DEVELOPMENT AND MANAGEMENT OF THE SMALL MARAIS

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DEVELOPMENT AND MANAGEMENT OF THE SMALL MARAIS

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PREFACE

Rwanda is running out of area to feed its rapidly growing population. Most available hillside land is already cultivated, leaving only the marais lands, which up until twenty years ago, were extensively used to support grazing animals. The marais lands, accounting for 7.5 percent of the total surface area, include the entire drainage network for the country. They are roughly divided into large and small sizes. Large marais, associated with major rivers draining areas over 25,000/km^2, cannot be improved by individual farmers. However, the remaining small marais, about one-half of the total marais area, are now being locally developed through the construction of beds.

In this report, we emphasize the small marais. The small marais are located between hills and are continuously wet throughout the year, periodically experiencing flash floods in the rainy seasons. Although by law these lands belong to the State, local officials currently allocate plots. Farmers manage the developed small marais by carefully controlling water availability. During the monsoon season, the water table is lowered by drainage, and in the dry season, irrigation is used to replenish the groundwater supply beneath the beds.

Although the Rwandan Government has worked in cooperation with donors to implement projects to improve marais development and management (particularly physical infrastructure), a serious lack of knowledge about the marais environment contributed to less than optimal results. In 1987, a special one-year study program was begun to gather some of the necessary background information and to formulate specific recommendations for the Rwandan Government on productive and environmentally sound methods for marais development. A joint field team of Rwandan and American experts, in

cooperation with a field coordinator, carried out the project. The team prepared a report (Annex B) and discussed the results during a two-day national workshop in Rwanda, which included the participation of various ministries, prefectural representatives, and scientists. Specific recommendations were presented following the workshop. This report was written by the joint field team and includes comments made at the workshop.

Team members who wrote various parts of the report (in alphabetical order) include Michel Kayihura (Chapter 10); Japhet Ngendahayo (Chapter 8); Barabwiliza Runyinya (Chapters 5 and 9); Roelof Sikkens and Aaron MaKuba (Chapters 1, 2, and 3); and Chapters 4 and 11 were jointly created by the team members.

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We would also like to thank all the marais farmers for their special patience and understanding in answering our numerous questions. Farmers in the Ilibunga and Nyarutovu marais, where we did field work, generously gave their time.

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NOTE: English translations for government bureaucracies and institutions are used throughout this paper. The original French can be found in Annex D, List of Acronyms for Important Government Bureaucracies.

CHAPTER ONE

THE RWANDA CONTEXT

INTRODUCTION

Rwanda is a small landlocked country 1 to 3 degrees south of the equator in east central Africa, with a surface area of 26,338 km^2. In 1987, the population was estimated at 6.5 million persons, with an average density of over 250 persons/km^2. This, along with an annual population growth rate of 3.7 percent, makes Rwanda one of the fastest growing, most densely populated countries in the world. It belongs to a region of high population density along with Burundi and the Kivu Province of Zaire. This is in sharp contrast to surrounding, lower lying areas, which are less densely populated. Favorable physical and climatic conditions have contributed to the sustained growth of the large and burgeoning population.

The typography of Rwanda is rolling, with a continuous pattern of hills and valleys. Virtually all of the population is located in dispersed family compounds on the hill slopes, where traditional agricultural practices are used. In the valleys, there are many lakes and wetlands. These wetlands, the marais, cover the lowest parts of the narrow valleys. Only 4 percent of the population resides in the two urban areas, Kigali (200,000) and Butare (20,000).

The Zaire/Nile divide, with altitudes of 3000 m in the north and 2200 m in the south, forms a physical backbone. These mountains are part of the Central African Rift Valley. Kivu Lake (1460 m) is located in a defaulted valley on the western side of the mountain chain and outlets via the Rusizi River. The Central Plateau and Eastern Savanna regions are east of the

divide and slope toward Lake Victoria in the Eastern Rift Valley. The highest point in Rwanda, the volcano Karisimbi (4507 m), is located in the Volcanic Region in the north.

Rwanda is clearly a developing country: the economy is almost entirely dependent on the agricultural sector; agricultural output is low; industrialization is almost nil; export income is dependent on a few agricultural crops; and educational levels are insufficient (only 35 percent of the population is literate). However, the equatorial mountain climatic conditions allow two harvests annually and are suitable to a wide variety of crops. This, along with well adapted, ingenious agricultural practices has, up until now, allowed Rwanda to maintain near food self-sufficiency. However, food deficits in 1974 and 1984, although not severe by African standards, are predictive of future more serious shortages that may occur as the population continues to grow.

Numerous books and reports summarize the geography, history, economy, and other aspects of Rwanda. A few of these are listed in the reference section at the end of this chapter. Table 1.1 shows some of the most important economic, social, and agricultural characteristics of Rwanda. In this chapter, we will highlight general features that are important in the context of agricultural development in Rwanda.

ADMINISTRATION

Rwanda is a republic with unicameral representation. There are thirteen ministries, all with central offices in the capital Kigali. Most ministries have representatives stationed in the ten **prefectures** (Figure 1.2). There are about twenty **sous-prefectures**, which presently have a

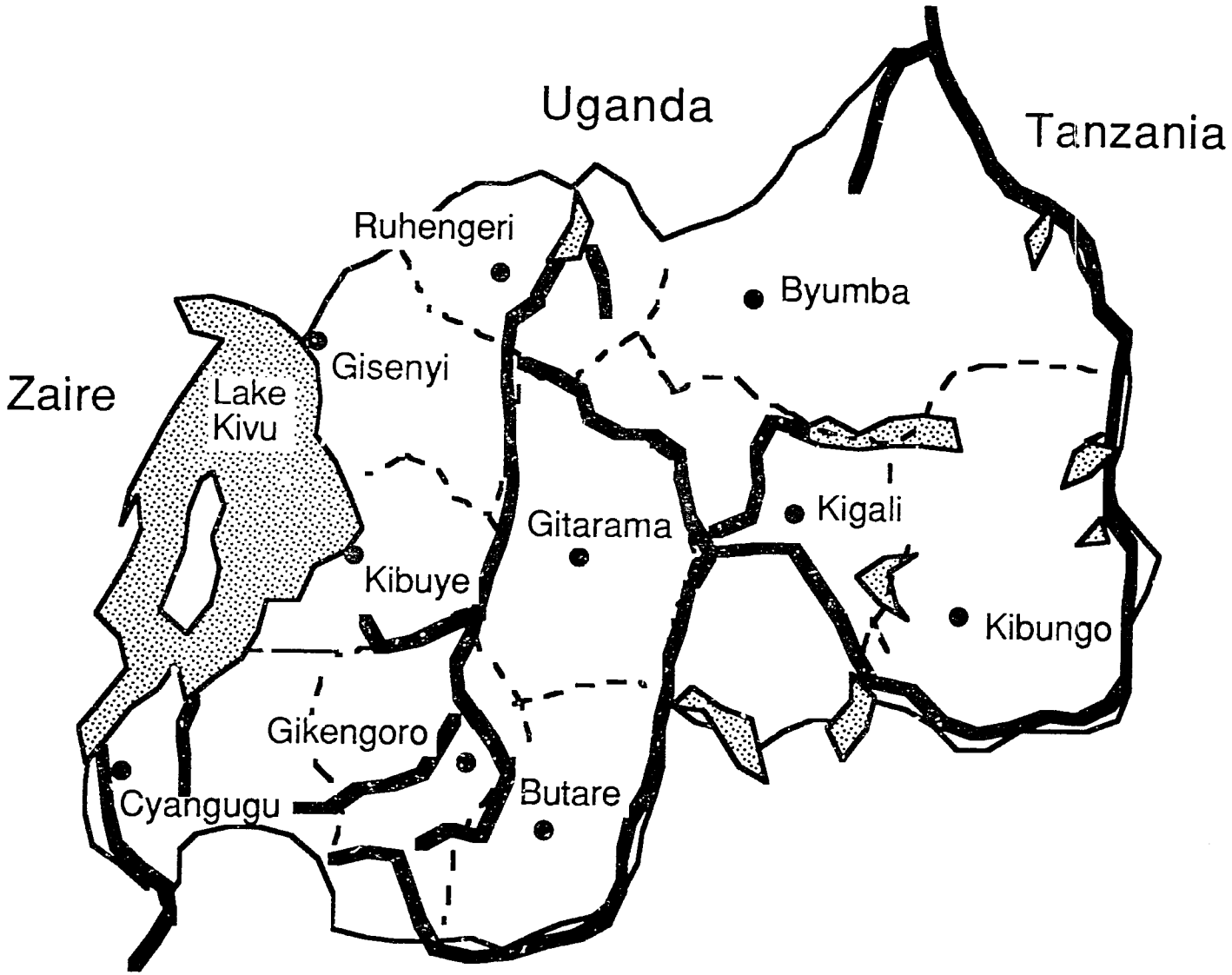

Figure 1.1: Map of Rwanda.

Table 1.1: Rwanda: An Overview.

