landscape from forest to farmland. Initially low population densities, however, favored an approach generally referred to as shifting cultivation. Under this system, agriculturalists would clear sections of forest or woodland (ceded by or taken from the Twa), cultivate the land for a few years, then move on to repeat the process at another site while permitting the forest to recolonize their former fields. This served as an extended fallow period until the original site was again put to use many years later. In this manner, farmers avoid both the extra labor demands and the risks of resource degradation and depletion associated with permanent clearing and maintenance of fields.

The ecological soundness of shifting cultivation, though, is largely a function of population pressure in relation to the available resource base. As long as population densities remain low, rotational cycles can be long enough to permit adequate regeneration of the natural vegetation cover and subsequent restoration of soil fertility. By the 16th century, however, political and land use conflicts with the pastoral Tutsi in surrounding areas led to increased immigration of agriculturalists into northern Rwanda. There, in the rugged terrain of Mulera, Bugoyi and Bukiga (modern Ruhengeri, Gisenyi and Byumba), independent Hutu kingdoms were established. Yet this political liberty was accompanied by increased ecological constraints as larger numbers of people placed greater demands on a limited land resource base.

By the end of the 19th century, population pressures had already resulted in major modifications in land use and associated tenure systems. Shifting cultivation had disappeared in all areas except the remnant forest fringe, to be replaced by various forms of more permanent agriculture. And the ubukonde tenure system had developed to assure long-term use rights to the initial landholders and their descendants. Clans retained use rights to large blocks of land which could then be subdivided among male members of the lineage in later generations through subdivision, inheritance or gift. Other immigrants could still obtain land in Ruhengeri, but only as tenants (abagererwa) of the original lineages and their land chiefs.

The arrival of the colonial period marked the effective end of ubukonde. It was replaced by the Tutsi ibikingi system already in force over the rest of Rwanda and, to a more limited degree, certain components of European tenure systems. Neither the pastoral orientation of the former nor the private property emphasis of the latter, however, was appropriate for the combined social, economic and ecological context of northern Rwanda. And neither could adequately fill the regulatory role of the ubukonde system with regard to land use.

Following independence, elements of the traditional system were restored in Ruhengeri (though all patron-client relationships were legally abolished as undesireable vestiges of a feudal past). Yet just as ubukonde originally evolved under the stress of earlier population pressures, so, too, would it be forced to change dramatically in the face of the demographic realities of the late twentieth century. The ultimate form of land tenure in Ruhengeri is currently in question; but there is no doubt that it will evolve in response to the demands of a rapidly expanding population on a limited land base.

Population and Demography.

In 1984, the population of Ruhengeri totaled approximately 619,000 and occupied the land at an average density of 368 persons per square kilometer (Table 3.1) If only arable land is considered, then this density figure rises to 524 per square kilometer. In addition, the distribution of this population is very uneven, with certain sectors surpassing 1000 residents per square kilometer (Figure 3.1). At these levels, the situation is already alarming; yet further consideration of the population's growth rate and structure provides additional cause for concern.

The evolution of the Ruhengeri population over the past 50 years is presented in Figure 3.2. From a base of roughly 229,000 in 1936, the population suffered a significant decline due to famine-induced mortality and emigration during the early 1940s. By 1950, however, numbers had returned to earlier levels and a long period of rapid growth began which resulted in a doubling of the population to roughly 458,000 by 1970. This translates into a 3.5% average annual rate of increase over the intervening period.

The reasons for such a phenomenal increase are quite straightforward. Birth rates have historically been high in all areas of Rwanda, and a recently completed fertility study (ONAPO 1986) found, in Ruhengeri, an average of 9.9 live births per woman by the end of her reproductive years. Traditionally, this productivity was offset to a large degree by extremely high mortality rates. In more recent times, however, improved health and nutritional conditions have served to significantly reduce infant and juvenile mortality and to extend life expectancy.

The phenomenon of a "population explosion" following radical improvements in the health and nutritional status of given populations has been observed in most parts of the world. After a certain lag time, however, it is usually followed by a decline in the birth rate. It is therefore disquieting to note that birth rates in Rwanda remain at traditionally high levels -- and that the national population continues to grow at an annual rate of roughly 3.5%.

The actual growth rate of Ruhengeri's population has been markedly lower than the national average over the past 16 years. This is primarily due, however, to emigration. Between 1970 and 1978, Ruhengeri contributed a high percentage of migrants to the newly-opened fron-

Table 3.1
Population Densities By Commune

Commune	Population 1984	Total Area (km2)	Population Density	Corrected Area*	Corrected Density*
BUTARO	46,719	141.6	330/km2	128.4	364/km2
CYABINGO	50,197	86.6	580/km2	86.6	580/km2
CYERU	51,296	180.9	284/km2	156.6	328/km2
GATONDE	32,108	76.3	421/km2	76.3	421/km2
KIDAHO	29,494	89.4	330/km2	73.4	402/km2
KIGOMBE	42,169	71.3	591/km2	71.3	591/km2
KINIGI	35,077	171.6	204/km2	113.4	309/km2
MUKINGO	27,544	106.3	259/km2	62.5	441/km2
NDUSU	37,143	92.2	403/km2	92.2	403/km2
NKULI	32,209	117.8	273/km2	103.4	312/km2
NKUMBA	33,704	101.3	333/km2	83.1	406/km2
NYAKINAMA	44,117	66.6	662/km2	66.6	662/km2
NYAMUGALI	39,243	126.6	310/km2	126.6	310/km2
NYAMUTERA	28,979	56.9	509/km2	56.9	509/km2
NYARUTOVU	45,462	125.3	363/km2	125.3	363/km2
RUHONDO	43,609	74.0	589/km2	57.2	762/km2
TOTAL	619,070	1684.7	367/km2	1479.8	418/km2

* Based on total area minus area in lakes and park.

Source: Ruhengeri Official Statistics (population)
RRAM Project planimetry (area)

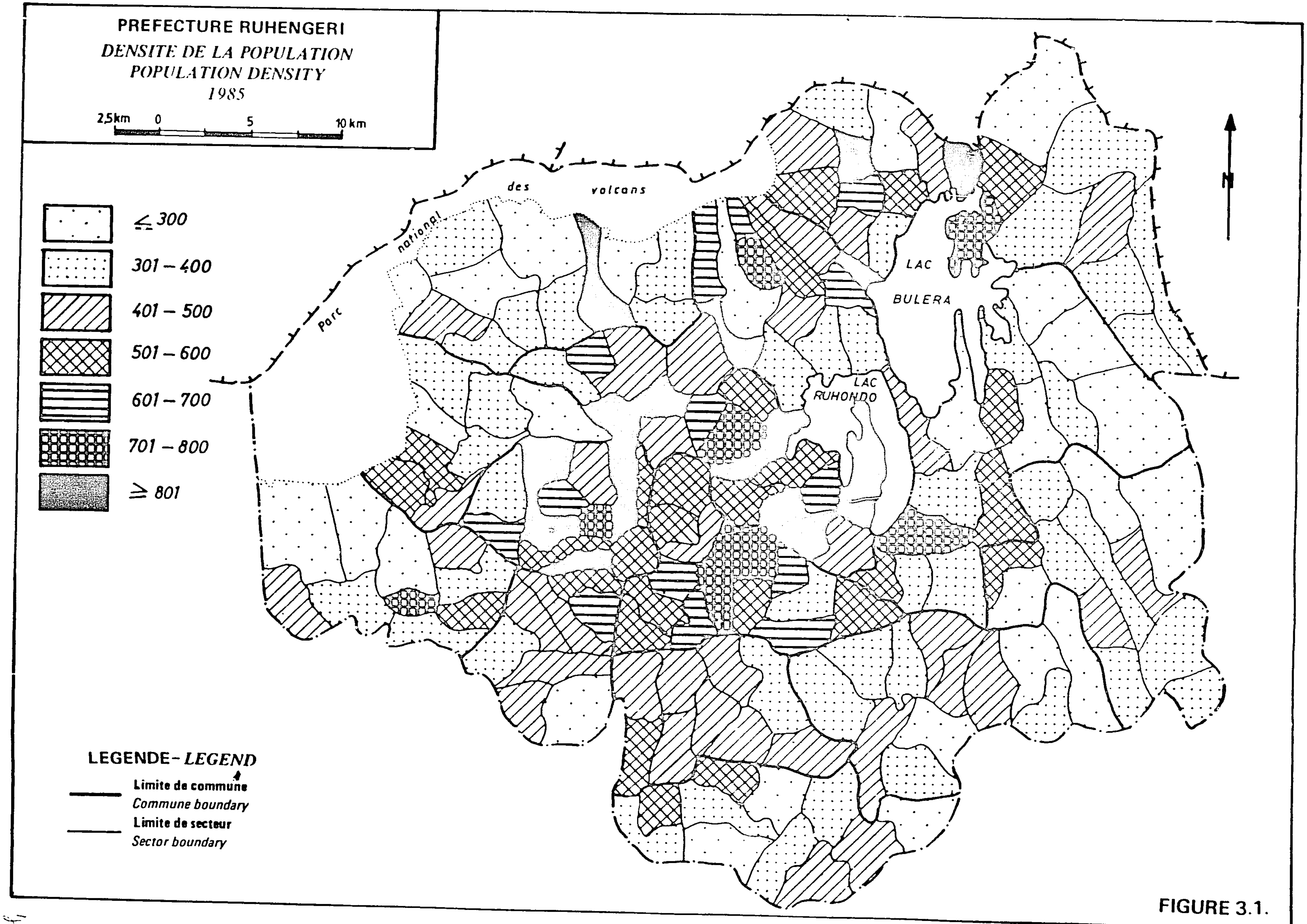
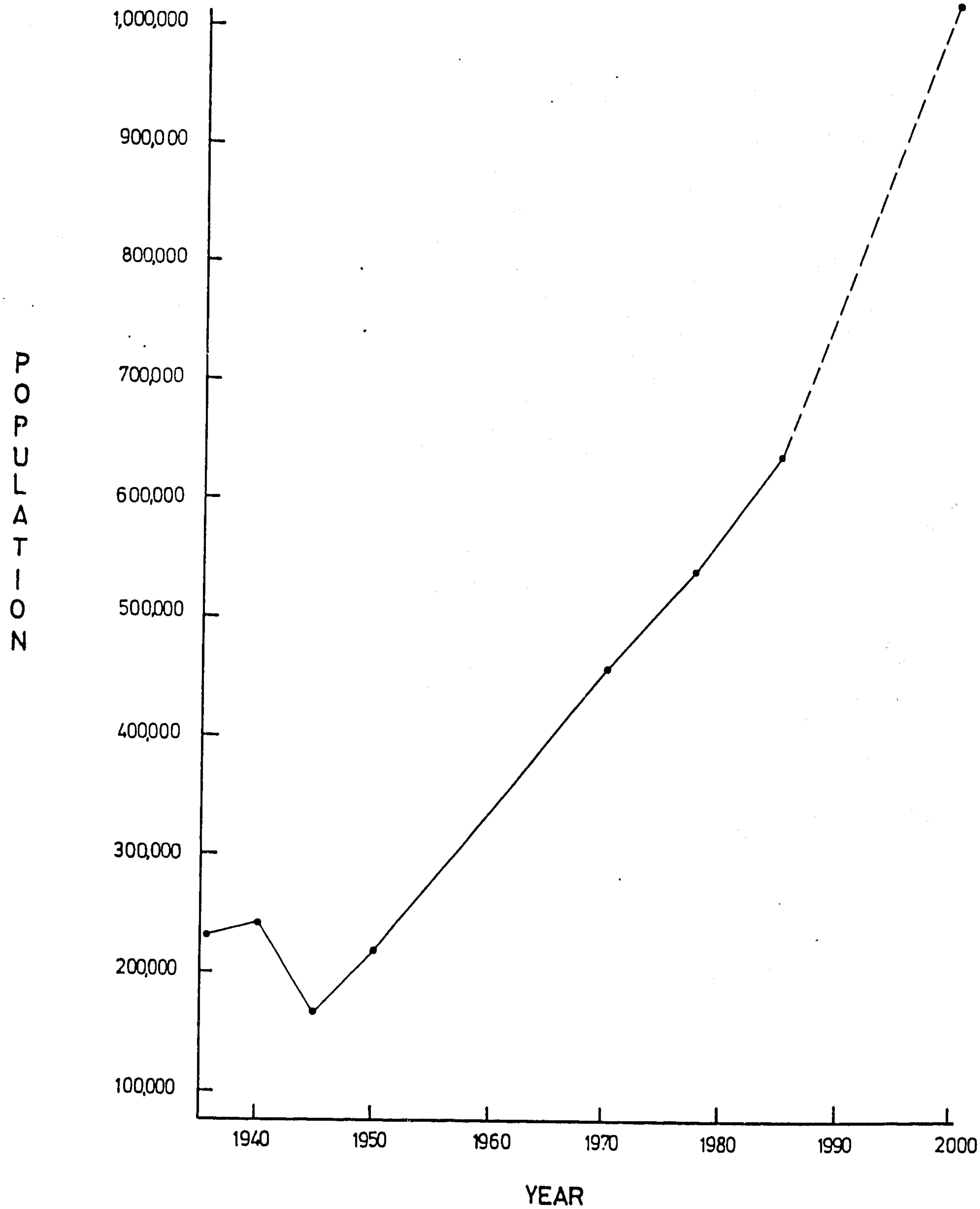

PREFECTURE RUHENGERI
DENSITE DE LA POPULATION
POPULATION DENSITY
1985
2,5km 0 5 10 km
≤ 300
301 – 400
401 – 500
501 – 600
601 – 700
701 – 800
≥ 801
Parc national des volcans
LAC BULERA
LAC RUHONDO
N
LEGENDE - LEGEND
Limite de commune
Commune boundary
Limite de secteur
Sector boundary

FIGURE 3.1.

FIGURE 3.2

Population Growth of Ruhengeri Prefecture



tier region of the Bugesera. As this area became saturated and colonists reported poor farming conditions, however, migrants focused on the more open spaces of eastern Kibungo: spaces which today are nearly all filled.

Thus, emigration to the few remaining internal frontier areas plus some movement across international boundaries limited Ruhengeri's growth rate to a modest 1.9% between 1970 and 1978, and an estimated 2.9% in more recent years. Yet a survey conducted by the RRAM project in 1986 found that only 7% of the prefectural population continued to view emigration as a viable solution to the regional land shortage. Thus, if migration is eliminated as an outlet for population pressure, Ruhengeri's intrinsic growth rate (births minus deaths) will lead to more rapid population increases in the future. At 3.5% per year, this would result in a doubling of the regional population to more than 1.2 million by the year 2006.

Adoption of birth control practices by a significant proportion of families could obviously help to lower the growth rate and prolong the doubling period. Yet the current structure of the Ruhengeri population mitigates against any rapid change in this regard. Nearly half of this population is now under 20 years of age, and the number of individuals in this group is double that in the 21 to 40 age category. As this large group moves into its reproductive period over the next 20 years, it will have double the growth potential of the group it replaces. Thus, even a halving of the birth rate will produce the same number of children. It is this demographic inertia contained in the present population structure which guarantees continued growth well into the next century. It also guarantees continued land and other resource use conflicts.

Land Use.

As noted in the previous chapter, very little of the Ruhengeri region remains unchanged by human activities. Unoccupied areas such as the park, lakes, watercourses and undeveloped wetlands total just 23,282 ha. The remaining 86% of the prefecture has been settled, cultivated, and transformed to an exceptional degree by man. Discussion in the following sections focuses in more detail on the principal components of this land use.

Agriculture.

The vast majority of land in Ruhengeri is in some form of agricultural use. An earlier study on "Land Use and Availability in Rwanda" (Prefol & Delepierre, 1973) estimated a theoretical maximum of 138,946 ha which could be used for agriculture in the Prefecture. From that total they subtracted another 20,842 ha of land which were considered inappropriate for farming (due to slope and soil characteristics) to arrive at a potentially arable land base of 118,104 ha. According to the authors, this land could support approximately 107,000 families on "minimal" farms averaging 1.1 hectares.

In 1984, the National Agricultural Survey found that nearly 125,000 families in Ruhengeri had landholdings which totaled 120,616 ha, or not quite one hectare per household. This average is misleading, however, as further analysis reveals that fully two-thirds of all families have less than one hectare; and of these, nearly 50% must live off of holdings of less than fifty ares (0.5 ha). Thus, the arable land base cited in the preceding study has already been surpassed and a far greater number of families than projected is living off of this land. This does not, however, mean that the study's conclusions are wrong. The farmers of Ruhengeri are simply working on increasingly smaller and more marginal plots of land: with long-term prospects that are troubling to consider.

In addition to their small size, Ruhengeri farms are characterized by a high degree of fragmentation. Each family farm is subdivided into an average of more than 6 parcels, often separated by several hundred meters. More than 75% of these fields are used primarily for agricultural production, with the remainder set aside for wood-lots, grazing plots, and the household complex (rugo) itself.

Food production on Ruhengeri farms is generally similar to that found in other parts in other parts of Rwanda, in that most farmers try to produce a mix of staple subsistence crops. At the same time, ecological conditions in this high elevation zone serve to limit production of certain crops and favor specialization on others.

Similarities appear when one considers that beans, bananas and corn occupy nearly two-thirds of the regional farmland over the course of the entire agricultural year (this includes two planting seasons, so totals are higher than the actual land base; in addition, only 40% of these crops are planted in pure formations, with the remainder in associations of two or more cultures). In terms of total production (in tons) bananas rank first, followed by white potatoes, sweet potatoes, beans, corn and sorghum (Table 3.2).

In terms of specialization, Ruhengeri appears to have a comparative advantage over other areas for the production of certain crops. In particular, the prefecture produces more than 80% of the national wheat crop (predominantly in the Buberuka and Lava ecological zones); 48% of the white potatoes (in the Lava and Zaire-Nile Divide zones); nearly 23% of the peas (Zaire-Nile Divide and Buberuka zones); and 19% of the national maize production (primarily in the ZND and Lava zones). Production levels for bananas, beans, sorghum and sweet potatoes, while important for Ruhengeri, tend to fall within expected ranges for a region which represents 6.6% of the national territory and which contains 10.6% of the national population.

Table 3.2
Production of Selected Crops in the Ruhengeri Prefecture

Crop	Area (ha)	Production (tons)	% Nat'l Prod'n
Bananas	42,751	134,270	6.8
Beans	50,477	23,045	9.0
Maize	32,170	21,224	19.0
Sorghum	19,518	13,202	7.8
Potatoes	19,950	122,023	48.5
Sweet Potatoes	17,180	67,927	9.3
Peas	11,979	3,812	22.6
Wheat	2,750	2,549	80.1

Source: National Agricultural Survey

MINAGRI 1986

With regard to cash crops, ecological conditions in the lava zone appear favorable to the production of both pyrethrum and tobacco. In 1975, nearly 2000 hectares in Ruhengeri were planted with pyrethrum and generated the majority of Rwandan export revenues from that crop. More recently, however, foreign demand for this natural insecticide has declined and no more than 1200 ha are currently under cultivation. Tobacco, on the other hand, remains a valued crop for the domestic market, though fewer than one thousand hectares are dedicated to its production.

Table 3.3

Selected Land Use Categories By Agro-ecological Zone

AGRO-ECOLOGICAL ZONES	TOTAL AREA* (km2)	RAISED BED BOTTOMLAND (ha)	PASTURE (ha)	TILLED FIELDS (ha)	RAISED BED UPLAND (ha)	BANANAS (ha)	PAYSANNAT (ha)
ZND	159	296	212	9547	2453	2472	0
(% zone)		(2)	(1)	(60)	(15)	(16)	(0)
PLATEAU	372	1786	454	24870	122	7634	0
(% zone)		(5)	(1)	(67)	(<1)	(21)	(0)
LAVA	426	276	1944	1812	25734	3918	4732
(% zone)		(<1)	(5)	(4)	(60)	(9)	(11)
BUBERUKA	492	2652	260	34737	944	3312	0
(% zone)		(5)	(<1)	(71)	(2)	(7)	(0)
TOTALS	1449	5010	2870	70966	29253	17336	4732

* Does not include parkland, lakes or Rugezi Marsh

Source: RRAM Project aerial photo-interpretation

For other export crops, the Ruhengeri environment appears less favorable. The region produces less than 4% of the national coffee harvest (Rwanda's principal source of foreign revenue), on fewer than 1500 ha of low elevation farmland. Production of tea, the second major source of agricultural export revenues, is even lower, although cultivation is now expanding in the Nkuli-Nyakinama area. This expansion has led to conflicts with the local population over land use, however, and future growth remains uncertain.

As indicated above, the vast majority of Ruhengeri farmers make their living from extremely small plots of land -- virtually gardens -- on which they grow a mix of primarily subsistance crops. Despite this relative homogeneity, however, some distinct regional differences do appear. From the selected land use categories presented in Table 3.3, bananas can be seen to occupy a much more important role in the Central Plateau and ZND regions, especially along the flanks of the Mukungwa valley. This valley also contains a high percentage of the Lava zone's banana plantations. Lower temperatures limit cultivation of this economically important crop, however, in the upper Lava zone, as well as across much of the Buberuka region.

Raised bed farming in bottomlands (principally of sweet potatoes and white potatoes) is another feature of the Ruhengeri landscape which shows important regional differences. Of the 5000 ha under this form of exploitation across the prefecture, more than half are located in the extensive valleys and wetlands of the Buberuka region. A similar percentage (5%) of the Central Plateau is also planted in bottomland raised beds, but physical conditions in the ZND and Lava zones limit the extent of this practice.

Upland raised bed cultivation, however, is a distinctive and widespread practice in the Lava zone. The vast majority of crops (especially potatoes) in this region are grown on large linear mounds, due to the particular water retention qualities of the volcanic soils. These formations are also common in the paysannat sector of the Lava zone, which is characterized by both the regularity of its layout and the continued presence of pyrethrum.

One major land use category in most parts of Africa which is almost totally lacking in Ruhengeri is that of pasture lands. As a result of pressure to convert available land to crop production, the prefecture's natural pastures declined from 2,870 ha in 1980 to only 120 ha in 1984, according to official statistics. In addition, private grazing plots averaging only 2 ares per household covered another 2000 ha. This represents a totally insufficient resource base for a region in which 76% of the population owns livestock, even though most of these are sheep and goats (Table 3.4).

Table 3.4
Ruhengeri Livestock Populations

Type	% Own	Average Number	Total Population
Cattle	13.1	2.4	39,518
Goats	42.4	2.6	136,239
Sheep	54.9	2.1	143,717
Pigs	7.3	1.8	16,431
TOTAL	76.5	3.5	335,905

Source: National Agricultural Survey MINAGRI 1986

Ruhengeri's ability to maintain this population up to now is due primarily to the extensive use of roadsides, crop residues, forest plantations and other sites not in agriculture as alternative grazing sites. In addition, two more intensive techniques have been introduced to the region. Increasing numbers of farmers now plant grass crops of Setaria, Trypsacum and Pennisetum along contour lines with the double objective of controlling erosion and providing additional forage for livestock. Permanent stabling is also now practiced by 20% of all cattle owners. Both of these practices must continue to spread at a rapid pace, however, if Ruhengeri is to maintain its current livestock populations in the face of steadily decreasing availability of traditional grazing lands.

Forestry. Another major category of land use in Ruhengeri is that of forest cover. Official statistics from Ruhengeri state that 10,353 ha were under tree cover in 1985. This represents 7% of all land in the prefecture, excepting the park and lakes. Studies carried out by the RRAM project, the National Agricultural Survey and other sources, however, indicate that this total may reach as high as 15,000 ha, or 10% of the regional land base (See Chapter 5 for a detailed analysis of this and other forestry issues).

The wood resources of Ruhengeri occur in three principal forms: large plantations, small private woodlots, and individual trees dispersed across the landscape. Plantations range in size from a minimum of one hectare to nearly 200 ha. They are primarily owned and managed by the communes, which benefit from the use and sale of their wood products, with a small percentage run by private enterprises or the national Forest Service. Roadside plantations are also included in this general category. Homogeneous stands of Eucalyptus species predominate in virtually all of the large plantations, though pine production has increased in recent years.

Private woodlots represent the majority of forest cover in Ruhengeri. According to the 1984 Agricultural Survey, these stands cover a total area of nearly 7,500 ha, yet average less than 6 ares per family. A RRAM project survey of 660 households in the prefecture found that more than 80% of all families maintained their own woodlot, but most felt that it was insufficient to meet their needs. This wood shortage was felt especially strongly in the Buberuka and Zaire-Nile Divide zones. Eucalyptus is again the predominant species found in private woodlots, though cyprus and a few native species are also present.

Isolated trees represent the final category of forest resources. Their dispersed nature, however, makes quantitative estimates of their total cover very difficult. What can be said is the following: that the majority of farmlands contain such trees; that they exist as a diverse mix of primarily native species; that they satisfy a variety of needs, beyond that for firewood, as sources of medecine, food and construction materials; and that they represent the foundation of traditional agroforestry systems. Thus, while their total cover may not be very great, it is certain that dispersed trees are a resource of considerable value.

In many respects, forestry trends in Ruhengeri are positive. Based on historical accounts, photographs and the observations of longtime residents of the region, more of the prefecture is now covered by trees than at any other time in this century (with the qualification that forest cover in earlier times was far greater and that natural forest has continued to decline up to the present). Reforestation has also increased significantly in recent years. Official figures show that the total planted area has grown from 4,282 ha in 1975, to 5,317 ha in 1980, to 10,353 ha in 1985. The major part of this increase (more than 4,400 ha) has come from planting by private individuals on their own lands. In addition, it is quite likely that these figures underestimate the total forest resource base.

Yet even the most optimistic estimates of forest cover indicate an annual yield of 0.23 m3 of wood per person per year: less than one-third of the estimated annual demand. This means that the capital of standing wood volume is being exploited to meet demand: a trend which is unsustainable in the long-term. However, at a time when agricultural land is at a premium, it is highly questionable whether forest lands can be tripled to meet this demand without incurring serious land use conflicts. And the 600% increase required to satisfy the needs of a projected one million people living in Ruhengeri in the year 2000 is problematic in the extreme.

Infrastructure. Another important way in which humans transform the environment is through their creation of road networks, urban centers, industrial complexes, etc. Ruhengeri's infrastructure of this sort is relatively less developed than that found in many other parts of the world and represents a minimal component of regional land use. Yet with continued population growth and development, it will certainly expand.

A network of 1,827 km of roads represents the region's most extensive form of infrastructure development. Based on average widths of 10, 15 and 25 meters for communal (1303 km), national (424 km) and paved (100 km) roads, respectively, a total area of 2189 ha is covered by this network. In addition, large areas along these roads are unusable due to associated erosion and roadside tree plantations. Still, the present road system covers less than 2% of the prefecture; and although it will necessarily grow in coming years, proper planning could assure its beneficial aspects while limiting negative impacts.

The only significant urban concentration in the prefecture is the capital city of Ruhengeri, with an estimated population of 20,000. Covering an area of less than 2 square kilometers, Ruhengeri includes a commercial district and market, a government office complex, a major hospital, a military camp, a prison, and a regional airport. Plans for the rational future expansion of the city are now in progress.

Villages are virtually non-existant in Ruhengeri, as elsewhere in Rwanda. The closest approximation is found in the northern Buberuka region, where scattered examples of "grouped habitat" can be found in linear formations, generally on sloped ridges. Yet the housing units required by more than 128,000 dispersed families nevertheless occupy a certain amount of space which should be taken into consideration. Assuming an average of 200 m2 per traditional <u>rugo</u> enclosure (still used by one-third of the population) and 150 m2 for the newer rectangular structures, a total of 2,125 ha emerges as a rough estimate: nearly the same as the area covered by roads. Thus, while the promotion of villages or grouped habitat may improve the provision of services, it should not be seen as a means of reducing this already low level of land use for housing.

Ruhengeri's few industrial complexes are visually striking, but of minimal importance with regard to overall land use. The two principal wolfram mines in the prefecture cover barely 2 km2 of denuded hills. In the case of the

Gifurwe mine, however, an impact zone of associated erosion and arsenic pollution extends several kilometers down the Nyamusanze valley to Lake Bulera (see Chapter Six).

Brick-making operations should also be included in the mining category, given their extractive practices in clay-rich bottomlands. Estimates of the area covered by such operations, however, are non-existant, and the best one can say is that they are extensive, uncontrolled. and increasingly in conflict with alternative agricultural uses of the same sites. Peat production is a similarly extractive process; but its extension is currently limited to a few dozen hectares of marshland with few competing uses.

Finally, two sites in Ruhengeri have been dammed for hydroelectrical production purposes. As both involve only the redirection of existing lake outlets, however, common problems of upstream flooding have been avoided. Conversely, in the case of the Lake Ruhondo outlet dam, several kilometers of former river have been dried up by the Mukungwa I bypass tunnel. Plans for a third dam on the lower Mukungwa indicate that a similar impact will occur.

Health.

An important indicator of a population's well-being is its relative state of health. High incidences of particular illnesses are also indicative of possible ecological imbalances or environmental stress due to population pressure. While Ruhengeri is considered to have a healthy environment, specific problems do exist and show a high correlation with particular ecological zones.

Incidence rates for five major types of illness treated at Ruhengeri's 23 health centers in 1985 are shown in Table 3.5. These data are grouped according to ecological zones to help identify environmental factors which may play a role in the distribution of various diseases.

The most extensive health problem in Ruhengeri is that of intestinal disorders: primarily worms and simple diarrhea, with much lower rates of amoebic and bacillic dysentery. Nearly 11% of the prefectural population was treated for these illnesses in 1985. Although centers of high incidence appear to be dispersed across the region, these areas share common problems related to water -- the principal medium for intestinal disease transmission. In the Lava zone, people suffer from both a water shortage and difficulties of latrine construction due to the sub-surface volcanic rock. In parts of the Central Plateau and Buberuka, a lack of clean water sources is the principal cause. And in Ruhengeri itself, the problem of maintaining non-polluted water supplies is that of any growing urban area without adequate delivery and sanitation services.

Respiratory illnesses represent the second largest health problem, and their distribution is more closely linked to particular environmental conditions. The three highest incidence centers are located in the western Lava zone, where the combination of high altitude and high humidity provides ideal conditions for pneumonia and other respiratory ailments. Other areas with high rates for these diseases are also generally located at higher elevations.

Malaria and Bilharzia, while less common than the preceding, are both very serious illnesses which are linked specifically to standing water. Malaria is the more common and also the more geographically widespread of the two. Four of the five highest incidence centers for this disease are found

Table 3.5
Incidence of Selected Illnesses

Health Center	Eco-zone	Population	Respir. Illness	Intest. Illness	Malaria	Malnu-trition	Bilhar-zia
Gasiza	Lava	21,742	7.2	10.6	0.9	0.20	0.00
Kinigi	Lava	23,757	4.8	22.3	0.6	0.21	0.00
Bisate	Lava	11,325	19.0	6.6	0.4	0.10	0.00
Shingiro	Lava	18,343	18.5	8.3	0.9	0.30	0.00
Ruhengeri	Lava	51,329	8.1	13.6	2.8	0.03	0.02
Gitare	Lava	28,296	12.7	12.5	2.4	0.41	0.40
Kinoni	Lava	25,742	10.3	11.7	1.5	0.15	0.04
Busogo	Lav/ZND	21,172	20.6	30.5	0.7	0.09	0.00
Rwankeri	Lav/ZND	33,227	7.3	8.3	0.7	0.43	0.00
Nyakinama	Lav/ZND	31,120	7.6	8.9	1.6	1.52	0.00
Ntaruka	Lav/Bub	18,762	10.7	5.9	2.6	0.07	2.00
Rwaza	Bub	37,545	2.8	4.5	1.6	<0.01	0.01
Butaro	Bub	26,252	5.6	12.1	4.0	0.15	0.05
Kinyababa	Bub	15,081	8.4	9.5	1.6	0.11	0.01
Rusasa	Bub	12,843	16.0	15.8	1.6	2.80	0.00
Rwerere	Bub	30,646	1.7	4.1	4.1	0.10	0.01
Mucaca	Bub	33,265	2.3	1.6	1.3	0.07	<0.01
Nyamugali	Bub/CP	21,705	4.4	9.6	1.2	0.11	0.00
Nemba	CP/Bub	80,828	2.8	13.5	0.8	0.08	<0.01
Cyabingo	CenPlat	35,313	3.5	5.7	1.4	0.08	0.00
Gatonde	CenPlat	28,694	7.1	15.4	1.9	<0.01	0.00
Janja	CenPlat	15,964	5.7	15.0	1.4	<0.00	0.00
Busoro	CenPlat	15,205	3.6	10.5	1.5	<0.01	0.00
AVERAGES			7.3	10.8	1.7	0.32	0.08

Source: Région Sanitaire de Ruhengeri (1985) around the lakes and marsh complex of northeastern Ruhengeri, which provides excellent habitat for the aquatic stage of the mosquito vector. Malaria rates are also high in Ruhengeri town, where a high population density favors the spread of the disease from nearby sites of standing water.

Bilharzia is much more localized, with only two significant centers, both around Lake Bulera. This debilitating disease was introduced in the 1970s to the lakes region, where the Schistosoma mansoni parasite found a suitable host in the snail population of Biomphalaria pfeiferi, which inhabits the marshy lake edge. From there it infected humans frequenting the lake, who then returned the parasite's eggs to the water via their fecal matter. This cycle can only be broken in two ways: through elimination of the snails and their habitat, or through extensive public health education to improve sanitation practices. In the case of Lake Bulera, the latter approach has served to reduce the incidence of Bilharzia from nearly 5% in all areas bordering its western edge in 1980 (Bilharzia Mission Report, 1982), to only one site higher than 0.4% in 1985. The rate of 4% at Ntaruka, however, indicates that serious eradication efforts must continue until this disease is eliminated.

The final disease category treated in this section is that of malnutrition, for which there are only two significant centers in the prefecture: Nyakinama and Rusasa. Neither one, however, appears to be linked to any particular ecological conditions, nor do the two have much in common. The Nyakinama center services residents of the Mukungwa valley as well as people living on the eastern flank of the ZND. While the former area is quite productive, much of the land is in bananas as a cash crop and subsistence crops may therefore be neglected. For those from the surrounding hills, as well as for the Rusasa population, the most likely explanation for malnutrition is that of either land shortages or poverty.

A final comment on the health situation in Ruhengeri is that those most seriously affected by disease are generally the young. While it is true that infant mortality in Rwanda has declined by almost half since the early 1950s, nearly 12% of all children continue to die before their first birthday and 23% live less than five years (ONAPO 1986). And for many who do survive, the effects of disease can seriously retard their development and limit their eventual contribution to society.

Attitudes Toward Environmental Issues

Human ecology is generally considered to be the study of people's relation to and use of the bio-physical resources of a particular region. Environmental problems occur when imbalances in this relationship are observed. Although technical analyses by specialists can reveal these problems, it is also important to consider how they are perceived by the general public.

The RRAM project carried out two surveys in Ruhengeri in an effort to better understand this question of popular attitudes and awareness. Table 3.6 presents the results of a survey of 320 households in which people were asked to list, in priority order, the major problems which they perceived at three different levels: their own household, the current population of their commune, and this same communal population 10 years from now. Analysis of these results reveals that certain environmental issues are considered to be very important across the entire prefecture, although regional differences also arise.

Table 3.6
Ranked Perceptions of Priority Problems
by Ecozone

Problem	Family: Rank by Ecozone LAV	ZND	BUB	PC	TOT	Region: Rank by Ecozone LAV	ZND	BUB	PC	TOT	Future: Rank by Ecozone LAV	ZND	BUB	PC	TOT
Lack of Land	3	1	2	1	1	2	1	1	1	1	1	1	1	1	1
Poverty	1	2	1	3	2	3	4	3	3	3	3	4	3	4	4
Soil Erosion, Degradation	6	3	3	2	3	6	3	2	2	4	6	8	7	5	6
Water	2	4	4	6	4	1	2	4	6	2	7	-	10	-	9
Wood	7	6	6	4	5	7	6	6	5	5	10	9	-	6	8
Food	8	5	8	5	6	13	7	7	8	7	4	3	4	3	3
Pastureland	5	7	7	7	7	9	10	10	7	9	12	7	10	10	10
Health	9	8	5	8	8	7	11	5	13	11	7	5	-	8	7
Housing	4	9	12	9	9	5	15	13	-	12	9	-	-	-	12
Education	11	10	9	11	10	12	8	8	9	10	5	6	5	7	5
Overpopulation	14	12	11	10	11	16	9	9	4	8	2	2	2	2	2
Lack of Roads	15	11	13	12	12	4	5	11	10	6	-	9	-	8	15
Dowry	16	14	10	14	13	11	14	12	12	14	-	-	6	12	11
Animal Damage	10	-	-	-	14	10	-	-	-	15	11	-	-	-	13
Climate	17	13	14	13	15	14	12	15	11	13	-	11	8	10	14

Note: Lower numeric values indicate higher priority rankings.
Totals (TOT) represent weighted rankings for the entire prefecture.

Source: RRAM Project Survey 1986

According to the survey, the number one problem faced by most households in Ruhengeri is lack of land. This is supported by findings from the second RRAM project survey, which asked 637 households whether their farmlands were sufficient to satisfy current and future needs (Table 3.7). The results indicate that less than 30% of the population feels that their current farms are sufficient; and only 11% believe that the next generation will have sufficient land. Regional differences appear quite strongly, with residents of the Zaire-Nile Divide and the Central Plateau most pessimistic in this regard.

Table 3.7
Sufficiency of Farm to Meet Needs

	Lava %	ZND %	BUB %	CP %	TOTAL %
Current					
Yes	33	15	34	22	29
No	67	85	66	78	71
Future					
Yes	13	0	14	10	11
No	86	100	85	88	88
Don't Know	1	0	1	2	1

In addition to the highest priority land problem, results from Table 3.6 indicate general agreement that poverty, soil erosion/degradation, lack of good water, and wood shortages are also critical problems for current households. The lack of food and pastureland, as well as inadequate health, housing and educational facilities, appear as a secondary set of concerns.

Despite agreement on these issues, however, there are certain regional differences which also emerge from the survey results. Poverty and the lack of water rate higher priority than land shortages in the lava zone, and the lack of suitable housing material (clay) is the fourth most frequently cited problem in that area. Lava zone residents who live near the park also cite wild animal damage to crops as a significant issue. In the Central Plateau area, soil erosion and wood shortages rank higher than in other areas. Finally, health issues concern more families in the Buberuka region, in apparent confirmation of the technical assessment presented in the last section.

When individuals were asked to think beyond their own concerns and consider the entire population of their commune, the problem set remained constant, but certain priorities changed. In particular, water issues move up to second place ahead of problems related to poverty and soil degradation. In addition, the lack of access roads and overpopulation appear as more significant issues at the communal level. Regional differences are also evident at this level, with higher priority given to water in the ZND and Lava zones, erosion in Buberuka and the Central Plateau, health in Buberuka, and overpopulation in the Plateau.

The most dramatic changes, however, appear in regard to future problems. While land remains the primary concern, overpopulation and food shortages climb to the second and third positions, followed by poverty and the lack of educational opportunities. The impression that emerges from this is that people think about more general issues as they consider the future. Regional differences also appear to give way to more homogeneous concerns about a future in which there are too many people growing insufficient food on too little land.

It is clear tnat the rural population of Ruhengeri is aware of the critical environmental and resource management problems which confront them. Land, soil, water, wood and overpopulation all rank high on people's priority lists -- lists which appear to be in close accord with those derived from more technical assessments. These, and other sources of information, are considered in more detail in the analysis and recommendation chapters which follow.

A\l

CHAPTER FOUR: SOIL EROSION AND DEGRADATION

"Soil erosion is a natural and world-wide phenomenon."

— D.J. Greenland

"Civilization can survive the exhaustion of oil reserves, but not the continuing wholesale loss of topsoil."

— L.R. Brown

In these statements can be found two fundamental truths about soil erosion; and in their apparent contradictions lies the reason why this problem is so difficult to treat. Erosion is certainly a universal and timeless natural phenomenon. Without erosion, the earth would be a barren hunk of rock, incapable of supporting life. Yet the same process of erosion, which combines with that of organic decomposition to create soil, can get out of control and destroy the thin layer of topsoil on which virtually all plant and animal life depends. The difference is that natural erosion is usually a slow process which acts principally on exposed rock surfaces; accelerated erosion occurs where vegetative cover has been removed — generally by human activities — and acts most destructively on the exposed topsoil. When this topsoil is seriously degraded, its productivity inevitably declines.

Thus, in Ruhengeri, the erosion process which created its rugged landscape over eons has been accelerated by human activities over recent time. The majority of the regional land base which is in agricultural use is repeatedly stripped of its vegetative cover each year and exposed to the erosive effects of rainfall. Deforestation, mining and construction activities can have an even greater, though more localized, effect.

From all indications, erosion and other forms of soil degradation represent one of the highest priority problems in Ruhengeri. Sheet, rill, gully and stream bank erosion are present in almost all areas; landslides occur on the most susceptible sites; and point-source erosion is obvious around mines and along roads. The following sections present different diagnoses of the erosion problem and recommendations for its treatment.

Analysis.

Diagnostic assessments of soil erosion and degradation problems in the Ruhengeri region are seriously limited by the general lack of quantitative data on the subject. In particular, no detailed soils map yet exists for the prefecture, which precludes refined analysis of soil erosion risks. In addition, the existing topographic map does not permit sufficiently precise slope calculations. Both of these gaps are critical; yet they should be filled with the publication of national soil and topographic maps within the coming year. In the meantime, valuable observations can nevertheless be made from the compilation and analysis of available information sources.

Prefectural Assessment. In recent years, the Rwandan government has required the creation of commissions to assess the advancement of erosion control efforts in each prefecture of the country. As elsewhere, the Ruhengeri commission has proceded by touring each of the 16 communes to observe conditions in the field. From these tournées, estimates are made of the total area protected by various erosion control structures such as infiltration ditches, hedgerows and terraces.

In 1985, 53% of the prefecture was estimated to be protected by these structures, with communal rates ranging from 34% to 67%. By the end of 1986, the regional average was determined to be 87%, with a range of 80 to 94%. To a certain degree, this 66% increase reflects the considerable effort which the Ruhengeri population has put into erosion control recently. At the same time, however, criteria were changed in 1986 to include the "natural protection of low relief", especially in the Lava zone. While the concept of lower risk factors is certainly relevant, it nevertheless changes the basic equation and makes trend analyses fairly meaningless.