Selected indicators	Rwanda	Compared to other Subsaharan countries
Area (land and lakes)	26,338 km2	third smallest
Cultivable area	about 50 percent	-
Population (1987)	6.5 million	-
Population density	250 inh/km2	highest
Projected population (year 2000)	10.2 million	
Population growth rate	3.7 percent	among the highest
Labor force in agriculture	91 percent	13 percent more
Labor force in industry	2 percent	8 percent less
Energy consumption (1983)	35 kg eq	21 kg equiv. less
Mineral fertilizer per ha (1983)	1 kg	3 kg less
Urbanization level (1983)	5 percent	15 percent less
Life expectancy at birth:		
men	44 years	
women	47 years	
Literacy rate:		
men age 15 or more;	35 percent	-
women age 15 or more	22 percent	-
GNP per capita (1983)	$US 270	average
Gross domestic product (GDP):		
market prices (1984)	$US 1681 mln	-
factor costs (1984)	$US 1449 mln	-
Contribution to GDP (factor costs):		
primary sector	43 percent	-
secondary sector	21 percent	-
tertiary sector	36 percent	-
Average growth rate 1962 - 1986	6 percent	twice the average
Growth rate (1984)	4 percent	-
Value of exports f.o.b. (1983)	$US 124 mln	-
Value of imports (1983)	$US 197 mln	-
External debt (1983)	$US 324 mln	-
International assistance (1984)	$US 167 mln	-
USAID assistance (1984)	$US 16.2 mln	-
Internl. assistance per capita (1984)	$US 28	$ 10 per capita more
Debt service ratio (1985)	8 percent	1/3 of average

Sources: Scheffer (1986), World Development Report (1985), World Bank Report (1986), Delepierre (1975).

limited role in the administrative hierarchy. There are 143 **communes** (**communities**), which are centers for rural development activities because of the government's policy of decentralization to the commune level. Each commune is governed by a **bourgmestre** selected by the central government. Communes are divided into **secteurs**, each headed by elected **conseillers**. The smallest administrative unit is the **cellule**, which includes twenty to 100 families.

TRANSPORTATION

Although there is a good transportation network within Rwanda, with about 1000 km of paved roads joining all but one of the prefectures, international linkages are very poor. Not only are international routes inconvenient to use, but the distance - Mombasa to Kigali, 1600 km - means very high transport costs. The lack of economical international transshipment routes is likely one of the most substantial bottlenecks to continued economic development in land-locked Rwanda. Related difficulties include problems with customs, control, safety, and international conflicts.

Although Rwanda's primary agricultural exports, coffee, tea, and pyrethrum, have a high value per unit weight, 15 to 30 percent of the received prices are used to transport the crops to East African ports (Jones and Egli, 1984). Obviously, bulky, low-value crops such as maize, manioc, beans or potatoes could not be economically exported. Unfortunately, Rwanda must import all but the most basic industrial products. High transport costs for these will also inhibit future development in Rwanda.

CLIMATE AND CROPPING SEASONS

Because of elevation (on average, 1800 m above sea level) Rwanda's

average temperature, 19°C, is much lower than its equatorial location would indicate. Precipitation decreases as one moves east. In the most western portion of the country, the average annual rainfall is 1500 mm and in the east, 1100 mm (Agrar-und Hydrotechnik GMBH, 1986), with an overall average of 1250 mm. The average, maximum, and minimum amount of precipitation, the number of wet days, and the potential evaporation for each month is given for the Central Plateau in Table 1.2. The precipitation pattern is typically monsoonal, with two distinct wet and dry seasons. Because of elevation, precipitation is also more moderate than other equatorial locations. The duration of the seasons varies among the regions, with longer dry seasons in the east and longer rainy seasons at higher altitudes.

The four seasons in Rwanda are

1. The short rainy season **(umuhindo)** from the middle of September till the middle of December. This is the first growing season.
2. The short dry season **(urugaryi)** from the middle of December till the middle of February. This season often passes unnoticed because rainfall is reduced rather than absent.
3. The long rainy season **(itumba)** from the middle of February till early June. This is the second growing season.
4. The long dry season **(icyi)** from early June till the middle of September. Most of the country has no rainfall for two or more months.

AGRICULTURAL REGIONS

There are three basic ecological zones - the highland zone, the middle altitude zone, and the lowlands - in Rwanda. Characterization of these zones is based on the interrelationships among natural and human phenomena,

Table 1.2: Precipitation and Evaporation for Mwogo Watershed at Nyabisindu, Butare.

	Precipitation Average mm/month	Maximum mm/month	Minimum mm/month	Average number of wet days	Potential evapotation mm/month
January	113	287	20	24	114
February	124	214	54	23	131
March	149	288	63	27	144
April	204	349	87	28	123
May	165	328	27	24	127
June	26	149	0	9	130
July	10	54	0	4	133
August	33	117	0	9	138
September	82	210	8	20	142
October	110	245	37	25	148
November	134	297	56	27	133
December	115	252	9	26	142

Source: Meulenberghs (1986).
Based on twenty-one stations with precipitation records for the period 1931 to 1981. Elevations in the watershed range between 1500 and 2300 m. Coefficient of variation varies between 7 and 8, except for the precipitation in June and July when it was 10 and 12, respectively.

altitude, climate, soil, temperature, population, and markets. Each includes a distinct set of agricultural activities and land uses. Delepierre (1975) divides the three zones into twelve agroclimatic regions (Figure 1.2)

The highland zone includes the **Volcanic Region** and the **Highlands of the Zaire/Nile Divide Region**. Altitudes range from 1900 - 2500 m on the Zaire/Nile divide and higher still in the northern volcanic area. Average annual temperatures are cool (15° - 17°C), and rainfall is generally reliable (1250 - 2000 mm/yr average). Some areas are covered by forest, but most are planted to a wide variety of crops including potatoes, peas, wheat, barley, maize, millet, tea, quinine, and pyrethrum. The Volcanic Region is densely populated because of fertile soils (500 inh/km^2 or more), whereas the Zaire/Nile divide has only 300 inh/km^2.

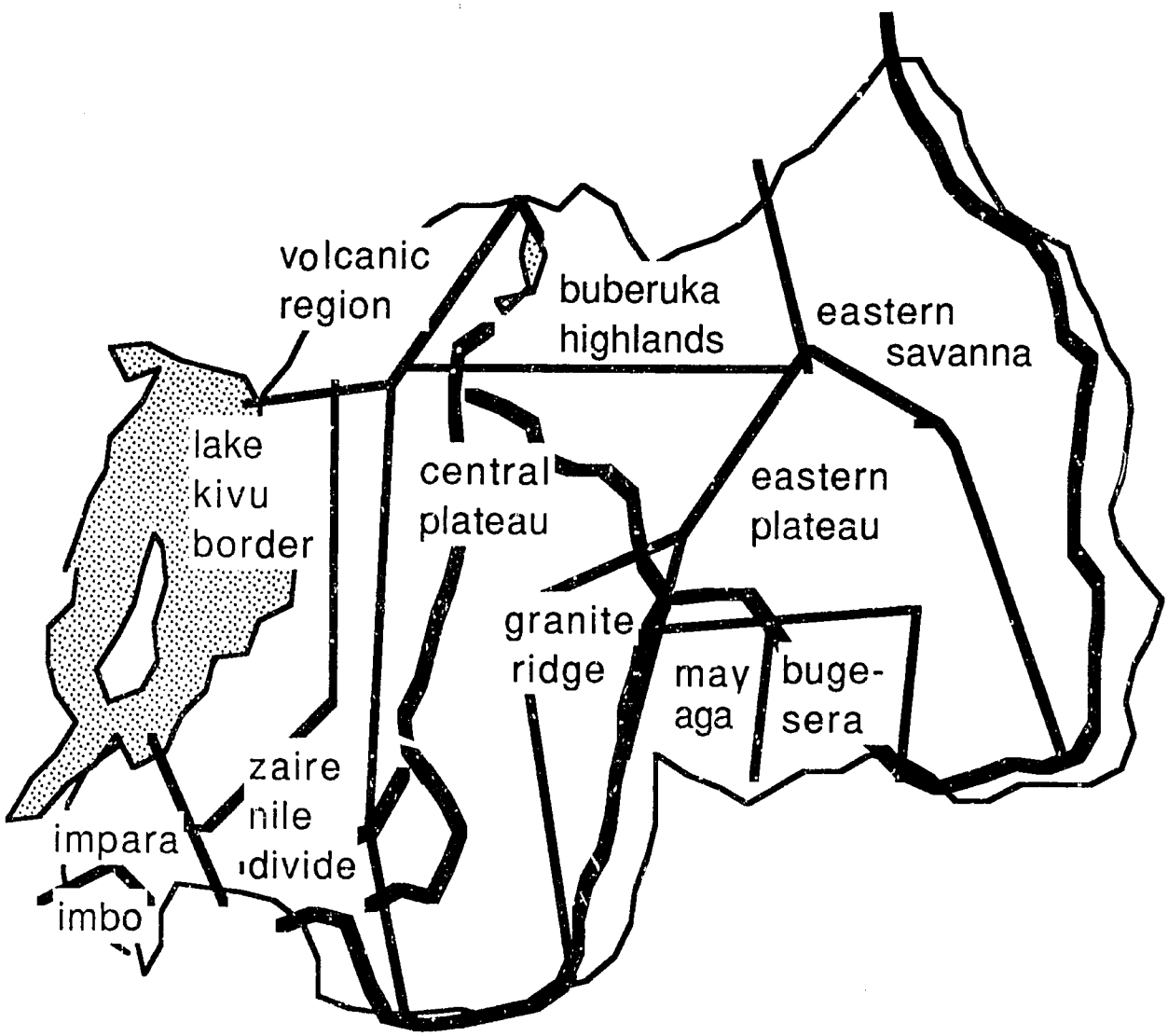

Figure 1.2 Agroclimatic Regions and Prefectures of Rwanda.