Two additional problems with the prefectural assessment serve to limit its usefulness. First, it does not include any attempt to determine the degree or extent of erosion itself. Second, it does not attempt to assess the effectiveness of the erosion control structures that it measures. To be sure, these two activities are not among the commission's official responsibilities. Their inclusion, however, would greatly enhance the diagnostic value of the commission's annual report. Means of moving toward this goal are included in the Recommendations section below.

Agricultural Survey. The National Agricultural Survey is an on-going effort to provide reliable statistics on agricultural land use and production in Rwanda. As such, it includes several components of relevance to soil erosion and management. Information is broken down by prefecture and ecological zone; but since the latter areas extend beyond prefectural boundaries, they are not entirely reliable for analysis of conditions within a single prefecture. All Survey results presented below are for the year 1984.

Although hard data are still lacking on qualitative aspects of soil degradation (as opposed to physical erosion), certain Survey results help to shed some light on this subject. Slightly more than 50% of the farmers in Ruhengeri felt that the productivity of their fields was declining. Roughly 19% attributed this decline to the effects of erosion, while 59% said it was due to over-cultivation (especially in the Lava zone). This is hardly surprising given several related findings. First, more than one-third of all Ruhengeri fields have been in cultivation for at least 50 years. Second, only about 14% of fields are fallowed each year -- and then only for increasingly shorter periods. Finally, fewer than half of all farmers reported using fertilizer or mulch on any of their fields. Under such conditions, it is not at all surprising that productivity is declining on a majority of farms.

A second area in which the Agricultural Survey provides some useful information concerns the erosion risk factors of slope, crop cover and protection. Approximately 70% of all cultivated fields in Ruhengeri are located on the upper and middle slopes of hills. As a direct result, nearly half of these fields are on slopes of more than 37 percent (unfortunately, this is the highest slope category in the Survey and fails to reflect the true steepness of many fields). In addition, several of the principal crops grown on these fields (especially maize, potatoes, sorghum and peas) are among those most susceptible to erosion (Table 4.1). Bananas, on the other hand, are noted for their soil protection qualities; but most banana stands are on lower, more moderate slopes. Finally, Survey results indicate that approximately 40% of all agricultural fields and 20% of those fields not in crops were protected by erosion control structures in 1984. This figure is lower than that of 53% established by the Prefectural Commission in 1985, yet the difference could easily be explained by progress in erosion control over the intervening year.

The most recent Agricultural Survey study ("Pertes de terre dues à l'érosion", SESA/MINAGRI 1986) is also the most relevant for the purposes of this chapter. Combining the field data described above with direct measures of erosion on 100 sample fields, and then applying both to the Universal Soil Loss Equation (USLE), this preliminary report represents a significant contribution to the quantitative assessment of erosion in Rwanda.

The USLE (Wischmeier & Smith 1965, 1978) was developed as a tool for estimating soil losses under a broad range of field conditions. Although derived from studies in the United States, it has been modified for applications in numerous tropical countries. The basic formula for the equation is represented as:

$$A = R*K*L*S*C*P$$

where

A is the quantity of soil lost per unit area;
R the rainfall erosivity factor;
K the soil erodibility factor;
L the length of slope factor;
S the slope gradient factor;
C the crop cover factor; and
P the erosion control factor.

Values for the length and gradient of slopes were obtained from direct measures of the Survey's 10,000 sample fields. These also provided data on crop cover and erosion control, but values for these factors were then modified based on results from the 100 erosion monitoring sites. Rainfall erosivity and soil erodibility values were determined from existing maps of general climatic and lithologic features.

Results from this pilot study reveal a serious average soil loss in Ruhengeri of 13.3 tons per hectare per year. The breakdown of this total loss in Tables 4.1 - 4.4, however, indicates potentially even more severe problems.

Table 4.1
C-Values by Type of Crop or Association
(higher values = more erosion)

Crop/Association	C-Value
Coffee	0.02
Bananas	0.04
Bananas/Beans	0.10
Non-cultivated Field	0.10
Soy/Bananas	0.11
Beans/Bananas	0.12
Bananas/Taro	0.13
Bananas/Sorghum	0.14
Sweet Potatoes/Beans	0.14
Maize/Bananas	0.15
Peas	0.15
Sweet Potatoes/Bananas	0.15
Sorghum/Taro	0.17
Sorghum/Bananas	0.18
Taro/Bananas	0.19
Beans	0.19
Beans/Manioc	0.20
Beans/Peas	0.20
Beans/Potatoes	0.20
Beans/Sweet Potatoes	0.20
Manioc/Taro	0.20
Pyrethrum	0.20
Sorghum/Sweet Potatoes	0.20
Potatoes/Maize	0.21
Manioc/Beans	0.22
Manioc/Sweet Potatoes	0.22
Potatoes	0.22
Sweet Potatoes	0.23
Finger Millet	0.25
Maize/Sweet Poatoes	0.25
Manioc	0.26
Beans/Maize	0.30
Maize/Beans	0.30
Maize/Peas	0.31
Sorghum/Manioc	0.31
Maize/Tobacco	0.32
Taro	0.35
Maize	0.35
Sorghum/Maize	0.35
Sorghum	0.40
Tobacco	0.45

Source: National Agricultural Survey MINAGRI 1986

The figures presented in Table 4.1 demonstrate that most of Ruhengeri's principal crops (especially sorghum, maize, potatoes and sweet potatoes) have high C-values which indicate a high potential for erosion. Bananas are a notable exception, while fields under beans and bean associations fall into a moderate risk category.

Table 4.2 converts these C-value classes into actual soil losses per hectare. From these figures, and earlier crop production data, it can be seen that more than one-third of Ruhengeri's fields are in the highest loss category of 18.5 T/ha/year.

Table 4.2
Average Soil Losses by C-Value Classes
(Tons/Ha/Year)

C-Value Class	Soil Loss
0.02 - 0.09	1.1
0.10 - 0.14	7.8
0.15 - 0.24	11.4
0.25+	18.5

A further subdivision of the erosion study provides soil loss averages for different slope categories. These data, presented in Table 4.3, demonstrate the significant correlation between high slope values and increased erosion. The results are particularly troubling for Ruhengeri, where 35% of all agricultural fields and 58% of non-agricultural fields fall into the >37% slope category, in which soil losses average 25.7 tons/ha/yr.

Table 4.3
Average Soil Losses by Slope Class
(in Tons/Ha/Year)

Slope Class	Soil Loss
0 - 9 percent	1.1
10 - 18 percent	4.2
19 - 36 percent	11.9
37 + percent	25.7

A final treatment of the erosion study data concerns soil loss differences among Rwanda's 12 ecological zones (Table 4.4). These results show the Zaire-Nile Divide region to have the highest average erosion rate of 21.7 T/ha/yr. The second and third worst rates were found in the Lava and Buberuka zones, with 13.6 and 12.3 T/ha/yr respectively. The Central Plateau (8.8 T/ha/yr) was the only zone present in Ruhengeri below the national average of 10.1 T/ha/yr.

Table 4.4
Average Soil Losses by Ecological Zone
(in Tons/Ha/Year)

Ecological Zone	Soil Loss
Zaire-Nile Divide	21.7
Lava	13.6
Buberuka	12.3
Kivu	12.0
Imbo	11.4
Impara	11.3
Central Plateau	8.8
Granite Ridge	6.2
Mayaga	5.1
Eastern Savanna	4.5
Eastern Plateau	3.3
Bugesera	2.6
AVERAGE	10.1

The results presented above come from a pilot study. As such, their accuracy and utility are somewhat limited by a number of factors: a lack of site-specific rainfall and soil characteristics data; questions about precise modifications of the Universal Soil Loss Equation for Rwandan conditions;

and, finally, limits on subregional analyses due to a small sample size of 100 erosion monitoring sites. Still, these Survey findings add considerably to our understanding of erosion issues in Rwanda and help to indicate several potential problem areas specific to the Ruhengeri region. In particular, they highlight the fact that significant areas of the prefecture -- notably those with steep slopes and/or under certain forms of crop cover -- require priority attention for erosion control.

RRAM Project Studies. As part of its general inventory of environmental issues in the Ruhengeri prefecture, the RRAM project conducted two separate studies which concern soil erosion. The first was a survey of 660 households which dealt with popular perceptions of the problem. In the second, a series of technical maps was compiled, then combined in an attempt to determine priority problem sites.

One section of the RRAM survey asked a series of questions about soil productivity, erosion and erosion control. Table 4.5 presents responses to the question: "How has productivity on your hillside fields changed in recent years?" Results show that a large majority of 82% of the population feels that their land has become less productive. The most negative responses come from the Zaire-Nile Divide region, while conditions appear most positive in the Plateau zone.

Table 4.5
Perceived Changes in Soil Productivity

	Lava %	ZND %	BUB %	CP %	TOTAL %
Better	14	0	13	21	14
Same	17	6	10	17	13
Worse	69	94	77	62	73

The reasons most commonly cited for increased or stable productivity are the use of compost (59%) and improved erosion control methods (23%). In the Buberuka region, erosion control is rated a more important factor. The principal reasons cited for declining productivity are: reduced fallow periods (56%), erosion (24%) and the perception that the soil is "tired" (11%). Regional differences on this point are not very significant, although residents of the ZND and the Plateau cite erosion more frequently.

With regard to erosion and its control, regional differences emerge quite clearly in response to several questions. Asked whether signs of erosion were visible on their fields following a heavy rainfall, 82% of those from the ZND responded yes. The Plateau and Buberuka regions were next most affected (64 and 62%, respectively), while only 48% of those from the Lava zone perceived erosion problems of this order.

Virtually all farmers report using some form of erosion control on at least some of their fields. Of those using a single method (29%), grass hedgerows are cited as the preferred technique by 69%. The majority of farmers, however, prefer a combination of hedgerows, infiltration ditches, and terraces (in the broadest sense of the term; not to be confused with radical terraces). The hedgerow - terrace combination is most prevalent in the ZND region, whereas infiltration ditch combinations are more widespread in Buberuka and the Central Plateau. A surprising finding is that 11% of all farmers report using trees as part of their approach to erosion control on fields. Most of the latter come from Buberuka, though, where an agroforestry extension effort has been underway for several years.

Nearly two-thirds of the population feel that their erosion control efforts have a positive effect, with little variation among regions. Among those who experience failure, steepness of slope is most commonly given as the reason. This is especially true in the ZND zone, where 77% state that slope conditions render their methods ineffective. Slightly more than half of those from Buberuka cite similar problems. One additional reason given for erosion control failure is peculiar to the Lava zone, where 29% of the farmers report significant damage to their hedgerows by animals from the park.

The final RRAM project contribution to the analysis of erosion problems involves cartographic methods. In this approach, certain types of information are ranked as risk factors for erosion, then put into map form. These base maps are then combined to make a final map of high-risk erosion sites. This is generally referred to as the Geographic Information System (GIS) approach.

A complete GIS analysis of erosion risk sites would involve mapping of information on several key variables: soil types, slope, rainfall, vegetation cover, and population density. Given current gaps in the available data base, however, the RRAM GIS uses a more limited set of variables. Slope and general soil surface characteristics are combined to first make a map of natural erosion risks, then population density data are applied to arrive at a final map of theoretical erosion risks.

Figure 4.1 shows the Ruhengeri prefecture broken down into six general slope categories: (1) <2%; (2) 2 to <7.5%; (3) 7.5 to <15%; (4) 15 to <30%; (5) 30 to <60%; and (6) more than 60%. As these categories are derived from the topographic map in Chapter 2, it should be recognized that they represent general groupings within a range. They are nevertheless sufficient for the purposes of this analysis, and serve to identify the major areas at risk due to a high slope factor.

Lacking a suitable soils map, relative soil erodability values were derived from lithologic factors (see Figure 2.6 in Chapter 2), general silt:clay ratios, and field observations. Thus, until the new soils classification map is ready, the resulting categories permit a first approximation of different soil formations' susceptibility to erosion:

1. Low Risk: Those areas covered by the Virunga lava flow;

2. Medium Risk: Soils evolved primarily from quartzite;

3. High Risk: Soils evolved primarily from substrata of mixed schist and granite;

4. Very High Risk: Soils evolved from granite.

The combination of slope and soil characteristics produces a map of Natural Erosion Risks (Figure 4.2) based on the following matrix:

Natural Risk = Slope + Soil Value	
Very Low	= (1,1)(2,1)(1,2)
Low	= (3,1)(4,1)(2,2)(2,3)(3,2)(1,3)(1,4)
Medium	= (5,1)(4,2)(3,3)(2,4)
High	= (6,1)(5,2)(6,2)(4,3)(3,4)(4,4)
Very High	= (5,3)(6,3)(5,4)(6,4)

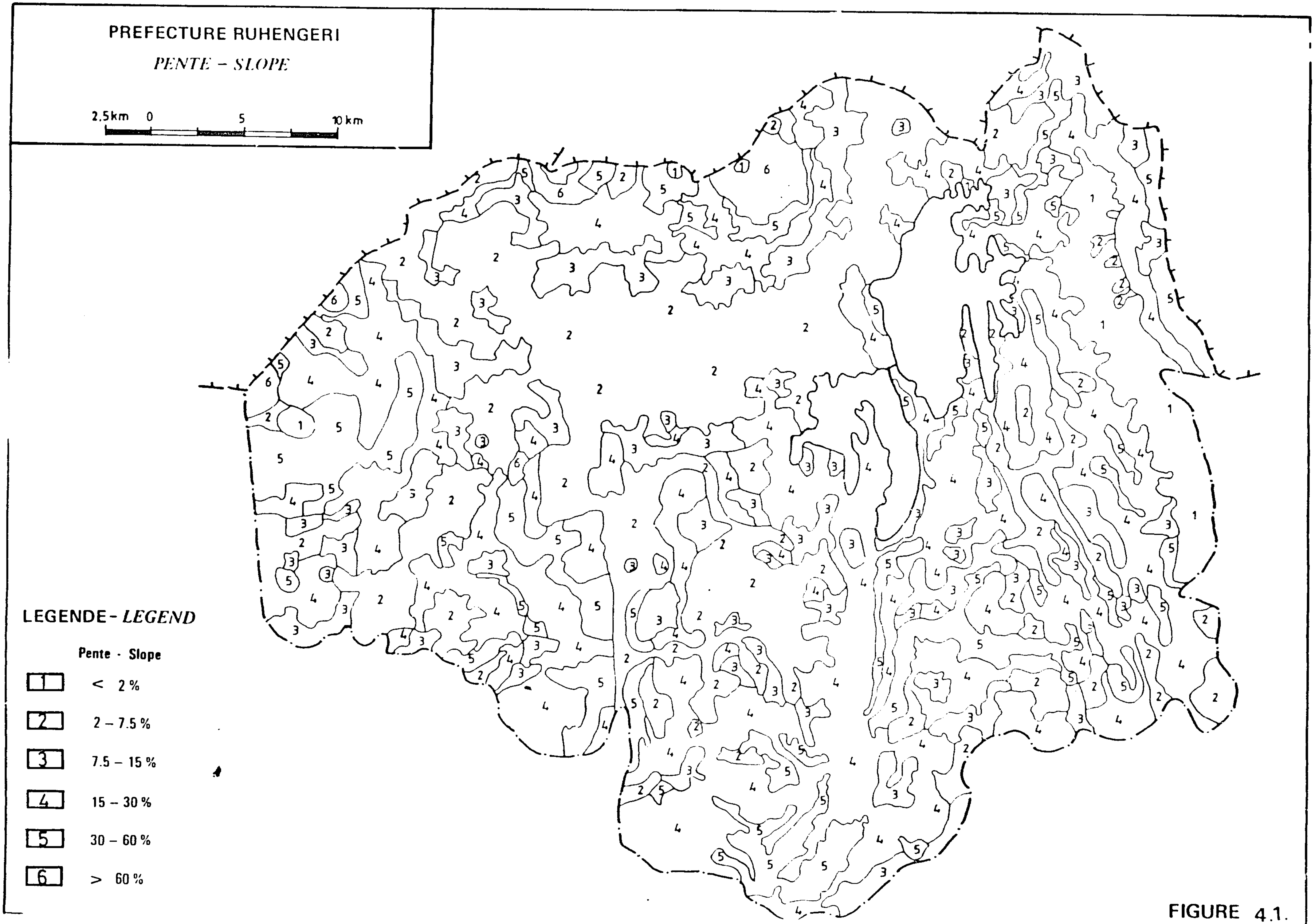

PREFECTURE RUHENGERI
PENTE – SLOPE
2,5km 0 5 10 km
LEGENDE - *LEGEND*
Pente - Slope
1 < 2 %
2 2 – 7.5 %
3 7.5 – 15 %
4 15 – 30 %
5 30 – 60 %
6 > 60 %

FIGURE 4.1.

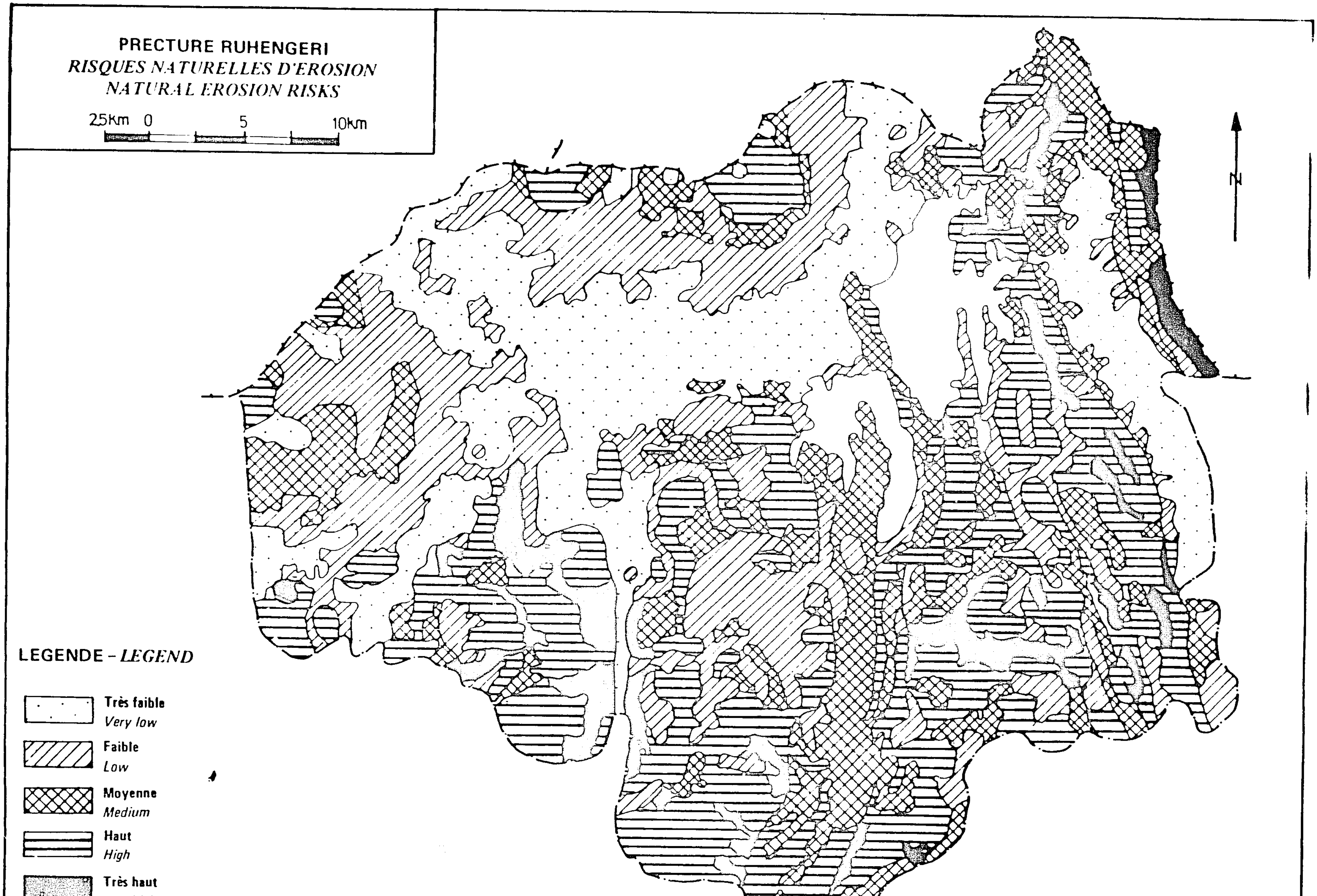

PRECTURE RUHENGERI
RISQUES NATURELLES D'EROSION
NATURAL EROSION RISKS
2,5Km 0 5 10Km
N
LEGENDE - LEGEND
Très faible
Very low
Faible
Low
Moyenne
Medium
Haut
High
Très haut
very high

FIGURE 4.2.

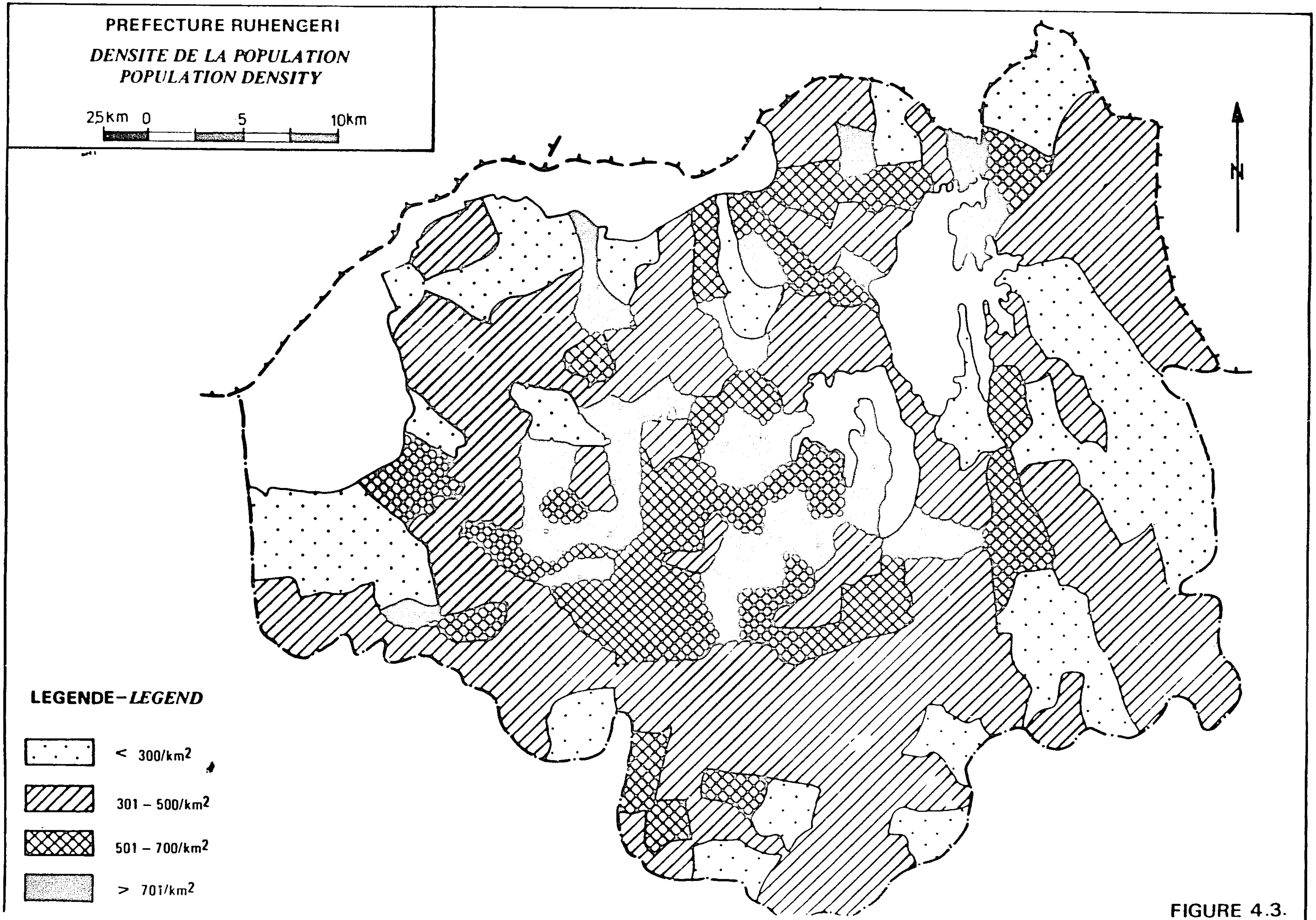

PREFECTURE RUHENGERI
DENSITE DE LA POPULATION
POPULATION DENSITY
25km 0
5
10km
N
LEGENDE-LEGEND
< 300/km2
301 – 500/km2
501 – 700/km2
> 701/km2

FIGURE 4.3.

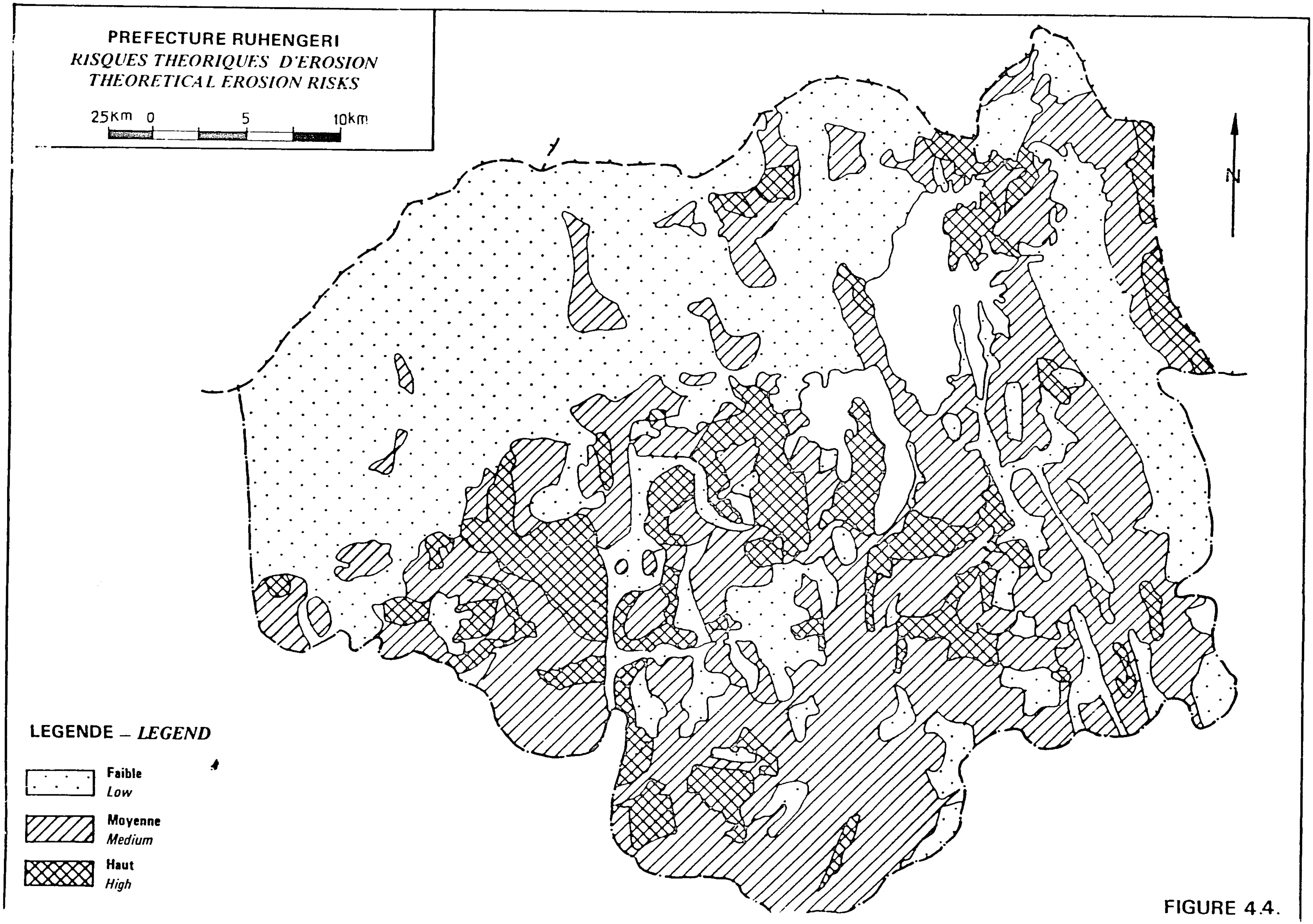

PREFECTURE RUHENGERI
RISQUES THEORIQUES D'EROSION
THEORETICAL EROSION RISKS
25Km 0 5 10km
N
LEGENDE – LEGEND
Faible
Low
Moyenne
Medium
Haut
High

FIGURE 4.4.

The Natural Erosion Risk map highlights three areas with potentially serious problems: almost the entire Zaire-Nile Divide region, most of Ndusu and Nyarutovu communes in the Central Plateau, and the belt of schist-quartz ridges which surrounds the Rugezi depression. If the general rainfall figures presented in Chapter 2 were considered, this factor would probably accentuate erosion risks in the first two areas, and serve as a moderating influence in the eastern Buberuka region.

Physical characteristics alone, however, do not represent the entire range of erosion risk factors. Land use factors are also extremely important. As described in earlier sections, only two areas in Ruhengeri remain in more or less natural condition: the Volcanoes Park and the Rugezi Marsh. The former is generally protected by its dense vegetation cover (although landslides do occur on its steepest slopes), while the latter is protected by both its vegetation and minimal slope. Beyond these areas, however, the landscape has been transformed by human activities and agriculture is the predominant form of land use.

Despite certain regional differences with regard to crop selection, the agricultural landscape is also relatively homogeneous. For this reason, population density was selected as a primary indicator of human impact on the land for the RRAM GIS analysis. As can be seen in Figure 4.3, this population has its highest concentrations in the central part of the prefecture, with additional pockets of high density in the eastern Lava zone and northwestern Buberuka.

The combination of population density with the factors of slope and soil erodability produces the final map of Theoretical Erosion Risks in the GIS series (Figure 4.4). This map shares several similarities with that of natural erosion risk, but is also different in certain important respects. The major part of the Zaire-Nile Divide remains a high risk area, as does the western edge of the Plateau region. In Buberuka, however, the population factor brings most of the land to the west and south of Lake Ruhondo, plus the area northeast of Lake Bulera, into this highest risk category. A similar change also occurs on the southeastern flank of Mt. Muhabura in the Lava zone.

Conclusions.

Ruhengeri has a potentially very serious erosion problem. The average soil loss of 13.3 T/ha/yr, as determined by the Agricultural Survey, is considered to be a preliminary -- and quite conservative -- figure by those responsible for the study. It is virtually certain that erosion monitoring trials now underway in different parts of the coutnry, including Ruhengeri, will reveal higher losses.

In addition, erosion risks are not homogeneous across the prefecture. The Zaire-Nile Divide region is clearly at highest risk, followed by major parts of Buberuka and the Central Plateau. Within these regions, those areas with steep slopes, poor soil structures, high population densities and a predominance of certain crops have significantly higher soil losses. The Agricultural Survey finding of high erosion rates in the Lava zone appears to contradict other indicators of lower risk in this particular area. Yet there is general agreement that qualitative soil degradation, as seen in declining productivity, is as serious a problem in the Lava zone as in others.

With regard to soil degradation, it should also be remembered that the majority of Ruhengeri farmlands have been in almost constant cultivation for more than 20 years; that fallow periods have been reduced or eliminated in most areas; and that inputs of fertilizer and organic matter are inadequate. Under these conditions, it is not surprising that four out of every five farmers report declining productivity on their lands: a subjective measure for sure, but one which perhaps best reflects the current state of affairs.

A final conclusion is based upon consideration of the diverse conditions described above and the fact that Rwanda does not have the means to attack the soil problem at all levels in an optimal manner. Given this situation, a triage approach to the problem may be appropriate.

The practice of triage, developed under wartime conditions, calls for the differential treatment of the injured. Those with minor injuries who are likely to survive without assistance, and those with critical wounds who are likely to die no matter what, are left untreated so that limited medical resources can be directed toward those who will respond most positively to their use.

In Ruhengeri, as elsewhere in Rwanda, the government has declared war on soil erosion; yet it has limited resources at its disposal to deal with the problem. Under these conditions, a modified triage approach is required, in which no areas are totally abandonned, but priority attention is given to those sites where the trade-off between potential and risk is such that protective benefits are optimized. The details of such an approach, as well as other recommendations, are presented in the final section below.

Recommendations.

Action is required at three different levels to deal more effectively with soil erosion and degradation problems in Ruhengeri. This includes improved methodologies for conceptualization, analysis and planning; applied research to provide essential information where it is lacking; and action to be taken immediately, based on the best available knowledge of field conditions.

Methods.

1. A modified form of the triage system should be applied to problems of soil erosion and degradation. To this end, the limited resources available for analysis and management should be first applied to those areas where serious problems have been identified, yet the potential remains for corrective action.

In Ruhengeri, this means that both research and erosion control activities should focus primarily on arable lands where there are steep slopes (between 20 and 60 percent) and a combination of the following factors: soils with a high susceptibility to erosion; high population densities; and/or crop mixes which include a high percentage of erosion-prone cultures. The likely result of this approach will be a focus on the ZND region and other high-risk areas of Buberuka and the Central Plateau. Yet attention must also be given to the ecological micro-zones described in Chapter Two. Under this zonation scheme, ridgetops and the upper slopes of most hills should come under more strict management practices than lower slopes and valleys.

The triage approach does not mean that other areas should be abandonned. For those areas or sites with lower risk ratings, a certain minimum effort must continue to assure that they remain productive. As for high-risk (more than 60% slopes) or already degraded sites, alternative land uses such as forestry should be mandated.

2. The Geographic Information System approach should be used for the preliminary determination of priority erosion control sites. These sites must still be examined in the field, but the GIS analysis can help to focus attention on potentially high risk areas.

The limited GIS developed by the RRAM project has demonstrated considerable potential for analysis and planning purposes, despite a serious lack of data. As additional information becomes available, however, it can be readily integrated into the existing GIS structure. The use of computer technologies in this regard can also greatly increase the speed and facility with which this updating and modification can be carried out (for a more complete description and presentation of the computerized GIS program used by the RRAM project, see Appendix I). A final advantage of the GIS approach is the cartographic format of its products. Maps are currently underutilized in Rwanda. Yet they have a proven value as tools which permit resource managers to rapidly visualize and understand a given situation and to plan appropriate action within a spatial context.

Research.

3. Some of the most important research for improved understanding of soils and their erosion potential has recently been completed by the National Soils Classification and Mapping project. When this information becomes available, it should be incorporated into the GIS data base. The same applies to the new topographic map of Rwanda, which will permit more refined and precise slope calculations.

4. If the new soils map goes no further than classification, then additional research will be required to determine soil erodability values. These can be determined from analyses of sand content, organic matter, soil structure and permeability.

5. New sources of remote sensing information must be acquired and analyzed as soon as possible. The existing aerial photos are at least 7 years old and no longer reflect the reality of field conditions. The major uses of new imagery would be: 1) a rapid and accurate quantification of the extent of the current erosion control effort (thus reducing much of the work now done by the Prefectoral Commissions); 2) the identification and classification of current erosion sites; and 3) the production of a land use map which would both reflect current conditions and permit an anlysis of changes since the 1978 - 1980 period covered by the RRAM mapping effort.

The best source of this information would be a new set of 1:20,000 aerial photos from low level overflights. Satellite imagery should not be ruled out, though, despite certain problems of cloud cover and scale. In particular, such imagery can be obtained obtained more quickly and cheaply than traditional aerial photos.

6. Additional information is also required from field studies. While the pilot Soil Loss survey has provided some useful preliminary information, it is still true that far too little is known about the nature and scale of erosion in Rwanda. The best way to obtain this information is to measure soil losses under a variety of field conditions.

Such measures should be made at two scales: large-scale monitoring of sediment transport within watersheds and more localized measures of soil losses from individual fields or other specific sites. The former would permit gross quantification of soil loads carried by rivers and essentially lost from the agricultural system. If sufficient care is taken in the selection of representative watersheds, then results from one site could be extrapolated to other areas with similar characteristics. Under the best of conditions, however, this approach would not be of much help to determine the specific sources of the measured sediment.

For this more specific information, micro-scale field measures are essential. These require the installation of soil traps under a variety of conditions (e.g. different slopes, land uses, erosion control systems, etc.). A great advantage of this approach is that it permits the modification of certain variables, such as different erosion control techniques and spacings, over time to assess their relative effectiveness. There are also disadvantages in that the measures must be made at multiple sites over several seasons. Yet the information to be gained is of such critical importance as to warrant the expense of both time and effort.

Action.

7. The erosion control and soil improvement campaigns conducted by the government over recent years have had an overall beneficial effect. Yet certain practices, such as infiltration ditches, have proven to be counterproductive on high-risk sites, while others have not been fully effective due to their inappropriate installation, spacing and maintenance. To improve this situation, the following guidelines are recommended:

- Combinations of physical and biological techniques offer the best possibility of success in erosion control. Progressive terrace formation structures should thus be reinforced with solid rows of permanent vegetation cover (ideally a mix of grasses, shrubs and trees);

- Much more attention must be given to the maintenance of both physical and biological erosion control structures if they are to be fully effective:

- The width and spacing (vertical intervals) of erosion control structures should vary in relation to the slope;

- Mulching, composting, mixed cropping and cultivation along contour lines should continue to be encouraged, as these practices both inhibit erosion and improve soil qualities;

- Infiltration ditches should be discouraged on steep and unstable slopes.

8. Agroforestry techniques should be vigorously promoted as a key element in intensified erosion control in those areas identified as high risk sites. These techniques should be modified in the following ways in relation to degree of risk:

- Woody shrubs and appropriate tree species should be mixed with grasses along contour lines in all moderate to high risk areas. This should result in increased stability due to deeper root structure, nitrogen-fixation (from leguminous species), improved organic content in soil from leaf-fall, and increased wood or other secondary products (see Chapter 3 for a more complete description of this technique);

- In areas with very steep slopes yet established farming populations (especially in the ZMD region), more complete mixing and rotation of trees and crops, along the lines of the taungya system, should be tried as an alternative to the conversion of farmlands to forestry.

9. Reforestation is the most appropriate corrective action to be taken on

the highest risk and already degraded sites. These include ridgetops, gullies, landslide sites where some soil remains, roadsides, and abandonned mining sites. New approaches are required in this effort, however, which emphasize the establishment of more complete ground cover (grasses, shrubs) and the use of tree species which promote soil conservation objectives. In the particular case of roadsides, it is absolutely essential that spills be recolonized with grass and shrub cover as soon as possible after construction activities are completed.

10. Stream bank erosion appears to be on the increase in all parts of the prefecture as a result of the removal of riparian vegetation and subsequent cultivation right up to the stream edge. An erosion control zone of at least 3 meters should be established along each side of all waterways. Cultivation within this zone should be forbidden in favor of re-establishing ground vegetation and tree cover. In the particular case of torrential erosion in the lava zone, this approach will have to be reinforced by the use of gabions to halt extreme bank destruction in certain areas (e.g. in Kinigi, where the Rwebeya threatens to cut the commune's principal road in two).

11. Specific soil conservation and management guidelines should be developed for the Ruhengeri prefecture, based upon existing information, as well as that which can be derived from the preceding recommendations. These guidelines should be presented as a series of flexible options which are adapted to specific site conditions and which can be understood, accepted and implemented by the rural population.

12. Expanded and improved training and education are required to implement a coherent and comprehensive erosion control strategy. This effort must aim at three critical levels: advanced training of central government planners and technicians who establish policies; both basic and cyclical training of those field technicians in the prefectures and communes who must oversee the implementation of these strategies; and the development of appropriate extension education programs for the general public which should be the primary executor and beneficiary of an improved erosion control program.

CHAPTER FIVE: FORESTRY

For rural populations in developing countries, trees are a critical resource. Their primary use is as fuel-wood for cooking, while they are also essential for most construction needs. In addition, trees provide several important tertiary products such as medicines, dyes, rope, utensils, and food for people and animals. Lastly, trees play very important roles in the maintenance of ecological stability through their reduction of erosion, their retention of excess water, and their contribution of organic matter to soils.

The people of Rwanda and their leaders are highly aware of the value of trees and have made major efforts to protect remnant natural forests and to reforest formerly denuded areas. Yet the information necessary for better planning and management in this resource sector is seriously deficient. General estimates have been made of wood supply and demand at the national level; but these suffer from questions about their completeness and accuracy -- and they provide little help for an analysis of conditions within a more restricted region such as the prefecture of Ruhengeri.

Sufficient information does exist, however, to indicate that Ruhengeri faces a potentially serious wood shortage problem due to population growth and land use conflicts. The following sections present an analysis of this situation and recommendations for priority research and intervention activities.

Analysis.

Official Statistics. Recent trends in reforestation are very positive in Ruhengeri. Between 1981 and 1985, the total area planted in trees nearly doubled from 5,487 ha to 10,354 ha according to official statistics from the prefecture (Table 5.1). Of the current total area, 4,358 ha (42%) are in the form of large plantations of at least one hectare and up to a maximum of 200 hectares. These are primarily managed by the individual communes, with private enterprises and the central government owning significantly smaller areas. Another 628 ha are planted along the regional road network. The majority of the total forested area, however, consists of thousands of much smaller private woodlots. Eucalyptus species make up an estimated 90% of all trees currently growing in the prefecture; but this percentage has dropped in recent years as cypress has gained in popularity (23% of all trees planted in 1984).

Unfortunately, official statistics do not include any information on either the standing volume nor the annual growth of Ruhengeri's forest resource base. Taking consumption figures from a national forest survey, it is nonetheless clear that the 10,353 ha cited above do not come close to satisfying current annual demand (see supply - demand discussion below). Other sources of information, however, indicate that these official totals underestimate the true forest cover and wood availability in the region.

Agricultural Survey. According to the Agricultural Survey, there were nearly 7,500 ha of small woodlots (average size = 5.5 ares) on individual farms in Ruhengeri in 1984. This figure is triple that given for the same year in Table 5.1. Additional information presented below supports this higher figure, and the discrepancy is best explained by past dependence on inaccurate inventory techniques for small woodlots and dispersed tree clusters. Large plantations did not figure in the Survey analysis.

Additional Survey data on small woodlots indicate that these occupy more than 70% of the 10,500 ha of non-cultivated fields in the prefecture. This percentage is more than double the national average, indicating the high value that the population of Ruhengeri places on trees. It also relects the lack of alternative public sources of wood for domestic consumption.

Due to the limited sample size of the Agricultural Survey, it is difficult and dangerous to use their data for analysis of conditions within sub-regions of the prefecture. It is revealing, however, to note certain regional differences which appear from such an analysis. In particular, the Lava zone appears to have the highest percentage (14.6%) of fields in woodlots, followed by the Central Plateau (10.1%), Buberuka (6.1%) and the Zaire-Nile Divide (4.7%). For the ZND, however, this low figure nevertheless represents more than 90% of the uncultivated land in that ecozone.

RRAM Project. Three different types of forest resource studies were carried out by the RRAM project: an aerial photo assessment of tree cover, sample field measures of standing volume and growth, and a survey of rural perceptions of the forestry situation. These studies provide some of the information needed to fill certain gaps, but also raise additional questions for further investigation.

aerial photo analysis

The aerial photo analysis covers the period up to 1980, the latest date for which imagery is available. Measures were made of all forest plantations of more than one hectare, dispersed tree clusters of < 1 ha, and linear formations along roads and rivers. Results of this analysis indicate that more than two and one-half times the officially reported area was under forest cover as of 1980.

All forest surfaces larger than 1 ha were identified from aerial photos and mapped at a scale of 1:100,000 (see Figure 5.1 for a sample from the southern part of the prefecture). These were divided into three categories according to crown cover:

low = 20 - 50% cover
medium = 51 - 70% cover
high = > 70% cover.

The total area covered by such large plantations was found to be 9,630 ha (Table 5.2). Even if the low density area is halved to reflect its lower standing volume, the corrected total of 8,416 ha remains more than double the 3,992 ha reported in Table 5.1.

Similarly, calculations of linear tree formations (mostly roadside plantations plus a few remnant galleries) were made by converting measures from aerial photos to equivalent hectares. The results show a total of 537 ha of such formations across the prefecture This, too, is significantly greater than the reported figure of 170 ha for 1980.

Finally, dispersed tree measures were also made from the aerial photo analysis. These involved the grouping of all visible trees, not already counted as plantations or linear formations, into three density categories and subsequent extrapolation of equivalent forested areas per km2, as follows:

low density = 1.5 ha/km2
medium density = 7.5 ha/km2
high density = 15 ha/km2.

The result of this calculation is a total of 5,542 ha of predominantly small woodlots and isolated trees: an increase of 419% over reported figures for the same period.

Table 5.1

Evolution of Forest Cover in Ruhengeri
1980 - 1985
(in ha)

Year	Large Plantations	Roadside Plantations	Small Woodlots	Total
1980	3,992	170	1,325	5,487
1981	3,838	170	1,379	5,387
1982	3,991	201	1,458	5,650
1983	3,997	244	2,385	6,626
1984	4,474	356	2,532	7,362
1985	4,358	629	5,367	10,354

Source: Official statistics of
Ruhengeri Prefecture

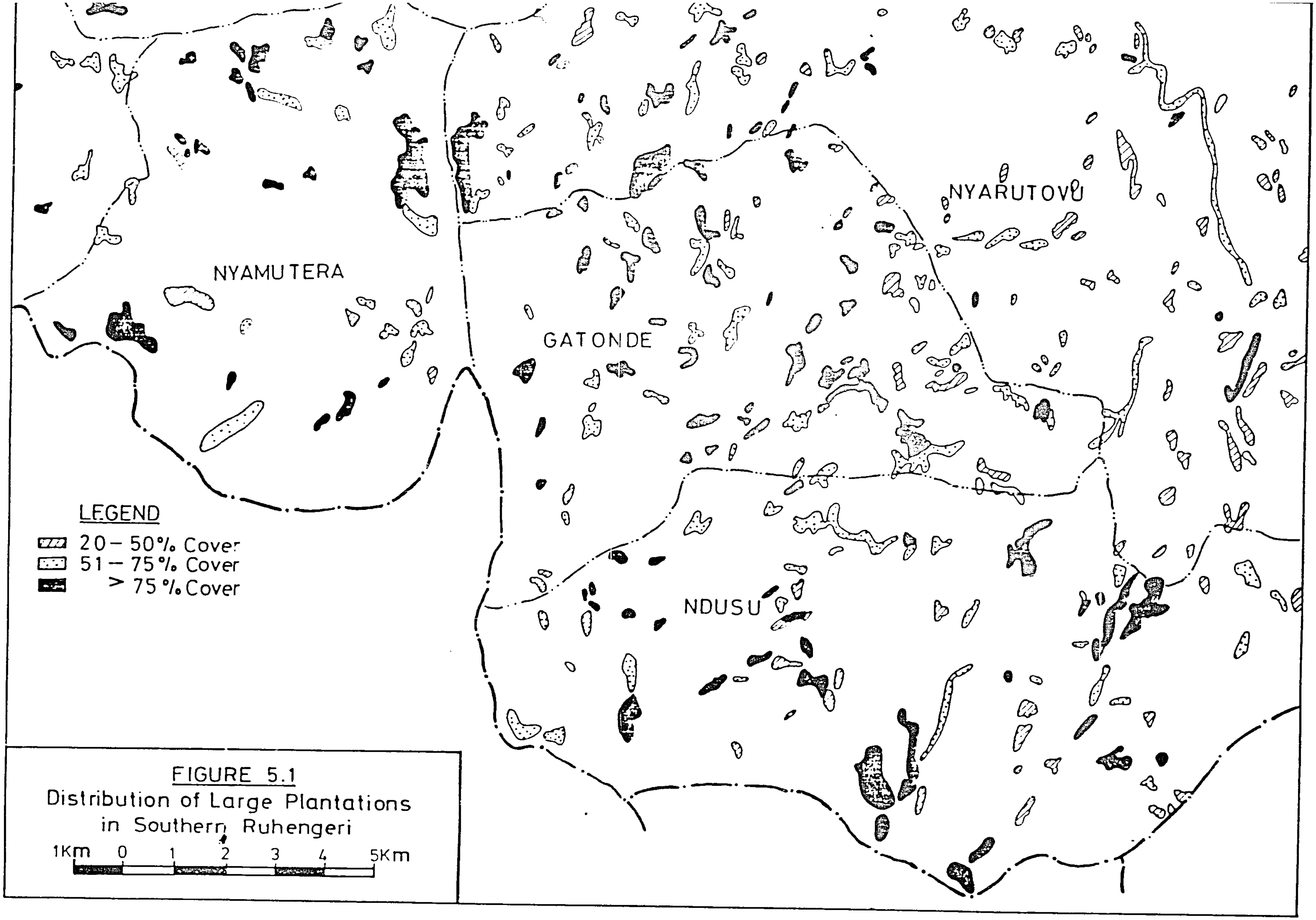


FIGURE 5.1
Distribution of Large Plantations in Southern Ruhengeri

Table 5.2
Forest Plantation Areas by Agroecological Zone
(includes only forested areas larger than 1 ha)

AGROECOLOGICAL ZONES	LOW DENSITY FOREST (ha)	MEDIUM DENSITY FOREST (ha)	HIGH DENSITY FOREST (ha)	TOTAL FOREST	% AREA
ZAIRE-NILE DIVIDE	186	394	384	964	6.1
CENTRAL PLATEAU	1086	1316	990	3392	9.1
LAVA ZONE	501	762	920	2183	5.1
BUBERUKA HIGHLANDS	651	1098	1342	3091	6.3
GRAND TOTALS	2424	3570	3636	9630	5.7

Source: RRAM Project land use analysis of 1978 - 1980 aerial photography

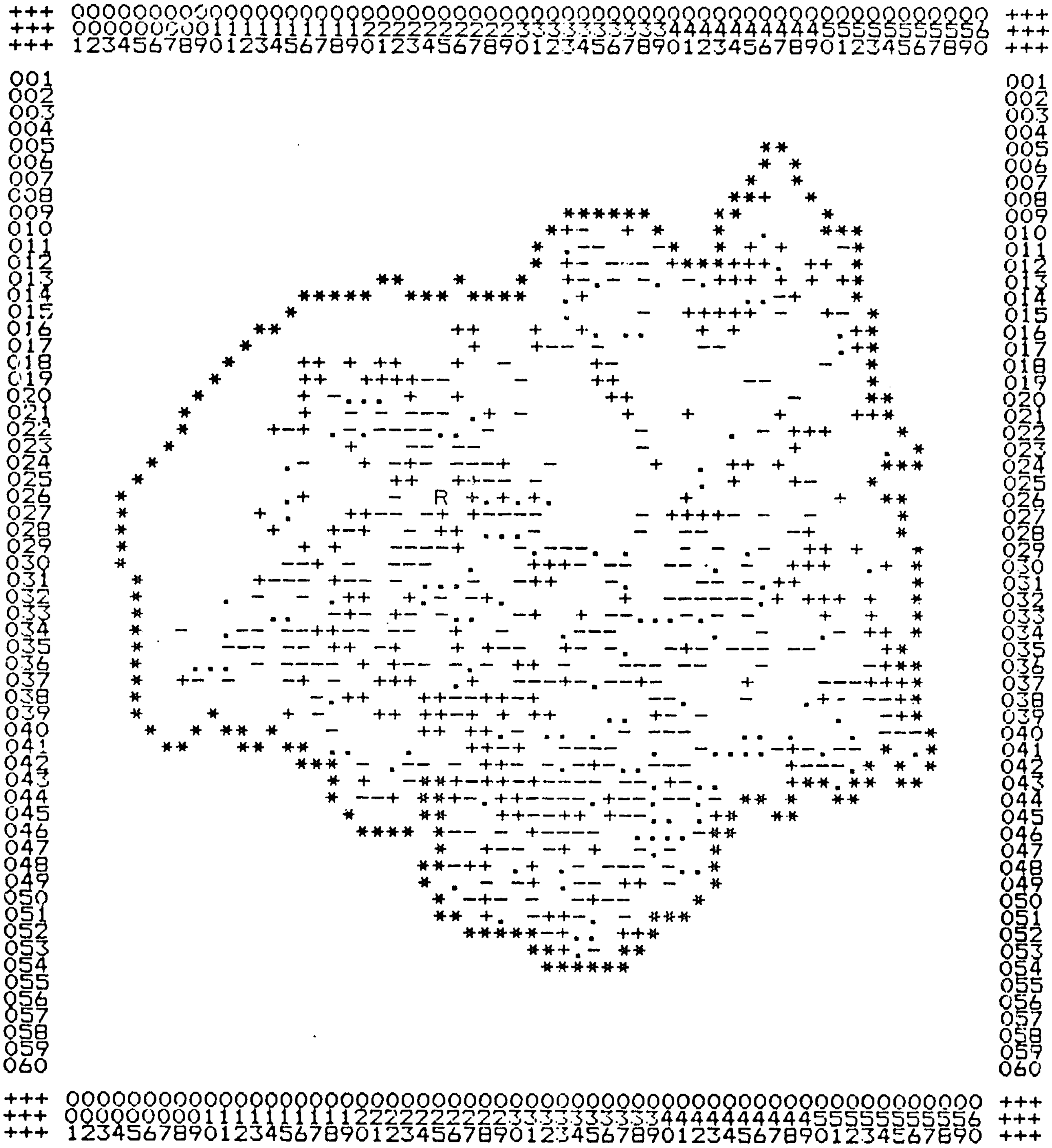


Figure 5.2
Distribution of Large Plantations

Symbol	Label	Cells (km2)	% Prefecture
..	Low Density	128	8.44
==	Medium Density	310	20.45
++	High Density	240	15.83

Each symbol/cell represents an area of 1 km2. Figures in parentheses are averages. For a detailed explanation of the computerized mapping system, see Annex B.

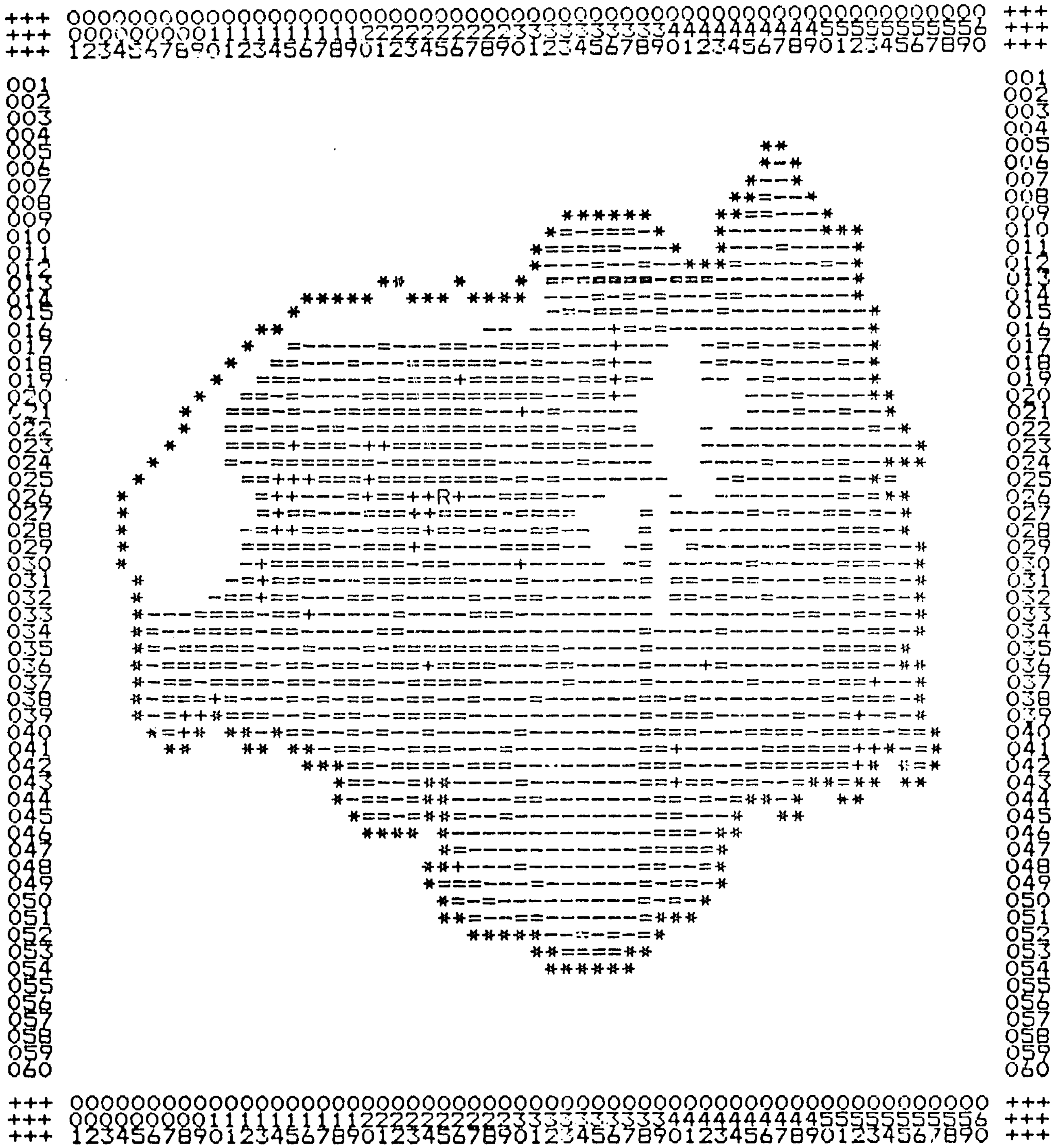


Figure 5.3
Distribution of Dispersed Trees

Symbol	Label	Cells (km2)	% Prefecture
--	Low Density (1.5 ha/km2)	787	51.91
==	Medium Density (7.5 ha/km2)	576	38.00
++	High Density (16 ha/km2)	46	3.03

Each symbol/cell represents an area of 1 km2. Figures in parentheses are averages. For a detailed explanation of the computerized mapping system, see Annex B.

The aerial photo analyses also permit the determination of regional differences within the prefecture, at least as of 1980. Thus, a much higher concentration of large plantations appears in the Plateau region (9.1%), whereas the lava zone has the least coverage of this kind. On the other hand, it is in the Lava zone that the highest concentration of trees in small woodlots is found -- a finding which supports that of the Agricultural Survey. Linear formations appear to be the most evenly distributed across the prefecture. The spatial distribution of plantations and woodlots is presented in Figures 5.2 and 5.3 in computerized map format.

wood resources inventory

In order to calculate the available supply of wood resources in Ruhengeri, the RRAM project also carried out an inventory of both standing volume and annual growth in various tree formations. More than 40 plantations and 100 other sites were sampled on a systematic basis (see F. Weber, 1986, for methodology) to provide this information.

Selected results of the wood resources inventory are presented in Table 5.3. Small private woodlots emerge as the most productive interms of both standing volume (200 m3/ha) and annual growth (12.6 m3/ha/year). These are followed by larger plantations, for which volume and growth averages were calculated to be 168 m3/ha and 8.7 m3/ha/yr, respectively. Linear formations were found to have the lowest volume and growth rates.

To have any meaning, however, these figures must be first extrapolated to the total forested area of the prefecture, then set against demand factors of total population and per capita consumption. These calculations are presented in the Supply and Demand section below.

Table 5.3

Standing Volume and Growth in Woodlots and Plantations

Category	Volume (m3/ha)	Growth (m3/ha/year)
Plantations	167.7	8.7
Individual woodlots	199.9	12.6
Roadside plantations	130.4	6.9

Source: RRAM inventory with volume tables from D-G Forestry

public perceptions

The third RRAM activity related to forestry issues was the project's survey of popular attitudes and perceptions. Selected results from this survey are presented in Table 5.4.

Most rural households (83%) in Ruhengeri have a small woodlot on their property, with little variation across regions. Fewer than half (44%) of these woodlots, however, are able to fully satisfy the family's needs. This is especially true in the Plateau and Zaire-Nile Divide zones, where only 29% and 36% of those surveyed perceived their woodlots to be sufficient. Self-sufficiency in wood was reported by 57% of all households in the Lava zone. In addition, more than three-fourths of those surveyed reported isolated trees elsewhere on their property. A list of these predominantly native species is presented in Table 5.5.

Slightly more than 60% of all families planted trees on their own land in

Table 5.4 (cont.)

Preferred Tree Species by Ecozone
(n=660)*

	Lava (%)	Zaire-Nile Divide (%)	Buberuka (%)	Plateau (%)	TOTAL (%)
Eucalyptus	59.1	71.0	60.7	49.7	57.9
Cypress	48.5	64.5	24.3	20.8	34.4
Fruit trees	21.2	12.9	29.4	30.6	25.7
Markhamia	7.1	12.9	28.5	16.9	17.4
Grevilea/ Cedrella	4.0	11.3	15.4	7.7	9.4
Reeds	1.0	0	14.0	1.1	5.2
Ficus	1.5	3.2	8.9	2.2	4.3
Bamboo	8.6	1.6	0	0	2.7
Pine	0.5	8.1	1.9	0.5	2.3

* Includes multiple responses

Table 5.4

Responses to Wood Resources Survey
by Ecozone (n=660)

	Lava (%)	Zaire-Nile Divide (%)	Buberuka (%)	Plateau (%)	TOTAL (%)
1. Do you have a family woodlot on your land?					
Yes	81.8	91.3	79.9	86.9	83.4
No	18.2	8.7	20.1	13.1	16.6
2. Is woodlot sufficient for family needs?					
Yes	57.4	35.7	46.8	28.9	43.6
No	42.6	64.3	53.2	71.1	56.4
3. Families with isolated trees on land:					
	63.6	62.9	76.2	94.5	76.3
4. Families which planted trees on own land in 1985:					
	53.0	74.2	62.6	62.3	60.7
5. Species planted*:					
Eucalyptus	75.2	95.6	89.5	70.2	80.9
Cypress	39.0	47.8	20.1	32.5	31.8
Fruit trees	20.9	4.4	17.9	24.5	19.0
Grevilea	0	2.2	13.4	6.1	6.5
6. Principal sources of firewood*:					
Family woodlot	73.7	80.7	74.8	79.8	76.5
Gathering	28.2	14.6	46.7	26.2	32.4
Purchase	25.7	25.9	19.7	30.0	24.9
7. Other sources of energy*:					
Banana leaves	4.5	0	19.2	4.4	8.9
Sorghum/ corn stalks	6.6	6.4	1.9	1.6	3.6
Shrubs	3.0	0	6.1	2.2	3.6
Reeds	0.5	1.6	2.3	6.6	2.9
Bamboo	5.6	0	0.5	0	1.8
Charcoal	4.5	1.6	0	0.5	1.7

* Includes multiple responses

Table 5.5

Native Tree Species Found in Agricultural Areas
in Ruhengeri Prefecture

Local names	Scientific names
Umuvumu	Ficus spp. *
Umurehe	Ficus vallis-choudae
Umwongo	Polyscias fulva
Umukore	Dombeya goetzenii
Umugano	Arundinaria alpina *
Umusave	Markhamia platycalyx
Umuko	Erythrina abyssinica
Umuhati	Dracaena afromontana *
Umuravumba	Iboza riparia *
Umubilizi	Vernonia amygdalina
Umucundura	Erythrococca fisheri *
Umwumba	Prunus africana
Umuzibaziba	Mitragyna rubrostipulosa
Umuhanga	Kotschya strigosa
Umuhondohondo	Dracaena steudeneri *
Umusene	Dasylepsis racemosa
Umubonobono	Ricinus communis
Umushishi	Symphonia globulifera
Umushwati	Carapa grandiflora
Umushayishayi	Harungana montana
Umusekera	Macaranga neomildbraedina
Umutagara	Senecio manii *
Umutobotobo	Solanum aculeastrum
Umuyogera	Crotolaria spp.
Umuyoka	Cassia occidentalis
Umuyenzi	Euphorbia tirucalli *
Umusibya	Apodytes dimidiata
Umuduha	Euphorbia candelabrum *
Umufatangwe	Caesalpinia decapetala
Umubonobono	Croton macrostachyus
Umuhulizi	Podocarpus milanjianus
Umuhumuro	Maesopsis eminii
Intomvu	Lobelia giberroa
Umugeshi	Hagenia abyssinica
Umukoni	Synadenium grantii
Umukoli	Markhamia obtusifolia

* multiplication by cuttings; all others by seed

1985. Farmers in the ZND region were most active in this regard, while only 53% participated in the Lava zone. The vast majority (81%) of these trees were Eucalyptus species, followed by cypress (32%), fruit trees (19%) and Grevilea (6.5%). The latter two categories were least common in the ZND, while Grevilea was planted more frequently in Buberuka, where a USAID project was promoting its use.

Asked to name their principal sources of firewood, 77% of all respondants listed their family woodlot first, with little variation across regions. Nearly one-third of all households reported gathering dead wood and other plant matter (with a high of 47% in Buberuka versus 15% in the ZND), while 25% said that they sometimes needed to purchase fuelwood. Among other sources of combustible energy, banana leaves were most commonly cited, especially in Buberuka (19%). Sorghum and corn stalks were preferred in the ZND and Lava zones, bamboo in the Lava zone, and reeds in the Plateau region. Charcoal purchases were reported by nearly 5% of all families in the Lava zone.

Preferred tree species for all uses are also presented in Table 5.4. Eucalyptus again heads the list with 58%, followed by cypress (34%) and various fruit trees (26%). The native species Markhamia (umusave) is considered desireable by 17%, with a higher percentage in Buberuka where its trunk is valued for dugout canoe construction. Grevilia, Cedrella and Ficus species were also more commonly cited in Buberuka, while cypress and pine ranked highest in the ZND. Two other plant species were also cited as important within certain regions: bamboo in the Lava zone and reeds in Buberuka.

Supply and Demand. The vast majority of Ruhengeri's wood supply comes from within its prefectural boundaries. To quantify this supply, however, requires reasonably precise estimates of the current forested area, as well as its standing volume and annual growth.

The current forested area of Ruhengeri is certainly greater than indicated by official statistics. This conclusion is supported by complementary findings from both the National Agricultural Survey and the RRAM aerial photo analysis. Problems arise, however, from the fact that the former was limited to on-farm woodlots, while the latter was based on imagery from 1980. Certain extrapolations from combined information sources can nevertheless be made.

Accepting the RRAM photo analysis as reasonably accurate, there were 14,495 ha of forested land (not counting the park) in Ruhengeri in 1980. This total included 5,542 ha of dispersed trees, primarily in small woodlots. As of 1984, the Agricultutal Survey determined that such woodlots covered a total of 7,498 ha. This represents an increase of 1,956 ha over four years, or an average annual increase of 8.8%. Using a more conservative rate of 5% for the following two years, one arrives at a total of 8,267 ha in 1986.

Extrapolations for large plantations and linear (roadside) formations are less certain, as they lack supportive data from the agricultural survey. Using results of the photo analysis as a starting point, however, there were 8,416 ha of large plantations and 537 ha of linear formations in 1980. According to official statistics (see Table 5.1), an additional 366 ha of plantations and 459 ha of roadside plantings were made over the following five years. Assuming a continuation of these trends, there were 8,855 ha of plantations and 1,088 ha of linear formations in Ruhengeri in 1986.

Adding the small woodlot figures from above, a total of 18,210 ha of currently forested land is thus reached for the entire prefecture (Table 5.6). This estimate appears to represent a reasonable figure for further calculations.

According to a national survey conducted by the Direction-General of Forests (DGF) in 1982, per capita consumption of wood products in Rwanda averages 0.91 m3 per year, more than 90% of which is used as firewood. If this figure is applied to Ruhengeri, then set against the production totals above, a simple supply:demand ratio can be established.

Ruhengeri's 18,210 ha of forested area contain 3,279,432 m3 of wood. This represents a resource base of five m3 per person, or nearly six years of supply (though it should be noted that the general population does not have equal access to all of these forested areas, especially the larger plantations). Wood, however, is a renewable resource and this standing volume should be treated as the capital which produces an annual increment which can then be exploited on a recurrent basis. If the capital is depleted, productivity declines until the entire resource is consumed. It is therefore the annual growth, or the sustainable yield, which is of interest to forest managers and planners.

From Table 5.7, it can be seen that the annual growth from Ruhengeri's forests now provides only 0.29 m3 per person, or less than one-third of the current demand. Certain hypotheses could help to explain this apparently large deficit. First, people could be exploiting the standing volume of the region to make up the difference. This would represent a total of 406,408 m3, or the equivalent of 2,257 ha cleared each year. Yet while some of the wood capital is certainly being exploited (and many of the region's older stands should be cut to permit new growth and greater productivity), there is no evidence of such widespread clearing at this time.

A second explanation is that standing volume and productivity are greater than assumed. Standard volume tables only consider the trunk and do not include branches which may represent 10 to 20% of the available wood. In addition, these volume tables have not yet been adapted for use in Ruhengeri, where ecological conditions may favor greater growth. Furthermore, it is certain that the people of Ruhengeri use other plant matter in addition to wood for making fires (although it should be noted that this practice contributes to declining soil fertility). And finally, per capita consumption levels may be lower than believed.

All of the above may combine to reflect a more positive supply:demand ratio in the region at this time. As shown in Table 5.7, however, simple projections of population growth indicate that the current forest resource base will be totally inadequate to meet future demands. If presently accepted figures are accurate and conditions do not change (see Assumptions in Table 5.7), then one-half of all available land in the prefecture would have to be forested to provide the necessary wood, on a sustained yield basis, for Ruhengeri's population in 1996. If one projects conditions to a period 40 years from now, then every square centimeter of the prefecture would have to be forested to satisfy the needs of 2,000,000 people with no place to live but the city of Ruhengeri.

This scenario will not come to pass. Some of the baseline data are almost certainly inaccurate and conditions inevitably change. Whether they change for the better or the worse, however, will depend on current efforts in

Table 5.6

Wood Supply and Productivity in Forested Areas of Ruhengeri (1986)

Type Forested Area	Area (ha)	Average Volume (m3/ha)	Average Growth (m3/ha/yr)	Total Volume (m3)	Total Growth (m3/yr)
Plantations	8,855	167.7	8.7	1,484,984	77,039
Woodlots	8,267	199.9	12.6	1,652,573	104,164
Linear Plantations	1,088	130.4	6.9	141,875	7,507
TOTAL	18,210	180.1	10.4	3,279,432	188,710

Table 5.7

Wood Demand in Ruhengeri: Current and Projected

Year	(1) Population	Current Forested Area(ha) (1986)	(2) Available Annual Growth (m3/pc)	(3) Required Annual Growth (m3/yr)	(4) Required Forested Area (ha)
1986	655,497	18,210	0.29	596,502	57,356
1996	872,418	18,210	0.22	793,900	76,337
2006	1,161,123	18,210	0.16	1,056,622	101,598
2016	1,501,815	18,210	0.13	1,366,652	131,409
2026	1,998,805	18,210	0.09	1,818,913	174,895

Assumptions:
(1) Current population growth rate (2.9%) unchanged.
(2) Current forested area and annual growth (10.4m3/ha) unchanged.
(3) Current per capita consumption (0.91 m3/yr) unchanged.
(4) Current annual growth and per capita consumption unchanged.

managing population growth and the balance between wood production and consumption.

Conclusions.

Current reforestation efforts in Ruhengeri have resulted in a significant increase in the total forested area over recent years. In fact, this area appears to be much larger than currently indicated by official statistics. In addition, the population of Ruhengeri appears to be convinced of the value of trees, as indicated by their willingness to plant woodlots on their own farmland.

At the same time, extremely serious problems remain. Even under the most optimistic scenarios, demand for wood resources probably exceeds the current sustainable supply. And projected population increases threaten to overwhelm the region's capacity for wood production. In addition, the current emphasis on plantations and woodlots of primarily Eucalyptus has resulted in overdependence on a monoculture which degrades the soil and excludes all other uses, forcing a trade-off between wood and food production. Alternative tree species and planting techniques, which permit complementary farming, forestry and soil conservation practices, must be developed in order to put the region's limited arable land base to its best use.

Recommendations.

The preceding analysis demonstrates the need for both additional applied research and monitoring, as well as for immediate action. Priority activities in each of these areas are outlined below.

Applied Research and Monitoring.

1. The most immediately useful information to be obtained is that which only aerial or satellite imagery can provide. The forestry situation has changed considerably since the most recent aerial photos were taken (1978 - 1980). The RRAM analysis from that period found a highly significant discrepancy between officially reported figures and the extent of forest cover visible on the photos. New imagery is essential to update this information, both for Ruhengeri and at the national level. This would also permit analysis of changes and trends since 1980.

Aerial photos at a scale of 1:20,000 (1:10,000 would be better, but considerably more costly) are preferable to satellite images due to their better resolution of ground cover, especially dispersed trees. Satellite images also suffer from problems of cloud cover. They can nevertheless be obtained more quickly and cheaply than complete aerial coverage and should be tried as a rapid sampling and monitoring technique.

2. Systematic ground sampling of forest resources is an indispensible complement to remote sensing. Extensive tree and stand measurements must be carried out across a broad range of sites and ecological zones to quantify the available wood resource base. Cutting, measuring and weighing an adequate number of different tree species, growing under different conditions, is the only way to obtain more accurate volume tables.

3. Market and consumer surveys are required to obtain more information about the value of and demand for wood products. The RRAM survey indicated that a significant proportion of the population already pays for wood on at least an occasional basis. This is an essential step toward better management of forest resources, and improved understanding of consumers' needs and ability to pay would be very useful for planning purposes. It would also be

very helpful to conduct additional domestic and commercial wood consumption studies to better estimate demand for various wood products.

4. New tree species and planting techniques must be tested as rapidly as possible to provide a broad range of technology options to foresters and farmers. This is especially critical in the high elevation areas of Ruhengeri, where ecological conditions limit species selection to begin with, and where little testing of species and practices has been conducted.

Emphasis for such trials should be placed on trees with multiple, though variable, attributes. Rapid growth is definitely valued by most people, which is one reason why eucalyptus remains a preferred species. Some other species grow nearly as fast, however, and improve the soil while permitting intercropping. Others may not grow as fast, but favor the development of undergrowth for grazing or soil stabilization. Woody shrub species have also been neglected, despite their usefulness in erosion control and the production of wood, forage and other tertiary products. To be used, however, they must first be tested and made available. Potentially valuable tree and shrub species and their uses are listed in Table 5.8.

Action.

5. Where different species and techniques have already been identified, these should be put into application as rapidly as possible. This is especially necessary in the area of agroforestry. Expanded agroforestry practices offer three important benefits to the farmers of Ruhengeri: wood production is increased without ceding more land to woodlots and plantations; erosion control is improved through the planting of tree and shrub species along with those grasses already used along contour lines; and the combination of nitrogen-fixation and increased organic matter from leaf-fall improves soil quality.

Several tree species such as Sesbania, Grevillea, and Cedrela have already proven their value in alley cropping trials in the Ruhengeri region. In addition, native species of Markhamia, Ficus and Polyscias have traditionally been grown in both open fields and banana plantations. Finally, popular interest is growing in fruit trees (avocado, guava, mountain papaya, etc.) for planting around household compounds. All of these activities shoud be encouraged and supported by government policies, practices and personnel.

6. Afforestation efforts on sites that are inappropriate for agriculture must also be improved and adapted to local needs and objectives. Numerous steep ridges, roadsides, gullies and abandoned mine sites in Ruhengeri need to be forested to both produce wood and stabilize the soil. Yet the current practice of planting monocultures of Eucalyptus only satisfies the first of these objectives. Plantations which reproduce characteristics of a natural forest, with its multiple tree layers and extensive ground cover, are far more likely to satisfy the required multiple objectives.

High potential species for this kind of afforestation include Acacia melanoxylon (Black Wattle), Alnus, Grevillea and Ficus. For some gullies and ravines, bamboo is also valuable for its ability to stabilize steep slopes. Ground cover plants (shrubs and grasses) will develop naturally under the tree species listed above, although the process of colonization can be quickened through direct planting.

7. Most of the existing large plantations in Ruhengeri need to be better managed to assure higher productivity

and the satisfaction of multiple needs. Conversion from current monocultures to more diverse associations of species, however, is difficult and costly. In many cases, the roots of Eucalyptus must be dug up to permit the establishment of new species. This effort should therefore be made on a trial basis to determine costs and the ability of communal populations to provide the necessary labor. The tree species cited above for afforestation are also suitable for conversion purposes, as are native species of Maesopsis, Albizia, Podocarpus and Polyscias.

8. The recommendations made in sections 4, 5, 6 and 7 require a greater diversity of species than has traditionally been planted in Ruhengeri. Seed sources for all of the cited trees exist in Rwanda, but problems of production and distribution have limited their use.

Ruhengeri should establish its own sources of seeds for the species described above. In addition, the existing network of nurseries for tree production and distribution should be expanded and diversified to provide increased access to a greater variety of species. In this regard, private nurseries should also be encouraged, in which families produce trees which they and their neighbors desire. This emphasis on decentralized seed and tree production would not only help support the activities described above, but could also help to generate rural employment opportunities.

9. The use of new species and techniques also requires forestry personnel with the necessary training to understand and apply them to conditions in Ruhengeri. The current number of forest monitors in the prefecture is insufficient, and many of them are not well-informed about new approaches. Training of new monitors and retraining of the old is therefore an essential component of any effort to move forestry practices in new directions. In addition to technical information on production and planting, the monitors should also receive training in extension techniques. Agroforestry, in particular, requires a flexible approach and a two-way exchange of information to best match available technologies with individual farmers' needs.

10. The communal forestry plans proposed in the new National Forestry Law represent an excellent means of coordinating implementation of many of the recommendations described above, as well as others contained in the legislation itself. The focus of these plans, however, appears to be on the management of larger plantations (4 ha or more). While improved management of these areas is essential, two important points should be remembered: (1) the majority of wood produced for domestic consumption comes from much smaller private woodlots; and (2) future expansion of the region's forested area will require the planting of thousands of small areas (gullies, household enclosures, rocky outcroppings, trails and roadsides) which are currently unexploited.

It is impractical to propose that individual plans be developed for these smaller areas. It is nevertheless essential that communal forestry plans include at least general guidelines for improved management of small woodlots and the optimal use of all available space in the prefecture.

11. Urgent attention must be given to alternatives to current energy use practices. Successful implementation of all of the above recommendations will not guarantee that Ruhengeri will be able to produce enough wood to satisfy future demand. Nor will it eliminate conflicts over alternative land uses, especially for food produc-

tion, in the face of future population increases.

Since 83% of the wood produced is burned as fuel, significant gains can be made by reducing this single demand factor. A first step would be the use of more efficient wood-burning stoves. Numerous models of such stoves have been tested in Rwanda, and their widespread use could definitely reduce consumption by at least 10 - 20%. Considerable progress has also been made in the development of practical and economical solar cookers in recent years. Other options include the use of kerosene, or even imported coal from Zaire: both of which, however, would entail increased costs to consumers and the expense of precious foreign currency. Even more radical would be a national program of rural electrification. This would require not only massive investment on the part of the government and foreign donors, but would also require a total reorganization of currently dispersed Rwandan settlement patterns into more centralized villages and towns.

Radical ideas are needed to deal with this situation, however. There will always be a demand for trees; but the burning of 80% of them is a practice that cannot contune indefinitely. Planning should therefore begin now for a transition to alternative energy sources.

Table 5.8
RECOMMENDED AGROFORESTRY SPECIES BY USE
1400 - 1800 METERS

Use	Recommended Species*
Production:	
Fuel	Eucalyptus, Cupressus, Callitus
Poles	Grevillea
Logs	Ficus, Markhamia, Grevillea, Erythrina cedrela
Food	Avocado, Citrus, Cajanus, Guava
Fodder	Ficus
Conservation-Protection:	
Organic Matter	Maesopsis, Grevillea, Albizia gummifera
Soil Nutrients	Cedrela, Casuarina, Grevillia, Measopsis, Alnus spp.
Live Fence	Euphorbia, Ficus, Morus alba, Caesalpina decapitala
Borders	Markhamia, Erythrina, Cassia, Vernonia
Roads, Trails	Eucalyptus, Markhamia, Grevillea
Waterways	Mitragyna rubrostipula, Cassia, Grevillea, Alnus, Polycias fulva
On-farm erosion control	Sesbania, Gliricidia, Tephrosia, Albizia gummifera, Casuarina, also fruit trees, Cajunus, Morus alba
Degraded Soils:	Callitris, Acacia melanoxylon, A. mearnsii, Alnus accuminata or nepalensis, Acacia sieberiana, Entanda abyssinica
Medicinal Plants:	Senecio manii, Ibozariparia, Vernonia amygdalina, Mitragyna rubrostipulosa

*Species of primary interest and proven value are underlined.

Table 5.8 (cont.)

RECOMMENDED AGROFORESTRY SPECIES BY USE
1800 - 2200 METERS

Use	Recommended Species*
Production:	
Fuel Poles	Eucalyptus, Cupressus, Polycias
Logs	Croton, Ficus, Mitragyna, Newtonia, Podocarpus
Food	Mountain papaya, Prunus japonica
Fodder	Albizia, Ficus
Conservation-Protection:	
Organic Matter	Alnus, Croton, Grevillea , Mitragyna, Tephrosia
Soil Nutrients	Alnus, Newtonia
Live Fence	Euphorbia
Borders	Mitragyna, Grevillea
Roads, Trails	Mitragyna, Grevillea
Waterways	Mitragyna, Bamboo
On-farm erosion control	Cajanus, Sesbania
Degraded Soils:	Alnus, Callitris, Cajanus, Acacia mearnsii

*Species of primary interest and proven value are underlined.

Table 5.8 (cont.)

RECOMMENDED AGROFORESTRY SPECIES BY USE
ABOVE 2200 METERS

Use	Recommended Species*
Production:	
Fuel	Eucalyptus, Cupressus lusitanica, Pinus patula
Poles	Bamboo (Arundinaria alpina), Podocarpus
Logs	Ficus, Dombea
Food	Avocado, Citrus, Cajanus, Guava
Conservation-Protection:	
Organic Matter	Newtonia, Dombea
Soil Nutrients	Markhamia
Live Fence	Euphorbia, Cupressus, Ficus, Solanum aculeastrum
Borders	Markhamia, Erythrina, Cassia, Vernonia
Roads, Trails	Erythrina abyssinica
Waterways	Mitragina, Arundinaria alpina, Alnus, Newtonia buchananii
On-farm erosion control	Sesbania, Calliandra, Setaria sphacelata

*Species of primary interest and proven value are underlined.

Source: F. Weber/ICRAF 1986.

CHAPTER SIX: WATER RESOURCES

Ruhengeri is relatively rich in water resources, as described in Chapter Two. The distribution of these resources is unequal, however, and several important problems have arisen in recent years with regard to their effective management. The following sections present an analysis of current conditions and recommendations to deal with the most urgent problems facing the prefecture.

Analysis.

For the purposes of this analysis, water resource issues in Ruhengeri are divided into two categories. Those which concern the use and modification of water as it moves through the regional hydrologic network are considered to be resource management issues. Those which have to do with domestic consumption are treated as water supply issues.

Water resource management. A schematic profile of the principal hydrologic surface features of the Ruhengeri prefecture is presented in Figure 6.1. Its primary features include the Rugezi Marsh and Lakes Bulera and Ruhondo to the east, and the Virunga water catchment zone in the northwest. Both systems feed into the Mukungwa River, which also drains most of the remainder of the prefecture as it flows south to join the Nyabarongo. A detailed map of the entire hydrologic network of the prefecture can be seen in Chapter Two, Figure 2.7.

water balance

The surface water resources of the region are maintained and replenished by rainfall, which is both plentiful and regular (Tables 6.1 and 6.2; also see Chapter Two). Water balance equations for the four principal watersheds of the prefecture (Table 6.3) show that the major part of this precipitation is recycled into the atmosphere through evapotranspiration. A small amount infiltrates into groundwater storage, and the remainder is captured as runoff and flows through the surface water system.

Some significant differences and potential anomalies appear from this analysis of water balances. First, evapotranspiration rates are much higher in the Rugezi and Lakes Basin watersheds. This is normal for areas with large bodies of standing water and would, in fact, be higher if it were not for the low temperatures associated with high elevation. The infiltration rate of 7% in the Lower Mukungwa system is also noteworthy. While the Lava Zone, which makes up a major part of this catchment area, is known for its highly permeable soils, this finding supports the belief that most of this infiltration reappears as surface flow at lower elevations. The negative infiltration rate for the Lakes Basin is equally interesting, yet also easily explained. In this case, infiltration is represented by a drop in the water volume of Lake Bulera. Since 1973, water levels in this lake have averaged 1.5 meters lower than in previous years. This is primarily due to high levels of production from the Ntaruka hydroelectric station at Bulera's outlet, which require higher discharge rates (runoff) from the lake reservoir.