The middle altitude zone, also referred to as the hill lands (1500 - 1900 m), includes five agroclimatic regions: **Central Plateau**, **Buberuka Highlands** (Byumba Plateau), **Granite Ridge**, **Impara**, and the **Lake Kivu Border**. Average annual temperatures are in general higher (17° - 20°C) and average yearly rainfall is lower, although adequate for most purposes (1000 - 14000 mm). Precipitation patterns are, however, less regular. The middle altitude zone is the most densely populated zone in Rwanda (44 percent of the total area, with more than 55 percent of the population). Locally (especially near Butare), there are rural population densities of more than 750 persons/km^2. Bananas, beans, sorghum, sweet potato, arabica coffee, peanuts, and soybeans are produced there.

The lowlands (900 - 1500 m) are characterized by lower, more uncertain rainfall amounts (800 - 1000 mm) and significantly higher average daily temperatures (24° - 29°C). The lowland zone can be subdivided into five agroclimatic regions: **Mayaga**, **Bugesera**, **Eastern Plateau**, **Eastern Savanna**, and the (very small) **Imbo**. The lowlands are less densely populated than the other zones. Agricultural potential is severely hampered by the risk of droughts. When sufficient rainfall is available, the lowland zone is well suited to rice, sugar cane, coffee, maize, beans, bananas, and sorghum production.

AGRICULTURAL POTENTIAL AND PRODUCTION

In the 1970s, Préfol and Delepierre (1973) calculated that about one-half of the total area of Rwanda (1,385,000 ha) was potentially cultivable. The other half is either unavailable (lakes, water courses, undrainable marais, national parks, natural forests, urban areas, roads, etc.) or unsuitable for agricultural purposes (rocks, permanently eroded surfaces,

etc.). The potentially cultivable area includes large tracts of marais land and the Mutara hunting estate[1].

According to the 1984 National Agricultural Survey, 1.35 million ha were available to the agricultural sector. Of that, 1.1 million ha were used for agricultural production, while the remaining 0.25 million ha were used for homesteads, hedges, etc. Seventy-five percent of the cultivated land was used to produce primary food crops, and the rest was in pasture, afforestation efforts, etc.

Bananas, primarily for wine production, are the predominant crop, covering 20 percent of the cultivated land (225,000 ha). Annual production totals almost 2 million mt, and yields average 5 mt/ha/yr. Because bananas are often intercropped with beans or other crops, average yields per unit area are difficult to calculate.

Beans are the staple food in Rwanda, with 390,000 ha cultivated. This includes area for both growing seasons and area intercropped with bananas, maize, sweet potatoes, sorghum, etc. Average yields are about 670 kg/ha/season.

In 1986 and 1987, the Forestry Board of the Ministry of Agriculture, Livestock and Forestry carried out a detailed survey on the use of soils in Rwanda (Table 1.3). 1:20,000 scale maps were produced. However, the study used aerial photographs taken in 1978 and 1979.

THE FARMERS

In 1979, the National Agricultural Survey found 1.1 million agricultural households consisting, on average, of five members each. With

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[1]The Mutara hunting estate is a safari area where big game hunting is still allowed.

Table 1.3. Area Under Various Types of Cultivation in the Marais.

Land-use category	Type of culture	Area (ha)
Natural vegetation	natural forests,	158,827
	tree savanna,	28,532
	bush savanna,	223,761
	grass savanna,	134,196
	marais w/papyrus.	105,744
	steppe in the forests.	9,250
	Total:	660,309
Reforestation		69,409
Perennial crops	bananas,	230,251
	coffee,	16,417
	tea (assume 50 percent in marais*),	8,465
	quinine,	820
	pyrethrum,	862
	sugar cane,	1,147
	fruit trees.	195
	Total:	258,157
Annual crops, seasonal crops	fallow < 10 percent,	451,186
	fallow > 10 percent but < 30 percent,	338,880
	fallow > 30 percent but < 50 percent.	121,221
	Total:	911,287
Developed valleys and depressions	rice fields,	1,921
	annual crops other than rice,	64,454
	not occupied or fallow.	3,201
	Total:	69,576
Grazing lands	natural pastures or > 50 percent fallow,	399,718
	improved pastures.	5,489
	Total:	405,204
Other	fish ponds,	51
	homesteads and urban areas.	5,166
	Total:	5,217

(Table 2.5 continued)

Land-use category	Type of culture	Area (ha)
Non-exploitable areas	steep slopes,	1,324
	subject to erosion,	2,244
	rocks or laterite crust,	9,283
	drainage problems.	0 0
	Total:	12,851
Total area measured		2,392,013**

*Tea is also cultivated on hill slopes.
**Apparently did not include lake areas, which were planimetered in 1973 at 127,700 ha (Préfol and Delepierre, 1973:96).
Source: Direction-Générale des Forêts, MINAGRI, "Land Use Study 1986/87", Kigali.

1.3 million ha of cultivated land, "average" farm size was 1.2 ha. However, farm sizes vary widely. Twenty-six percent of all farms are less than 0.5 ha, and 16 percent have more than 2 ha. Most farming enterprises make very intensive use of available land, often in a manner more akin to gardening. Individual landholdings tend to be fragmented. On average, each farm consists of five blocs, with one or more fields in each bloc. Average field size is 7 ares.

GOVERNMENT INVOLVEMENT IN THE AGRICULTURAL SECTOR

The Ministry of Agriculture, Livestock and Forestry (MINAGRI) has primary responsibility for the Rwandan agricultural sector, but other ministries also play important roles. The Ministry of the Interior and Communal Development (MININTER), under which the communes function, is responsible for extension activities. The Ministries of Primary and Secondary Education (MINEPRISEC) and Higher Education and Scientific Research (MINESUPRES) are responsible for agricultural education. The Ministry of Youth and Cooperatives (MINIJEUCOOP) is active in the formation

and support of agricultural cooperatives and other groups. Because of the heavy dependency of the country on the export of agricultural products, the Ministry of Finance and Economy (MINIFINECO) also influences the agricultural sector. Other ministries, such as Planning (MINIPLAN) and Transportation and Communication (MINITRANSCO) are also active in the rural areas.

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CHAPTER TWO

THE MARAIS LANDS OF RWANDA

THE FORMATION OF THE MARAIS

Rwanda's underlying bedrock belongs to the Rusizien (200 billion years old) and Burundien series (170 billion years old) and was formed during the Precambrian Era. During the Cretaceous and Tertiary periods, the African socle became well metamorphosed and granitized and was subject to faulting and uplifting. Geological faulting was strongest in East Africa, where several mountain chains and rift valleys were formed. Rwanda lies on one of these mountain chains, and Kivu (to the west) and Victoria lakes (to the east) are in two rift valleys.

Geological faulting also invoked volcanic activity. The Rusizi Valley in the southwestern corner of Rwanda is covered with volcanic material from the Tertiary period. In the north, eight volcanoes erupted during the early Quaternary period (five of which are located in Rwanda) and formed the Birunga Mountain chain.

This tectonic cataclysm gave Rwanda ten distinctly different physical regions, and resulted in a complicated drainage system. Water originally drained to the north and became part of the Zaïre Watershed. When the Birunga volcanoes erupted, this drainage pattern was changed, and the rivers drained east to Lake Victoria and became part of the Nile Watershed. During the wetter periods of the Quaternary, Victoria, and Kyoga were much higher and larger than in the present day and together formed the ancient Buganda Sea. This was followed by drier periods, and the Buganda Sea

shrank to the present day Victoria and Kyoga lakes. The slopes of the rivers increased, improving drainage of the highlands. However, alluvial deposits that were formed earlier partly blocked the rivers and resulted in many valley lakes and the formation of large areas of marshes and organic soils.

DEFINING THE TERM MARAIS

According to the Petit Larousse (1972), marais can be defined as: *Low-lying regions with stagnant water accumulated to variable depths, with an associated vegetation. Also land where vegetables and early fruits are cultivated.* Gérard (1983) offers the following definition for marais-*all lands that are located in saturated on flooded longitudinal depressions containing running water.* Synonyms in English include marsh, swamp, and the more general term wetland.

In the Rwandan context, the dictionary definition describes most of the lands that are termed marais, but not all. This is because marais also has an administrative context, that is, all valley bottom lands are called marais lands. Also they are generally (but not always) publicly owned unlike hill land. Also included are small depressions (bas-fond) and valleys that are not saturated (vallée sèches), etc.

The Rwandan law on the development and management of the marais, currently under preparation, defines them in the following manner: *marais consist of alluvial valleys, areas alongside rivers and lakes characterized by both the storage and continuous flow of water during the dry season and distinct soil and vegetation that is different from the surrounding hills. Two zones are distinguished: the marais itself and zones of up to 10 meters at the fringes of the marais which are used as a right of way.*

In this study, we use the Rwandan definition of marais as formulated by the law, and all valley bottomlands are included.

MARAIS SIZE

It is important to classify the marais according to size because development efforts must increase in scale and in environmental and technical complexity as the size increases. Because marais size and river magnitude are directly correlated, it is also necessary to study river drainage patterns.

Water leaves the country at two well defined locations. For the Nile Watershed, the exit is near Kagitumba through the Akagera River, while the Zaïre Watershed drains through the Rusizi River via Lake Kivu. Also, two small watersheds in Byumba prefecture drain directly into Uganda (Mulindi and Kiruruma).

Going upstream from the outlet locations, each watercourse fits into a hierarchically structured drainage pattern. We divide watercourses into seven descending levels, summarized in Table 2.1 and shown in Figure 2.1.

Table 2.1 Hierarchical Classification of Rwandan Watercourses.

Orders	Watercourse	Marais Features
I	major rivers of Rwanda	very large areas, uninterrupted marais
II	important watercourses	medium to large marais, depending on geological location
III	secondary watercourses	medium size marais areas
IV	tertiary watercourses	small marais
V	small streams	small and very small marais
VI	vallées séches (dry valleys)	too dry to have wetlands
VII	bas-fonds (local depressions)	very small marais

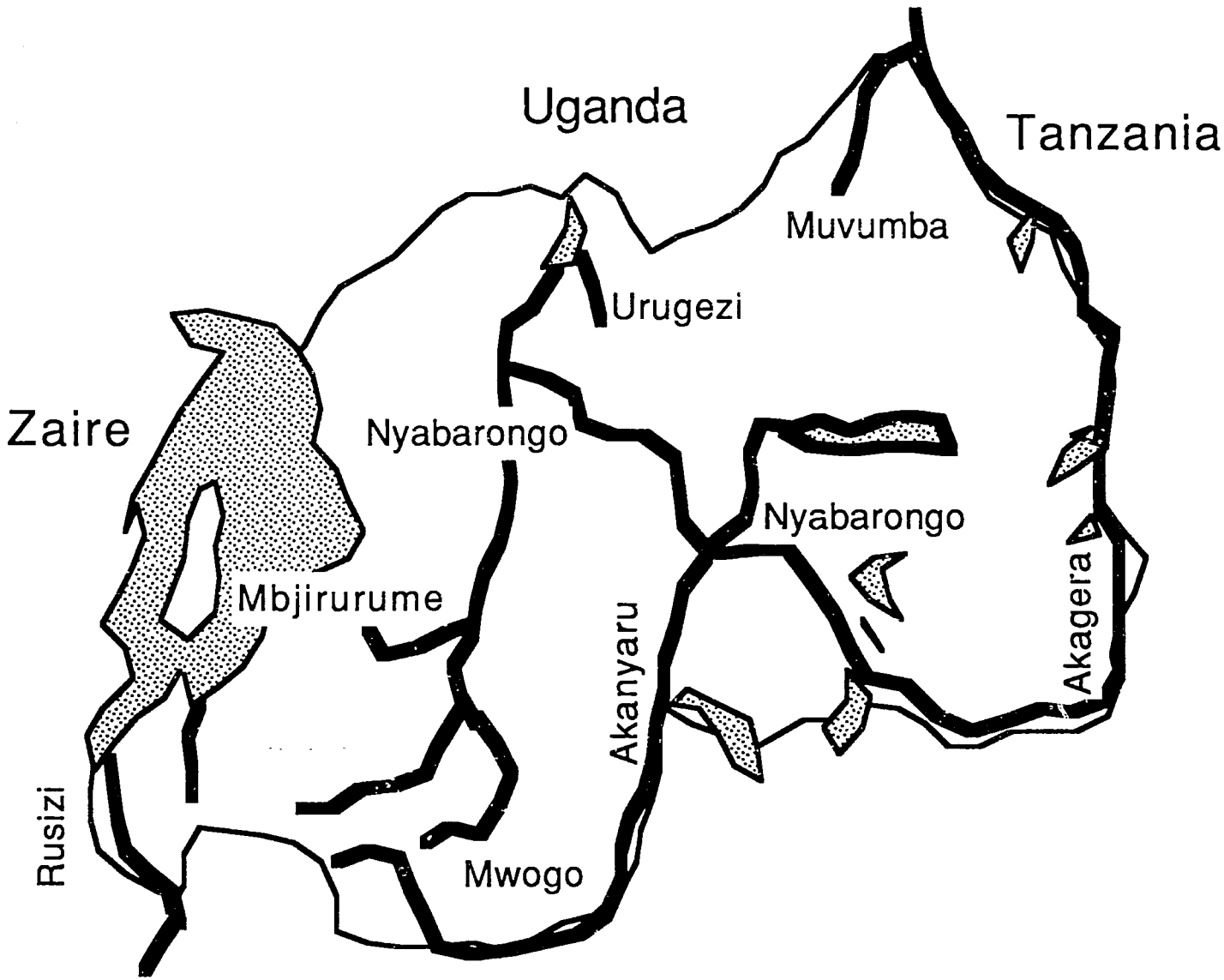

Figure 2.1 Hierarchical Structure of Marais Lands

Order I consists of the major rivers, such as the Akagera, the Akanyaru, the Nyabarongo, and the Rusizi. Order II are the major contributing watercourses such as Muvumba, Mugo, Mbirurume, Rukarara, Mukungwa, and the Nyabugogo. Order VI, the dry valleys, have a distinctive stream bed, but dry season discharge is small. Moreover, valley land is generally too dry for agricultural purposes without supplemental irrigation. The bas-fonds (local depressions) have very high water tables and marais-like features, but do not have a distinctive watercourse.

In this report, the large marais are associated with watercourses of orders I and II. All other marais are classed as small marais. We will concentrate on the small marais, in which technical and managerial intervention by farmers is possible.

THE ECOLOGY OF THE MARAIS

To describe the ecology of the marais, Cambrezy's (1981a) classification is shown in Table 2.2. He categorizes the marais according to size and elevation, i.e., large and small and altitudes over and below 2000 meters. Large marais are only located at elevations less than 2000 meters.

Table 2.2. **Typology of Marais According to Cambrezy (1981a).**

Type	Designation	Location	Area (estimate)
I.	large marais	east Rwanda	50,000 ha
II.	high-altitude marais	*west and north Rwanda	30,000 ha
III	small marais	central and south Rwanda	45,000 ha

Marais along Kivu Lake and Bugarama Plain are included in Type II, west Rwanda.
Source: Cambrezy, 1981.

The large marais in eastern and central Rwanda directly result from the inversion of the drainage pattern on the eastern slope of the Zaïre-Nile divide. The large marais are located along the biggest rivers, the Nyabarongo, from Kigali downwards, the Akanyaru, which drains the southern part of Rwanda and large parts of the Burundi highlands, and the Akagera. Marais lands form an uninterrupted chain of several hundred kilometers, stretching from the border of Burundi in the south, to the Akagera outlet at the Uganda/Tanzania border in the north. A major portion of the marais along the Akagera River lie within the Akagera National Park.

The soils in the large marais are, without exception, organic, extending several meters into the profile. Meyer (1958) reports deposits of more than 10 meters at many locations. The marais behave like large flood plains during the long rainy season (February to May) each year, when they are covered with 1 meter or more of water for several months. The large marais perform an important buffer function in the Rwandan hydrological network, reducing peak discharges and helping to maintain dry season river flow.

Most of the large marais are still covered in natural vegetation and have not been developed for agricultural purposes. The natural vegetation is papyrus (Cyperus papyrus) swamp with a few palm trees (Phoenix reclinata). Cambrezy (1981a) reports that the fringes of the marais are often covered with associations of Polygonum pulchum and several Cypecus species (latifolius, platycanlis dives, etc.).

Unlike the large marais, the small-marais are almost all cultivated, with no remaining natural vegetation. In the past few decades most have been cleared, reclaimed, and intensively cultivated. Only in the eastern part of the country and at high altitudes on the Nile-Zaïre divide can small

undeveloped marais still be found. Though organic soils are present in small marais, in general, mineral soils are more dominant (Chapter 6).

The hydrologic regime of the small marais are determined by watershed conditions, and they are very wet in the rainy season. Clearing these marais for cultivation reduces their overall natural buffering capacity. However, initial data collected during this study indicate that storage capacity in the small marais does not change too much between seasons. The effect of rainfall in the catchment area is intense but short lived. A cloudburst quickly results in a peak discharge, but in a few hours, outflow returns to a more or less constant quantity, with little fluctuation between seasons. As a result, several small marais are subject to flash flooding after heavy thunderstorms or after several days of continued rainfall. Flash flood problems are even more pronounced in the flatter, medium-sized marais with large drainage areas.

Most small marais are drained by a single stream, which carries water throughout the year (although the discharge can be quite minimal at the end of the dry season). The central drain bed is often well developed, lying 1 to 2 m. below the marais surface. The natural vegetation, gone in most marais, is dependent on altitude, with papyrus varieties dominant at lower levels and grass varieties at higher elevations.

Small marais at higher altitudes in the Zaïre-Nile divide and in the volcanic north contain predominantly organic, strongly acidic soils of 10 m or more in depth. High-altitude marais are generally small- to medium-sized, with the exception of the large Usugezi marais in the north (6300 ha, outlet at the Rusumo, 2044 m.). Some high-altitude marais still retain their natural vegetation because climatic conditions do not favor agricultural use, soils are too acidic, or simply because they are located

in protected forest areas. Vegetation includes tree species, with many types of ferns, lichen and mosses, grasses, and papyrus.

For administrative reasons, one location in Rwanda with an altitude of less than 1000 m, the Bugarama Plain in the southwest, is also considered to be a marais area. The plain, which is much more tropical than the rest of Rwanda, belongs to the much larger Imbo Plain of Burundi and has distinctive vertisol soils.

The Rwandans use several special terms to describe various marais. A dry valley is called **imburamazi**, and a swampy marais is termed **igiyogo**. A spot where cattle can drink at a water course is called **umwaro**. The common name for marais land is **igishanga**, and its fringes are called **igikuka**. Marais where grasses grow are called **igigaga**.

EXTENT OF MARAIS LANDS IN RWANDA

There is no official or complete survey of marais land in Rwanda. However, some available data allow us to construct a rough appraisal of the extent of marais area. Préfol and Delepierre (1973) estimated total marais area at 83,840 ha (Table 2.3), based on data gathered during a national planimeter survey on land availability and use. The measurements were made on a 1/250,000 scale map of Rwanda.