A final observation to be made from this water balance analysis concerns recent rates of streamflow in the Lower Mukungwa. As seen in Table 6.4, these rates have increased considerably over the past five years, thus increasing the percentage of runoff assigned to the entire watershed. Inaccurate rainfall data, due to an insufficient number of measuring stations, could partially explain this anomaly. Yet, since precipitation and other stream-

Table 6.1
Average Monthly Rainfall
(in millimeters)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Ruhonde	90.5	110.9	145.0	232.6	143.7	36.8	18.6	48.1	114.2	118.9	146.8	99.9	1306.0
Rwankeri	75.9	95.1	135.5	194.2	149.7	42.9	20.1	52.9	116.1	132.2	143.5	93.3	1251.4
Kinoni	76.6	98.3	128.7	152.1	127.7	41.6	15.5	72.7	114.7	134.0	132.7	84.0	1178.6
Nemba (Nord)	110.3	135.8	160.7	221.7	166.6	56.7	20.9	51.5	125.0	152.3	218.3	132.8	1552.6
Ruhengeri	79.3	102.1	145.5	199.0	160.3	50.1	25.8	55.9	115.3	153.1	150.7	98.4	1335.5
Karisoke	100.9	123.3	205.7	308.9	193.7	91.7	71.7	137.4	154.2	203.0	188.4	143.2	1922.1

Source: National Meteorology Statistics

Table 6.2
Average Days of Rainfall

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Ruhonde	10.5	11.9	13.7	19.5	14.5	4.2	2.1	5.7	11.7	14.0	16.2	11.4	135.4
Rwankeri	11.3	12.2	16.1	18.5	16.6	5.8	2.5	7.0	13.4	16.6	17.9	13.5	151.4
Kinoni	11.9	14.1	17.7	19.8	17.3	6.5	3.4	8.7	15.1	18.4	19.4	14.0	166.3
Nemba (Nord)	13.1	14.6	17.4	23.3	17.0	5.4	3.4	6.1	13.4	18.7	22.0	15.7	170.1
Ruhengeri	12.0	14.0	19.5	23.0	19.1	6.7	3.7	7.4	15.8	20.1	20.8	16.5	178.6
Karisoke	18.7	18.1	26.5	28.1	24.4	14.7	12.0	15.8	21.5	25.2	26.5	22.6	254.1

Source: National Meteorological Statistics

Table 6.3
Water Balance Equations
in Four
Ruhengeri Watersheds

Rugezi Marsh

Precipitation	1,254 mm	100%
Runoff	233 mm	18%
Evapotranspiration	788 mm	63%
Infiltration	243 mm	19%

Lakes Bulera-Ruhondo

Precipitation	1,131 mm	100%
Runoff	474 mm	42%
Evapotranspiration	788 mm	70%
Infiltration	131 mm	-12%

Lower Mukungwa

Precipitation	1,480 mm	100%
Runoff	660 mm	45%
Evapotranspiration	709 mm	48%
Infiltration	111 mm	7%

Cyohoha-Base

Precipitation	1,552 mm	100%
Runoff	507 mm	33%
Evapotranspiration	709 mm	46%
Infiltration	336 mm	21%

Source: Roark & Dickson/RRAM 1986
Based on official rainfall data from the Ruhunde, Kinoni, Ruhengeri and Nemba stations, and streamflow data from the Rusumo, Rwaza, Ngaru and Rwerere Sud stations for the period 1973 - 1985.

flow levels were uniformly lower across the prefecture during this period, this seems unlikely. Another possible explanation is that conditions at the Ngaru measuring site have changed (e.g. the river bed has risen or the guage itself may be damaged), without anyone taking note. If this turns out not to be the case, then a third, and more disturbing, possibility becomes more likely: that the measures accurately reflect increased runoff due to radically changed landuse practices (wetlands drainage, deforestation, inadequate soil and water conservation practices on farmlands) throughout the watershed. In this case, seasonal fluctuations would be more extreme and the risk of serious flooding would increase significantly.

The water balance equations presented above are based on extrapolations and generalizations from limited information sources. An enlarged network of hydro-climatological monitoring stations would permit more precise calculations. Given the possibility that water is moving more quickly through the regional hydrologic system as a result of extensive changes in landuse, such information could be extremely valuable.

wetlands and bottomlands

Climate and geomorphology combine in Ruhengeri to favor the presence of wetlands (characterized by permanent standing water) and bottomlands (valley formations characterized by high soil moisture content and subject to seasonal flooding). These areas represent an important resource with multiple values. In their natural state, they regulate water flow by absorbing excess runoff in their soil and vegetation, then gradually releasing this water during times of ebb flow. In addition, natural wetlands provide critical habitat for the rich diversity of water birds found in Rwanda.

Table 6.4
Annual Stream Flow
(cubic meters per second)

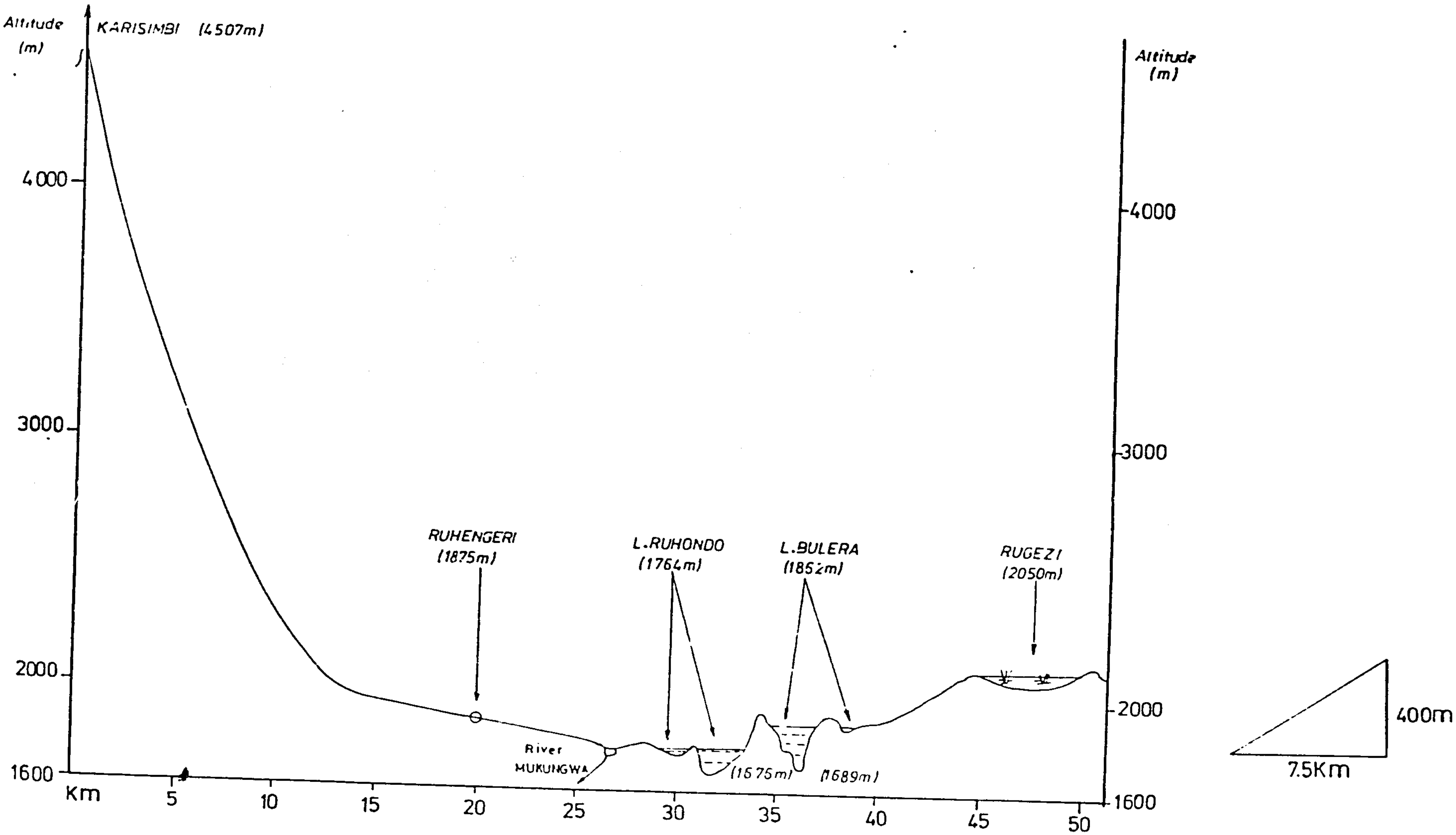
Year	Mukungwa River Ngaru Station	Mukungwa River Rwaza Station	Rugesi River Rusomo Station	Cyohoha/Base Rivers Base Station
1985	50.98*	7.59*	1.08*	2.24*
1984	40.35	7.02	1.01	--
1983	44.85	--	1.24	1.62
1982	45.82	--	1.14	--
1981	38.39	10.36	1.23	2.46
1980	26.15	--	1.16	1.68
1979	--	9.21	1.27	2.78
1978	17.03	8.85	2.39*	2.41
1977	18.98	9.86	1.42	2.20*
1976	21.57	9.03	1.14	1.47
1975	23.10	9.07	1.54	1.96
1974	30.24	--	1.52	1.96
1973	28.27	8.17	1.15	2.22
1972	--	7.41	1.64	3.93
1971	--	7.70	1.27	3.76
1970	--	6.88	0.96*	--
1969	--	6.94	--	--
1968	--	6.94	--	5.49
1967	--	--	--	4.40
1966	--	--	0.99	4.15
1965	--	--	--	--
1964	--	--	0.99	--
1963	--	--	1.87*	--
1962	--	--	--	--
1961	--	--	--	--
1960	--	--	.72	--
1959	--	--	1.22	--
1958	--	--	1.62	--
1957	--	--	1.31	--
Total	385.73	115.03	29.88	44.73
Years	12	14	23	16
Average	32.14	8.22	1.30	2.80

Source: National Hydrologic Service

* Extrapolated or interpolated data.

FIGURE 6.1

Schematic Profile of the Mukungwa Watershed



Wetlands, and especially bottomlands, however, are also highly valued for their potential agricultural productivity. Thus, while Ruhengeri is rich in these areas, it is also confronted with difficult problems which arise from conflicts over their most appropriate use.

Nearly 9,000 ha of wetlands and bottomlands cover more than 5% of the Ruhengeri prefecture. This resource is unevenly distributed, however, with more than half of the total area located in the three easternmost communes of Cyeru, Nyamugali and Butaro (Table 6.5). According to the RRAM Project's land use analysis from aerial photos, 56% of this area was already developed as of 1980. More recent observations in the field indicate that at least 1000 additional ha have been converted to agricultural production over the past six years. A major part of this conversion has occured in Nkuli, where formerly undeveloped bottomland has been put into tea production. Most of the former marshland in Butaro has also been drained and cultivated.

The Rugezi Marsh comprises the bulk of the remaining undeveloped wetlands in the prefecture. Despite the drainage of the entire Kamiranzovu branch and the development of raised bed cultivation along most of its edge, roughly half of the marsh remains in a more or less natural state (Figure 6.2). Miscanthidium, Papyrus, and Cyperus combine with other plant species to form a dense mat over the floating peat formation in its deeper waters. This complex plays a major role in the regulation of water flow to downstream lakes and rivers. It also supports an important bird population, and its plants are used in numerous ways by the local population. Yet its future is not at all certain.

Drainage of the Rugezi has been proposed at many times over the past several decades. The most serious attempt occured in 1972, when a natural rock wall in the southeast corner was dynamited to create the Fels outlet, which sent water to a tea project in Byumba. Water levels in the marsh fell too rapidly, however, resulting in drying of the peat soils and a serious threat to hydroelectric production from Lake Bulera (see below). The outlet was subsequently dammed and the project abandoned. Based on this experience, most authorities are now opposed to any major drainage efforts in the Rugezi, and no projects are currently being planned. Yet rising demand for land could change this situation, and the Rugezi remains defenseless without any official protected status.

The actual impact of any proposed drainage scheme could only be determined from the content of the plan. It is nevertheless certain that largescale development would result in increased total flow, higher flood peaks, and increased sedimentation downstream. Any attempt to radically modify this complex and valuable ecosystem should therefore be approached with extreme caution.

The bottomlands of Ruhengeri are much more extensive and more evenly distributed than its wetlands. They are also qualitatively different. The vast majority of these areas are already developed, and the nature of their exploitation has changed considerably in recent years. Formerly used for dry season farming, most bottomlands now appear to be in year-round cultivation. The immediate catalyst for this change was the drought of 1984; but it was probably inevitable given demand for increased food production.

According to the RRAM Project survey, 19.5% of all households have a parcel which they cultivate in a valley bottom. This figure varies considerably, however, with a high of 40% in the

Table 6.5
Wetlands and Bottomlands by Commune

COMMUNE	WETLANDS (water & vegetation) (ha)	UNDEVELOPED BOTTOMLAND (no standing water) (ha)	RAISED BED BOTTOMLAND (ha)	TOTAL (ha)
Butaro	432	0	846	1278
Cyabingo	10	2	348	360
Cyeru	1589	0	622	2211
Gatonde	0	0	268	268
Kidaho	72	2	44	118
Kigombe	58	0	402	460
Kinigi	0	0	8	8
Mukingo	0	2	0	2
Ndusu	0	0	382	382
Nkuli	120	480	52	652
Nkumba	0	6	108	114
Nyakinama	28	46	182	256
Nyamugali	1072	4	478	1554
Nyamutera	0	0	232	232
Nyarutovu	6	2	546	554
Ruhondo	16	0	492	508
TOTALS	3403	544	5010	8957

Buberuka region and a low of only 2% in the Lava Zone. Roughly one-third of these parcels were inherited, while one-fourth are rented from the commune. Another 13% were purchased.

The primary technique for the exploitation of bottomlands in valleys and along the shallow edges of lakes and marshes involves the formation of parallel rows of raised beds, between which water flows (or is retained following flood periods) in shallow canals. The combination of a steady water supply and rich soils, renewed by erosion from surrounding hills, makes these areas highly productive. What is not certain, however, is whether the removal of natural vegetation and canalization have a significant impact on water flow and retention. No measures have ever been made of outflow from such areas; and the fact that virtually all bottomlands are now in cultivation makes future comparative studies (before-after, or developed-undeveloped comparisons) problematic. An attempt at such studies should be made, however, given the potentially disruptive impact of such extensive modification on overall regional water flow patterns.

Lacking more quantitative data, popular impressions of conditions provide some interesting information. Results of the RRAM survey indicate that only 12% of the population feel that flooding has increased over the past 10 years. This figure rises to 26% in the Lava Zone and 33% in the ZND; but it is still clear that people do not perceive this to be a widespread problem. Among those who actually cultivate bottomlands, however, nearly 25% (30% in Buberuka) cite flooding as a major problem. Another 10% cite sedimentation from hillside erosion or upstream sources. Asked to describe general changes in their bottomlands, however, 93% of all answers were of a negative nature: 38% stated that their yields had declined; 36% cited the loss of natural vegetation; and 8% felt that the regular water flow had decreased.

lakes

Lakes are another resource of proven multiple use value for water storage, fish production, recreation and tourism. In Ruhengeri, Lakes Bulera and Ruhondo are most valued for the production of hydroelectricity, while other aspects have been less developed. Recreation and tourism are virtually non-existant in the region, except for passive observation of the lakes and Rusumo Falls by a very limited number of visitors. One reason for this is the lack of any supporting infrastructure; another is certainly the presence of bilharzia in the lakes. The latter has also sharply reduced the value of the lakes as reservoirs, though the local population in many areas remains dependent on them as a source of water, despite their insalubrity (see below).

The lakes' fish resources are definitely valued, but remain underdeveloped. According to several studies, Lake Ruhondo has greater potential than that of Bulera, but both are relatively impoverished lakes because of their marginal ecological conditions. More than 200 fishermen work the lakes from pirogues. They report, and official statistics confirm, that production has declined considerably over the past 10 years. This could be due to several factors, among which are: over-fishing, destruction of the shoreline vegetation which provides breeding habitat, or the lowering of lake levels. This subject will be examined as part of an on-going study of fisheries development in all of Rwanda's major lakes, supported by the Ministry of Agriculture. Yet it should also be noted that this study's preliminary reconnaissance of Ruhondo and Bulera found their potential to be far greater than indicated by current production levels.

FIGURE 6.2

RUGEZI Marsh

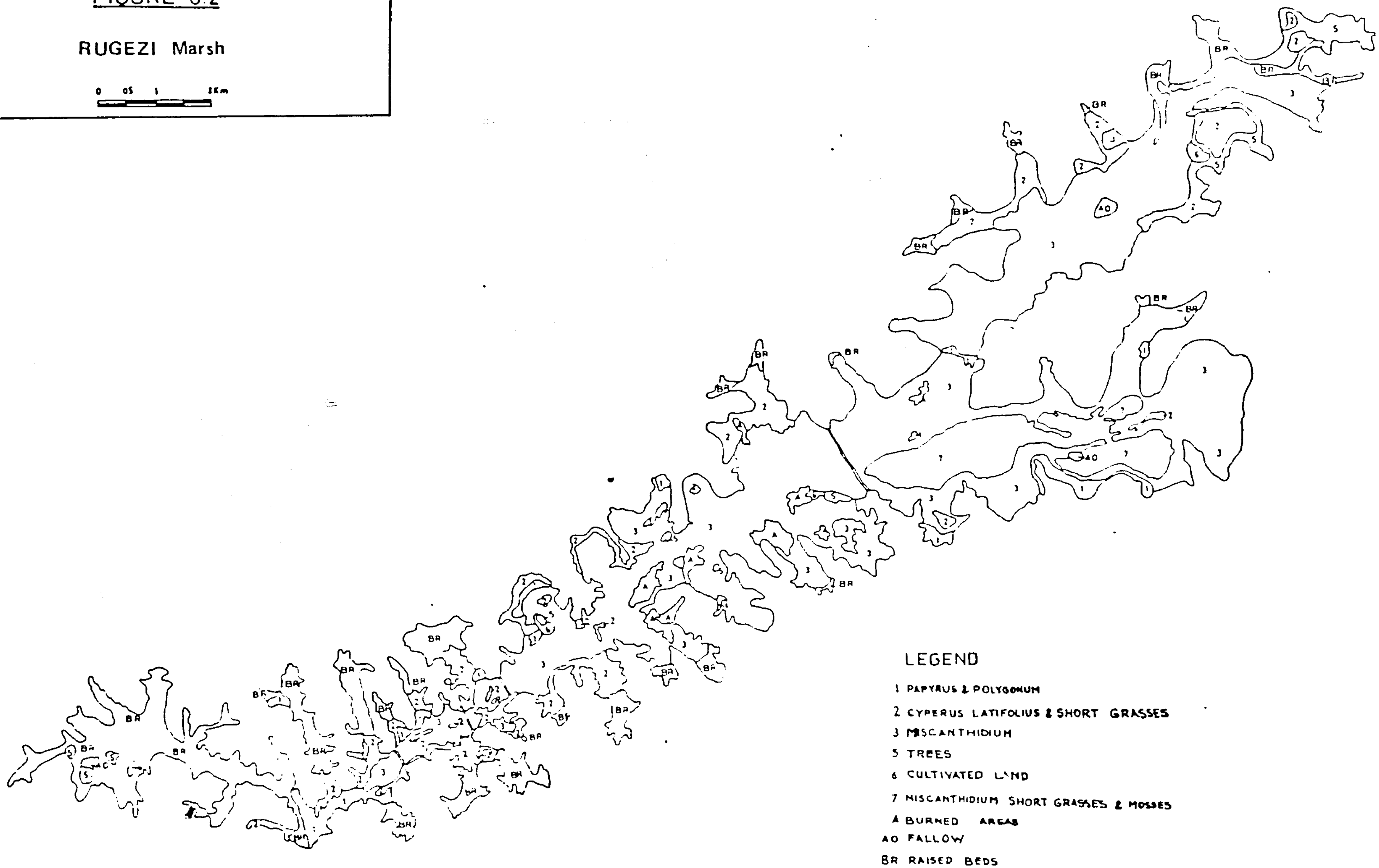


FIGURE 6.3

Evolution of Water Levels in Lake Bulera

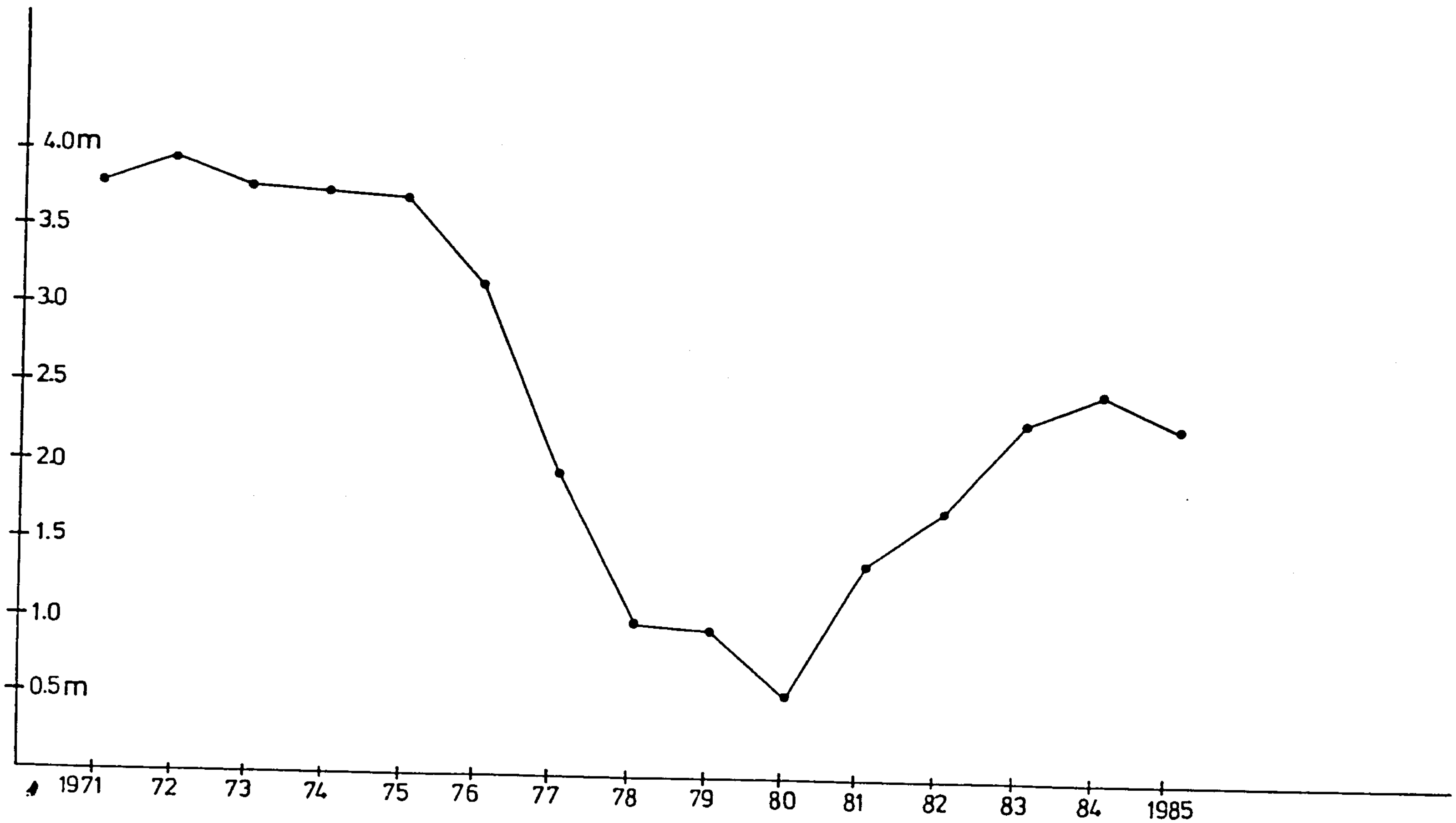


Table 6.6
Laboratory Analyses of Arsenic Contamination
in the Nyamusanze Valley

Sample Content	Source of Sample: Mid-stream Nyamusanze River	Sediment at River's Edge	Sediment 2m from River's Edge	Dried Mine Tailings	Mid-stream
pH, Standard Units	5.9	x	x	x	6.1
Total Organic Carbon, Mg/L	7.0	x	x	x	12.0
Total Arsenic	<0.010 Mg/L	146 Mg/Kg*	116 Mg/Kg*	36 Mg/Kg*	<0.10 Mg/L
Total Volatile Solids, % by Wt.	x	5.0	1.3	0.9	x
Total Solids, % by Wt. **	x	99.6	99.9	72.7	x

Source: Roark and Dickson 1986, based on a report by Camp Dresser & McKee, Inc. for SECID, March 1986.

x = Analysis not requested

* Dry weight basis

** These numbers reflect sample status "as received".

The principal resource value of the lakes thus remains their proven capacity for the production of electrical energy. The combined output from the two hydroelectric stations at Ntaruka and Rwaza represents more than half of Rwanda's annual production of electricity. Yet it is quite likely that over-production has been responsible for lowered lake levels over the past decade.

Between 1975 and 1980, the water level in Lake Bulera dropped more than 3 meters (Figure 6.3). Among the principal factors which affect water levels in the lake, rainfall and inflow from the Rugezi were stable or higher than average during this period, whereas hydroelectric production rose to a peak level of over 4 million Kwh in 1977. Subsequent reduction of this ouput coincided with a rise in water level, though not to previous levels. Today, annual electrical production of 2.75 million Kwh appears to be in phase with annual outflow from the lake. Should future energy demands increase, however, lowered lake levels should again be expected.

erosion and sedimentation

While the erosion issue has been considered in detail in Chapter Four, it is worth noting that this issue is closely related to that of water management. Failure to control erosion on hillsides results in water moving more quickly into streams and rivers, which then carry an increasingly heavy load of sediments. Some of this sediment load is recycled for agriculture in raised beds, but most of it is carried away and serves to increase the destructive scouring power of rivers. This is most obvious in the torrents of the Lava zone, but its impact is also evident in streambank erosion along most of the region's waterways. Unfortunately, no studies exist of sediment transport, nor of its impact in the Ruhengeri region. Such studies are essential to effective water resource management.

pollution

Water pollution is a major problem in industrialized countries, but is considered to less serious in less developed countries. Although adequate data are lacking, conditions in Ruhengeri would seem to support this general observation. A preliminary analysis by the RRAM Project of runoff from one wolfram mine in Cyeru commune, however, indicates that potential problems do exist.

Since 1947, the Gifurwe mine has generated an average of more than one million cubic meters of tailings each year. These are left exposed at the mine site, from where they are washed down the Nyamusanze valley and eventually deposited in Lake Bulera. Laboratory analyses indicate that this transported sediment contains arsenic at concentrations which reach 146 parts per million (Table 6.6). According to the U.S. Department of Agriculture, levels over 100 ppm can lower crop production and local farmers, in fact, report low yields from raised bed agriculture in the Nyamusanze valley. While this could also be due to the low nutrient content of the mine tailings, the arsenic factor should not be overlooked. Arsenic poisoning of humans appears to be a less serious problem, due to the low arsenic content of the water itself, although medical studies in Taiwan have documented a relationship between skin cancer and regular contact with arsenic. Its uptake and concentration in fish could also prove to be a problem for human consumers. Given that two major mines, at Gifurwe and Bugarama, produce runoff into Lake Bulera, this problem should continue to be monitored.

Water supply. Human beings must drink at least 1-2 liters of water per day to survive. In Rwanda, it is often estimated that 10 liters per capita per day (lpcd) suffice for all domestic consumption purposes. Beyond this minimal requirement, however, a level of 20 lpcd for drinking, cooking, washing clothes and bathing is often recommended to obtain the optimal health benefits associated with improved hygiene. Water supply in Ruhengeri is generally adequate to meet minimal requirements. The availability and quality of water resources, however, varies considerably across the prefecture.

Table 6.7 shows that 46% of the Ruhengeri population obtains its water from improved springs: natural underground sources which have been capped and channeled through a spout, sometimes with a faucet to control its release. This system is most prevalent in the Buberuka region (63%) and least common in the Lava Zone (31%). Natural springs represent the primary source for 19% of all households, with a high of 42% in the ZND region. Another 14% are served by public piped systems, along which there are faucets at certain intervals. This system is most developed in the Lava Zone, where 33% of all families depend on it for their primary source of water. Barely 20% of Ruhengeri's households get water from other sources, but these can be of local importance. Rivers and streams provide water for 15% of families in the Plateau region, and 13% in the ZND. Lakes are the primary source for 10% of those in Buberuka, while ponds or other forms of standing water serve nearly 13% of the population in the Lava Zone.

Two-thirds of the Ruhengeri population has a primary water source within one kilometer of their house. This figure rises to 90% within a two kilo-

Table 6.7

Survey Results on Water Supply Issues

	Lava %	ZND %	BUB %	CP %	TOTAL %
Primary Source					
Improved Spring	31	39	63	44	46
Natural Spring	12	42	11	27	19
Piped System	33	0	8	11	15
River/ Stream	10	13	5	15	10
Standing Water	13	7	5	3	7
Lake	1	2	10	0	3
Distance					
< 1 km	58	71	77	67	68
1-2 km	26	25	19	22	22
> 2 km	16	4	4	11	10
Shortages					
Yes	66	12	15	9	29
No	34	88	85	91	71
Daily Trips for Water					
1 trip	41	28	31	26	32
2 trips	50	49	55	58	54
3+ trips	9	23	14	16	14
Daily Household Consumption					
20 liters	41	21	32	25	32
60 "	48	58	53	55	52
100 "	11	21	15	20	16
Water Quality					
good	75	66	80	83	78
bad	25	34	20	17	22

Source: RRAM Project Survey

Table 6.8
Existing Water Supply Systems By Commune

Commune	Population 1985	Piped Systems: Number	Piped Systems: Total Yield lps*	Improved Springs: Number	Improved Springs: Total Yield lps	Total Sources: Number	Total Sources: Total Yield lps	Average lpcd** 1985
Butaro	47,807	4	.00	45	7.54	49	7.54	14
Cyabingo	51,144	0	.00	41	8.69	41	8.69	15
Cyeru	52,501	5	1.30	60	14.86	65	16.16	27
Gatonde	32,827	5	.00	39	7.83	44	7.83	21
Kidaho	30,203	1	20.00	2	0.86	3	20.86	60
Kigombe	43,343	4	20.70	37	3.79	41	24.49	49
Kinigi	35,956	12	22.00	0	.00	12	22.00	53
Mukingo	28,273	4	26.75	3	0.62	7	27.37	84
Ndusu	37,437	8	.00	40	11.68	48	11.68	27
Nkuli	32,730	5	11.39	33	6.05	38	17.44	46
Nkumba	34,192	3	20.00	6	2.12	9	22.12	56
Nyakinama	46,206	12	7.30	42	8.84	54	16.14	30
Nyamugali	39,735	5	2.15	47	7.90	52	10.05	22
Nyamutera	29,327	6	1.26	42	4.77	48	6.03	18
Nyarutovu	47,226	7	2.07	47	14.10	54	16.17	30
Ruhondo	44,596	4	1.73	43	14.70	47	16.43	32
Total	633,503	85	136.65	527	114.35	612	251.00	34

Source: RRAM Project/Roark and Dickson 1986

* Liters per second.
** Liters per capita per day.

Table 6.9
Estimated Water Demand By Commune

Commune	Population 1985	Population 1995	Domestic Water Demand 1985 lps*	Domestic Water Demand 1985 m^3/day	Domestic Water Demand 1995 lps	Domestic Water Demand 1995 m^3/day
Butaro	47,807	63,628	13	1,114	27	2,291
Cyabingo	51,144	68,069	14	1,192	28	2,450
Cyeru	52,501	69,875	14	1,223	29	2,515
Gatonde	32,827	43,690	9	765	18	1,573
Kidaho	30,203	40,198	8	704	17	1,447
Kigombe	43,343	57,686	12	1,010	24	2,077
Kinigi	35,956	47,855	10	838	20	1,723
Mukingo	28,273	37,629	8	659	16	1,355
Ndusu	37,437	49,826	10	872	21	1,794
Nkuli	32,730	43,561	9	763	18	1,568
Nkumba	34,192	45,507	9	797	19	1,638
Nyakinama	46,206	61,497	12	1,077	26	2,214
Nyamugali	39,735	52,884	11	926	22	1,904
Nyamutera	29,327	39,032	8	683	16	1,405
Nyarutovu	47,226	62,854	13	1,100	26	2,263
Ruhondo	44,596	59,354	12	1,039	25	2,137
Total	633,503	843,145	172	14,762	352	30,354

Source: RRAM Project/Roark and Dickson 1986.

* Liters per second.

Note: The average per-capita water demand is assumed to be as estimated in the World Bank/BCEOM Lava Zone Project, that is: 1985 = 23.3 lpcd; 1995 = 36.0 lpcd. These amounts allow for higher usages in developed areas, institutional uses, and 20 percent losses from the water system.

meter radius. It is important to notehowever, that over 16% of those from the Lava Zone, and 11% from the Plateau region, must walk more than 2 km to obtain water. This situation is greatly aggravated in the Lava Zone by the fact that two-thirds of all people report water shortages at their primary source (versus 12% for the rest of the prefecture). These shortages are most common during the dry season, but also occur frequently due to damage to the piped delivery system or its faucets.

The importance of distance from water can be seen in the number of trips a family member makes to the source each day and, thereby, the daily amount of water consumed by the family. Residents of the Lava Zone are much more likely to make only one such trip each day (41% versus 28% for other areas). These families are thus limited to the contents of one 20-liter jerrycan, or an average of only 4 lpcd for a household of 5 persons. Given this situation, it is no surprise that people in the Lava Zone cite water shortages as the most important problem facing their region (see Chapter Three).

Despite the lack of adequate water in certain areas, a steady majority of families across all parts of the prefecture report average consumption levels of around 12 lpcd. The recommended level of 20 lpcd, however, is only reached by about 16% of all households (21% in the ZND). As for water quality, a large majority of the Ruhengeri population believes that their water is "good". The highest percentage of those rating their water quality as "bad" is in the ZND (37%): a fact which is probably due to that region's high dependence on undeveloped sources.

supply and demand

As of 1985, at least 527 improved springs and 85 piped delivery systems had been developed in Ruhengeri (Table 6.8). The total output of these water sources was 251 liters per second (lps), or enough to provide 34 lpcd to the entire population of Ruhengeri. As shown in Table 6.9, this is more than enough to satisfy current demand of 172 lps, even assuming a high consumption rate of 23 lpcd. By 1995, however, demand should increase to 352 lps, or 40% more than current capacity.

The current problem in Ruhengeri is therefore not one of supply, but rather distribution. Sufficient water supplies exist, but they are currently being underutilized because they are too far from potential users. In the commune of Kidaho, for example, the existing systems produce enough water to provide each resident with 60 lpcd: yet there are only 3 such systems in the entire commune. Nyakinama has a much lower total production, but there are 54 distribution points. The only solution to this problem -- and that of future demand -- is to establish more distribution points through the development of new sources and piped delivery systems in water-deprived areas.

technological approaches

Between 1980 and 1984, the number of developed water sources in Ruhengeri increased by 37%, according to official statistics from the prefecture. Most of the new sources were capped springs, although a number of gravity-flow piped systems were also installed. The continued use of these technologies is appropriate for several reasons. First, natural springs are plentiful in most areas except the Lava Zone. Second, the technology is relatively simple and can therefore be maintained by user groups with limited outside assistance. Finally, these systems are not expensive. Simple capped springs cost an average of only a few hundred FRw per user. Piped delivery systems have averaged roughly 3000 FRw per user over recent years, but have the considerable advantage of serving a much larger area.

The development of water supply systems in the Lava Zone presents particular problems. As mentioned at several points in this report, the extremely porous soil and rock structures of this region prevent the retention of surface water. For this reason, the area was sparsely inhabited until the Belgian colonial government constructed an extensive water distribution system in 1956. This consisted of a 63 kilometer gravity pipeline, which carried water from the rich (more than 200 lps) Mutobo Spring in Mukingo all the way to the Ugandan border in Kidaho. By the mid-1970s, however, the system's steel piping was highly corroded, many of its faucets were plugged or broken, and the funding required for maintenance was not available.

Following an assessment of this situation by a French firm (BCEOM), the World Bank agreed in 1986 to finance replacement of the old system. In its place, a new gravity pipeline will be constructed which will follow the former line, but along 2 parallel tracks and with several extension spurs. The new system will also include a water treatment facility and a pumping station to send water from Mutobo over the divide into Gisenyi prefecture. This network will certainly provide more regular delivery of water to a greater number of distribution points. However, the majority of households in the Lava Zone will still find themselves several kilometers from the nearest faucet. In addition, the cost of the entire system is estimated to be nearly $18 million, or $150 per user. While this will not be directly paid for by the affected population, users will be expected to pay a $25 annual fee per family: an amount which past experience indicates may be difficult to collect.

Despite questions about its cost and overall efficiency as a water supply network, the World Bank system is likely to be installed as planned. Yet consideration should also be given to rainwater catchment systems as an alternative water supply technology for the Lava Zone. Between 1978 and 1985, several hundred cistern and rainwater collection systems were constructed and installed in households in the Ruhengeri prefecture. These consisted of simple gutters and a spout which channeled roof runoff into a cement cistern reinforced by bamboo. People were generally very satisfied with the performance of these systems, but two potential drawbacks could limit their widespread use: storage capacity and cost.

More than three-fourths of all houses in Ruhengeri now have corrugated metal or tile roofs, with a mean surface area of 36 m2. With rainfall averaging 4 mm per day (based on data from Kinigi), a cistern which holds only 150 liters could thus collect enough water to provide more than 20 lpcd for a family of six. Rain does not fall every day, however, so storage capacity would have to be great enough to assure continual supply. The average size of cisterns built in Ruhengeri is 1,200 liters: enough for a 10 day reserve, or 20 days at a consumption level of 10 lpcd. During the nine months of the year when rainfall averages more than 100 mm, this represents a more than ample reserve. In June and August, rainfall drops to 60 mm per month, but this would still provide an additional 12 lpcd beyond the 1,200 liter stored capacity. The problem arises in July, when the average of 26 mm of rain would produce only 5 lpcd. Even this deficit could probably be managed through careful rationing, but it is probable that people would be partially dependent on alternative sources during this period.

Another problem with rainwater catchment systems is their cost. The 1,200 liter cisterns described above have cost an average of about 19,000 FRw ($240) to build. Experience in Burundi indicates that this could be reduced to around $200, but this would still represent a significant expense in a region where annual incomes average only $260. Subsidies represent one possible solution to this problem. For one-third the cost of the World Bank project ($825 per family), a cistern system could be purchased and installed in every household, and the resulting government debt would be reduced.

Another solution would be to promote (and possibly subsidize) the development of inexpensive cisterns by the national plastics industry. A few 100-liter barrels would satisfy the vast majority of household needs, and would have the added advantage of plastic's longevity and ease of cleaning. Finally, even the limited option of installing a collector system of gutters and spouts to fill five 20liter jerrycans would cost no more than $40 per family, and would provide a significant amount of water.

No matter which level of development is pursued, the extension of rainwater catchment technologies to the Lava Zone, and other parts of the prefecture, would have enormous benefits. The region's high rainfall assures regular supplies during most of the year; water would be immediately available within the household complex, thus eliminating the thousands of hours per year which women now spend on its transport; and the construction and installation of such systems would generate significant employment opportunities.

Conclusions.

Three major problems confront the Ruhengeri prefecture with regard to the management of its water resources. First, accelerated changes in land use appear to be affecting water flow in the region's complex network of rivers, lakes and marshes. This can be seen in changing lake levels, higher runoff and streamflow levels, and indications of hydro-ecological changes affecting marshes and bottomlands. Second, water supply sources are unequally distributed across the prefecture, resulting in serious shortages for thousands of families. Finally, an inadequate information base inhibits action to deal with these problems. This is especially true with regard to management of the overall hydrologic system; but the lack of information also affects efforts to improve water supply through the selection of appropriate sites and technologies.

Recommendations.

Applied Research.

1. The prefecture, in collaboration with the appropriate national services, should increase and improve its existing hydro-climatological monitoring network. This requires the installation of additional rainfall measuring stations in areas which are now inadequately served. Priority areas would include the communes of Nyamugali, Cyeru, Ndusu, Nyamutera and the lava region of Nkuli, as well as at least one other site in the Virunga rainforest (see Figure 2.4 in Chapter Two).

Additional streamflow gauges should also be installed at a variety of points. These should include representative smaller streams, such as the Nyamutera, Gicive and Mukinga, which feed into the Mukungwa River, as well as one or two other streams from the southeastern corner of the prefecture. The Kamiranzovu branch of the Rugezi Marsh should also have a measuring station to determine effects of its recent canalization. Any marsh or bottomland which is not yet drained should have a water gauge installed to provide comparative data, especially if the area is planned to be drained in the future. Similarly, all projects which include wetlands or bottomlands drainage components should be required to monitor changes in water flow which may result from their intervention activities.

In addition to providing information on water levels and volume, all of these stations should also serve as sites for the periodic monitoring of sediment transport. Finally, the accuracy of existing stations (especially the one at Ngaru) should be examined by competent authorities, and new installations made where necessary.

2. Arsenic levels should be periodically monitored in streams and lakes which receive runoff from wolfram mines. Samples of plants and fish from affected areas should also be examined to determine levels of arsenic uptake.

3. An accurate map of all existing water delivery systems in the prefecture should be made (a preliminary map at 1:100,000 has already been completed by the RRAM Project, but needs to be updated). This should be accompanied by tables listing essential information for each source such as yield, number of users, date of construction, etc.

4. A detailed study of the role of hydroelectrity generation on water levels in Lakes Bulera and Ruhondo should be made prior to any decision on significantly increasing power production at either the Ntaruka or Rwaza stations.

Action.

5. Further drainage of the Rugezi Marsh should be prohibited. Its fragile ecology and critical importance in regulating water flow should preclude alternative development options. Consideration could be given to designating the marsh as a natural reserve, although it should be recognized that the entire complex is used in various ways by the local population.

6. Priority attention should be given to the development and distribution of rainwater catchment systems throughout the Lava Zone and other parts of the prefecture where water supply is a chronic problem. A thorough approach to this matter should include research, development and demonstration components. Subsidies for alternative designs and, eventually, production and purchase arrangements will almost certainly be required.

CHAPTER SEVEN: VOLCANOES NATIONAL PARK

The Volcanoes National Park (VNP) is a natural area of regional, national and international importance. It covers 7.4% of the Ruhengeri prefecture and represents a significant source of local employment in addition to its role in water catchment and regulation. At the national level, the park and its gorillas attract tourists and foreign revenue equivalent to more than two million dollars annually. Finally, the VNP has been designated an International Biosphere Reserve in recognition of its unique biological attributes.

All of the above have created a positive situation in which the park stands out as one of Africa's premier natural reserves. Yet at the same time, the Virunga ecosystem remains poorly understood and, partly as a result of this, several important management problems remain to be dealt with. Given the lack of detailed studies of this area and its problems, the following sections combine general description with analysis, from which are then drawn certain conclusions and recommendations.

Description and Analysis.

Historical. The Virunga ecosystem was officially protected within the Albert National Park -- the first such reserve in Africa -- in 1926. The creation of a Gorilla Sanctuary in the contiguous Ugandan sector of the chain, in 1930, brought the total area under protection to nearly 700 km2. At the end of the colonial period, administrative responsibility for the major part of this reserve was split between Zaire (Virunga National Park) and Rwanda (Volcanoes National Park).

Initially, the VNP was managed by the Direction of Water and Forests within the Rwandan Ministry of Agriculture. In 1973, responsibility was transferred to the newly created Office of Tourism and National Parks (ORTPN). This Office has been aided in its management efforts by the Belgian Technical Assistance program and by an international consortium of conservation groups (see below).

Conversion trends. The Rwandan sector of the Virunga ecosystem has been drastically reduced in size over the past 30 years. Just prior to Independence, in 1958, Belgian authorities permitted nearly 7,000 ha of the park to be cleared for human settlement. Between 1969 and 1973, another 10,500 ha of parkland were converted to agricultural uses under a cooperative development project managed by the Rwandan government and the European Economic Community. Then in 1979, an additional 1,300 ha were cut to make room for more settlers in the western sector. A rare exception to this negative trend occurred in 1986, when several hundred hectares along its border were reincorporated into the park.

As a result of these conversion activities, the total area of the Volcanoes Park has been reduced by 54%, from 328 km2 to a remnant 150 km2 today (Figures 7.1 and 7.2). Since this conversion occured primarily within lower elevation zones, the associated loss of biological diversity has been significant. The VNP still retains considerable biological value, however, and recent conservation trends have been very positive.

Vegetation. As described in Chapter Two, the VNP ecosystem contains the upper stages of the afromontane vegetation sequence. The most diverse montane forest zone was largely eliminated by the clearing activities described above. A relic band remains, however, between Mts. Gahinga and Sabyinyo. There, _Neobutonia_, _Mimulopsis_, _Agauria_, _Prunus_, _Bersama_, _Xymalos_, and _Vernonia_

98

FIGURE 7.1

Volcanoes National Park

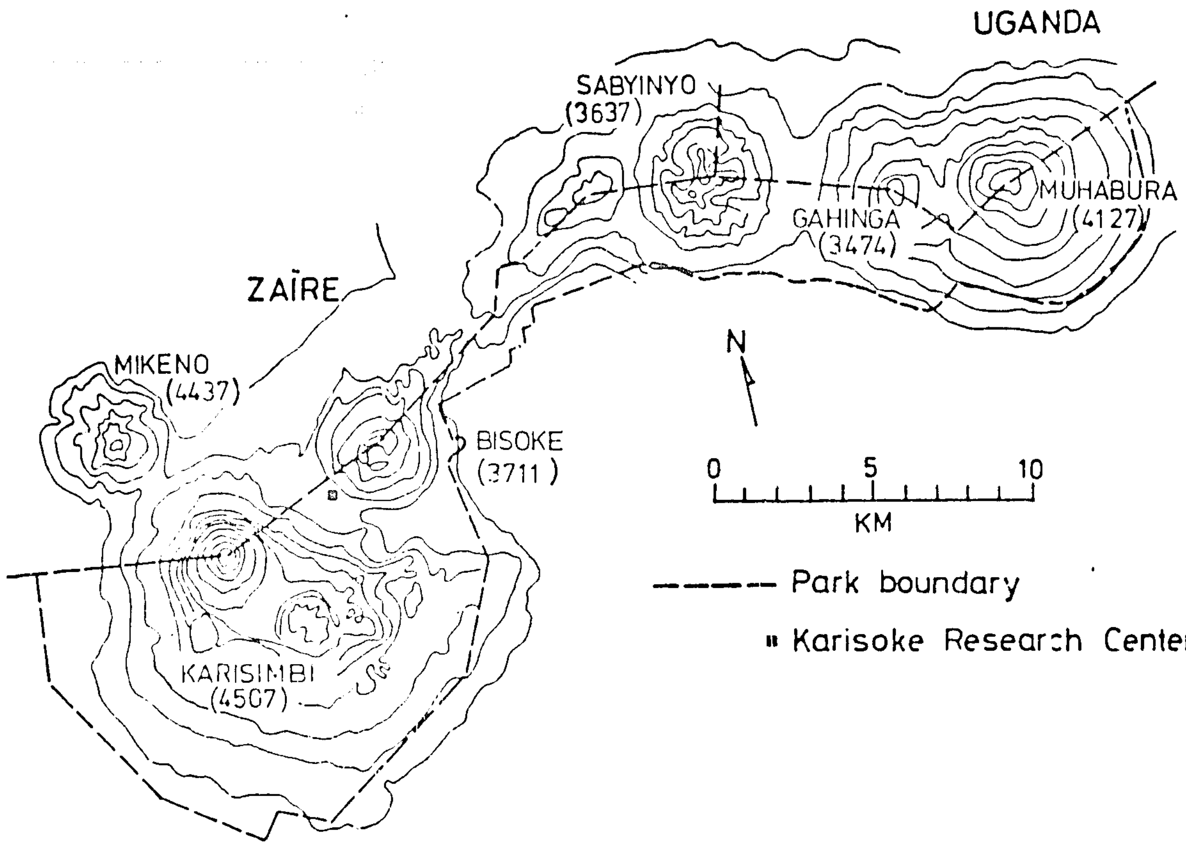
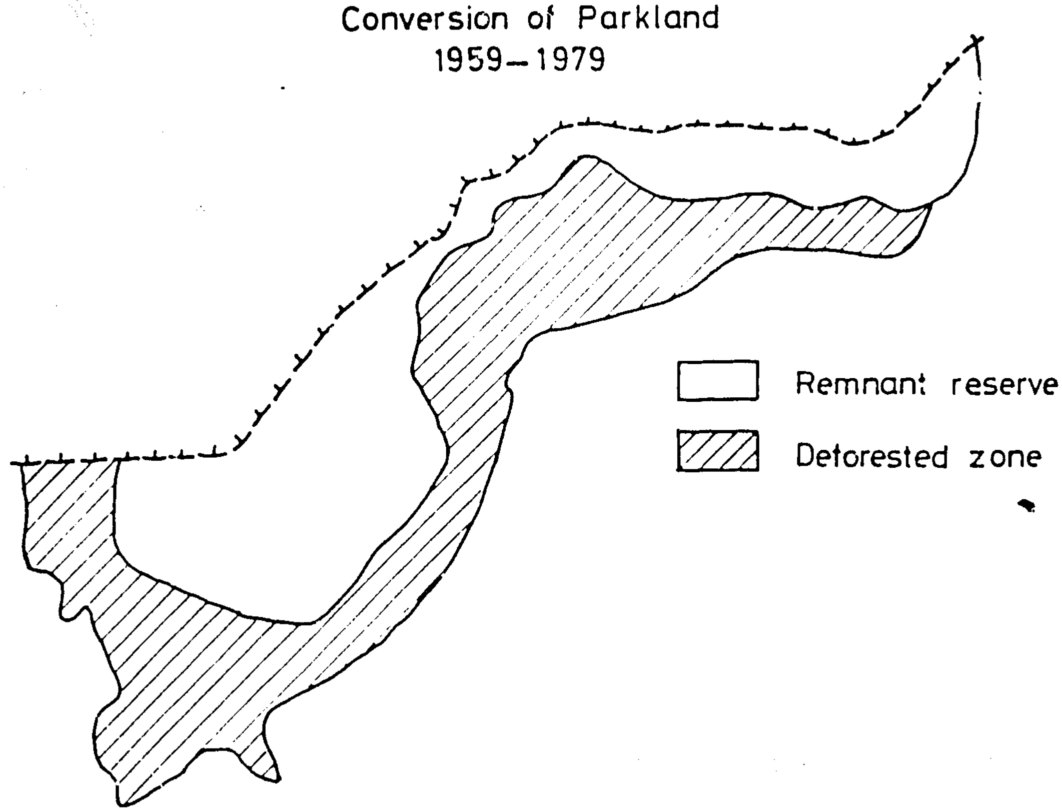


FIGURE 7.2

Conversion of Parkland
1959–1979



combine with numerous lianas, epiphytes and grasses to form a relatively rich community. Along most of the park's lower boundary, though, homogeneous stands of bamboo (Arundinaria alpina) predominate, interspersed with grassy clearings.

With increasing elevation, bamboo gives way to open woodland formations between 2700 and 3200 meters. The dominant tree species in this zone, Hagenia abyssinica and Hypericum lanceolatum, do not form closed canopies and therefore permit extensive clearings of abundant herbaceous vegetation. Marsh communities also exist within this zone, where physical conditions favor their establishment, especially in the saddles between volcanoes.

Sub-alpine vegetation covers the zone between the elevations of 3000 to 4000 meters. Giant heath formations of Phillipia and Erica extend down into the forest zone along exposed, rocky ridges, while giant forms of Senecio and Lobelia predominate higher up. The ground cover throughout this zone is characterized by communities of Rubus, Alchemilla, Helichrysum, and Volkensia shrubs, mixed with various grasses and lichens. Where conditions permit, acidic marshes of Carex and Sphagnum also exist in this zone.

At the highest elevations, above 4000 meters, even shrubs disappear and give way to communities of grasses, mosses and lichens. These alpine formations are not only less diverse, but also more fragile than the other zones.

Although the afromontane vegetation is most easily understood as a succession of zones primarily determined by altitude, this approach oversimplifies the ecology of the Virungas. There is considerable overlap between zones and numerous mosaic patterns exist within the lower zones. The resultant transition zones where plant communities mix are called ecotones; and they are important not only for their greater floristic diversity, but also as primary habitat for park wildlife.

Fauna. The Virunga ecosystem includes more than 60 mammal species and at least 180 different kinds of birds have been identified from the region. Many of these are represented by sub-species or varieties whose distribution is limited to the remnant montane forests of central Africa: several are considered to be highly endangered.

A surprising number of carnivores appear among the mammals identified from the VNP since its inception. The presence at one time of lions, leopards, hyenas, jackals, civets, genets, serval cats, golden cats and 2 kinds of mongoose indicates an even greater variety and density of species upon which they preyed. Lions were last seen in the Virungas in 1943, however, and most of the others have been eliminated or seriously reduced in number by habitat loss and poaching over the past 30 years.

Today, the principal large mammals which remain in the park are the elephant, buffalo, bushbuck, and black-fronted duiker. The giant forest hog (Hylochoerus meinertzhageni) and the yellow-backed duiker (Cephalophus sylvicultor) are near extinction, if not already gone. The buffalo is a notable exception to the declining status of most other large, terrestrial mammals in that its numbers appear to be increasing recently. This could be due to decreased poaching and/or predator pressure, reduced competition from other herbivores, vegetation changes, habitat loss, or a combination of these and other factors. What is certain is that the buffalo have become a major management problem (see below) and that some basic information on their population dynamics and ecology is required before any effective action can be taken.

Eight types of primate have been identified from the Virungas. These include the mountain gorilla (*Gorilla gorilla beringei*), possibly 3 races of *Cercopithecus mitis* (*kandti*, *doggetti* and *schoutedeni*), and two nocturnal primates: *Perodicticus potto* and *Galago senegalensis*. In addition, there have been irregular reports of *C. l'hoesti* and *C. ascanius* from the eastern sector of the park. As with the other mammals cited above, very little is known about the ecology and status (not to mention the existence) of most of these primates. The extreme exception to this rule, however, involves the mountain gorilla.

Throughout this century, the Virunga volcanoes have been primarily known for their population of gorillas. The first examples of this subspecies known to science were shot by a German officer on Mt. Sabyinyo in 1901. Twenty-five years later, the fact that this population was endemic to the Virungas provided the principal raison d'être for the creation of the national park. In 1959-60, the first major field study of gorillas was conducted in this area by George Schaller. And from 1969 through today, the long-term studies of Dian Fossey and other scientists working at Rwanda's Karisoke Research Center have provided the world with detailed knowledge of the behavior and ecology of the mountain gorilla. They have also made its endangered status an international cause for concern.

In 1960, Schaller reported a population of between 400 and 500 gorillas in the Virungas (for the purposes of this section and most other matters relating to management of the Virunga ecosystem, it is generally inappropriate to make distinctions along artificial national boundaries). The next gorilla census, conducted in 1971 - 1973, found that this number had been reduced dramatically to only 274 (Table 7.1). This sudden drop was attributed to a combination of poaching in the Zairian sector and, to a lesser degree, habitat loss in Rwanda. The next census, in 1976 - 1978, found a population of 2[illegible]. While this represented a more gradual decline than before, the low number of immature gorillas (36%) was alarming in its implications for future reproduction.

Concern over the gorillas' declining status resulted in the creation, in 1979, of the Mountain Gorilla Project (MGP) as a collaborative effort between the Rwandan government and an international consortium of conservation groups. The MGP's objectives were: (1) to reduce poaching pressure on the gorillas and other wildlife of the VNP; (2) to stimulate increased tourism revenues through controlled visits to habituated gorilla groups; and (3) to increase public awareness of the park and its values through education.

Today, the MGP is widely recognized for its successes in all three areas. No gorillas have been killed since 1983 (8 were killed 1978, the year before the MGP began) and poaching of other animals appears to have been reduced as well. Tourism revenues have also risen dramatically, from a few thousand dollars in 1978, to more than two million annually over the past several years. Direct park entry fees alone surpassed $250,000 in 1985, making the VNP one of the few self-supporting parks in the world (Figure 7.3). The education program, too, has been successful in improving public awareness of and attitudes toward the park (see below). Recognition of these achievements has also resulted in support for similar projects in the Zairian and Ugandan sectors of the Virungas, which began in 1984 and 1987, respectively.

The true measure of the MGP's success, however, can best be seen in its

Table 7.1

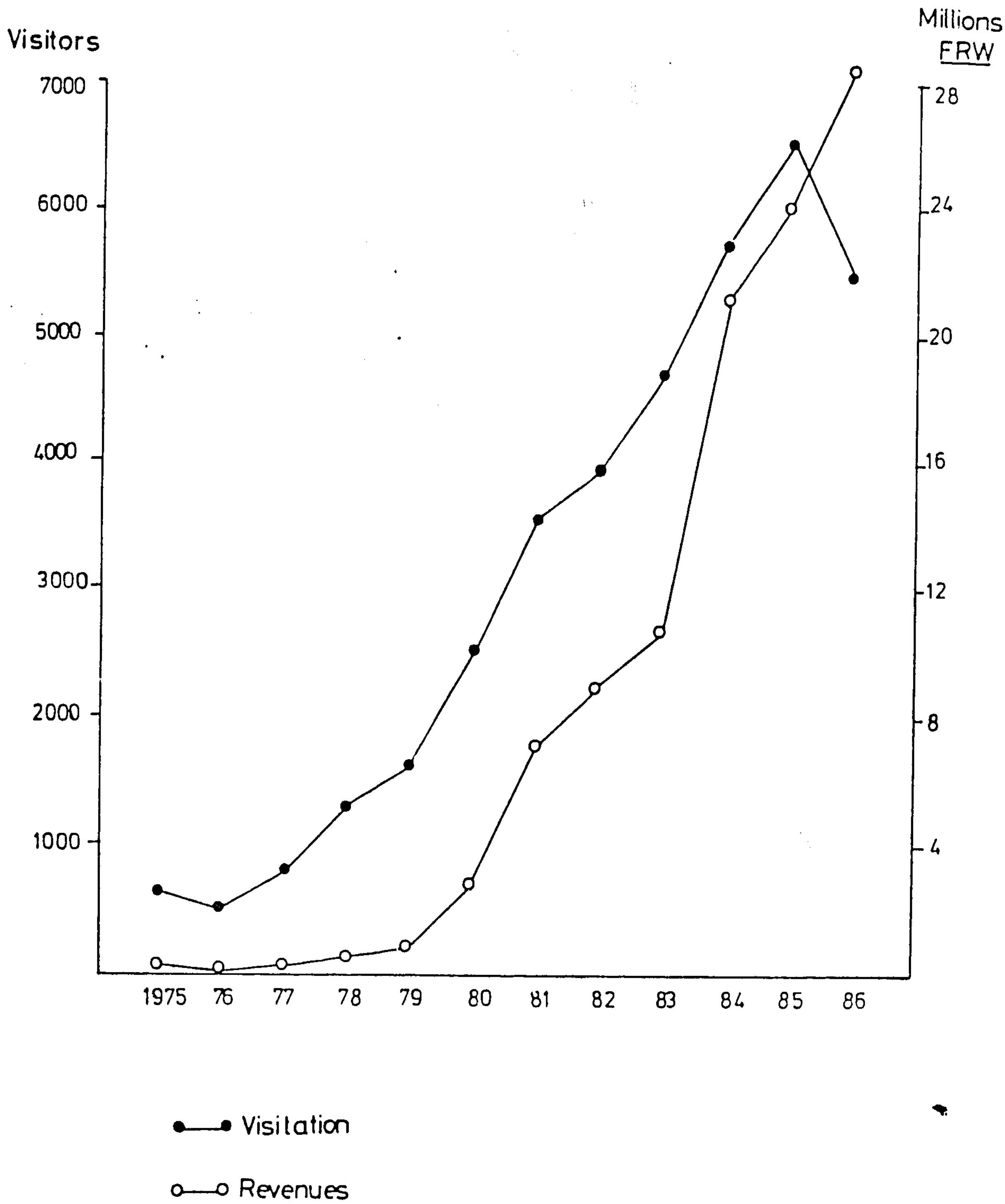
Evolution of the Virunga Gorilla Population
1960 - 1986

census period	total counted	no. of groups	no. in groups	lone males	% * adult	% * immature	total estimated	total (range)
1959-60	-	-	-	-	-	-	450	(400-500)
1971-73	261	31	246	15	60.2	39.8	275	(261-290)
1976-78	252	28	246	6	64.2	35.8	268	(252-285)
1981	242	28	237	5	60.3	39.7	254	(242-266)
1986	280	29	268	12	51.9	48.1	294	(280-308)

* % adult and immature calculated from population in groups (lone males excluded)

Source: A. Vedder. 1986. Preliminary report on the population status and dynamics of the Virunga gorillas.

FIGURE 7.3
Park Visitation and Revenues : 1975–1986



Source : O R T P N 1987

contribution to the current improved status of the mountain gorilla. A census conducted in 1981 found that although the total population continued to decline to 254 individuals, the percentage of young gorillas had increased to nearly 40% (Table 7.1). Then, in 1986, the most recent census revealed some very positive changes. The total population had increased to 293 and the percentage of immature gorillas had risen to 48%. Average group size and number of young were also found to be higher in those groups which were regularly followed for tourism or research purposes, thus reducing concern that these activities might inhibit gorilla reproduction.

It is evident that the mountain gorilla is a subject of major concern in the VNP. Its behavior and ecology have been studied in detail, its population dynamics have been regularly monitored, and its conservation status is currently positive. It is appropriate that such information be known about the "flagship" species of the Virungas. It also stands in sharp contrast, however, to how little is known about the rest of this important ecosystem.

Socio-economic relations. The Virunga ecosystem does not exist in isolation. It is an island of natural conditions surrounded by an agricultural landscape, which is intensively exploited by a large and growing human population. The VNP's survival depends on its ability to provide benefits to this population.

A major value of the park lies in its role in water catchment and management. As described in earlier chapters, this consists of the generation of high rainfall, its capture in a way which does not provoke erosion, and then its gradual release to surrounding areas. The result is a perrenial supply of clean water to a major part of the Ruhengeri population.

More easily quantified is the park's value in income generation. 85 individuals are employed on a full-time basis by the park, most of them from the Ruhengeri region. Another 30 to 40 work part-time (as porters, watchmen, etc.) and hundreds have been employed to work on various construction activities over the past several years. In addition, many more permanent positions at hotels, restaurants and other establishments are supported by tourism in the region. This impact is even more appreciable in Kigali and Gisenyi, where tourists spend the majority of their time and money.

No detailed studies have been done of this tourism sector of the economy, however. The currently used figure of $2,000,000 per year in foreign revenues attributable to the park, is based on what appears to be a reasonable estimate: that the 5,000 foreign tourists who visited the park in 1985 spent an average of $400 each during their stay in Rwanda. But how much of this is offset by expenditures? How much goes into the regional economy of Ruhengeri? How could local populations benefit more from this industry? Answers to these questions could help to improve park management and assure its future survival.

A partial answer concerning the park's economic value can be found in a series of opinion surveys conducted in the area around the park over the past several years. Comparative results of attitudes toward tourism benefits can be seen in Table 7.2. In 1979, prior to the MGP's tourism development program, 65% of the rural population around the park believed that Rwanda benefited from tourism at the national level. Only 39% perceived any regional benefits, however, and barely onefourth felt that they personally profited from the situation (and then only as indirect recipients of national revenues). By 1984, this situation had changed significantly. Nearly 88% of those surveyed perceived national benefits of tourism, while 55% felt that the Ruhengeri region also profited. Fully 56% thought that they benefited personally, in some way, from VNP tourism. While they do not satisfy the need for more detailed information, such results do indicate an increased appreciation of the value of tourism development in the Virungas.

The local population has also come to recognize other values of the VNP, as shown in Table 7.2. Asked to list non-consumptive values of the natural forest, the majority of respondants in 1979 could not provide a single one. Among those values most commonly cited were its role in water catchment (19%) and as a wildlife refuge (19%). Despite the latter response, however, 58% of population could not give a single value of wildlife protection. Virtually all of those who did respond positively cited tourism benefits (39%), while barely 1% referred to research and aesthetic values of wildlife. Given this general lack of appreciation, it is not surprising that 51% of the sample felt that the park should be opened to exploitation by the surrounding population.

By 1984, though, a major change had occured. Asked the same series of questions, most respondants were able to give at least one value of forest preservation, with wildlife refuge cited by 30%, rainfall and climate control 25%, erosion control 9%, tourism 7% and research 2%. With regard to wildlife, the percentage of those who recognized their value for tourism increased significantly to 56%. Other values remained little appreciated. Of most importance, however, was the finding that more than 75% of those surveyed felt that the park should be fully protected: an increase of more than 50% from 1979.

Despite these positive changes, the issue of animal damage to crops remains a major problem. Respondants in the 1984 survey were unanimous in their perception that some park animals were a nuisance. Buffaloes headed their list of pests (96%), followed by elephants (69%), antelope (18%), and porcupines (3%). An analysis of this situation by the RRAM Project confirms the reality of this problem, but also raises certain questions with regard to its extent and nature.

Between September 1985 and June 1986, official records show that 89 claims of animal damage were filed against the park by farmers from the commune of Kinigi. This represents barely 1% of the commune's total households, but could equal 10% of those within one kilometer of the park boundary. More than 80% of the damage occured within 500 meters of the park, although some reports of buffalo damage came from several kilometers away. In more than one-third of the cases, the impact was limited to simple passage through a field. In another 22%, some crops were eaten, and in 43% of the cases, investigators found extensive damage (the latter instances, however, were often aggravated by people chasing the animals and thereby trampling crops). A total of 3.6 ha were destroyed during the 10-month period of the survey.

Cereal crops (especially corn), beans and peas appeared to be favored for eating, while potatoes were most commonly damaged by trampling. Buffaloes were to blame in the majority of cases (75%) and were also responsible for the most serious damage. Bushbuck and duiker were guilty in 20% of all cases, but generally for only minor damage. Elephants were far less responsible for crop damage (3% of cases) than generally believed; but the devastating nature

Table 7.2

Local Perceptions of Park Conservation Values

Subject Responses	1979 %	1984 %
Tourism		
national benefits		
yes	65	85
no	11	5
don't know	24	10
regional benefits		
yes	39	81
no	50	11
don't know	11	8
personal benefits		
yes	26	49
no	72	50
don't know	2	1
Forest Values*		
no value	17	22
rain/climate	19	21
erosion control	7	11
wildlife refuge	19	28
tourism	0	6
research	0	2
don't know	38	11
Wildlife Values*		
no value	14	24
tourism	39	52
research	1	1
aesthetic	1	1
species preservation	0	1
don't know	44	16
Open Park to Exploitation		
yes	51	29
no	49	71

* non-consumptive values; multiple responses permitted

source: AW Weber. 1986, 1981, and unpublished doctoral research of their passage through a field, no matter how infrequently, may help to explain exagerated local fears.

The preceding information helps to better understand the animal impact situation. It is apparently not as pervasive as popularly believed and it is largely due to one animal: the buffalo. The impacts are nevertheless serious within a restricted area around the park, where most of the people depend entirely on the agricultural production from very small farms. The park service has recognized this fact through its willingness to pay reasonable claims. Yet since the problem seems to be escalating in recent years, this matter should certainly be given greater attention as a management issue which, at the least, results in negative local attitudes toward the park.

Conclusions.

The overall situation in the VNP is positive. Park conversion appears to have been halted; poaching has been reduced, though not eliminated; the population of mountain gorillas is growing for the first time in nearly thirty years; local attitudes toward the park are increasingly positive; and significant tourism revenues provide both justification and support for intensified government efforts to protect the park and its wildlife.

The most immediate management problem to be dealt with is that of buffalo damage to crops. This should receive priority attention, with a dual emphasis on damage control and better understanding of the reasons behind the buffaloes' behavior. The lack of the latter, however, is symptomatic of a larger problem in the VNP: with the notable exception of the mountain gorilla, the available information about the Virunga ecosystem and its component species is seriously inadequate. Increased knowledge of these subjects is essential to improved, long-term park management.

Recommendations.

Applied research.

1. A study of the Virunga buffalo population should begin immediately. This should be designed to provide information on population dynamics, distribution, behavior and ecology. Following 1 -2 years of intensive study, sufficient baseline data would exist to permit periodic monitoring of the situation on a long-term basis. Results of the initial study, however, should be incorporated into management plans as soon as possible.

2. Studies of other animal populations should be conducted. Elephants and antelope would be obvious choices, given their uncertain status and their implication in crop damage. Birds, too, should be considered as priority subjects due to their proven value as indicator species of habitat change and degradation.

3. Detailed maps should be made from aerial photos of the different vegetation zones and plant communities of the park. At the same time, field studies should begin of these communities and the dynamics of ecological change and succession. This information is not only valuable on its own, it is also essential to a complete understanding of animal behavior and ecology.

4. A study should be conducted of the park's economic role at both the national and regional levels. This should go beyond simple entry fees to examine total tourist spending (foreigners and residents). Employment and income generated by VNP tourism should also be examined at both the primary (park) and secondary (hotels, restaurants, travel agencies, boutiques, etc.) levels. Such information would

not only help to better quantify tourism benefits, but could also help to identify areas where tourism revenues could be increased.

5. A study should be made of tourist use of and impact on the park. Currently, the vast majority of visitors come to see the gorillas. With only 21 places available per day, however, the total annual carrying capacity of the gorillas is 7,665 persons. This figure is rapidly being approached and is, in fact, surpassed during the peak tourism periods. The potential for developing and promoting other attractions (camping, hiking, specialty tours for birdwatching, etc.) within the park should therefore receive priority attention.

At the same time, an assessment should be made of current tourism impact on the park. This should focus on trail degradation, trampling of vegetation in the upper elevations, littering, and illegal woodcutting. Means to control such negative impacts should be established prior to any expansion of the current level of hiking and camping.

Management activities.

6. The role of the Karisoke Research Center (KRC) must be enlarged and better integrated into the management structure of the park. No modern park can function well without a research component to provide information on the state of the ecosystem. The applied research topics described above are examples of the kind of work which KRC could coordinate and analyze for park authorities.

Up to now, KRC has had a very narrow focus on gorillas. It has done this very well, and its research results have not only gained worldwide attention, but have also been applied to the development of a model tourism program in the VNP. While such research should definitely continue, KRC must also broaden its range of activities to include other species and more general aspects of park ecology. The physical infrastructure of the center is certainly able to support a larger team of scientists and recruiting is now underway to attract qualified individuals. By expanding its operations, Karisoke would not only increase its stature as an international research center, but would also make a greater contribution to park management.

7. Controlling buffalo excursions from the park should receive the most immediate priority. While waiting for results from the study proposed above, several other options can be tried. Shooting buffalo which leave the park has been tried with mixed results. It takes too much time to call a park guard to the scene, and the resulting damage to crops, especially from the crowd which invariably gathers, is frequently worse than that caused by the animal alone. The planting of an impenetrable hedge around the park represents a more passive approach which has recently been tried by the RRAM Project. Nearly three kilometers have thus far been planted with species of <u>Solanum aculeastrum</u> (umutobotobo) and <u>Caesalpinia decapitala</u> (umufatangwe), both of which are now beginning to form thickets. While it is too early to judge the effectiveness of this approach, it appears to be worth extending this trial over a larger area.

Neither shooting nor constructing a barrier, however, will totally stop buffalo excursions. Farmers living along the edge of the park will have to adapt to this fact of life. Such adaptations can already be seen in changes in crop selection, as many farmers are no longer planting corn. The recent creation of a project to introduce improved varieties of corn in this region, however, runs counter to this trend, and should be modified to avoid aggravating the situation. A useful first step should be to avoid planting within a one-kilometer band around the park.

8. Training is once again an essential component in the management of park resources. Rwandan personnel currently manage most aspects of the tourism program and are responsible for the day to day execution of park security operations. The MGP plays an important role in the organization of the latter, however. The establishment of close counterpart relations is therefore essential to assure that the necessary skills are passed on to Rwandan personnel.

Rwandan scientists with the training to conduct research on wildlife and natural ecosystems are almost totally lacking. As a result, research at KRC has been conducted almost exclusively by expatriate scientists. The recent creation of an ecology program at the National University, however, has begun to produce graduates with preliminary training in appropriate subjects. Some of these have conducted their research in the park under the supervision of the KRC Director. This program should continue, and provisions should be made for more advanced training and continued research support for the more promising participants.

9. Strong consideration should be given to some kind of revenue-sharing arrangement between ORTPN and the communes which border the park. This could be extremely helpful in promoting local support for park protection efforts, without incurring major costs for the park service. An arrangement could be made by which the six bordering communes would receive 5% of direct park revenues each year, the distribution of which could be made on the basis of relative area, or perhaps through incentive awards based on the relative incidence of poaching/tree cutting in each commune.

10. Numerous other recommendations have been made in a recently-approved 5-year management plan for the VNP (see References), developed by the MGP and Rwandan park authorities. This plan should be supported by appropriate domestic and international institutions so that it can be fully implemented as soon as possible.

CHAPTER EIGHT: LEGISLATION AND INSTITUTIONS

Human beings are natural resources which play a major role in the functioning of any ecosystem. They do so directly through their collective use of other resources, and indirectly through the activities of institutions which they create. In preceding chapters, the direct impacts of human resource use and abuse have been amply described. In this chapter, attention is focused on the role of institutional structures and their guiding legislation in environmental management.

Legislation.

There are no existing laws in Rwanda which treat the environment in a comprehensive manner. The patchwork legislation which does exist falls into two general categories: outdated relics of the colonial past, and more recent laws which tend to take a more narrow, sectoral approach to specific resource issues.

The colonial legacy includes numerous decrees which remain technically operative, but which no longer retain any _de facto_ value. These cover the conservation of forest resources (1915, 1930, 1933, 1953); the establishment of the national park (1925, 1934); the protection of water sources (1914, 1952); and a variety of human land use issues.

Following Independence, several modifications and additions to these laws were made, the most important of which concerned the creation of the Rwandan National Park Service (ORTPN) in 1974; the reclamation of abandoned mining sites (1971, 1976); and the establishment of a national law on soil conservation (1982). The latter is especially important as an attempt to regulate soil erosion and degradation in a comprehensive manner.

Other laws of environmental interest are currently being considered by the Rwandan government. The National Forestry Law would provide a legal structure for the protection of existing forests, the promotion of sound management practices at all levels, and a solid economic foundation for future wood resource development. It would also create Forestry and Environment Commissions in each of the country's 10 prefectures. The fact that this law has been under consideration for more than two years reflects both its comprehensive and, apparently, controversial nature. Its mere existence in draft form, however, should be recognized as a positive development.

Even more far-reaching than the forestry law is that which concerns land use and land tenure. First proposed in 1978, this law would result in a fundamental restructuring of land use rights and practices. While many are convinced of the need for such radical change -- in the interest of rational development and sound resource management -- the 10-year delay thus far in its implementation reflects an important fact: no matter how chaotic the traditional system may seem, it has the great advantage of familiarity. And it will probably take a crisis situation to bring about any fundamental change.

The final legislation of interest has a much more narrow focus on mining and other extractive operations such as brick-making and peat production. The proposals under consideration would serve primarily to regulate on-site impacts (pollution, erosion) and assure adequate reclamation of abandoned areas. While these are worthy goals, it should be recognized that the recent collapse of Rwanda's mineral export operations -- an important source of both foreign revenue and employment -- has resulted in economic considerations which currently outweigh those of environmental protection.

The legislative basis for improved resource management in Rwanda is thus not very sound. Whatever their merits, colonial statutes are no longer operative; modern laws have taken their place in some sectors, notably that of soil conservation, but not in others; and pending legislation on forestry and general land use has been held up because of the complexity of the issues involved. The latter situation would also seem to indicate that prospects for any more comprehensive legislation on environmental matters are not very positive. Yet even without the desireable legal framework, resource management does occur under the policies and guidelines established by Rwanda's institutional structures.

Institutions.

Whereas Rwanda may be poor in legislation, it is rich in institutions. For the purposes of this report, an institution is considered to be an organized administrative structure, which controls the use of certain financial, material and human resources to meet its established responsibilities and objectives. In Rwanda, most of these are central government agencies and services, while many fewer institutions operate at the regional or local level. There are virtually no non-governmental organizations of any significance. On a parallel track, however, there are many foreign institutions ranging from large multilateral and bilateral assistance agencies to a variety of NGOs. Most of these national and international institutions play some role in resource management; yet coordination among them is thus far poorly developed.

National. A multitude of Rwandan ministries and associated services are concerned, to varying degrees, with environmental and resource issues. The following list presents the principal actors and their responsibilities.

MINISAPASO. The Ministry of Public Health and Social Affairs includes an Office of the Environment. Officially, this office is charged with coordination of all activities relative to the "protection, conservation and promotion of the environment" at the national level. In fact, this office has very limited resources at its disposition for this task, and has thus far tended to focus on a more narrow range of environmental health issues. It did, however, take the lead role in organizing the First National Seminar on the Environment in September 1985.

MINAGRI. Despite MINISAPASO's official role, the Ministry of Agriculture, Livestock and Forests is without question the lead institution for most resource issues in Rwanda. This can be seen in the functions and responsibilities of three major divisions within this ministry.

The Direction-General of Rural Engineering and Soil Conservation contains several important services. The Direction of Soil Conservation is responsible for all aspects of erosion control; the Hydrologic Service is responsible for the collection and publication of all hydrological and agroclimatological data; and the division of Marsh Management oversees wetlands development activities. In addition, it has recently been proposed that an office of agroforestry be established within this Direction-General.

The Direction-General of Forests is another important branch of MINAGRI. It is responsible for virtually all aspects of forestry, from strategic planning to the identification of appropriate species and techniques. The DGF is also noteworthy for its relative depth of qualified personnel, including hundreds of foresters now working with projects in the field. International assistance has helped support the training of these cadres.

The third branch of MINAGRI with direct involvement in resource issues is the National Agricultural Research Institute (ISAR). This institute is charged with the responsibility to carry out research of relevance to agricultural development in Rwanda. The question of relevance is an important one for ISAR, as its work has often been criticized as too academic or too removed from the country's true needs. Recently, however, the Institute has increased its commitment to applied research on agroforestry and erosion and seems intent on making a greater contribution in these areas.

MINITRAPE. The Ministry of Public Works and Energy is also involved in multiple aspects of environmental management. Its Cartographic Service is responsible for the production and dissemination of all map products, as well as for the maintenance of past aerial photos. In addition, other branches of MINITRAPE are charged with the planning and oversight of all building, urban development and road construction projects in the country; the management of rural water supplies and lakes; and the development of traditional and alternative energy sources. The technical staff required to carry out these tasks has been both enlarged and improved over recent years; but insufficient attention still appears to be given to environmental impact assessment of the ministry's various projects.

MINIMART. The Ministry of Mines and Industry has obvious linkages with environmental issues. Yet it must be noted that impact assessment and control have been given relatively low priority in favor of exploration, exploitation and commercialization activities.

ORTPN. The Rwandan Office of Tourism and National Parks has comparable status to that of a ministry through its direct attachment to the Presidency of the Republic. Created in 1974, ORTPN is uniquely responsible for the management and protection of Rwanda's two national parks. It is also legally responsible for the conservation of all natural flora and fauna outside of the parks. The application of this more general mandate, however, has thus far proven to be quite complicated, due to overlapping responsibilities and interests of other ministries.

MINEPRISEC. The Ministry of Primary and Secondary Education has played an increasingly important role in environmental education in recent years. The extensive revision of school curricula in the late 1970s provided an opening for the improvement and addition of courses ranging from general environmental studies to more specific courses on ecology, forestry and nature conservation. While many teachers still have inadequate training in these subjects, they at least now have the texts necessary to help promote environmental awareness among their students.

MINESUPRES. The Ministry of Higher Education and Research should be the first institution to benefit from the improved education provided at the primary and secondary school levels. This ministry is responsible for both the national university system (UNR) and the national scientific research institute (INRS). The former can be criticized for its overemphasis on traditional academic courses, which do not necessarily respond to the country's needs. With regard to natural resources, however, the Ruhengeri campus has a well-developed geography program, and the Butare campus has recently added a small program in ecology. Interdisciplinary programs in environmental studies or natural resource management, though, are totally lacking. INRS does not fill this void, either, as it is primarily oriented toward the humanities and supports very little current research in the natural sciences.

ORINFOR. An institution which does not receive sufficient credit for its contributions to environmental education is the Rwandan Office of Information. Through its programming on Radio Rwanda, ORINFOR has the capability of reaching a greater percentage of the population than any other medium. The accent placed on "Information and Environment" in 1986 served to highlight the potential of this service.

MININTERDECO. In addition to its function of coordinating regional and local government functions, the Ministry of the Interior and Communal Development is also charged with oversight of all extension education programs taught at Communal Centers for Permanent Training and Development (CCDFP). These cover a broad range from literacy and health programs to those concerned with erosion control and agroforestry. The national network of CCDFPs is not yet complete, however, and it is too early to judge its effectiveness.

MINIPLAN. The Ministry of Planning plays the central role in the formulation of national development plans. As such, it deserves considerable credit for the emphasis on sound resource management which appears in the most recent Five-Year Plan (1982-1986). At the same time, however, it must be noted that responsibility for execution of specific policies falls on the other ministries more directly concerned.

Thus, it can be seen that there are multiple institutions with overlapping environmental responsibilities. Conspicuous by its absence from this list is a Ministry of the Environment, or of Natural Resources. Nothing of this name or equivalent function exists in Rwanda. This absence in itself does not necessarily pose serious problems; yet it does preclude the presence of a lead institution which can coordinate activities in this critical area.

The mechanism by which the Rwandan government currently deals with issues requiring such coordination is the Interministerial Coordinating Commission (ICC). Established in 1984, there are now six ICCs, each of which is composed of representatives of those ministries concerned with particular issues. Their areas of responsibility range from political security to education, but none is specifically charged with natural resources or the environment. Two of these, however, deal with the related topics of Rural Development and Health, and Land Use, Water and Energy. It remains to be seen whether these institutions can adequately serve their intended functions of liaison and coordination, especially with regard to environmental issues.

International. The number of international agencies and organizations present in Rwanda is even greater than that of national institutions. They generally provide technical and financial assistance to the government, and many are involved with resource and environmental issues.

The largest of the multilateral assistance agencies is the World Bank, which is primarily a lender institution. In addition, there are several multilateral donor agencies, such as the European Development Fund, the United Nations Development Program and the U.N. Food and Agriculture Organization.

In addition to their support for the multilateral organizations above, many countries also maintain bilateral assistance programs in Rwanda. The principal donor nations include Belgium, France, West Germany, Switzerland, Canada and the United States. Each of these missions supports a variety of projects, with an increasing emphasis on resource management issues, such as the conservation of forests, soils, wetlands and parks.

A large number of non-governmental organizations also provide technical assistance to Rwanda. These NGOs represent a broad spectrum of foreign interest groups, ranging from religious institutions to wildlife conservation organizations. While the latter (World Wildlife Fund, African Wildlife Foundation, New York Zoological Society) are obviously concerned with environmental affairs, it should also be noted that many other NGOs are active in the natural resources sector.

Analysis and Conclusions.

Rwanda does not have a strong legal foundation from which to attack environmental problems. Yet even with such a foundation, the primary responsibility for dealing with these problems would still lie with the appropriate national institutions. As described above, these are numerous, varied and increasingly dedicated to effective resource management. At the same time, they suffer from a common lack of personnel, funding and coordination.

Institutions are only as good as the people who staff them. In the past 10 years, Rwanda has greatly increased both the quantity and quality of its technical and administrative personnel through improved training and recruitment programs. Numerous problems remain, however. First among these is the overwhelming fact that there are still too few people for the work that needs to be done. The national soil conservation program, considered to be of primary importance, is run by a technical staff of 3 persons. The national forestry program has the luxury of a slightly larger staff, but many other programs have no more than one or two responsible persons. In addition, many of these individuals must play dual roles as both technician and administrator, with the latter often taking precedence in the case of conflicts.

There is also a question of the nature of the training of key personnel. Most of those now responsible for natural resource or environmental programs have university level educations. Their training has been primarily in agronomy, however. None of the current decision-makers have advanced degrees in either general environmental studies, or more specific areas such as soil conservation or water resource management. This combination of limited personnel and a lack of appropriate training has serious impacts on the formulation and execution of policies, as discussed below.

These issues become even more critical at the regional and local levels. Each prefecture has one agricultural agent and one forester to represent MINAGRI and oversee the implementation of its policies at the regional level. Communes and sectors are also supposed to have their own such agents; but since responsibility for their salaries was switched to local governments, their numbers have decreased. It is also generally true that level of training declines as one moves down the hierarchical structure from the central government to the localities. Yet it is the local agent who is the critical link in the transmission of policies and techniques to the general population. Thus more technicians need to be trained, and their training needs to be of higher quality.