Marais areas in Akagera National Park were not included. Because of the difficulty in planimetering marais and bas-fonds lands smaller than 14 ha, these also were not included. Utilization level of the marais lands was estimated at 20 percent in 1973. The utilization rate would likely be higher if the small marais areas were included.

A report on the exploitation of marais and bas-fonds lands during the dry season of 1986 (Direction Générale du Génie Rural, 1987) indicated that

there are innumerable marais smaller than 14 ha. In the prefecture of Giterama alone, the total area of very small marais amounted to more than 600 ha. The researchers found that the small and very small marais are almost all fully cultivated, with values ranging from 80 to 100 percent. Unfortunately, there is little consistency in the data from the Génie Rural's report.

Table 2.3. Distribution of Marais Lands (1973 Survey).

Marais	Planimetered area
Nyabarongo marais	24,698 ha
Akanyaru marais	12,546 ha
Akagera marais, excluding area in the national park	12,227 ha
Kagitumba Valley	7,100 ha
Rusizi marais	6,294 ha
5 marais 1000 - 5000 hectare	9,904 ha
6 marais 500 - 1000 hectare	4,288 ha
26 marais 100 - 500 hectare	5,322 ha
16 marais 50 - 100 hectare	1,143 ha
11 marais 14 - 50 hectare	318 ha
Total = 70 marais and valleys	83,840 ha

Source: Préfol et Delepierre, 1973.

The Forestry Board of MINAGRI 1986-1987 survey based on 1978-79 aerial photographs. Table 1.3 indicates that about 40 percent of the total marais area was cultivated in 1978/79. Ten years later, it appears that most of the large marais area is still unclaimed, but small marais use has increased

dramatically. We estimate that the overall use rate for all marais lands (small and large) is about 50 percent.

LEVEL OF DEVELOPMENT IN THE MARAIS

Initial efforts to reclaim marais lands were made by farmers themselves. For technical and organizational reasons, they limited their activities to the small marais. Most of these are now in use for agricultural purposes. The extent to which the marais are used is directly related to food needs. Based on this, evolutionary development stages in the marais can be distinguished.

Stage I: Natural habitat. The marais are covered with natural papyrus vegetation and herbaceous plants. The large marais in the eastern and northeastern parts of Rwanda are still in this stage. There, population pressure is still relatively low, or the marais are specifically protected against intrusion. Some marais along the Nyabarongo and Akanyaru rivers in central Rwanda still have natural vegetation because adequate drainage is extremely difficult to install.

Stage II: Natural habitat interspersed with extensive use of the marais for periodic grazing. Marais in this stage can still be found in eastern Rwanda, where population pressure is relatively low and not all available hill land is already cultivated. Hill slopes alone provide sufficient family food, and marais lands are only cultivated in deficit years. Under normal conditions, lack of human resources and markets for extra produce limit additional use.

Stage III: Mixed use of the marais for grazing lands and crop production. Currently, most marais on the Central Plateau are in Stage III. The conversion of marais from grass to arable land occurs gradually as

available hill slope land is used up. Food production could be increased by improving output per unit area on already cultivated land, but economics dictates that farmers open new lands in the marais. This is because intensification would require the purchase of inputs with scarce cash (primarily chemical fertilizer), while marais lands can be initially cultivated during the dry season when labor is traditionally surplus and drainage problems are least severe. Fifty to 75 cm high beds that are 4 to 7 m wide are constructed to drain the land. Ditches range from 0.75 to 2.0 m. in width.

Stage IV: Intensive use of the marais for crop production. As available marais area is all cultivated, it pays to begin improving water management by installing well-balanced drainage and irrigation works, by enlarging beds (i.e., reduce the amount of land "lost" in canals between the beds), or by increasing the use of mineral fertilizers. Marais used for rice or tea production fall in this category. Because of large governmental subsidies, producers can afford to improve water management and use purchased inputs.

In 1978/79 an extensive survey of uses of marais lands was carried out in Burundi. Van Leeuwen (1984) found when available land in the hills fell below 2 ares/person, then the cultivation of the marais became much more intensive. When rainfall was unreliable the farmers began cultivating marais lands when holdings fell below 4 ares/person. Further, when the marais were difficult to drain, farmers would choose to more intensively cultivate hill land instead.

The use of an evolutionary classification is also supported by other activities in the marais. In one province, drainage of the marais was extremely difficult to carry out, and farmers operating in Stage II chose to

Table 2.4. Marais Development Projects.

Project name and donor	Description
PAST PROJECTS	
Petits marais Gitarama (France)	Drainage of several small marais (1,183 ha).
Sugar plantation (China)	Development of sugar cane fields (1,200 ha). Nyabugogo and adjacent marais.
Water supply (MINITRAPE)	Construction of pumping plants in valleys; urban water supply systems.
ONGOING PROJECTS	
Project Nyabarongo (Rwanda)	Reclamation by local farmers of easily drainable areas in the Nyabarongo Valley. (2,000+ ha reclaimed).
Nyabarongo study (World Bank)	Establishment of global development plan for the lower Nyabarongo Valley. (20,000 ha).
Project Dervam (Canada)	Resettlement of 640 families in Mutara, construction of a 250 ha modern irrigation system + other infrastructure + rice research.
Bugarama Valley (North Korea Financing: Rwanda)	Construction of modern irrigation; systems ultimately to cover the entire valley (target: 1,200 + ha).
Rice perimeters (China)	Rice projects in Nyabugogo marais; Rwamagana area (several marais); Cyili marais.
Rice-Butare Préfecture (France)	Expansion of Cyili rice project into other marais in the Butare préfecture.
PIA - Gikongoro (FAO)	Drainage and irrigation in the top of the Mwogo Valley; fodder production in marais.
Project Kigali-Nord (France)	Field trials in Bahimba marais; drainage improvements small marais, Kigali préfecture.
Project Butare Global (European Community)	Marais improvements; management of already improved marais (Rwasave).
Small marais project (Canada)	Improvements of Kanyonyomba marais.
Fish culture (USAID)	Renovation and improvement of existing 2,000 + fish ponds.
Préfectoral prisons (Rwanda)	Labor-intensive marais use.
Communes (Rwanda)	Marais development with local farmers.

intensively cultivate the hillsides. In two other cases the rainfall pattern made cultivation of the hill slopes risky, even during the rainy seasons. However, the marais had a more reliable water supply, resulting in a doubling of cultivated area to 4 ares/person.

In the 1970s the French assisted in the drainage of several small and medium marais in Giterama Prefecture. This project has technical problems because designers failed to realize that a drainage infrastructure alone would not allow efficient use of marais lands. After 1970, many other marais development projects were initiated by numerous donors and the government. In Table 2.4 we list a few of these.

The Government of Rwanda has, for a long time, given scant attention to the development, protection, and management of resources in the marais. In 1984 the first initiatives were made, and planners began to realize the need for the development of an appropriate marais technology. Many marais development project have yielded disappointing results, and there are numerous technological issues not yet solved. Another set of problems (soil fertility, erosion, etc.) are frequently created as a spinoff of marais development, and solutions are not always apparent.

Chapter 3 elaborates on the need for a concerted national approach to future marais development.

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CHAPTER THREE

A NATIONAL STRATEGY FOR THE MARAIS

REASONS FOR A NATIONAL STRATEGY

Because of the rapid increase in population pressure on cultivable area in Rwanda, the intelligent exploitation of marais lands has become an important issue in the Government. Methods and policies need to be devised to guide the optimal social, economic, and environmental use of marais lands within the framework of the goal of food self-sufficiency. We should point out, however, that the Government has two sometimes conflicting roles: on the one hand, it owns and manages the marais with the aim of optimizing production without over-exploitation; on the other, the Government must, under all circumstances, work to improve the present well-being of its citizens. With respect to the marais, these two roles are closely linked.

In Chapter 5, we mention that the development of the small marais did not seriously begin until the 1960s. Since then, almost all of the small marais have been overrun by subsistence farmers in need of additional land. However, these farmers have not used the land to its fullest potential. This conclusion is based on the following observations:

- Most of the small marais are only cultivated during the long dry season (May - December) and consequently yield only one harvest per year, compared to two harvests in the collines. With proper management, two harvests are possible in the marais.

- Subsistence crops are the norm on the marais (sweet potatoes, sorghum, etc.), while cash or high-value crops (e.g., vegetables) are rarely grown.
- Yields are relatively low and do not differ much from those obtained on the hill soils, although there is little available data to confirm this. Field studies, carried out within the framework of this project, indicate that sweet potato harvests are low, from one ton to 20 t/ha, with an average between 6.5 and 11.5 t/ha (Appendix C, Table C.2).

These three observations are obviously generalizations. There are a few well-managed marais where more than one crop is harvested each year, farming practices are very intensive, and yields are quite high. These farms, although rare, confirm that the marais can support intensive exploitation without environmental degradation.

Most of the small marais were reclaimed and cultivated by the local inhabitants without outside assistance. Farmers used these marais lands to grow food for their own use and extensive farming practices predominated. A few small marais were used for experimental projects. These operations, often very costly (Table 10.1), rarely resulted in optimal use of the developed lands either. Even in the rice perimeters, considered to be the most successful development projects, harvests rarely exceeded 2mt/ha of paddy rice per season (5mt/ha/season is a normal yield).

The under utilization of the marais in combination with ever pressing needs for more cultivable lands, makes the development of a national policy for use of the marais lands a pressing Government priority. In the

following pages, we will define some objectives and present elements of such a plan, as well as describe steps already taken by the government.

THE OBJECTIVES OF THE NATIONAL STRATEGY

Before a strategy is formulated, objectives must be clearly and precisely defined. Without objectives, it is impossible to implement any strategy in a systematic manner. Likewise, evaluations of work in progress as well as necessary readjustments will be difficult to accomplish.

Objectives of a national strategy for the small marais have never been clearly defined, which is the purpose of this study. These objectives could also be used for the development of large marais. Objectives of the national strategy for the development of the marais follow:

1. To encourage and assure an optimal and efficient use of small marais, while satisfying the needs of both the local inhabitants (the users) and the entire nation. This is the overall goal for the strategy, and all others are based on it.
2. To safeguard and maintain the fragile environment of the small marais so as to assure their usefulness for future generations. The second objective is as important as the first. Indeed, they must always be considered in tandem.
3. To determine where Government involvement would improve the situation in the small marais versus where the private sector would be most effective in implementing needed change.
4. In those areas and instances where State involvement is necessary or required, assure that the most optimal and efficient means to achieve it are put in place.

5. To create a framework of coordination and cooperation within Government agencies involved in the development cf the marais.
6. To create efficient administrative structures for the marais that best satisfy the objective of their optimal use.
7. To obtain, where possible, income for the State from the development of the marais. Initiate a system of loans to farmers to finance development.

Overall, the marais are an enormous as yet untapped resource. Farmers on these lands obtain a livelihood from their agricultural endeavors. Because the State owns these lands, it is quite normal that some revenue be sought in return for their use, within the context of the well-being of the nation as a whole. In the beginning, money or agricultural products collected from land users should be used to fund the State's participation and investments in the marais.

ELEMENTS OF THE NATIONAL STRATEGY

The national strategy must encompass all aspects relating to the development and operation of the marais. Some of the most important elements in this strategy are included in the following basic categories:

- **Technological**: How and by what means can (a) optimal hydrologic conditions be created in developed marais and in those not yet cleared; and (b) how can the environment in the protected marais be maintained or how can safe alternative uses be devised?
- **Economic**: What types of farming are most profitable in the marais, and where can new markets be found for farm products?
- **Social**: What are the most favorable social conditions for users of the marais? We should point out that, in the final analysis, it is

the users of the marais who determine whether or not the wetlands (and the development projects set up there) are put to optimum use.

- **Pedological**: What types of soils exist in the marais; how suitable are they for sustained agricultural use; and how must they be managed to protect their long-term productivity?
- **Agronomic**: What crops, and what varieties are most suitable for the small marais? What measures must be taken to adapt the marais soils to these crops? What inputs must be used and in what amounts? What are the economic effects of these improvements on farmers and on the nation?
- **Ecological and environmental**: The marais constitute a very fragile part of the natural domain of Rwanda. The impact of every action undertaken in the marais should be evaluated.
- **Administrative**: What is the best way to manage projects in the marais and the marais themselves? What role can government and non-government agencies/individuals play in this management? What local organizations are best suited to administrative roles in the small marais and for what aspects should they assume responsibility?
- **Institutional**: What institutional arrangements would most effectively ensure the efficient execution of programs that are part of the national strategy for the marais?
- **Legislative context and landholding rights**: In what form are marais holdings to be accorded to the beneficiaries? Who will be responsible for ensuring that farmers make proper use of marais resources? Who will resolve disputes and determine compensation?

- **Research**: What kinds of research activities (applied and theoretical) must be undertaken to improve and optimize use of the marais? What hydrologic studies (large and small scale, mathematical models, etc.) need to be completed? What agronomic studies (soils, crops, etc.)? What multidisciplinary studies?
- **Planning actions**: What activities must be completed immediately? How should operational planning be developed (personnel needs, financial and logistical means), and what results are needed over the short, medium, and long term?
- **Forms of evaluation**: How can progress on projects be measured, improvements credited, and defects detected and remedied? What financial controls are necessary? Which impact studies would be most helpful?

The foregoing list of issues that should be considered in the formation of a national strategy for the development of the marais could easily be developed in greater detail. Most are individually covered in later chapters in this report. However, it must be kept in mind that all of these aspects are interrelated, one with the other. None should be considered in isolation when forming policy of any kind, and in particular, in the fabrication of the national strategy.

DIFFICULTIES IN DEVELOPING THE MARAIS

The Marais User's Situation

In order to clarify this interrelationship, let use first present the example of an ordinary farmer. This farmer uses several small parcels of land (***billons***) in several small marais. He inherited most of this land

from his father, the rest he cleared and reclaimed himself. The traditional form of inheritance left him several small but widely dispersed parcels.

In the farmer's mind, the parcels in the marais are his property (was it not he or his father who cleared them?) in the same way that hill lands belong to him. But he is nevertheless aware that in reality all the marais are State property. Actually, the Bourgmestre of his village allows him the privilege of farming his parcels. He knows that this favor can be withdrawn at any moment. He has already lost a few small parcels to youth groups and an agricultural cooperative. The farmer received no compensation for the parcels he was evicted from. Of course, he demanded compensation, but was told it was not possible because all marais belong to the State.

The farmer meanwhile continues to enjoy the use of the other parcels at his disposal in the wetlands, without paying any fee. He grows sweet potatoes during the dry season and, in a part of the marais less threatened by floods in March/April, grows sorghum during the second growing season. It is hard work because the wetlands must be deeply plowed. Yields are meager because soil fertility is low through years of cropping without fertilization. The farmer knows his parcels need manure (as do all tropical soils) but, because he does not even have enough for his hill fields, he never uses any on his marais plots. Besides, his animals are nowhere near the marais, and transportation of manure would be difficult if not impossible. Likewise, because he is uncertain about his future rights to use the marais land, he puts all his manure on hill land that he clearly owns.

In the marais, the farmer grows crops for his own consumption, particularly those varieties that involve the least risk. He does this because the soil in the marais is no better than that in the hills. He

could, of course, improve the soil and grow a cash crop, but this would require him to invest in costly inputs such as fertilizer or manure. Also, where could he, a small farmer, market his cash crops (vegetables, cereals, etc.) in a country where virtually the entire population lives in a subsistence economy and where purchasing power in rural areas is very low? Here again, uncertainty about his future rights to the marais plots and the fact that his holdings are widely scattered discourages the farmer still more. Given this, the farmer's choice, to do nothing, is the best for his situation. He grows cash crops (coffee, bananas, etc.) on his hill fields (near his *rugo* (homesite), low-risk lands) and less valuable crops for home use in the marais (high-risk lands). Moreover, the farmer is not completely free to choose what to grow on his marais holdings. His options are limited by what other farmers around him are doing because some crops cannot be grown in close proximity (problems of predators, insects, diseases, etc.). Because the farmer's home is distant from the marais, he is not able to watch his fields and risks theft if he chooses to plant a high-value crop.

Finally, the hydrological situation in the marais seriously limits the farmer's options. He presently almost automatically chooses crops and varieties that are drought tolerant, even if expected yields will surely be below others.

Constraints at the Level of the Users

The above example illustrates user constraints in the marais, which explain in large measure why farmer/users have not chosen to invest in improvements. Major constraints are listed below:

1. **Farmers have no secure or clear legal rights to the marais lands that they cultivate.** This creates special impediments to

investments in necessary land improvements by anyone. Such improvements include fertilization, use of soil-saving farming practices, and special measures to prevent environmental degradation and or further subdivision.

2. Markets for cash crops do not exist, ergo **there is no incentive for farmers to grow them.** Marketed, higher-value crops generate more profit for growers, increasing labor requirements per hectare of intensively cultivated land and encouraging farmers to invest in needed improvements to increase yields still further.

3. **Farmers have not organized themselves into cooperative groups** to make physical improvements or to market produce. Users, as individuals, do not have the financial or labor resources to physically improve their holdings or find markets for their produce alone. The lack of cooperative organizations seriously impedes (a) the execution of simple development projects (small irrigation and/or drainage ducts); (b) the initiation of improved agricultural practices (rotational irrigation, safeguards against theft, etc.); and (c) the intensive cropping of cash and high-value commercial products.

These are the three principal constraints that exist at the users' level. There are others, of course, but they are ancillary to these. The lack of trained personnel, for example, is reflective of the absence of any internal organization within the marais. Without organized cooperation among farmers, it would be difficult to introduce improved farming techniques to more than a few individual farmers.

Earlier, we outlined a list of elements that should be covered by the national strategy, but this list was constructed from the Government's

viewpoint. For the users, but also for the Government and the nation because the users' will ultimately determine the success of any program, it is of paramount importance that their constraints likewise be considered with equal efficiency and clarity in the formation of a national strategy.

The Principle of the Most Restrictive Element

The reality of the duality of the relationship between development and administration of the marais is nowhere more clear than in the principle of the most restrictive element (Figure 3.1). Addressing or resolving just one aspect of the range of constraints can only result in a partial improvement in the situation. For example, if a network of irrigation and drainage ducts are installed in a marais, optimizing the hydrologic situation, only a partial increase in productivity will result unless all other aspects are already in perfect order. Quickly, the next most limiting factor, perhaps the lack of a market, would become restrictive.

Here, then, we find the reason why many development projects in the marais have failed. Projects are frequently targeted at the identification and resolve of only one or two constraints. Our conclusion, based on past experience, is that the national strategy for the marais, as well as related development and improvement projects, must, at the outset, address all aspects and elements related to the development and management of these lands. Comprehensive approaches to the development of the marais are therefore recommended.