Increased hiring and training require additional funding. The central government, however, lacks the necessary resources for this effort, and local governments have even greater financial difficulties. International agencies have therefore been asked to help in this regard. Much of the advanced training of higher level technicians is now supported by these agencies. They have also invested in on-the-job training and helped to increase the number of technicians through direct hiring of Rwandan counterparts and other project personnel. This is a valuable contribution; but it is not without its own inherent problems. The principal question to be raised is whether the Rwandan government will eventually be able to absorb these people; or will the country continue to be dependent on foreign sources of support for critical personnel and services.

Coordination among the various institutions concerned with environmental affairs is also a major problem. There is considerable overlap of responsibilities, as well as many gray areas where responsibility is not clearly defined. MINITRAPE, for example, is responsible for road construction, but it is not at all clear who is responsible for the subsequent restabilization of roadsides. With regard to water, three different offices assume responsibility as it moves through marshes, into lakes and then through hydroelectric turbines. At a more general level, many services are dependent on ISAR for research results: but no mechanism exists for the necessary two-way information flow between planners and researchers. Finally, it is clear that there is no central institution which has taken full responsibility for the coordination of environmental affairs. MINISAPASO is charged with this responsibility, but does not have the personnel necessary to effectively do the job. The ICCs were created to assure such coordination, but none is specifically concerned with the environment or natural resources.

Coordination among the international agencies, as well as between the latter and the government, is also problematic. Due to a combination of inadequate communication and a certain degree of competition, the development agencies have not coordinated their activities to make the best use of their technical assistance. The result is redundant efforts in many areas, while other sectors receive little or no support. In addition, the financial power of these agencies enables them to establish programs which are not always in accord with government priorities.

Finally, it must be said that neither the government nor the international agencies have made sufficient efforts to include local interests in program development. Projects have tended to be developed in a top-down manner, with very little input from local populations or their regional governments. This is understandable given the relative weakness of the latter; the lack of established two-way lines of communication; and the limited time and personnel available for project development. Yet without input from those people most affected by various projects, failure rates in the field will be higher than necessary.

The combined effect of all these problems can be seen in resultant policies. Despite very good intentions and a lot of serious work, there are some important flaws in current environmental policies. First, there is no one central institution to focus attention on critical issues and to assure the communication and coordination necessary to deal with them. The result is a mix of more narrowly defined sectoral policies which sometimes miss important problems, and which often fail to take account of interrelationships between sectors.

These sectoral policies are further flawed by personnel problems. Lacking adequate support staff, decision-makers are forced to rely on global strategies, which often fail to take regional differences into account. Responsibility for the implementation of these strategies then falls to field personnel, who generally lack the numbers, training and local support structure to do an effective job. The end result is an inefficient approach to natural resource management.

Recommendations.

Legislative and institutional structures reflect a nation's particular history and state of development. As such, they show considerable variability from country to country. This is especially true with regard to environmental affairs, which have only recently emerged as a subject of importance. Many different approaches are thus being tried, and no one country has developed a universally applicable model. Rwanda can profit from the experience of others in this regard, but it will have to develop structures in accord with existing administrative and economic conditions. The following general recommendations are made in recognition of these limits.

1. Legislative initiatives should not receive priority attention, since they are likely to be ineffective without adequate institutional support. It would nevertheless be useful to establish a commission of jurists and resource specialists to review all existing legislation with regard to the environment. Following this review, the commission should make recommendations for reform, to be discussed in an appropriate national forum.

2. Effective environmental management requires a centralized institution responsible for its coordination. The creation of a Ministry of the Environment, however, seems neither necessary nor appropriate in the current Rwandan context. Instead, a National Commission on the Environment could be established under the auspices of the Presidency of the Republic. This Commission should be composed of appropriate representatives of the major ministries and services described above, and headed by a Presidential appointee. Its principal task would be to assure essential communication and coordination among its members and to propose specific actions where required. That such recommendations would have the necessary weight would be assured by the Commission's attachment to the Presidency.

3. Experience in most other countries has shown that government agencies are rarely able to combine research with planning and management activities. A National Institute for Environmental Studies should therefore be established to assure that the National Commission and concerned ministries will have adequate information on which to base their discussions and recommendations. To avoid replication of responsibilities and unnecessary expense, however, this Institute should also be formed from existing elements.

The most appropriate formulation would be to draw upon the personnel, infrastructure and resources of the National University and the research institutes of ISAR and INRS. The Institute would ideally be responsible for: all applied research relevant to resource management; specific studies requested by the National Commission or particular ministries; and direct collaboration with development agencies in pre-project environmental impact assessments. To assure communication of both needs and results, the Institute would be represented on the National Commission.

4. The Institute for Environmental Studies should also play an important role in improved in-country training and education. To this end, its personnel should help to develop and teach courses in an interdisciplinary program of environmental studies at the Natio-

nal University. In addition, they could organize seminars and short courses for government employees on appropriate topics. These two activities would not only help to produce more and better qualified technicians and managers, but would also serve to break down current barriers between academic studies and the real world.

Additional training of government personnel is also required, as described in previous chapters. Much of this will be in traditional disciplines and take place at foreign universities. A few qualified candidates, however, should also be identified for higher education in resource management or environmental studies. Such training is essential to provide the interdisciplinary perspective required to deal with increasingly complex and interrelated environmental problems.

5. The international organizations which operate in Rwanda can make two valuable contributions to improving the situation described in this chapter. First, they should increase the level of communication and collaboration among themselves and with the government to put their collective resources to best use. And second, as a result of this, they should make a long-term commitment of technical and financial assistance to help implement the recommendations on institutional development and training outlined above.

CHAPTER NINE: CONCLUSION

The preceding chapters have presented a general description of the Ruhengeri environment, followed by more detailed analyses of problems in five primary resource sectors: soils, wood, water, parks and human resources. This presentation has not been exhaustive, due to limits of time, personnel and the availability of information. Yet it is sufficiently complete to satisfy the objective of this report: to provide a comprehensive base of information on environmental issues, from which the discussion and planning of effective resource management policies can proceed.

In this final chapter, a summary description of the state of the Ruhengeri environment is presented, which includes current trends and a disquieting look at the future. This is followed by a concluding statement about the value of this report both as a product and as part of an on-going process of dealing with environmental issues.

The State of the Ruhengeri Environment

Its combination of bio-physical and socio-economic attributes makes the Ruhengeri environment extremely complex. Full understanding of this complexity is further hampered by a lack of complete information. Sufficient information now exists, however, to assess current trends and to consider where these might lead in the not-too-distant future.

Positive trends are evident in all of the major resource sectors considered in this report. After a long period of inadequate attention to the problem, a national policy which promotes soil conservation has been established. In Ruhengeri, the results can be seen in the serious effort which its population has made in recent years to control soil losses from farmlands. Similarly, reforestation efforts over the past 10 years have definitely reversed past trends in deforestation, resulting in a significant increase in total forest cover. The development of new water sources has also continued at a rapid enough pace to keep total supply ahead of demand. And conditions in the Volcanoes National Park have improved to the point where it is now cited as a model for park management in other areas. Finally, there is clear evidence of interest in resource issues on the part of authorities, planners, technicians and the general population: interest which is reflected in policies and the search for solutions to existing problems.

Yet, despite this progress on several fronts, there are also numerous trends of a more negative -- and worrisome -- nature. First and foremost among these is that of population growth. While the resource base remains constant, or at best expands on a linear scale, population continues to expand at an exponential rate. Ruhengeri's current population of 655,000 (1986 estimate) will reach 1,000,000 in the year 2000, at the present 2.9% annual rate of increase. And if outlets for emmigration are closed off, as now appears to be the case, that figure could be another 100,000 higher. The region's ability to provide land, wood and water (not to mention education and employment) in sufficient quantities for even this large a population is very doubtful. Its ability to support 2 million people by 2026 -- only 40 years from now -- seems entirely out of the question.

The stress of supporting just the current population is already evident throughout the Ruhengeri environment. At a general level, land use has become both more extensive and more intensive. Formerly marginal areas such as steep hillsides, rocky outcroppings and marshlands have all been brought into cultivation. Pasturelands are being converted to farmlands, and farmers report productivity declines on their older fields. This is largely due to reduced or abandonned fallow periods and the inability to replace depleted nutrients and organic matter. But in many areas erosion is also taking its toll. Despite increased soil conservation efforts, more land than ever is now cleared for cultivation and thus exposed to erosive rainfall. In addition, the construction of new roads and buildings has provoked considerable erosion, the control of which does not appear to be covered by current soil conservation policies.

The increased runoff which results from such extensive land use changes, in the absence of adequate soil and water conservation measures, has a significant impact on the region's hydrology. Water arrives more quickly into valley bottoms, where the removal of natural vegetation and the development of drainage systems combine to speed its passage into streams and rivers. Measures of water flow at the outlet of the Mukungwa River indicate that this situation may be widespread throughout the watershed, although the rapid fluctuations and flooding which usually accompany this phenomenon are not yet apparent.

Population pressure has also created increased demand for wood. Yet reforestation efforts increasingly face conflicts over competing land uses, especially for agricultural production. The result is growing unwillingness to dedicate significant areas to exclusive forestry uses. Water source development does not entail the same conflicts, but new sources are increasingly difficult to find and the level of technology required for their exploitation continues to rise. In the face of these multiple demands, even the Volcanoes Park is not immune to pressure to exploit its wood, water and wildlife -- not to mention its land.

Beyond these primary issues of land and resource use, there are other more general trends which complicate the situation in Ruhengeri. Technologies which are no longer appropriate continue to be promoted, while potential alternatives receive insufficient attention. Overdependence on plantation monocultures of Eucalyptus trees is one example. Current forest policies call for greater diversity in plantation stock and increased emphasis on agroforestry; but the required species and techniques have not been fully tested, let alone put into wide distribution. Reliance on infiltration ditches and grass hedgerows for erosion control is another example. The former technique has been shown to have a destabilizing impact under certain conditions, and the latter has proven its inability to succeed on steep slopes without additional physical or biological support. Yet government agents in the field continue to promote both techniques, lacking viable alternatives. Failure to develop and promote rainwater catchment systems and alternative energy technologies can also be included in this category.

To a certain degree, these problems of inappropriate technologies are a function of a broader problem: the general lack of flexibility in resource management strategies. Almost all of these strategies share three common characteristics: they are centrally conceived by national planners; they are based on a limited package of technological options; and they are then supposed to be uniformly implemented across the entire country. As seen from this report, however, the diverse ecological conditions in Ruhengeri require strategies which offer more flexibility, as well as more creative approaches to deal with changing conditions in a complex environment. This flexibility is even more important when one considers the diverse conditions present at the national level.

The current state of the Ruhengeri environment is therefore precarious. The many positive trends must be set against others of a negative nature: and while the present situation appears to be one of delicate balance, there are very strong indications of future imbalances, primarily due to uncontrolled population growth.

the future

Predicting the future is always a high-risk enterprise. This is especially true when human behavior and technological innovations are critical factors in the equation. Yet it is worth considering the following scenario of man:resource relations in Ruhengeri twenty years from now, in the year 2006:

-- Approximately 1,200,000 people will live in the prefecture, or nearly double the number at the time of the 1984 Agricultural Survey;

-- The size of the average farm will be only 50 ares, and one-third of all farm families will be forced to subsist on less than 25 ares;

-- A large percentage of those on the smallest and most marginal farms will be forced to abandon their uneconomic holdings, becoming tenant farmers or unemployed migrants to towns;

-- The quality of farmland will steadily decline, as size constraints preclude fallow periods and inhibit farmer willingness to "give up" land for erosion control structures;

-- Family woodlots of the current size (5.5 ares) will provide only 0.14 m3 of wood per person per year, yet will take up 11% of the farm;

-- To be self-sufficient in wood energy, the average family will have to plant 60% of its land in trees, leaving only 20 ares for food production;

-- Water sources capable of providing 24 million liters per day will have to be developed and maintained;

-- The prefecture's 23 regional health centers will each have to serve an average of 52,000 people.

This scenario is based on simple extrapolations from current conditions and trends, which it assumes will remain unchanged. As such, it is certainly open to criticism. Yet what are the indications that major, positive changes will occur within the next 20 years? There are three principal factors in this equation: land, people and technological innovation. The regional land base cannot increase in any significant way (even converting the park would only provide extremely marginal land for the equivalent of one year's population growth). Furthermore, people show no sign of voluntarily decreasing their high birth rates (fewer than 7% of all women in Ruhengeri were found to be practicing some form of contraception in 1983, according to the National Fertility Survey), which are the driving force behind rapid population growth. And while radical technological changes in resource use (improved farming techniques, alternative energy sources, etc.) could occur, few are evident at this time, and none are in widespread practice.

The scenario presented above thus retains a sufficient degree of validity as at least a starting point for reflection, discussion and, most importantly, action. And the future of the Ruhengeri environment must therefore also be seen in quite negative terms. Unless radical remedial action is taken soon, the regional ecosystem is heading towards a state of chronic, and potentially catastrophic, imbalance due to a population that is too large trying to live off of a limited, and decreasingly productive, resource base.

Information as Product and Process

The Introduction to this report was intended to place current environmental issues in Ruhengeri in a larger historical and international context. This was done in the belief that it is important to be aware of problems faced by other people, at other times, and in other places. But it is also important to recognize that many of these people and places have been able to resolve their problems and recover from ecological degradation. Ruhengeri is in a position to similarly save itself from potential disaster if effective plans are developed and the necessary actions are taken.

Before action can be taken, however, a certain amount of basic information is required. Just as no military commander would think of preparing an attack without an adequate reconnaissance of the situation (comparative strengths and weaknesses, problems of terrain, supply logistics, etc.), environmental problems cannot be combatted without prior assessment of their origin and nature. This report has been conceived and prepared to provide planners and decision-makers with such preliminary information on environmental conditions in the Ruhengeri prefecture.

It is also intended, however, that this report will serve a dual function as part product, part process. On one level, it is a finished product: the final report of the RRAM project's first phase. As such, it provides a comprehensive description and analysis of conditions and problems which should help to better inform anyone interested in the region. On another level, however, this report should be seen as part of a process. First, in every chapter, deficiencies and gaps in the available information base have been noted. Efforts should be made to correct or complete this information, and thereby maintain a continually improved data base from which updated status reports can be made. Finally, it is hoped that the present document will serve to stimulate interest and discussion, and thereby help to further the process of finding solutions to problems of primary importance to the people of Ruhengeri.

ANNEX A

PHOTOGRAPHS OF THE RUHENGERI PREFECTURE

1. Lower Mukungwa Valley, showing confluence with the Nyabarongo to the south, the Zaire-Nile Divide to the west and the Central Plateau region to the east.

2. Buberuka region south of Lake Ruhondo.

3. Northern Lava Zone with Mts. Karisimbi and Bisoke in background.

4. Deforested slopes of Mt. Kabuye.

5. Contact zone between the Rugezi Marsh (foreground) and surrounding hills of Buberuka.

6. Raised bed cultivation in the Nyamusanze Valley (Buberuka).

7. Vertical differentiation of land use, with houses, bananas and woodlots on lower slopes and other crops higher up.

8. Shoreline of Lake Ruhondo, showing extensive raised bed cultivation in bottomlands.

9. Reforestation on steep slopes above the Nyabarongo Valley in southern Ruhengeri.

10. Confluence of the Giciye River with the Mukungwa (background), near the scholastic center of Tubungo.

11. Outlet of the Rugezi Marsh (background) via Rusumo Falls.

12. Rusumo Falls.

13. Raised bed cultivation and bananas along the Lake Ruhondo shoreline.

14. Dam at natural outlet of Lake Ruhondo forces water through conduits to drive turbines of Rwaza I hydroelectric station downstream.

15. Extreme erosion has ravaged hillsides and flooded bottomlands in the Base Valley during recent years.

16. Erosion caused by secondary road construction in Cyeru commune.

17. Landslides and slumps are most common in the Zaïre-Nile Divide region, as here in Nyamutera commune.

18. Although generally protective of the soil, even banana stands can be washed away on unstable slopes.

19. Construction of the Kigali-Ruhengeri paved road resulted in major impacts on the local environment.

20. Failure to quickly re-establish vegetation cover on exposed roadsides has resulted in serious erosion problems along sections of the Ruhengeri-Kigali highway, 2 years after its completion.

21. The erosive power of Lava Zone torrents can be seen along the Rwebeya, where it threatens to cut off the principal access road to Kinigi commune and the Volcanoes Park.

22. Crop and streambank damage along the Rwebeya.

23. On-site erosion at the Gifurwe wolfram mine in Cyeru.

24. Mine tailings and arsenic contaminate the Nyamusanze River below the Gifurwe mine.

25. Raised bed cultivation and brick-making along the Mukungwa.

26. Confluence of the Mukungwa and Nyabarongo (foreground).

27. Mixed cropping of beans and bananas in Kinigi commune.

28. Old Eucalyptus plantation in Kinigi.

29. Remnant native tree species attest to the former presence of gallery forest below Rusumo Falls.

30. Isolated household complex (rugo) surrounded by trees, bamboo, bananas and potato fields in the Lava Zone.

31. Traditional rugo on lower slopes, with raised bed cultures in front and bananas, other fields and woodlot above.

32. Woman in front of entrance to traditional house.

33. Despite its problems, Ruhengeri is still highly productive.

34. The youth of Ruhengeri hold the key to the region's future: they are better educated, in better health -- and more numerous -- than preceding generations.

35. Hagenia silhouette at nightfall in the Volcanoes Park.

36. High rainfall and humidity support abundant vegetation growth in the Virunga natural forest.

37. Marsh communities of grasses, sedges, mosses and Lobelia are common in the saddles between the volcanoes.

38. The distinctive form of the Hagenia tree characterizes the forest in the western sector of the park.

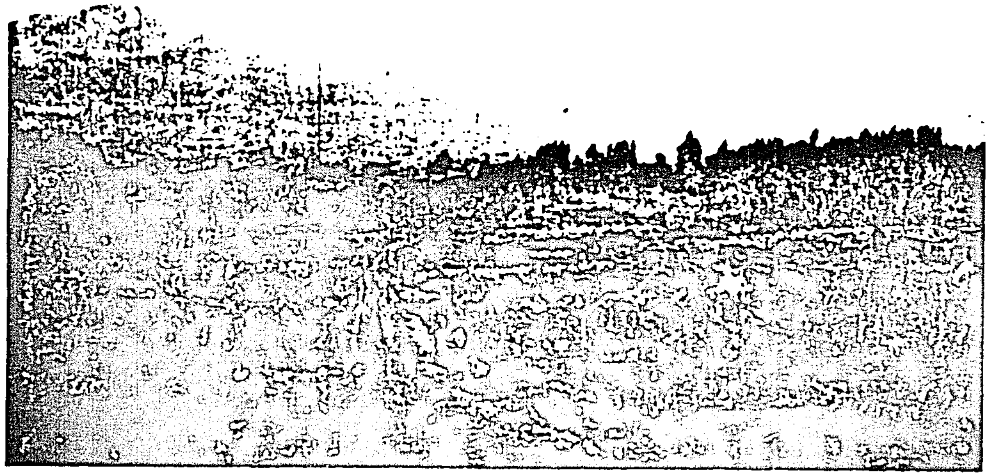
39. Mts. Bisoke and Sabyinio as seen from the sub-alpine zone on Mt. Karisimbi.

40. Gorilla mother and infant surrounded by other family members during a mid-day siesta.

41. Despite their superior size and strength, gorillas have proven to be remarkably tolerant of human visitors, thus permitting long-term scientific studies and the development of an economically important tourism program in the VNP.

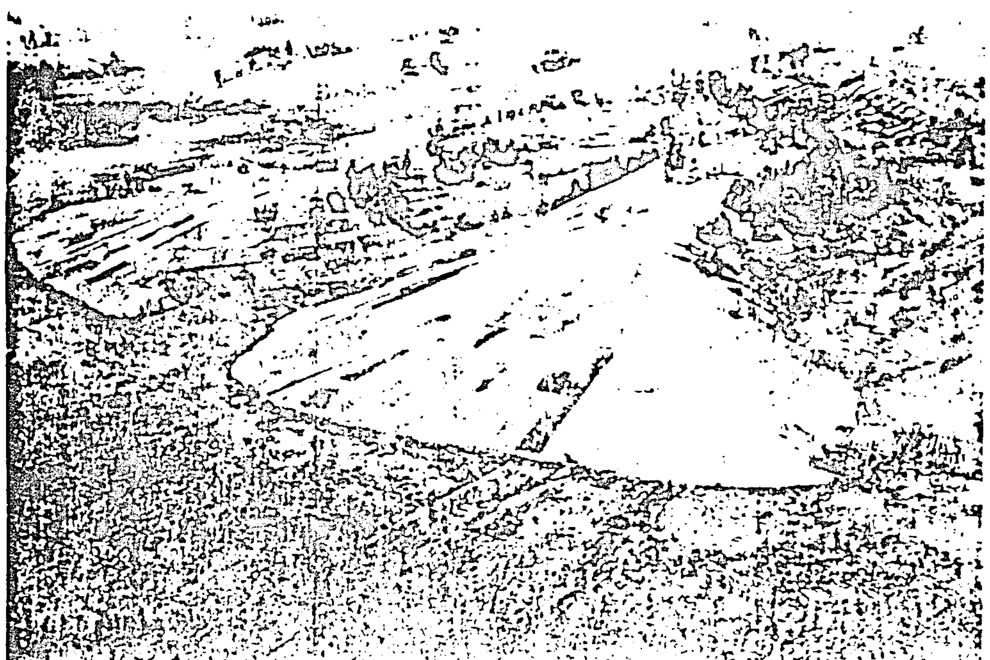
42. The black-fronted duiker (Cephalophus nigrifrons) is among the more than 60 species of mammals protected within the Volcanoes Park.

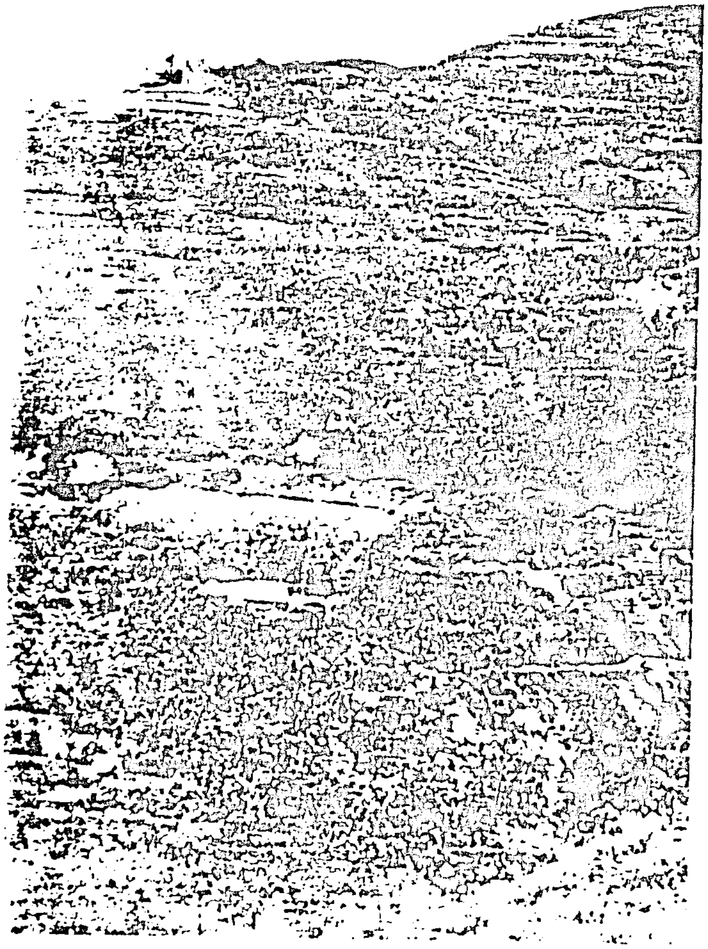
2



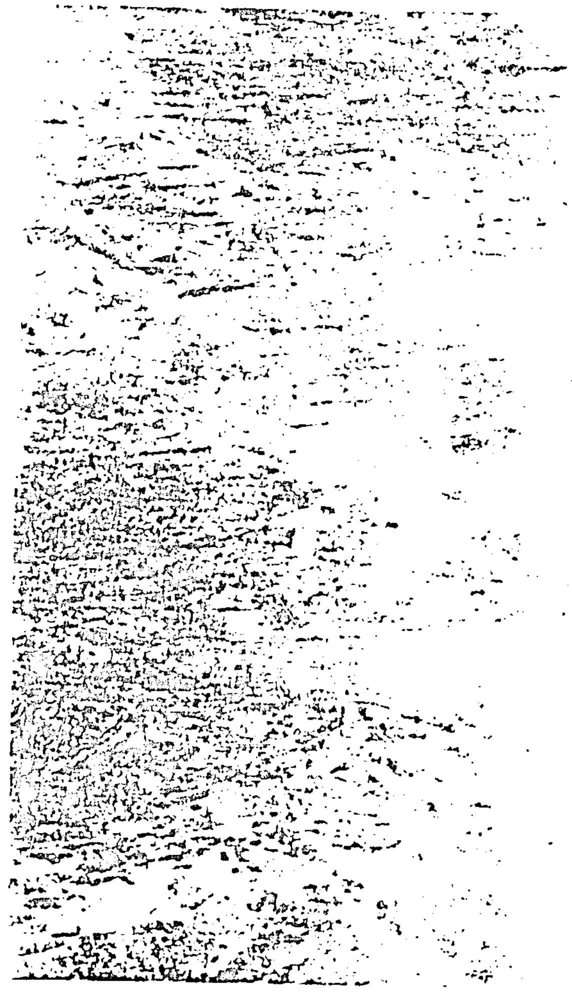
3

4





7

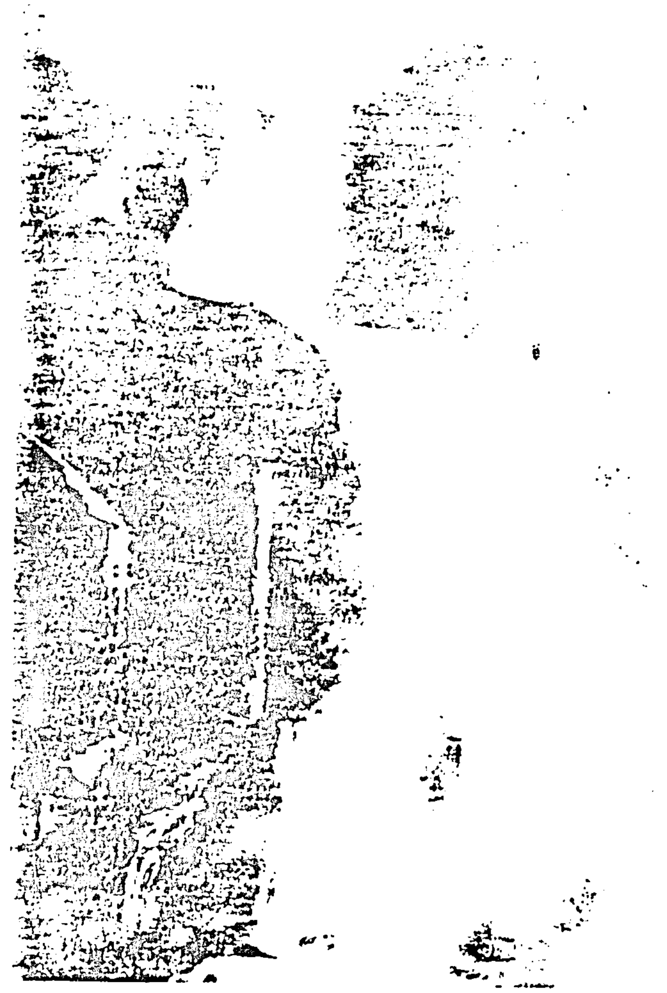


8

9

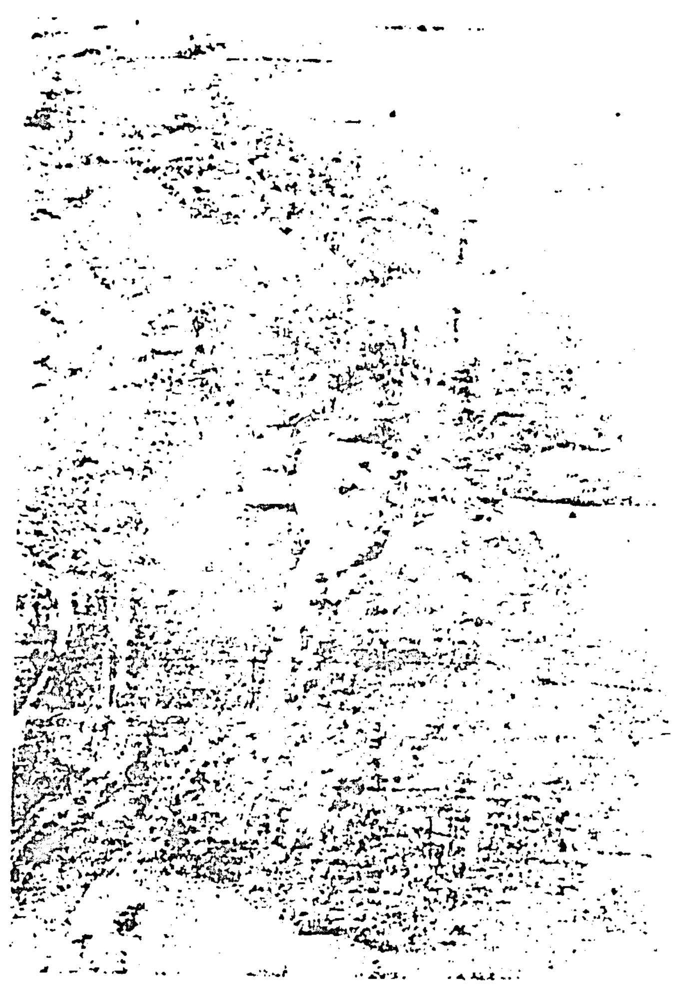
10

11

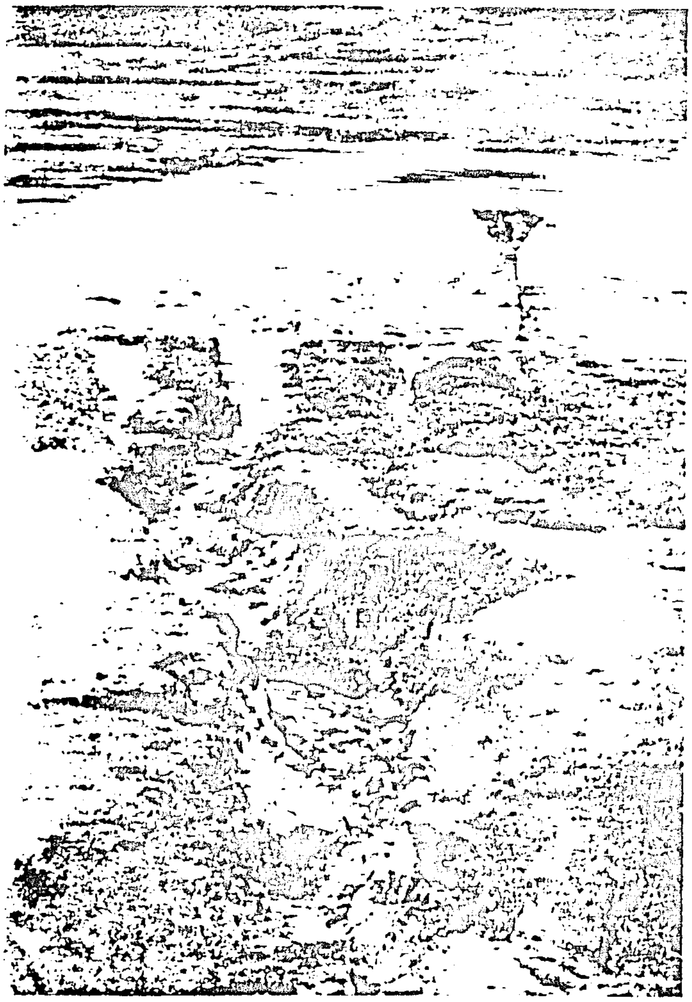


12

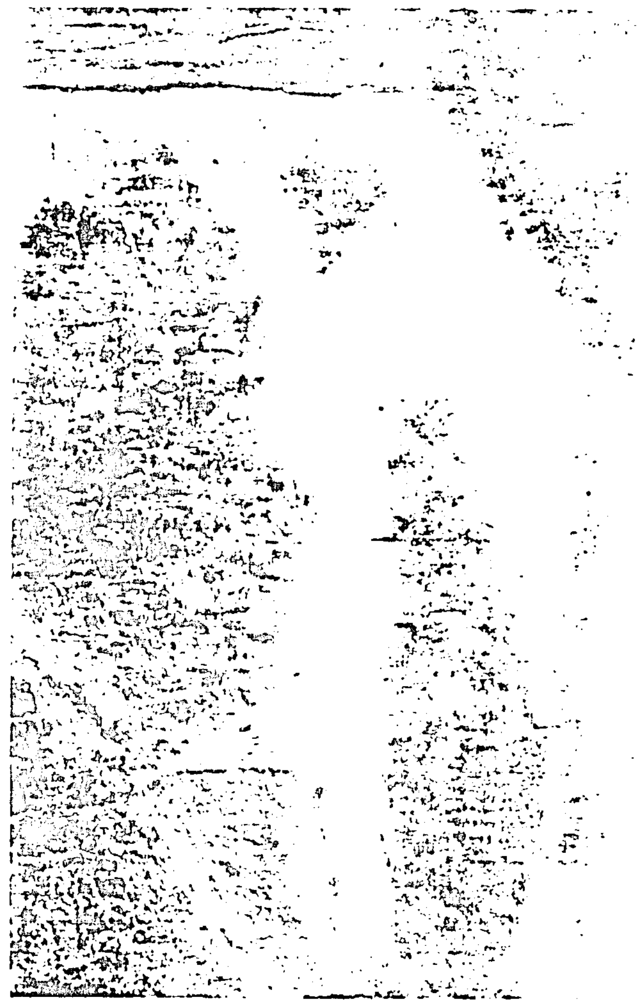
13



14

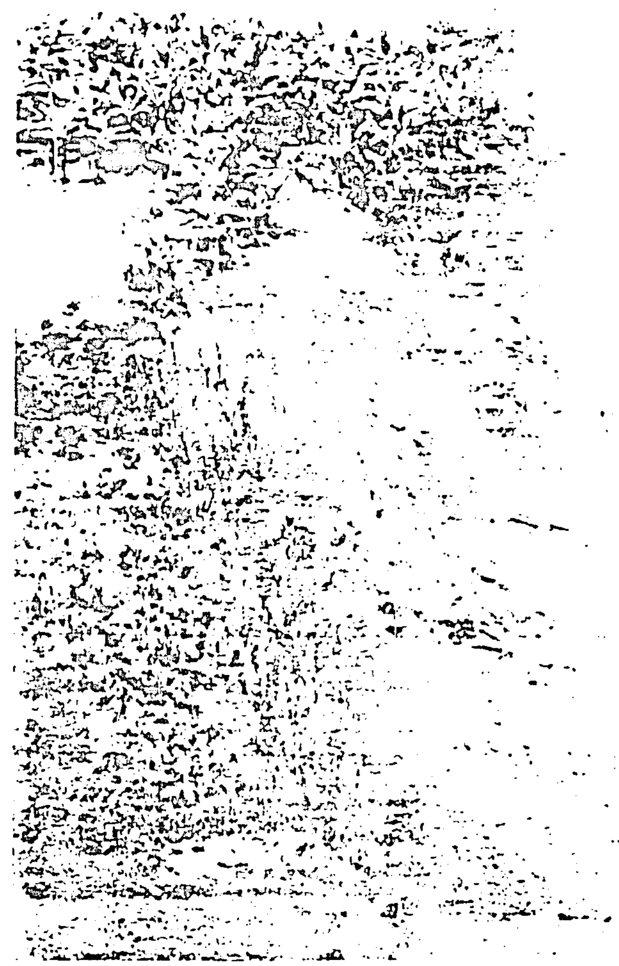


15



16

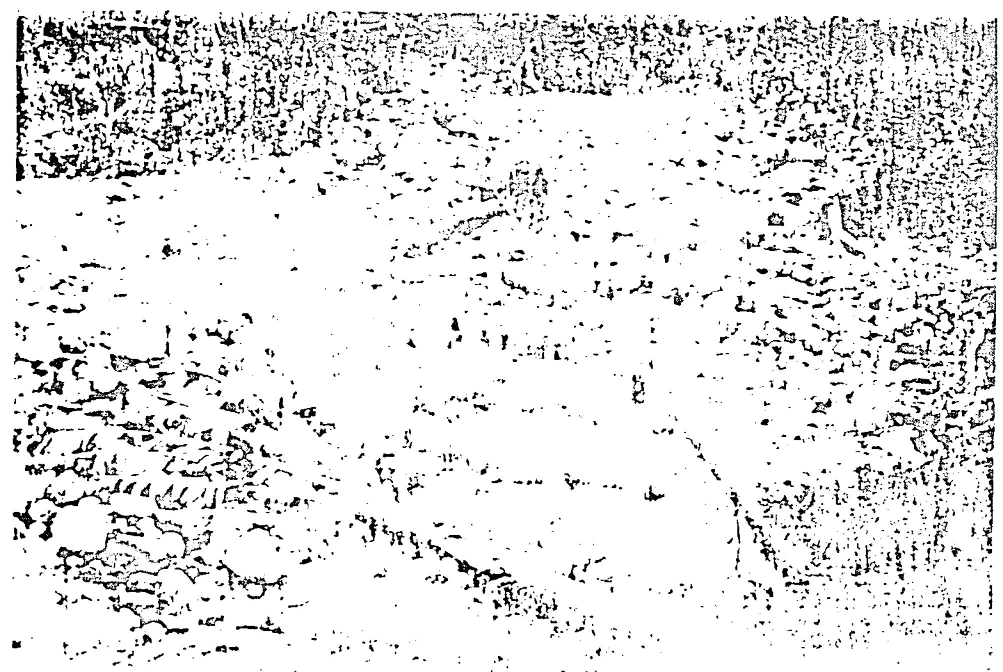
17



18

19

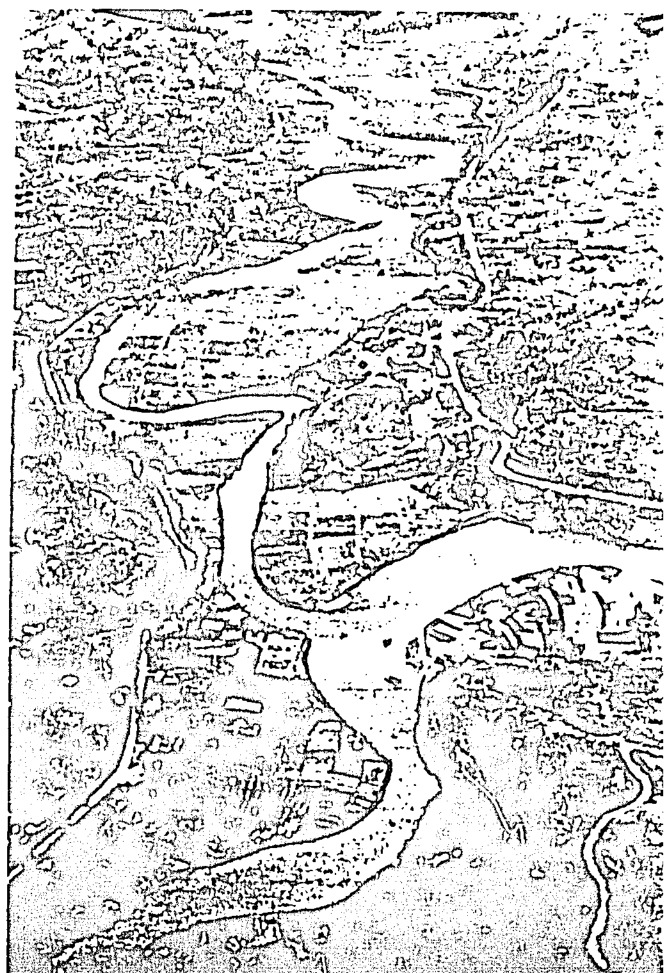
20

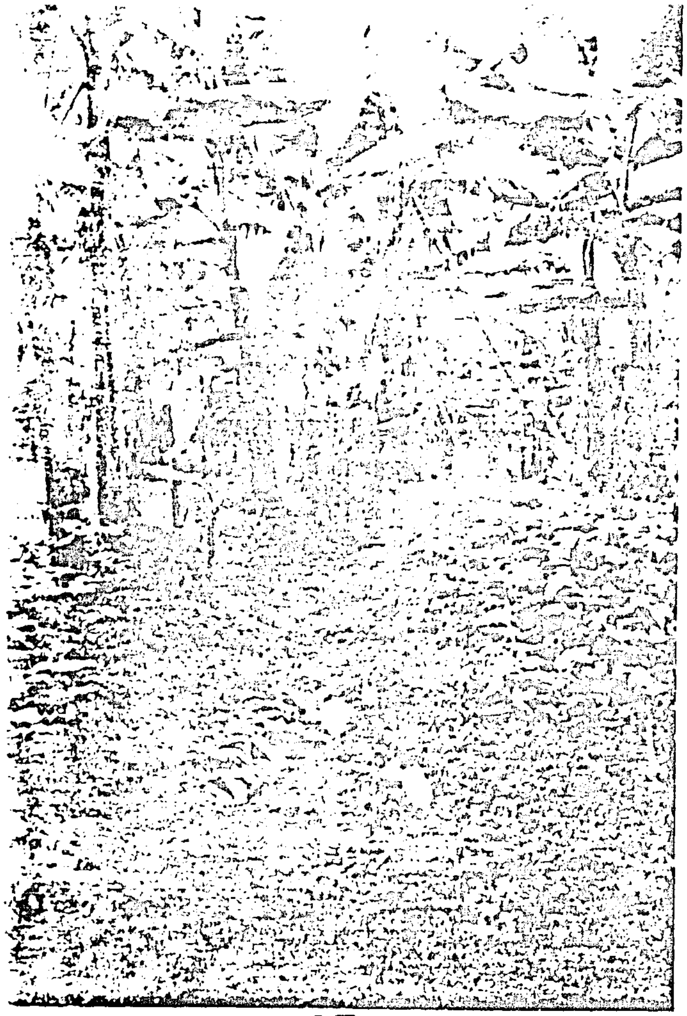



23

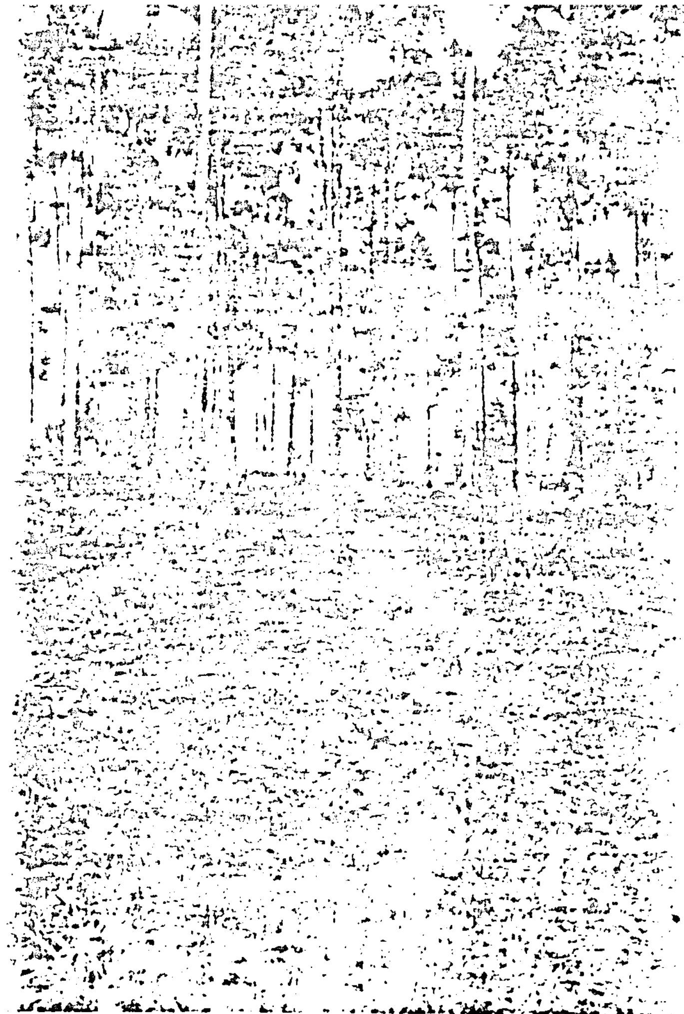

24


25


26

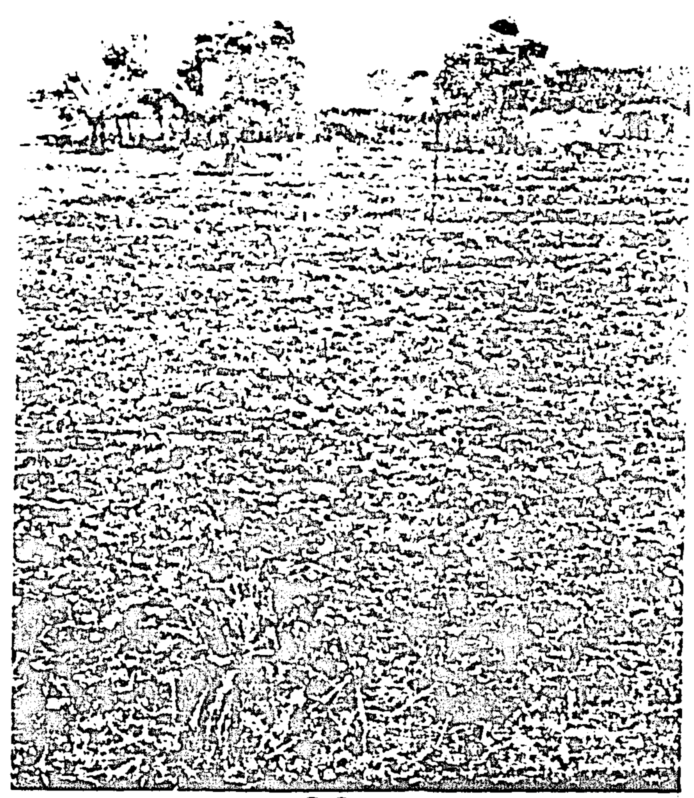


27



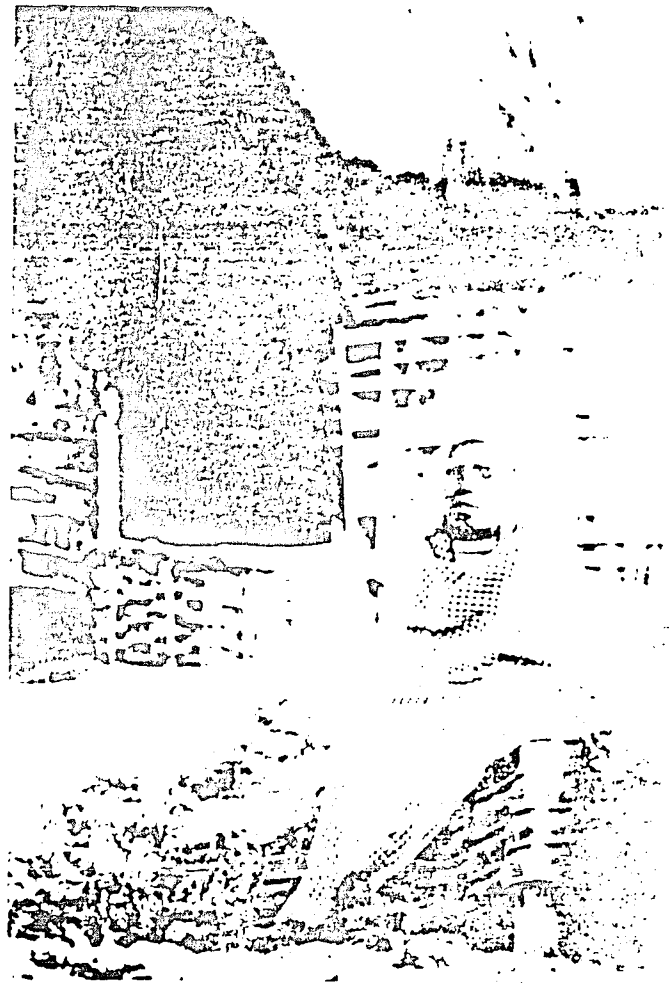
28

29



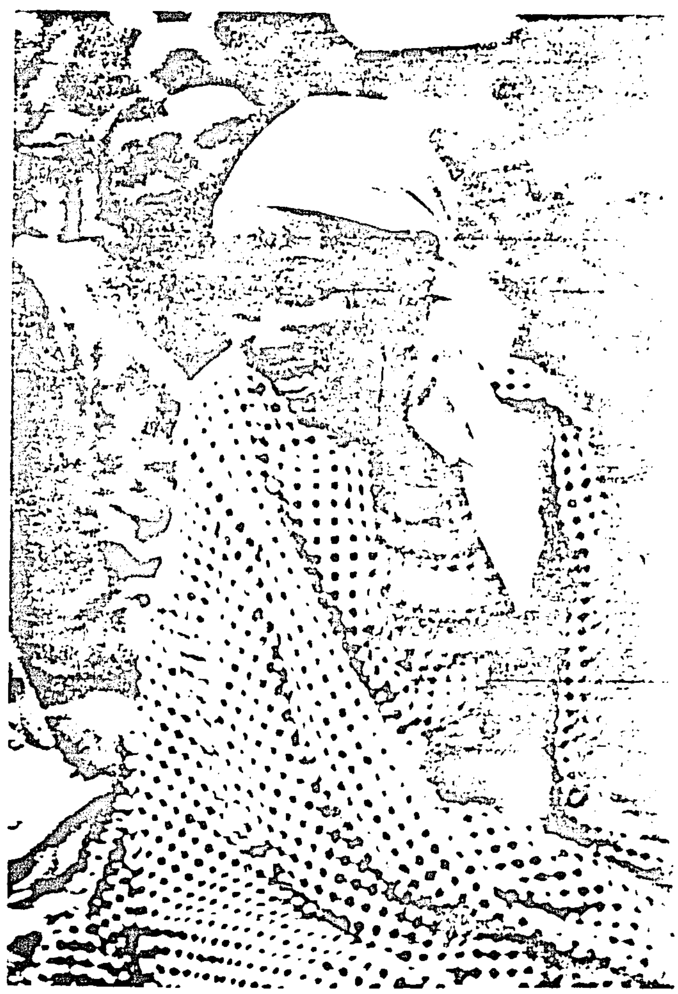
30

31



32

33



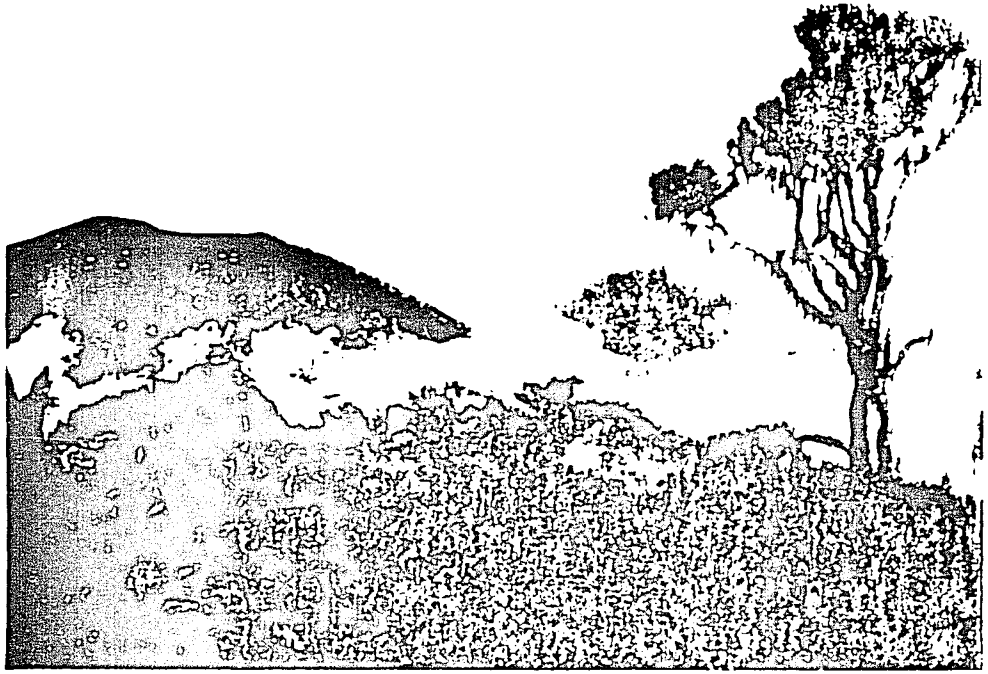
34

35

36

37

38

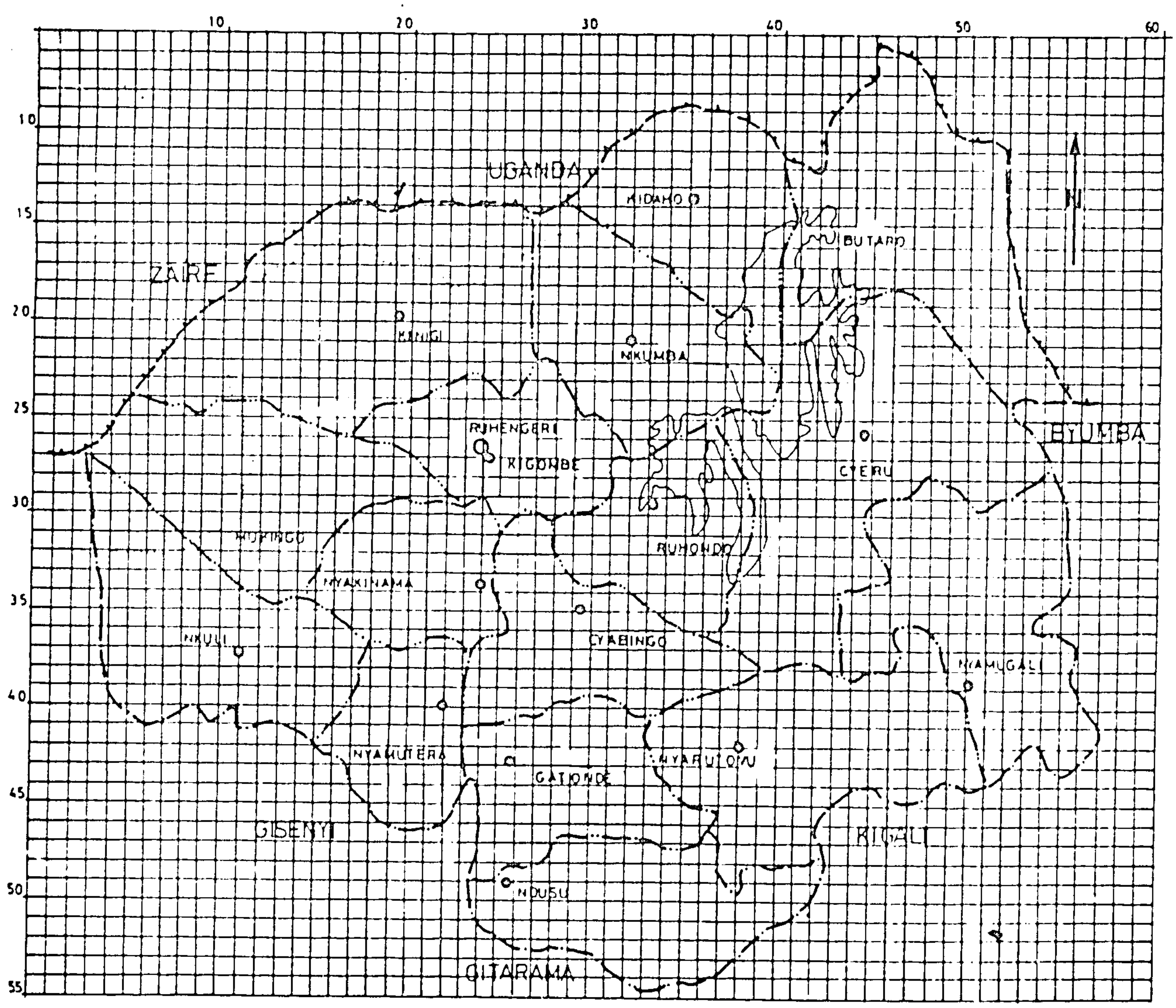


39

40

Figure B.1
LOCATIONAL GRID SYSTEM

This map shows the grid system used for PMAP data take-off. It is a reduced version of larger grids which were used for maps at scales of 1:20,000 and 1:50,000. Each cell represents one square kilometer. Exact locations on this and the following computer maps can be determined by reference to the numeric coordinates along the vertical and horizontal axes (e.g., the communal center of Kinigi is located in cell 20-20; that of Nyamugali is in cell 51-39).



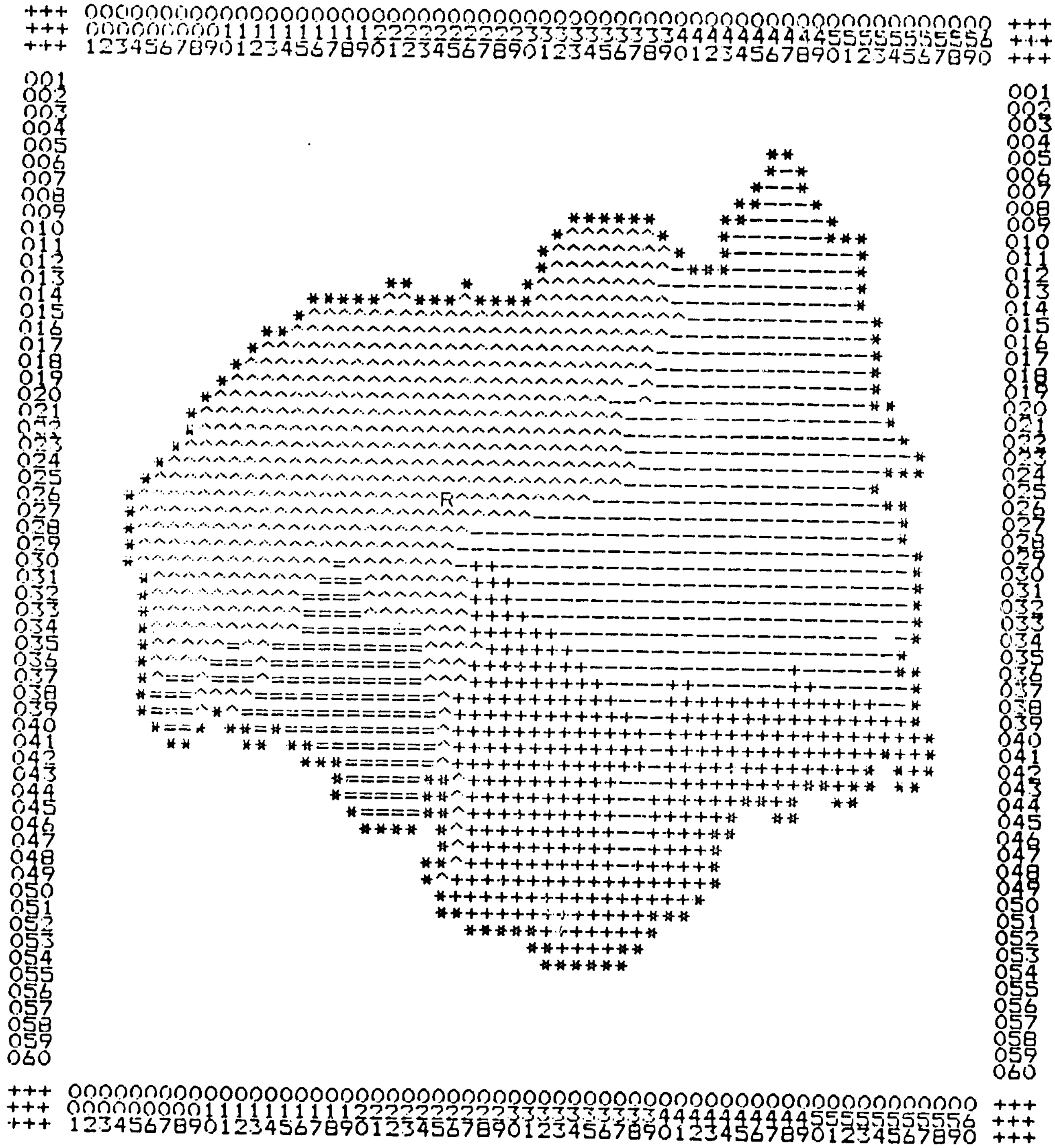


Figure B.2
ECOLOGICAL ZONES OF RUHENGERI

Symbol	Zones	Cells (km2)	% Prefecture
^^	Lava	572	36.32
--	Buberuka	535	33.97
++	Central Plateau	336	21.33
==	Zaire-Nile Divide	131	8.32
R	Ruhengeri	1	0.06

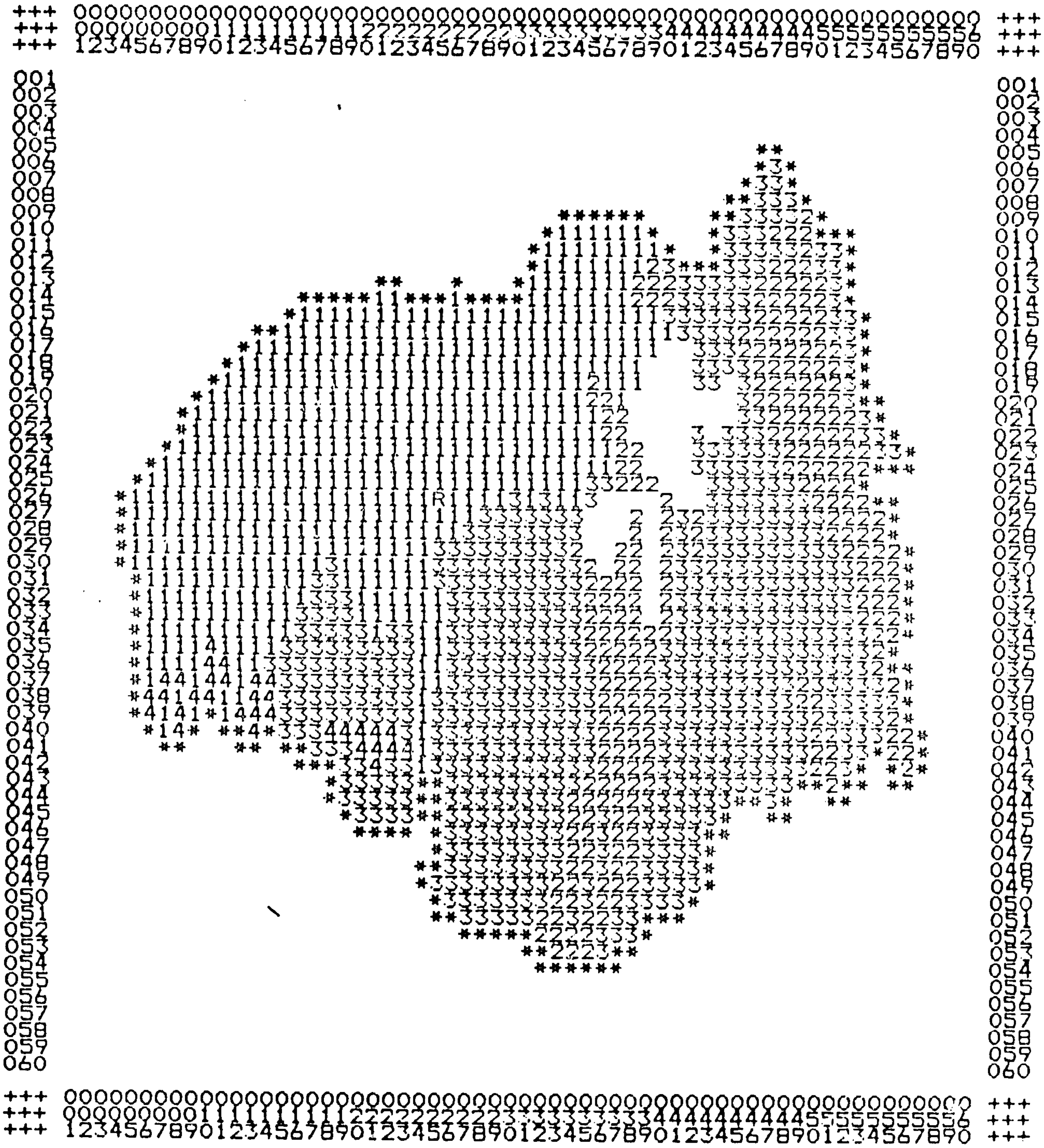


Figure B.3
LITHOLOGIC MAP

Symbol	Label	Cells (km2)	% Prefecture
1	Lava	574	36.06
2	Quartz	272	17.93
3	Schist and Granite	666	43.90
4	Granite	32	2.11

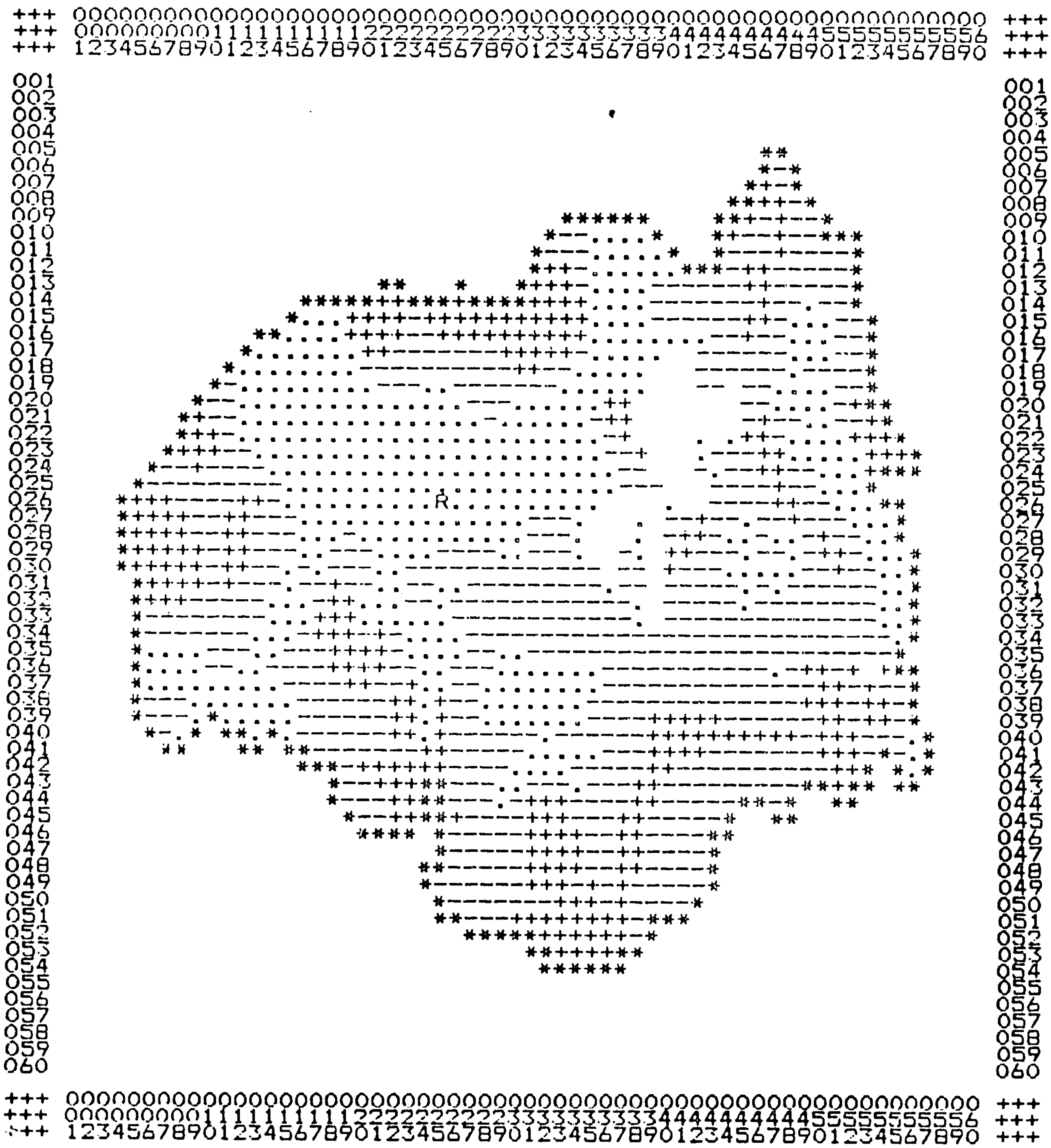


Figure B.4
GENERALIZED SLOPE MAP

Symbol	Label	Cells (km2)	% Prefecture
..	Low Slope (<7.5%)	490	32.32
--	Medium Slope (7.5-30%)	728	48.02
++	High Slope (>30%)	298	19.66

ANNEX B

RRAM PROJECT GEOGRAPHIC INFORMATION SYSTEM

The problems of environmental degradation described in this report require remedial action. Yet, in many instances, more complete understanding of the problem is required before action can be taken. To achieve this level of understanding, better information (more accurate, complete and current) must first be obtained, and then organized and presented in a format which is readily useful to decision-makers. The geographic information system has considerable potential as a tool for such organization and presentation.

Description.

The function of any information system is to provide information to users for decision-making in research, planning and management. Component processes in such a system can be itemized as 1) specification of data, 2) collection of data, 3) processing and organization of data, 4) synthesis and manipulation of data, and 5) display and dissemination of data. A good geographic information system (GIS) is very helpful in steps 3 and 4, and produces maps as final products which show information in a spatial, or locational, context.

The GIS used by RRAM was the computerized PMAP program, which was developed specifically for application to environmental problems. It was selected primarily because of its ease of operation, its adaptation for micro-computers, and its power. With regard to the latter, thousands of maps can be stored on a computer hard disk; these are organized for easy retrieval in a master directory; and operations of map synthesis, combination and printing can be carried out in a matter of minutes. In addition, PMAP is programmed to permit relative weighting of variables and automatically computes area coverage and percentages.

Development.

The first steps in the development of the RRAM GIS were to determine the type of information desired and to identify the best available sources of this information. Highest priority was given to a general land use map, based on the most recent aerial photo coverage of the Ruhengeri prefecture. This map was produced using traditional photo-interpretation and cartographic techniques. Additional thematic maps were copied or created from a variety of other sources.

To put this information in computerized format, and thus take advantage of the full capabilities of the PMAP program, however, required certain intermediate steps. First, a grid system was developed to permit a systematic spatial organization of data derived from various sources, at variable scales (Figure B.1). This grid was based on reference points from the new national map of Rwanda, now being produced, so that it could be easily replicated and extended to other parts of the country. Within this grid system, cells of any size could be used. The RRAM project has focused primarily on cells of 1 km2 and 4 ha, although some data were initially obtained at a scale of 1 ha units. Once the grid system was established, the next step was to transform all information into digital format, so that it could be entered into the PMAP program. This process of data coding and entry is initially time-consuming; but it yields considerable benefits at later stages due to the speed and flexibility of computerized operations using a digital format.

The final stage in the development of the RRAM GIS was the production of maps. These have included single theme maps of ecological zones (Figure B.2), lithologic formations, slope, forest resources, population density, and wetlands distribution, as well as multi-theme land use maps. By then combining selected maps, it was possible to create composite maps which help to identify problem areas, such as high erosion risk and potential agroforestry sites. Such products then permit resource planners and technicians to conduct more detailed field assessments and, eventually, intervention activities in these priority areas.

Examples.

Following are three examples of how the RRAM geographic information system functions. The first two examples move from simplistic, single theme maps through map mergers and intersections to final composite maps depicting just a few cells per map, which represent areas requiring priority attention. On these maps, each symbol/cell represents 1 square kilometer (see Note below). The third example exhibits land use maps at the 4 hectare scale (i.e., each symbol on these maps represent a 4 hectare area).

Note: Most of the following maps based on 1 kilometer cell units show the size of the Ruhengeri prefecture as 1517 km2. This PMAP area figure differs from the RRAM planimetry value of 1685 km2 for two reasons: 1) because lake areas were not included; and 2) because of the exclusive nature of the prefectural border within the PMAP data base. In reality, this border (shown by the symbol "*") should perform a dual function of displaying the limits of the prefecture and showing any information that may be found at that particular location. The duality of these border cells, however, was not possible to convey at this time using PMAP; therefore the base figure of 1517 km2 was used for all percentage calculations.

EXAMPLE 1
EROSION RISK ISSUES

The first step in developing a model depicting erosion risks within the Ruhengeri prefecture was to determine the various environmental parameters that affect erosion. Ideally, these should include soil type, slope, rainfall and land use. Due to the nature of available information, however, a more limited data set had to be used. In particular, lithologic characteristics were substituted for soil type and population density was used as a general indicator of the intensity of land use, while rainfall was dropped entirely because of a lack of sufficiently detailed data.

Once these factors were determined, the next step was to combine the elementary maps of lithology (Figure B.3) and slope (Figure B.4) to create a composite map of potential erosion risk due to these natural factors. This was done according to the following categorization scheme:

SLOPE VALUE	SOIL TYPE	EROSION RISK CLASS
Low	Lava	Very Low
Low Medium	Schists; Quartz Lava	Low
Low Medium High	Granite Schists; Quartz Lava	Medium
Medium High	Granite Quartz	High
High	Schists; Granite	Very High

The result of this combination can be seen in Figure B.5, which indicates potentially serious erosion risks in large parts of the Central Plateau and the Zaire-Nile Divide, as well as in more limited areas of the Buberuka region.

To further refine this analysis of erosion risk, however, the intensity of land use must also be considered. Population density factors (Figure B.6) were therefore added to the Natural Erosion Risk equation, according to the following matrix, to produce a series of Theoretical Erosion Risk categories:

NATURAL EROSION RISK CATEGORY	POPULATION DENSITY	THEORETICAL EROSION RISK CATEGORY
Very Low	Low; Medium	
Low	Low	Low
Medium	Low	
Very Low	High	
Low	Medium; High	
Medium	Medium	Medium
High	Low	
Very High	Low	
Medium	High	
High	Medium; High	High
Very High	Medium; High	

The resulting map of Theoretical Erosion Risks (Figure B.7), shows some interesting differences from that of Natural Erosion Risks. While concentrations of high risk areas continue to appear in the Central Plateau and ZND regions, the largest cluster emerges to the south of Lake Ruhondo, in the western Buberuka region. This analysis should not be considered definitive; yet it is interesting to note that field surveys confirm the presence of serious problems within most of the highlighted areas.

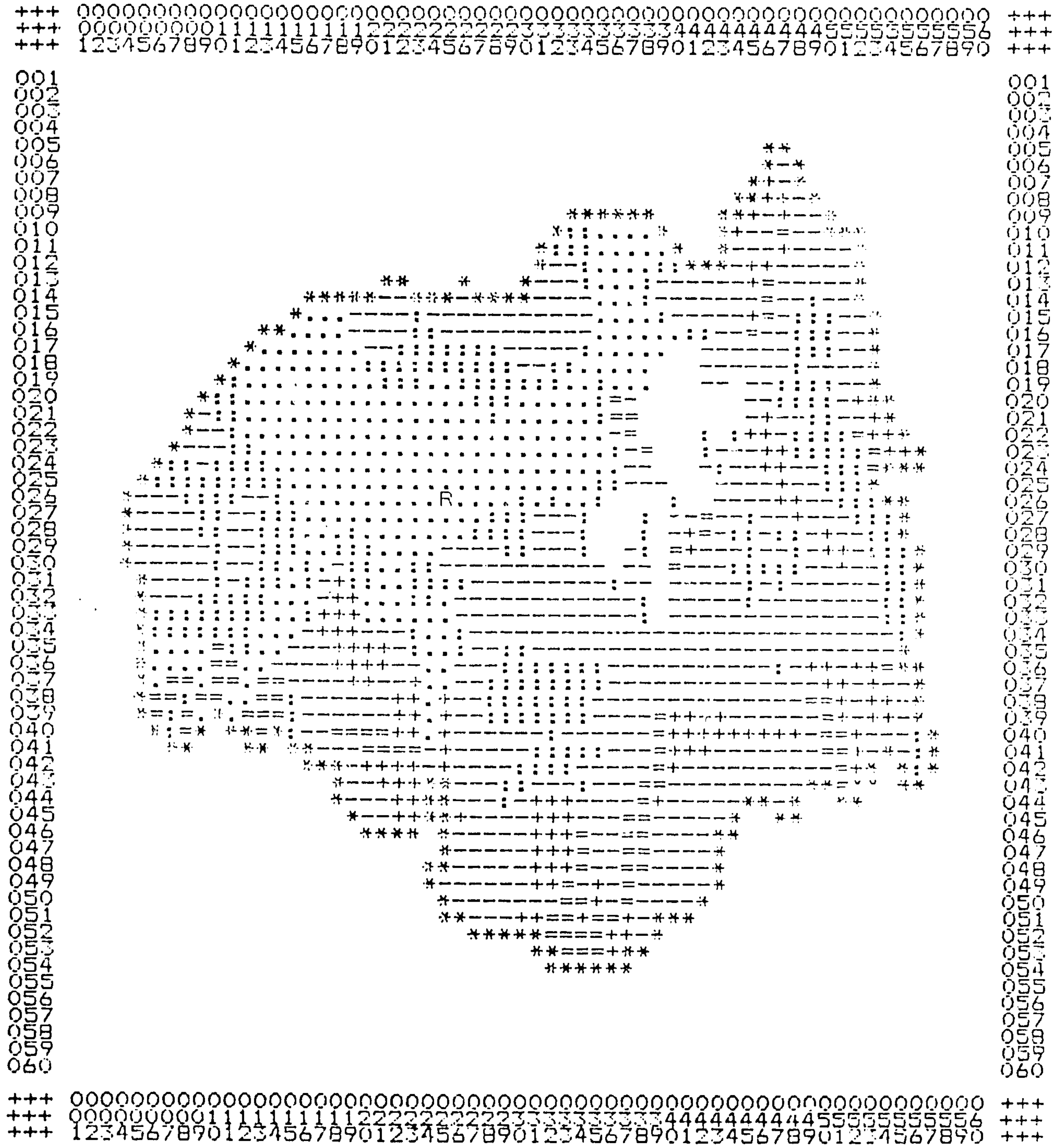


Figure B.5
NATURAL EROSION RISK MAP

Symbol	Label	Cells (km2)	% Prefecture
..	Very Low Risk	309	20.38
::	Low Risk	303	19.99
--	Medium Risk	676	44.59
==	High Risk	91	6.00
++	Very High Risk	137	9.04

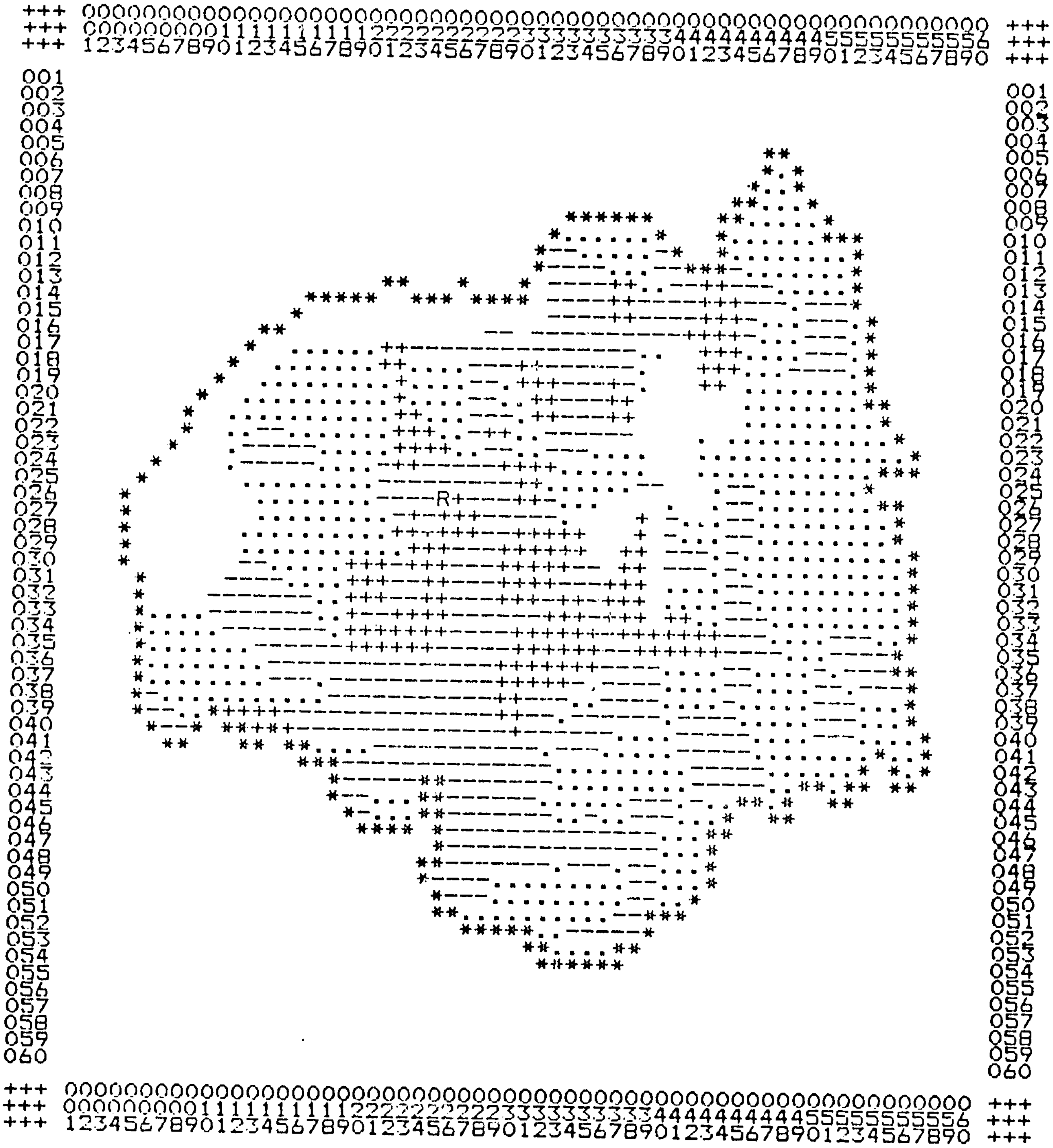


Figure B.6
GENERALIZED POPULATION DENSITY

Symbol	Label	Cells (km2)	% Prefecture
..	Low (<400/km2)	645	42.52
--	Medium (401 - 700/km2)	556	36.65
++	High (>701/km2)	209	13.78
	National Park	107	7.06

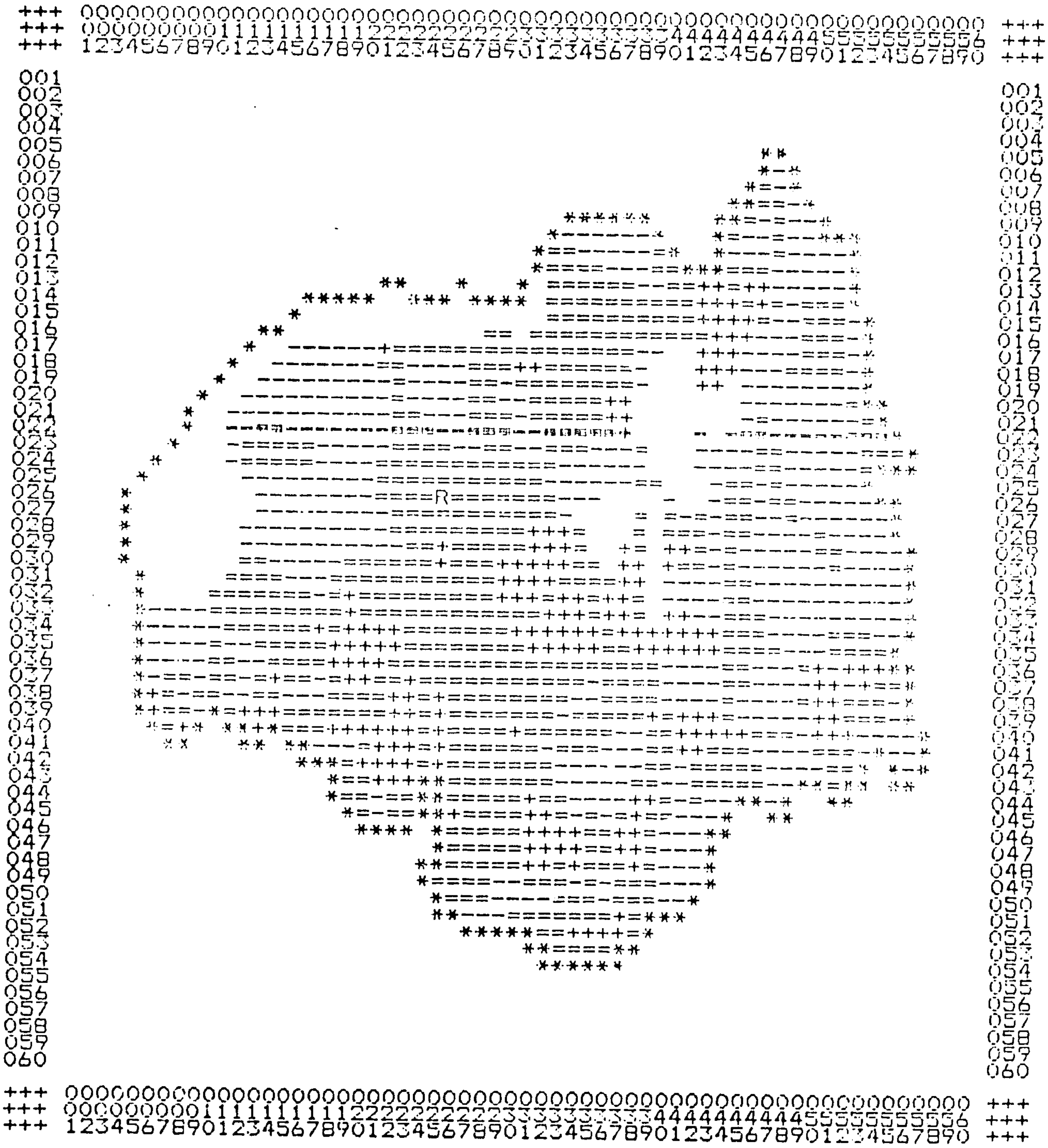


Figure B.7
THEORETICAL EROSION RISK MAP

Symbol	Label	Cells (km2)	% Prefecture
--	Low Risks	530	34.96
==	Medium Risks	679	44.79
++	High Risks	200	13.19
	National Park	107	7.06

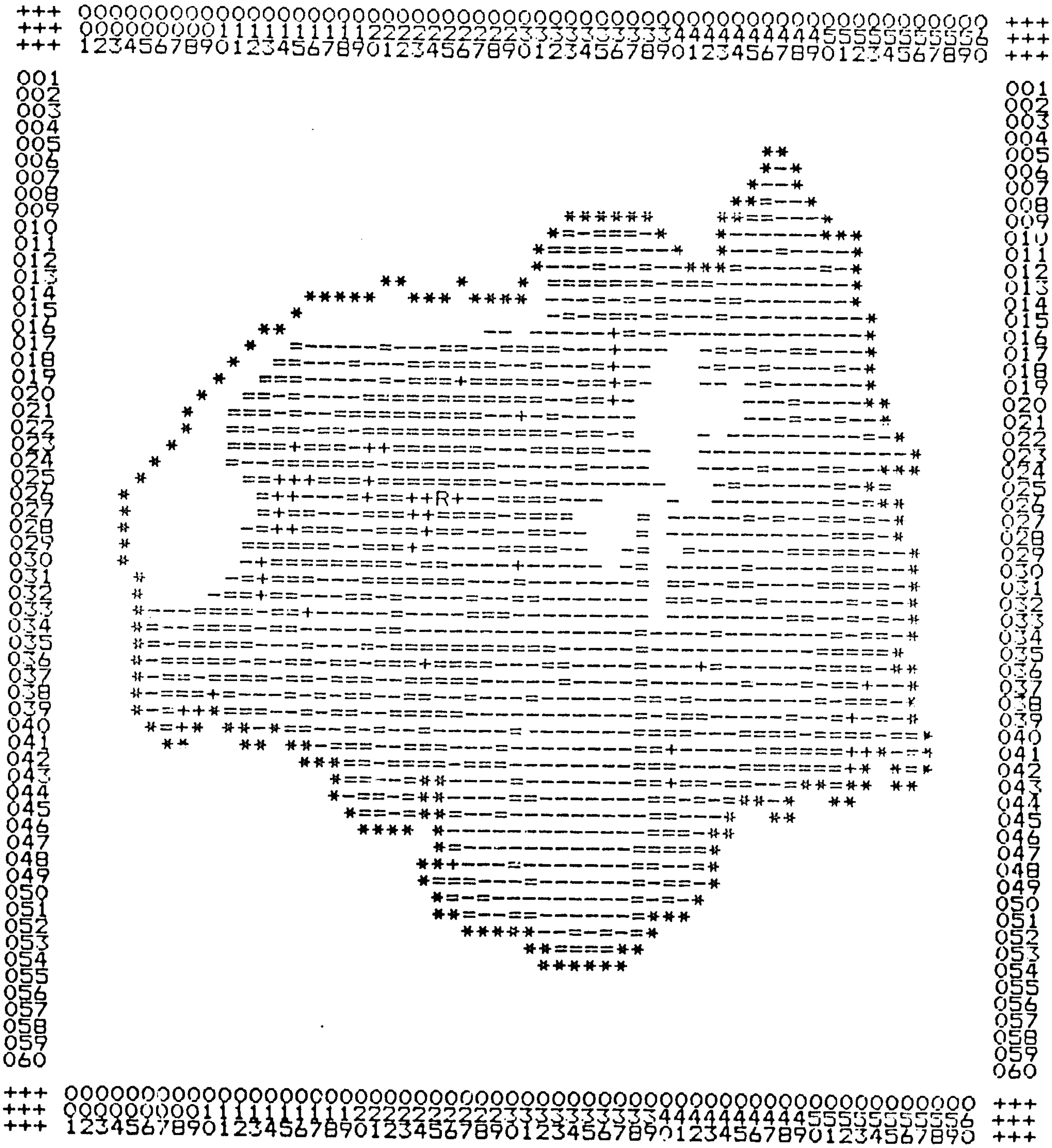


Figure B.8
DISPERSED TREE DENSITY MAP

Symbol	Label	Cells (km2)	% Prefecture
--	Low Density Trees	787	51.91
==	Medium Density Trees	576	38.00
++	High Density Trees	46	3.03

Does not include trees in plantations larger than 1 ha.