STEPS TAKEN BY THE GOVERNMENT

Despite three decades of reclamation and work in the small marais of Rwanda, no systematic approach has yet been put forth for their development

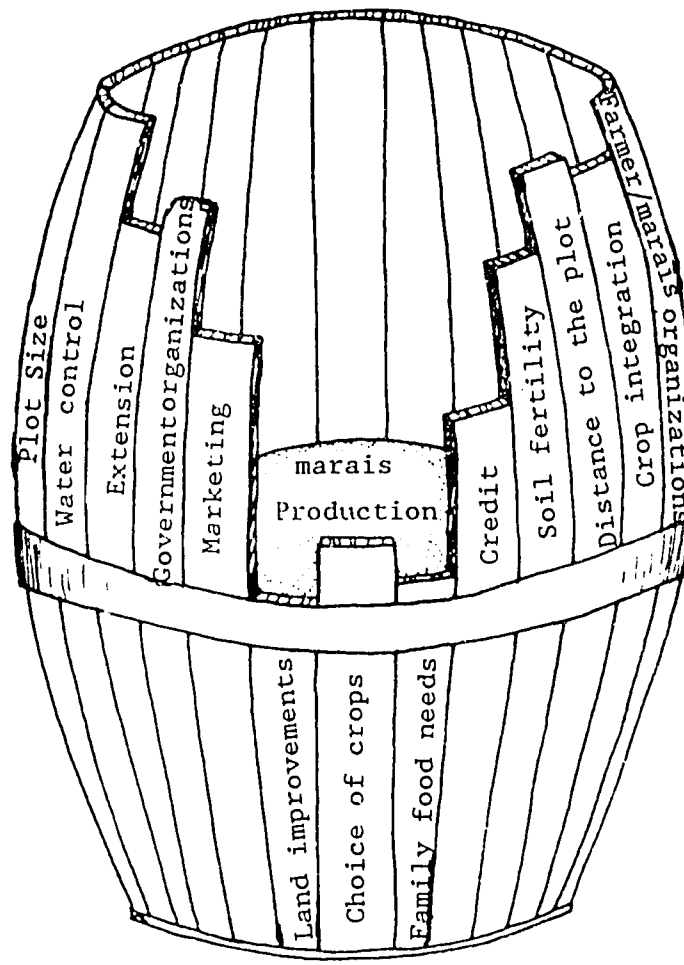

Figure 3.1 The Influence of the Most Restrictive Aspect on Production of the Marais. Marais productivity (represented here by a beer barrel) is a function of the most restrictive factor. If this restriction is removed, use of the marais (and productivity) will not immediately become optimal because another factor will become most restrictive.

and management. There are many reasons for this: on the one hand, there was no institutional capacity within the Government; and on the other, although donor agencies made considerable investment in the small marais, projects were oriented toward very specific aspects of development with narrow goals. This helps to explain why the same technical and socioeconomic errors that were made thirty years ago, continue to be made today in the marais. Understanding of the environment of the marais is not much better today than it was in the 1960s, and organizational infrastructure at the Government and local levels still does not exist. The Rwandan Government is aware of this situation, particularly since 1984 when, following insufficient harvests in the hills, the population was forced to resort to plots in the marais.

Besides creating a special budget for the development of the marais (Nyabarongo and small marais), the Government has initiated three draft projects to help create a policy vis-a-vis the marais:

- The formulation of a national strategy for the marais that will examine technological, socioeconomic, and institutional aspects, and that will result in an improvement in operations, in agricultural productivity, and in investigations into alternative uses of the marais.
- The codification of a law regarding marais improvements, which will, on the one hand, create the legislative framework to organize a more concerted approach and, on the other hand, regularize farmer ownership and rental rights.
- To make an inventory of all the marais in the country, taking into account what is legally defined as such. This appraisal will likewise collect data on the physical and socioeconomic

characteristics of the marais, as well as their use (actual and potential).

This study constitutes the first step made by the Government in the formulation of a policy concerning the development and management of the small marais. At the same time, in 1987, a bill dealing with improvements in the marais was drafted in collaboration with the Legislative Service of the FAO in Rome. With respect to the marais inventory project, a detailed proposal was drawn up in 1987. Given the scope and importance of such a project, the possibilities for technical and financial assistance from a donor agency are now being explored.

CHAPTER FOUR

WMS II STUDY OF THE SMALL MARAIS

FORMULATIONS AND OBJECTIVES OF THE STUDY

Jones and Egli (1984:23) and Willardson(1986:27) both note that a lack of basic knowledge hampers successful development of marais lands. As a result of these findings and USAID/Rwanda interest in the integrated approaches to marais development, a one-year applied research program was initiated in 1987 through the Water Management Synthesis II project at Cornell University to improve basic knowledge about all aspects of the marais and to gain insight into some of the special problems associated with development of the small marais in particular. The project fielded a multidisciplinary study team (Joint Field Study Team, Annex A), including experts in the fields of irrigation and drainage, sociology, agricultural economics, and agronomy.

Funding was provided by the Water Management Synthesis II project and the study was carried out under the auspices of the Rwandan Ministry of Agriculture, Livestock and Forestry (MINAGRI) in collaboration with the National University of Rwanda (UNR) in Butare and the Rwandan Institute for Agricultural Research (ISAR) in Rubona.

The study had the twin goals of both creating guidelines for the Rwandan government for the productive and successful development of the small marais and to initiate collection of base line data to ultimately aid in the conception of future marais development projects.

In particular, three questions were chosen for analysis:

- If introduced to small, farmer-managed marais, what specific agricultural practices could improve production without damaging the environment or destroying stable, sociopolitical relationships?
- What technical, economic, financial, agricultural, and institutional changes would be necessary to allow introduction of the recommended agricultural practices?
- Because introduced changes would have to successfully integrate with other production already underway in the marais, what would be the best way to approach development without upsetting the existing balance?

The final goal of the study was to present the Rwandan government with a set of recommendations tailored to guide long-term development of the small marais.

From the outset, because of the social and environmental complexity of the marais, it was evident that not only would we not be able to formulate concrete answers for all problems, but also it would be counterproductive to provide a rigid set of guidelines to the Rwandan government.

For these reasons, we narrowed the study focus to items we felt would be most helpful to future research and formulated a set of study goals.

- Only make recommendations on problems for which adequate knowledge is available.
- Identify important issues for future study on which sufficient knowledge is not available nor could be gathered during the study. Make suggestions as to how this information might be acquired.

- Indicate what government intervention in the development of small marais might be helpful and what might be harmful. Which institutional structures would be most appropriate.

The different activities carried out during the study years are shown in Figure 4.1. The study passed through three broad phases. During the first phase, January-March, a reconnaissance inventory was made of marais in Rwanda and Burundi. During April-September, field trials and measurements (Annex C) and a socioeconomic survey were completed. The joint, interdisciplinary field team gathered to debate issues and exchange ideas. In the third phase, data were analyzed, papers and reports were produced, and a formal advisory report was delivered at the National Rwanda Marais Conference in Kigali in which 45 Rwandan officials participated. Further information on reports and papers produced by the study may be found in Annex B.

STUDY PARTICIPANTS AND OUTPUT.

Study participants were chosen on the basis of expertise, while making the greatest possible use of Rwandan specialists, with supplemental assistance from American colleagues. The Joint Field Study Team formed the nucleus of the entire study activity. Participants are listed in Annex A. The team was composed of four Rwandan scientists and officials from four different institutions, and four American scientists. The Rwandan participants were from the Ministry of the Presidency, ISAR, the Department of Agronomy of UNR, and the Department of Economic, Social and Management Sciences of UNR. Americans were from Cornell University departments of