EXAMPLE 2
AGROFORESTRY AND EROSION CONTROL

As mentioned previously in this report, forestry issues are of major importance in the Ruhengeri prefecture. This is not only because of the obvious need for wood, but also because agroforestry techniques could be extremely useful in soil conservation. The RRAM Project has therefore also explored the potential applications of the PMAP geographic information system to these issues.

One important problem which required attention was the lack of information on forest resources outside of large plantations. These are generally in the form of woodlots and dispersed trees and represent the primary source of firewood for the rural population of the prefecture; yet they are rarely included in official forestry statistics. The RRAM project therefore used aerial photographs and dot grid planimetry techniques to classify tree cover (except plantations larger than 1 ha, which were measured and mapped in a separate process) according to high, medium and low density categories per square kilometer. The PMAP display of this analysis is shown in Figure B.8.

The Dispersed Tree Density map is useful by itself as an indicator of relative wood supply. As such, the northwestern part of the prefecture can be seen to have the most tree cover, whereas shortages would appear to exist in the northeast and south-central sectors. True shortages, however, are a function of both supply and demand. To include the latter factor, the population density map was merged with that of relative tree density. The resulting map (Figure B.9) shows those sites where low supply combines with high demand to create the most serious wood shortage conditions. As can be seen from this analysis, the major focus for remedial action should be on the central portion of the prefecture.

Agroforestry can certainly help to increase wood supplies, but it is most suitable for areas where wood shortages are combined with a need to improve soil stabilization practices through the use of appropriate trees and shrubs. For this reason, a further PMAP manipulation involved the combination of the tree density map with that of theoretical erosion risks. Only cells where low tree cover and high erosion risk intersected were printed (Figure B.10), thus highlighting those sites where agroforestry could prove most useful. A total of 123 cells emerge from this treatment, clustered in four major areas: south of Lake Ruhondo, north of Lake Bulera, along the eastern edge of the Zaire-Nile Divide, and a narrow band across the Central Plateau.

-149

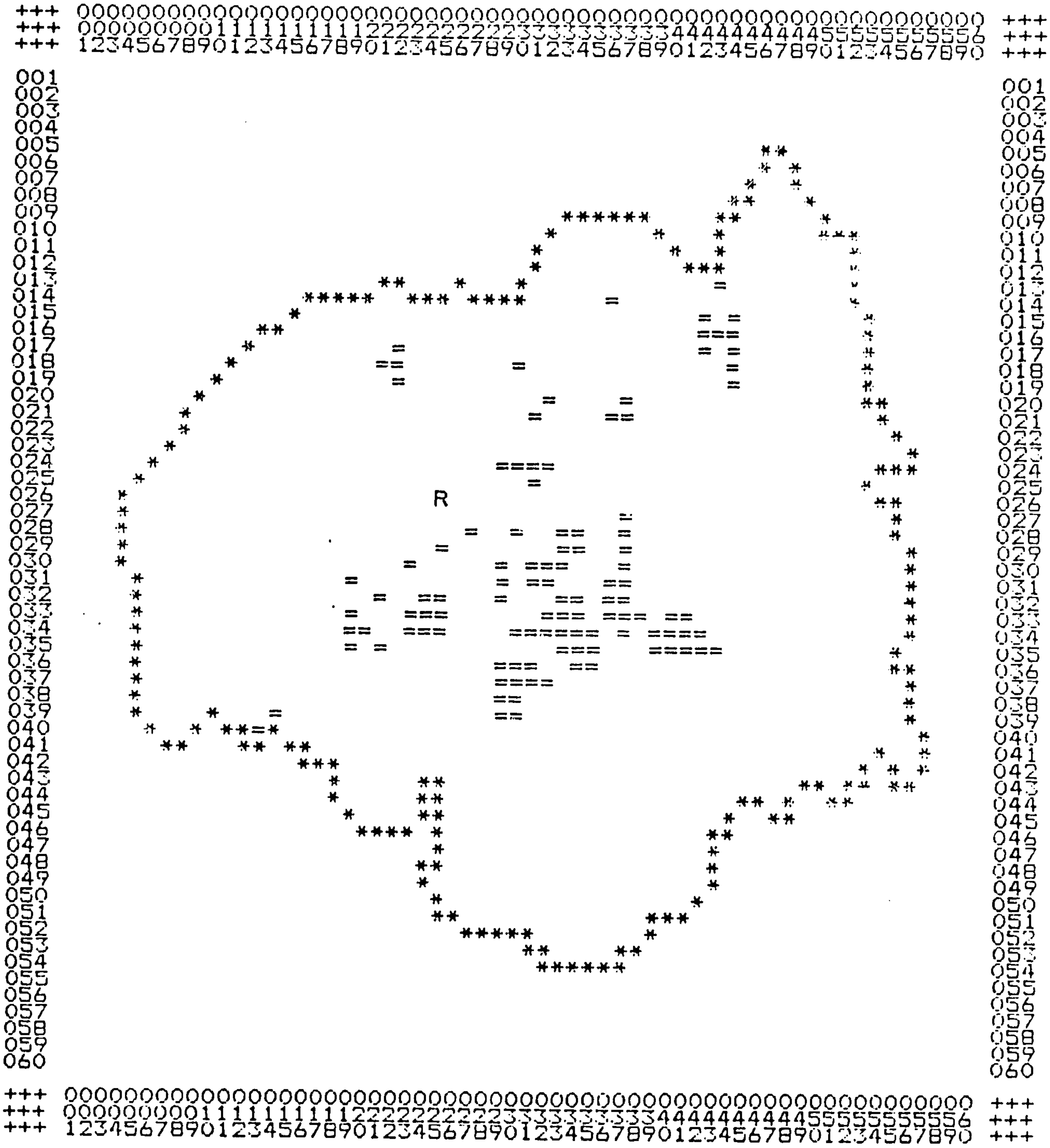


Figure B.9
POTENTIAL FUELWOOD DEMAND MAP

Symbol	Label	Cells (km2)	% Prefecture
==	Fuelwood Shortage Site	109	7.19

This map was created by intersecting the population map with the dispersed tree map. Each symbol represents those square kilometers where the highest population and lowest dispersed tree density overlap.

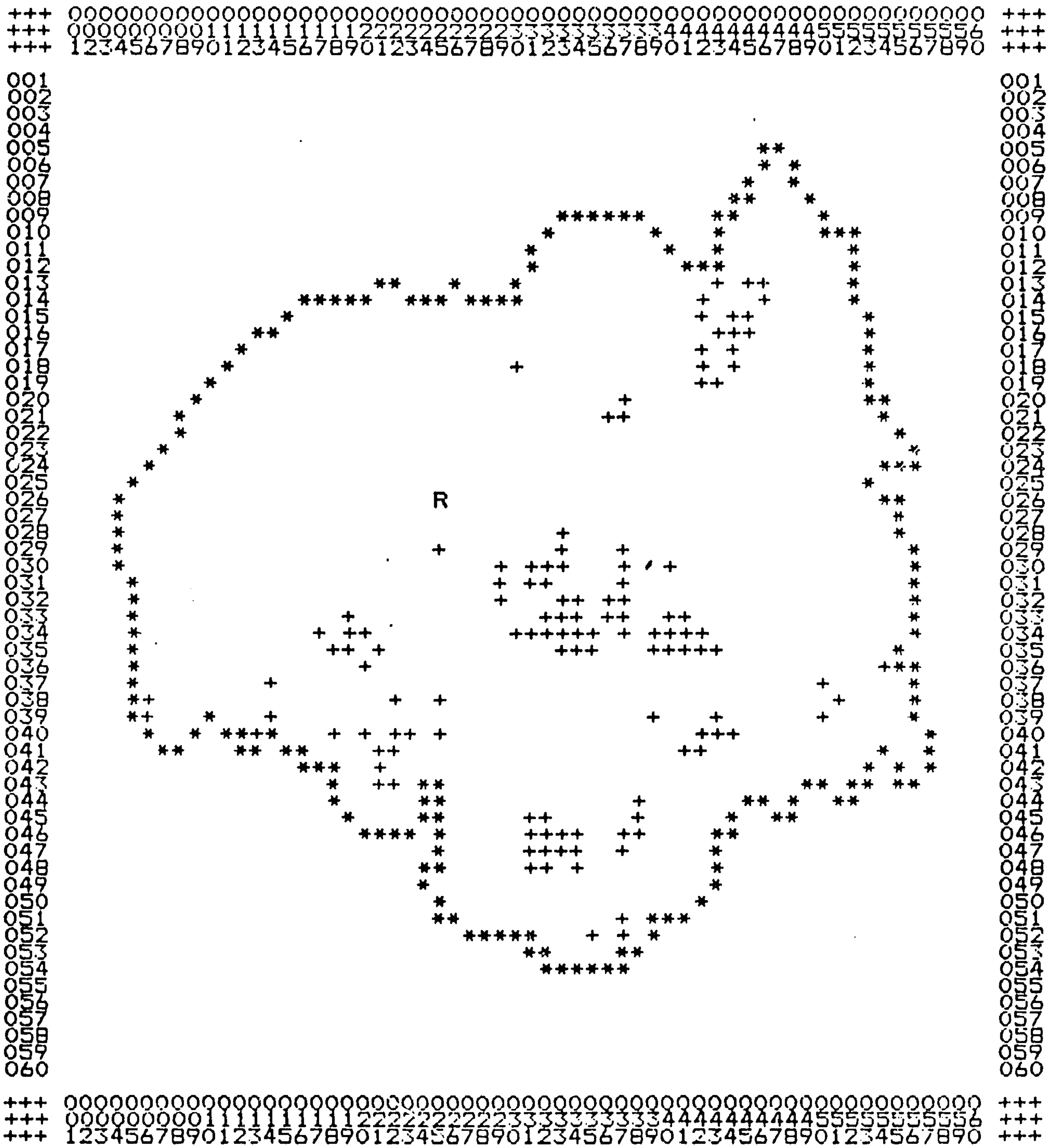


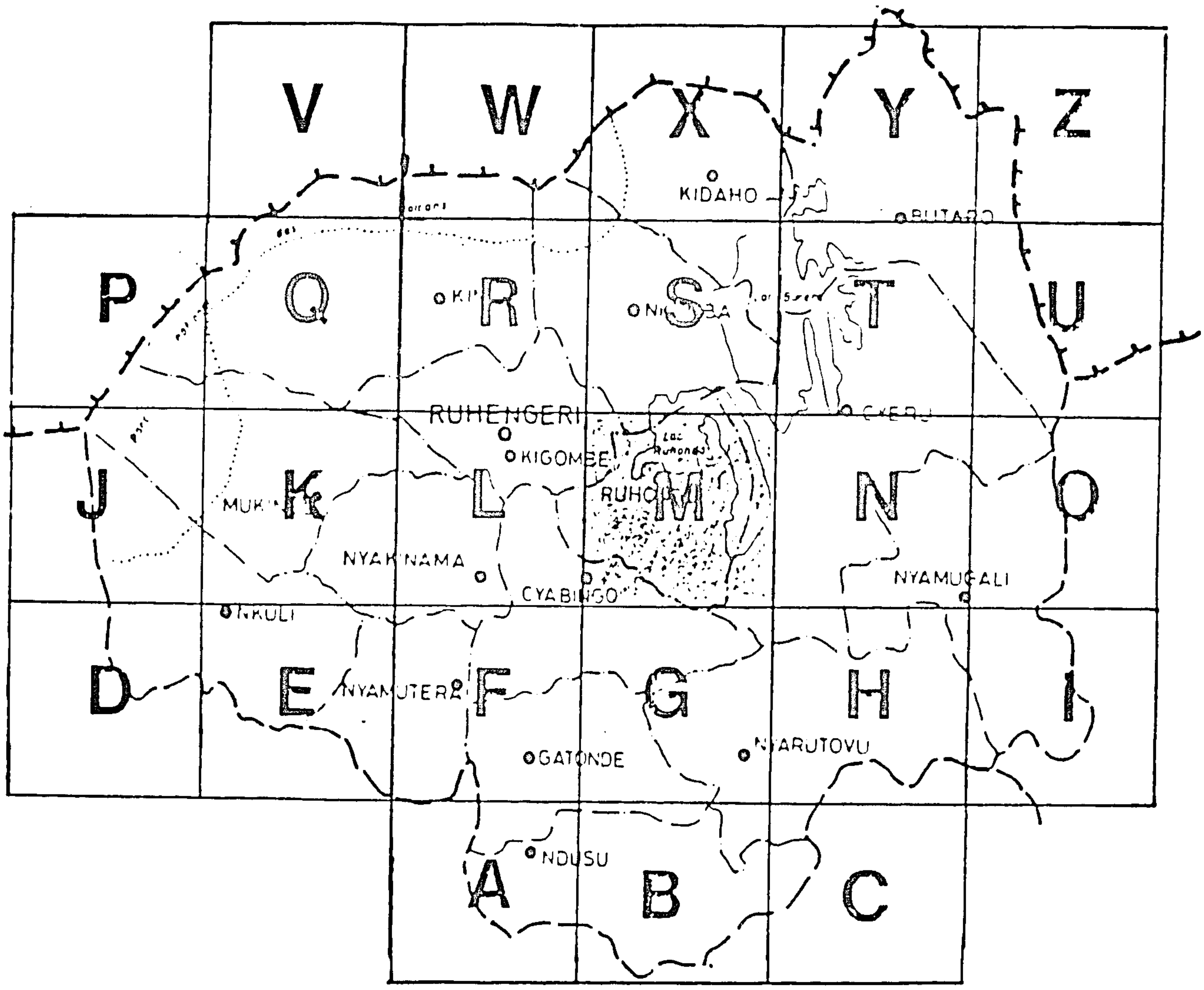
Figure B.10
HIGH POTENTIAL AGROFORESTRY SITES

Symbol	Label	Cells (km2)	% Prefecture
++	Priority Agroforestry Sites	123	8.11

This map was created by combining the theoretical erosion risk map with the dispersed tree density map. Each symbol represents those square kilometers showing high erosion risk and low density dispersed trees. Agroforestry techniques can help to both control erosion and increase wood supplies.

Figure B.11
LOCATION OF QUADRANT 'M'

This map indicates the geographic location of quadrant 'M', for which detailed land use patterns are shown in Figure B.12.



EXAMPLE 3
ENLARGED SCALE MAPS

The single-theme and combination maps presented thus far have all been based on cell sizes of 1 square kilometer. This scale has been used for three principal reasons: 1) it is convenient for demonstration purposes, as it permits the entire prefecture to be seen on one page; 2) some data are not available at larger scales; and 3) the RRAM project has not had the time or personnel necessary to do the amount of data processing necessary to produce more detailed maps. Despite their limited scale, these general maps have proven quite useful during the development phase of the RRAM GIS. To help assess the full potential of the PMAP program, however, some sample areas of the prefecture were selected for mapping at a scale of 4 ha units.

Example 3 shows a 100 km2 quadrant within the Ruhengeri prefecture that has already been mapped at this 4 hectare scale (Figures B.11 and B.12). This map indicates the predominant land use categories as determined from aerial photo analysis. Some of the categories are quite specific (e.g. bananas, forests), while others (cultivated fields) are necessarily general, depending on their relative ease of photo-identification. Nevertheless, it is clear that PMAP can organize and display more detailed information, and that the principal constraints come from the scale of available source materials.

Discussion and Conclusions.

The geographic information system thus far developed by the RRAM project represents a pilot effort in support of its first phase inventory and analysis work. Additional efforts are now underway to expand and improve upon the system, but sufficient experience has been gained to permit a preliminary assessment of the problems and potential of the PMAP GIS.

Problems. The aesthetic qualities of computer-generated maps do not compare with those of traditional cartographic products. Thus it takes some time for users to be comfortable with the unusual format and symbols. This problem, however, can be ameliorated through the development of improved symbols and the addition of linear features for boundaries, rivers, etc., all of which are possible within the existing PMAP program. In addition, recent developments in color printing greatly enhance the visual quality of the maps.

A more serious problem is that PMAP requires considerable data entry work before it can be put to use. The RRAM experience has been that at least two people are required: one to work on digitizing whatever source map is used, and another to enter the resulting number sequences into the computer program. Both steps also result in inevitable errors, so it is essential to establish a system of checks and controls. It should be noted, however, that once these techniques are established and technicians gain experience, data entry proceeds at an acceptable pace.

Problems of scale have already been referred to in earlier sections. While maps using 1 km2 cells are useful for general presentations, they do not permit more detailed analyses of specific field conditions. Even the 4 ha land use maps fail to satisfy the need for information at the level of individual farms, which average less than one hectare. This problem, however, is not a function of PMAP, which can produce maps at any scale -- even showing fields with a cell size of 1 m2. Rather, the problem lies with the nature of available source information.

The current information base for Ruhengeri is too often incomplete, inexact or out-of-date. Since GIS programs are dependent on the quality of their information sources, this situation severely limits the precision with which subsequent analyses and presentations can be made. Erosion risk analyses without adequate information on slope and soil types cannot be expected to achieve a high degree of precision. Similarly, aerial photos that are now 8 years old no longer reflect the rapidly changing land use patterns in the prefecture. In sum, the GIS can only be as good as the information on which it is based.

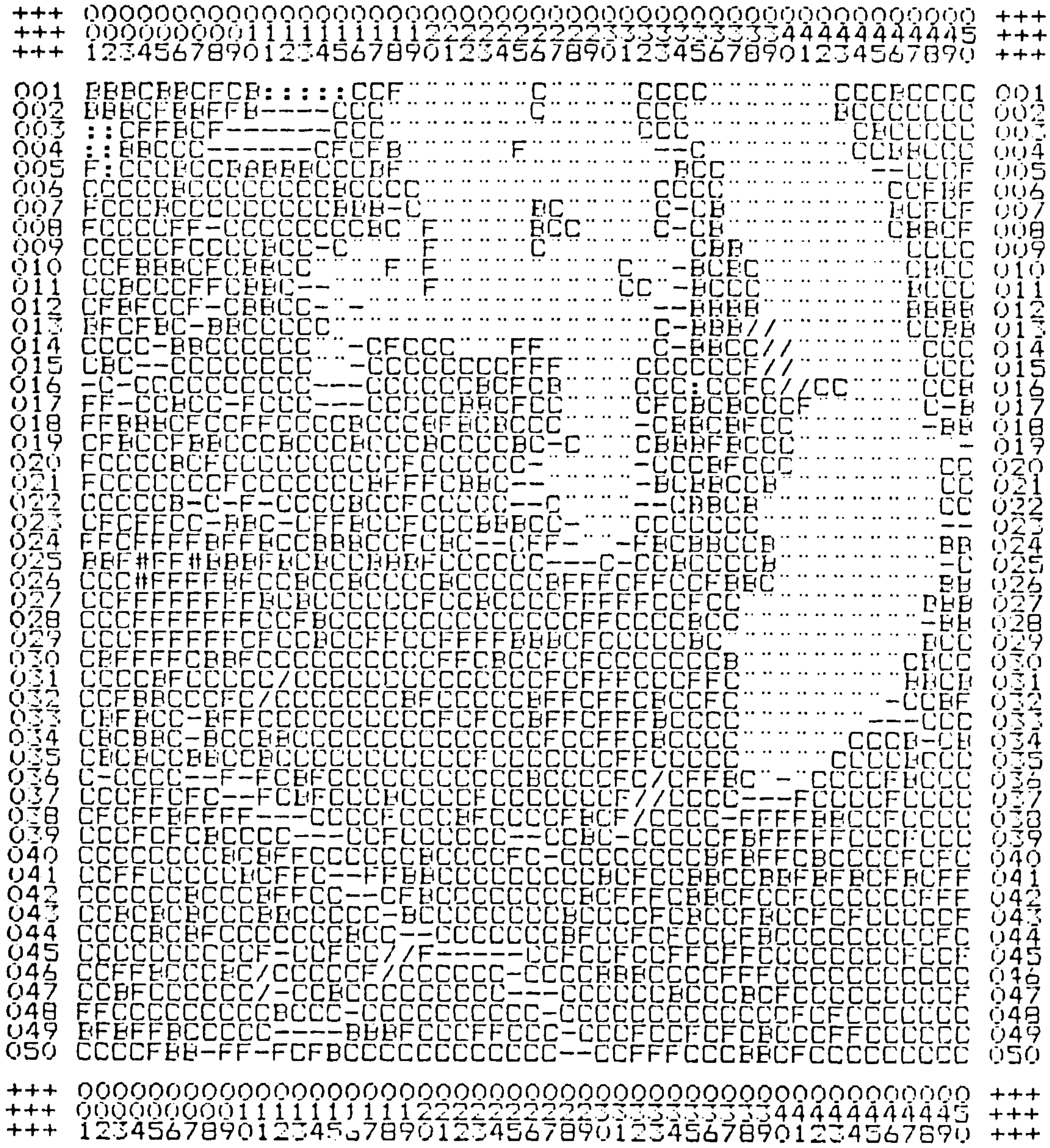


Figure B.12
LAND USE MAP OF QUADRANT M

Symbol	Label	Cells (4 ha)	% Quadrant
::	Raised Bed Agriculture	11	.44
--	Bottomland Raised Beds	141	5.64
//	Fallow/Non-cultivated	19	.76
##	Villages	3	.12
BB	Bananas	295	11.80
CC	Cultivated Fields	1190	47.60
FF	Forest Plantations	316	12.64
~~	Lake Ruhondo	525	21.00

Potential. Despite these problems, the GIS program has already demonstrated considerable potential for future use and applications. The power of the computer to organize, store and rapidly manipulate large quantities of data is evident. In addition, the resultant maps are comprehensible and their aesthetic quality can definitely be improved.

Now that the initial development phase has been completed, new data sources can also be rapidly incorporated into the existing system. The new national soils and topographic maps, now being finalized, will thus provide extremely valuable information that can be used to improve the precision of various analyses. Additional information sources which can be integrated into the RRAM GIS include: expanded climatological data, the 1988 census population census, new aerial photos, and results from various field studies of erosion, forest resources, etc. These additions will not only provide valuable new information, but will also permit improved data integration through their merger and synthesis with existing thematic and composite maps. With regard to the aerial photos, new land use maps can also be compared with those already developed to assess the nature and extent of changes over the past 10 years.

Conclusion. The preliminary development of a computerized geographic information system for Ruhengeri has demonstrated sufficient potential to justify its continued use as a tool for natural resource management. The RRAM Project will continue to work on improvements in both its form and content during its second phase operations in the Ruhengeri prefecture, and discussions are now underway with regard to possible GIS applications at the national level. The ultimate value of this approach, however, will depend on the quantity and quality of available information. Current efforts to improve this data base, therefore, represent a critical next step toward the development of a functional geographic information system in Rwanda.

ANNEX C

BIBLIOGRAPHY

AAAS (American Association for Advancement of Science). 1983. Resource inventory & baseline study methods for developing countries. AAAS, Washington, D.C.

Aderhold, E.L. and A.W. Weber. 1986. Development and applications of a geographic information system for natural resource management in Rwanda. Paper presented at the 20th International Symposium on Remote Sensing of Environment, Nairobi.

AIDR. 1981. Evolution entre 1958 et 1979 du couvert forestier et du débit des sources dans certaines régions du Rwanda. GEOMINES-SOMIRWA, Bruxelles.

Agarwal, A., J. Kimondo, G. Moreno and J. Tinker. 1981. Water, sanitation, health for all? International Institute for Environment and Development. Washington, D. C.

Anger, G., K. H. Duvel, R. Nitwail, and P. Pietrowixz. 1985. Recherche et vulgarisation dans la domaine agroforestiere au Projet Agropastoral de Nyabisindu. Bul. Agric. Rwa. Avril, 1985. Kigali, Rwanda.

Anonymous. 1985. Revue des programmes de cooperation entre le gouvernement rwandais et l'UNICEF, Bilan d'activités de technologie appropriée au CFNR à Ruhengeri. Centre de Formation en Nutrition de Ruhengeri, Rwanda.

Arid Lands Information Center, University of Arizona. 1981. Draft environmental profile on Rwanda. For National Park Service Contract No. CX-0001-0-0003. Office of Arid Lands Studies, Tucson, Arizona.

Avery, T.E. 1977. Interpretation of aerial photographs. Burgess Publishing Company, Minneapolis, Minnesota.

BCEOM. 1982. Renovation et extension des reseaux d'eau potable dans cinq centres secondaires et dans la region des laves. Pour MINITRAPE, Kigali.

Barney, L. 1980. Entering the twenty-first century: the global 2000 report to the president. U.S. Government Printing Office, Washington, D.C.

Berry, E., L. Berry, D.J. Campbell, D.C. Major. 1985. Regional reconnaissance of Rwanda, Burundi and Kivu Province, Zaïre). Clark University, Worcester, Massachusetts.

BGM. 1981. Etude socio-economique de la région du Bugesera. Kigali, Rwanda.

Charbonneau, G. 1981. Projets agricoles à petite échelle favorables à l'environment. VITA/CODEL. Washington, D.C.

Clark University, 1984. Renewable resource trends in East Africa. Worcester, Massachusetts.

Club du Sahel. 1984. l'Agroforestrie dans le Sahel ouest-africain. Ouagadougou, Burkina Fasso.

Committee on medical and biological effects of environmental pollutants. 1977. Arsenic. NAS (National Academy of Sciences), Washington, D.C., USA.

Dasman, R.F.,D. Poore. 1979. Ecological guidelines for balanced land use, conservation and development in high mountains. IUCN, Gland, Switzerland.

Dejaegher, Y. 1983. Essai d'une bibliographie sur le Rwanda dans le domaine agro-socio-economique. MINAGRI, Kigali, Rwanda.

Delepierre, G. 1982. Les regions agroclimatiques en relation avec l'intensite de l'erosion du sol. Bul. Agric. Rwa. Avril, 1982. Kigali.

Downing, T.E., G. Kamal, M. Karaba, L.A. Lewis, M. Ndonye. 1985. Monitering soil erosion in Kiambu and Murang'a districts, Kenya. ETMA, Nairobi, Kenya.

Dressler, J., and I. Neumann. 1982. Agriculture de couverture du sol (ASC) Bul. Agric. Rwa. Octobre, 1982. Kigali, Rwanda.

Eckholm, E.P. 1976. Losing ground--environmental stress and world food prospects. W.W. Norton & Co., New York, N.Y.

Eckholm, E.P. 1982. Down to earth -- environmental and human needs. W.W. Norton & Co., New York, N.Y.

Eckholm, E., G. Foley, G. Barnard and L. Timberlake. 1980. Fuelwood: the energy crisis that won't go away. International Institute for Environment and Development, Washington, D.C.

Egli, A. 1984. La conservation des sols à l'aide des méthodes agroforestières: le cas du Rwanda. ISAR, Butare, Rwanda.

Egli, A. 1985. La recherche agroforestière au Rwanda et l'expérimentation chez l'agriculteur éleveur. ISAR, Butare, Rwanda.

Egli, A., K. Raquet. 1985. l'Agroforestérie au service de la conservation du sol au Rwanda. ISAR, Butare, Rwanda.

FAO. 1977. Guidelines for watershed management. FAO Conservation Guide No. 1. FAO, Rome, Italy.

Faton, J.F. 1977. Etude de quelques proprietés des sol tourbeux et leur influence sur le drainage. IGR (Institut du Génie Rural, Lausanne, Suisse.

Folliott, P.F., and J.L. Thames. 1983. Environmentally sound small-scale forestry projects. CODEL/VITA, Washington, D.C.

Forbes, F., D. Rossiter, A.V. Wambeke. 1982. Guidelines for evaluating the adequacy of soil resource inventories. Cornell University, Ithaca, New York.

Gatera, F. 1978. Le bois et la charbon de bois dans la commune urbaine de Nyarugenge. National University, Butare, Rwanda.

Gotanegre, J.F., C. Prioul, P. Sirven. 1975. Géographie du Rwanda. Ed. de Boeck, Bruxelles-Kigali.

Hamilton, A.C. 1982. Environmental history of East Africa. Academic Press, London, England.

Hardy, E.E., and E.L. Aderhold, 1986. Report and technical manual for land use classification, RRAM Project/ Winrock International Institute for Agricultural Development, Morrilton, Arkansas.

IUCN. 1980. World conservation strategy. Gland, Switzerland.

Kayijamehe, A. 1982. Les differents types de fosses et de terasses applicable au Rwanda pour la conservation des sols et des eaux. Bul. Agric. Rwa. Avril, 1982. Kigali.

138

Kayumba, Z. 1986. Exploitation minière et environnement en préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Kunyarugero, G. 1981. Les systèmes agroforestières dans la production combinée de la nourriture et du bois. Bul. Agric. Rwa. Avril, 1981. Kigali.

Laure, J. 1982. Des vivres ou du thé? ORSTOM, Paris.

Linn, L. 1985. A summary of agroecological concerns for the Ruhengeri Prefecture, Rwanda. RRAM Project, Ruhengeri, Rwanda.

McNeely, J.A. and D. Pitt. 1985. Culture and conservation: the human dimension in environmental planning. IUCN, London.

McNeely, J.A. 1982. National parks: conservation and development. Smithsonian Institute Press, Washington, D.C.

MINAGRI. 1986. Plan de travail annuel, 1986. Kigali.

MINAGRI. 1982. Premier séminaire national sur la conservation, l'amélioration et la fertilité des sols au Rwanda. Butare, Rwanda.

MINAGRI/DGF. 1985. Plan quinquennel de développement économique, social et culturel, 1987-1992. Le sous-secteur forestier. Kigali.

MINAGRI/DGF. 1985. Résultats de l'enquête forestière, domaine milieu rural privé, Préfecture de Ruhengeri. Projet ADGF, Kigali.

MINAGRI/SESA. 1985. Résultats de l'enquête nationale agricole, 1984. Kigali.

MINAGRI/SESA. 1986. Pertes de terre due à l'érosion. Kigali.

MINEPRISEC. 1982. Rapport du 1er seminaire national pour l'education et la formation en matiére d'environnement, Kigali.

MINISAPASO/PNUE. 1985. Rapport du 1er seminaire national sur l'environnement. Kigali.

Ministère des Colonies. 1951. Plan décennal pour le développement économique et social de Ruanda-Urundi. Les éditions de Visscher, Bruxelles, Belgique.

Ministère des Colonies. 1954. L'agriculture au Congo Belge et au Ruanda-Urundi de 1948 à 1952. Services de l'agriculture du ministère des colonies et du gouvernement générale de Congo Belge, Bruxelles, Belgique.

Ministry of Environment and Natural Resources. 1985. Population and environment. NES, Nairobi, Kenya.

Monfort, N. 1986. Le parc national des volcans. Rapport du Projet RRAM.

Monfort, N. 1985. Les mammiféres du Rwanda. Rotary Club de Kigali, Kigali, Rwanda.

Morris, W.H.M. 1979. A report on agricultural production, marketing, and crop storage in Rwanda. USAID, Kigali, Rwanda.

Muhirwa, I., D. Biniga. 1986. La préfecture de Ruhengeri: état actuel et perspectives de développement. Présenté au 1er conférence sur l'environnement et le développement dans la préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Mutungirehe, I. 1981. Role de la foret rwandaise dans l'effort de protection et conservation de sols. Bul. Agric. Rwa. Janvier, 1981. Kigali.

Myers, N. 1980. Conversion of tropical moist forests. National Academy of Sciences, Washington, D.C.

NRC (Natural Resources Council). 1982. Ecological aspects of development in the humid tropics. National Academy Press, Washington, D.C.

Nyamulinda, V. 1986. Les contraintes écologiques dans le bassin de drainage de la Mukungwa. Présenté au 1er conférence sur l'environnement et le développement dans la préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Nyamulinda, V. 1986. Législation, structures institutionnelles et education en matière de l'environnement au Rwanda. RRAM Project, Ruhengeri, Rwanda.

ONAPO (Office National de la Population). 1983. Enquete nationale sur la fécundité. PrinterSet, Kigali.

OTA. 1984. Africa Tomorrow. Office of Technology Assessment. Washington, D.C.

Poore, D. 1979. Ecological guidelines for development in tropical rain forests. Morges, Switzerland.

Préfecture de Ruhengeri. 1985. Projet régional pour le IVe Plan Quinquennal de Développement, 1987-1991. Ruhengeri, Rwanda.

Prefol, B., G. Delepierre. 1973. Disponibilité et utilisation des terres au Rwanda. ISAR, Butare, Rwanda.

Prioul, C., P. Sirven. 1981. Atlas du Rwanda. Ministère de la Coopération Française, Paris.

Projet Agro Pastoral de Nyabisindu. 1984. Etudes et experience, No. 2, 4, 7. Kigali, Rwanda.

Projet Gorilles de Montagne. 1986. Plan d'amènagement du Parc National des Volcans. PGM/ORTPN, Kigali.

Roark, P. and B.H. Dickson, Jr. 1986. Ruhengeri water resources study, Rwanda. WASH field report no. 181. Prepared for RRAM Project, Ruhengeri, Rwanda.

RAPID. 1981. Les effets des facteurs démographiques sur le développement social et économique au Rwanda. The Futures Group, Washington, D.C.

Rutunga, V. 1986. Les sols de la région de Ruhengeri: leurs potentialités agricoles et leurs contraintes écologiques. Présenté au 1er conférence sur l'environnement et le développement dans la préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Saccuman, G. 1982. Guide technique de conservation des sols applicable au Rwanda. Preliminary FAO project document RWA/81/002. FAO, Kigali.

Schiller, E. 1985. Water Resources Survey, Ruhengeri. RRAM Project, Ruhengeri.

SECID. 1985. Ruhengeri resource analysis and management project. Memorandum of Understanding for RRAM Project. USAID, Kigali.

Sierra Club. 1983. Directory of [illegible] college and university programs in environmental studies and natural resources management. UNIPUB, New York.

Steinkamp [illegible]rier, L. 1986. Les paysans et leur environnment en préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Symoens, J.J., M. Burgis, J.J. Gaudet. 1981. The ecology and utilisation of African inland waters. United Nations Environment Program, Nairobi, Kenya.

Tenaille, G., and M. Denis. (1985) Alimentation en eau potable en milieu rural, renforcement des institutions et formation du personnel. World Bank, Kigali, Rwanda.

Tillman, G. 1981. Environmentally sound small-scale water projects. VITA, New York.

Timberlake, L. 1985. Africa in crisis. Earthscan, IIED, Washington, D.C.

Towner, J. 1985. Population status of and problems caused by buffalo of Volcanoes National Park. RRAM Project, Ruhengeri, Rwanda.

Troupin, G. 1982. Flores des plantes ligneuses du Rwanda. Institute National de Recherche Scientifique. Butare, Rwanda.

UNDP/WB (United Nations Development Program/World Bank). 1982. Rwanda: issues and options in the energy sector. Joint UNDP/WB Energy Sector Assessment progress report no. 3779-RW, UNDP/WB, Washington, D.C.

USAID (United States Agency for International Development). 1981. Energy in Rwanda. USAID, Kigali, Rwanda.

USAID. 1984. Energy, forestry and natural resources activities in the African region. USAID, Washington, D.C.

Vedder, A. 1986. Preliminary report on the population status and dynamics of the Virunga gorillas, 1986. Kigali.

Vander Zaag, P. 1982. La fertilite des sols du Rwanda. Bul. Agric. Rwa. Janvier, 1982. Kigali.

Wassmer, P. 1986. Géomorphologie et l'érosion en préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Wassmer, P. 1986. Les types d'érosion, leur mesure et les méthodes de lutte. Présenté au ler conférence sur l'environnement et le développement dans la préfecture de Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

Wassmer, P. 1981. Etude de l'erosion des sols et de ses consequences à Kibuye. Recherches morphographiques. Universite Louis Pasteur, UER de Geographie, Strasbourg, France.

Weber, A.W. 1986. Socioecologic factors in the conservat on of afromontane fores: .eserves, in Gartlan, J.S. et al., eds. Primate conservation in the tropical rain forest. Alan R. Liss, Inc., New York.

Weber, A.W. 1986. Le parc national des volcans biosphere reserve: cooperation between conservation and development. Parks 10(3):19-21.

Weber, A.W., A.Vedder. 1983. Population dynamics of the Virunga gorillas: 1959-1978. Biological Conservation 26: 341-366.

Weber, F. 1986. Forestry and soil conservation in Ruhengeri. RRAM Project, Ruhengeri, Rwanda.

World Bank. 1984. World development report 1984. The World Bank, Oxford University Press, Oxford, UK.