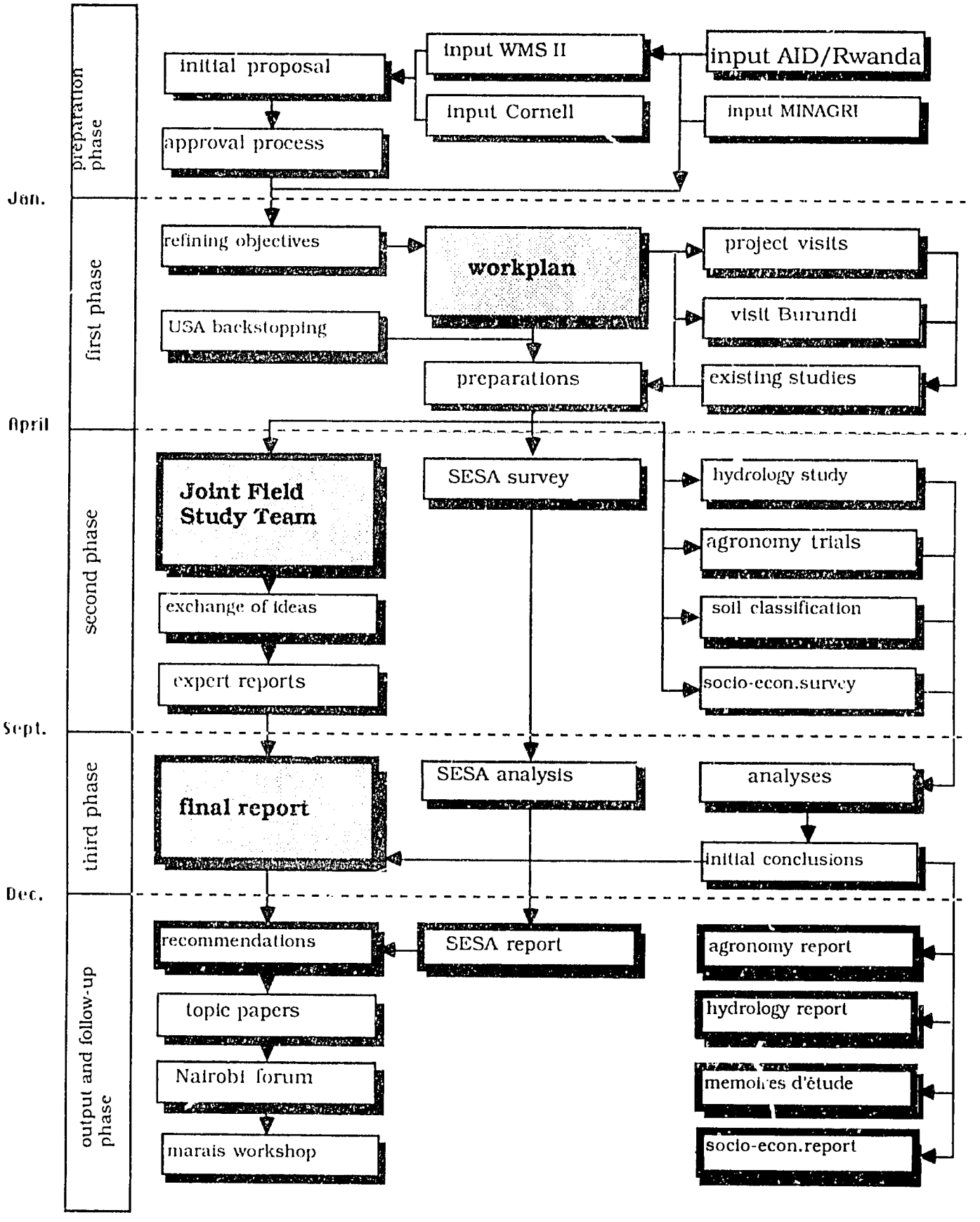

Figure 4.1: Input, Activities, and Output of the WMS II Study, 1987.

Agronomy, Rural Sociology, Agricultural Economics, and Agricultural Engineering and the University of Auburn departments of Rural Sociology and Agricultural Economics.

The Team further benefited from the participation of a representative from the Rwandan Government, who served as a liaison between the government and the project field study coordinator, as well as two graduate students from the National University of Rwanda.

Results of this study, along with the two other soil field studies in Zimbabwe and Niger, were presented in Nairobi, Kenya at the Forum on Irrigated Agriculture in Africa on January 18-22, 1988. The forum was organized by WMSII, with the main purpose of developing networking among African irrigation specialists. Three papers were presented (a) importance of the marais for Rwanda and institutional implications; (b) water management practices in the marais; and (c) socioeconomic context of marais development.

Finally, a workshop was organized on February 23-26, 1988 in Kigali, Rwanda under the auspices of MINAGRI and WMSII to synthesize, debate, and present the results of the year-long study. The project also organized the Workshop on the National strategy of the Small Marais in which Rwanda functionaries and scientists participated. A plan for the development of the marais was formulated based on the recommendations of the project and sent to the minister for approval.

FIELD STUDIES

Two small marais close to Butare in southern Rwanda were used for agronomic and hydrologic field studies to gather some basic data. For the agronomic study, field plots were set up to measure yields of several crops

using various amounts of fertilizers. For the hydrologic study, instruments were installed in the marais to measure groundwater table heights and outflow rates. The results of these studies are summarized in Chapter 7 and Annex C.

A socioeconomic survey was conducted in four small marais in Butare (3 marais) and Gikongoro (1 marais) prefectures in the three dry-season months (July-September). A total of 116 interviews were performed.

Because of the lack of basic information on the use of marais lands in Rwanda, a nation-wide survey on marais land use, marais plot holdings, cropping practices, and dry season yields is being carried out in cooperation with the National Agricultural Survey Department of MINAGRI.

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CHAPTER FIVE

HISTORY OF THE DEVELOPMENT AND USE OF THE MARAIS

EARLY AGRARIAN SOCIETIES

Rwanda has a long history of human habitation dating back to 685 B.C. (Van Grunderbeck, et al., 1983). At first, inhabitants were hunter-gatherers organized in loose bands. These primitive people had a minimal effect on the environment, including the marais. New archeological work (Van Noten, 1972; Van Grunderbeck, et al., 1983), however, indicates the presence of an astonishingly large concentration of sedentary people on the Central Plateau, particularly around the hills near Butare between 225 and 400 A.D. Deep clay soils to the west of the archeological sites encouraged the establishment of settlements based on permanent cultivation of the fertile land. Iron ore was easily accessible in quartzite deposits in the savannahs to the east (Van Grunderbeck et al., 1983), which also provided lush pastures for livestock. Although archeological remains cannot be recovered from the marshy marais, early peoples must have exploited them for food and housing materials.

For a long time, inhabitants of the hill slopes continued to move from place to place, whenever soils were exhausted by continuous cultivation. Population density was so low that there was always plenty of fertile land for everyone. The marais, which are more difficult to manage because of their marshy character, were not intensively used by any groups.

FARMERS VS. PASTORALISTS AND THE OPENING OF THE MARAIS LANDS

Most researchers (Delmas, 1950; Kagame, 1955;) agree that, prior to the tenth century A.D., social formations were organized around various activities associated with cattle husbandry, the most important economic activity. Crop farmers undoubtedly also existed (pollen grains of tame gramineaes, primarily sorghum, are found at archaeological sites), but their activities seem to have been considered less prestigious.

Animals were the primary social expression of property and wealth. Each owner personally cared for his own cattle, exchanging butter for various other agricultural products and honey. No one had any specific land rights per se because there was plenty for everyone. There were no limits on the amount of land to be used by any individual, and all land was held in common. It appears that the more powerful nomadic cattle breeders gradually pushed sedentary agriculturists off the best lands, forcing them to move to more marginal areas (Kagame, 1955). As the pastoralists became still more powerful, gradually forming a centralized power structure, competition between the two production modes further intensified.

By the nineteenth century, the pastoralists had gained firm control of political power, awarding the best lands to those engaged in animal production, and changing the liberal land use code. During the reign of Gahindiro, pasture lands were no longer considered to be available or open to anyone's use, and agricultural land use rights were nullified in favor of pastoralists rights to the same land (Maquet and Naigiyibi, 1957). Thus, for example, any political official could seize hundreds of hectares of cultivated land, even in the midst of densely populated areas, for exclusive pasture use.

What happened to farmers who lost their land and livelihood? Generally, because some land was still available, authorities would award the unfortunate farmer new virgin lands. As soon as the farmer cleared the native vegetation and established productive fields, he would be evicted again by land-hungry pastoralists. Gradually, peasants acquired the nickname ***umurimiramfizi***, literally, "he who breaks up the soil to create pastures for the cattle."

The feudal powers continued to employ these land use practices through the mid 1940s, even after the arrival of the Europeans. Peasants were always in an extremely insecure position. If they felt that they might be evicted, they destroyed still immature crops rather than leave them to the feudal lords, uprooting young sweet potato vines and cutting peas and beans while still green. Thus, the peasants lost their seed stock for the following season (Habumana, 1968). Further, from July until sorghum harvest, livestock herders had the right to pasture cultivated fields, even those planted to crops.

Desperate farmers began to consider development of the heretofore ignored marais. Later still, the European colonial administration started to support this development, using solutions proposed by farmers. First, the locally made iron hoe had to be replaced with steel, imported ones. New cultivation techniques had to be developed, and drainage principles had to be mastered and successfully employed. The colonial administrations' method of forcing farmers to cultivate marginal marais lands, with an eye to reducing famine, was to require every peasant to cultivate at least one are (100 m^2) of raised beds. This policy was called ***skiku***.

For nearly 40 years the marais were developed by farmers for the cultivation of crops. Gradually, however, animal breeders began once again

to covet the land, seizing control and evicting peasants. Local authorities, who should have protected peasants' rights, allowed farmers once again to be forced from the land. By this time, the marais were irrigated, providing crops in the dry season. The fact that they are green year-round made the marais lands even more desirable to herders seeking pasture in the dry season months. (Habumana, 1968; Harray, 1978).

Finally, the colonial administration began to legally intervene on the side of peasants. At a meeting of the pastoral chiefs in October 1925, the colonial administration warned them that the first time a famine occurred because of damage inflicted by herders' animals to cultivated fields, the administration would purchase food for the farmers using animals belonging to the chiefs as payment. These sanctions were later applied.

Administrative chiefs quickly sought a solution in distributing marsh lands to the peasants and enforcing the law to produce obligatory crops (Cambrezy, 1981). In 1932, there were 7,600 ha of beans and sweet potatoes in the marais during the dry season alone. However, this coercive action did not encourage farmers to work very hard at opening the marais, and until its repeal in 1958, little advancement was made in the development of the marais. In fact, if any hill slope land was available, farmers abandoned newly tilled marais lands. Only when population density increased to the point that people could no longer grow enough to satisfy their needs did the peasants reluctantly return to the marais.

DEMOGRAPHIC PRESSURE AND THE DEVELOPMENT OF THE MARAIS

As population continued to grow, the best, most easily developed lands were all used up. Through time, communal land use rights dissolved under the relentless pressure of more mouths to feed, and a gradual migration

began to poorer, more difficult to develop areas such as the marais. The progressive movement of people from every hill slope to marshy valley reenacted in microcosm the migration that occurred throughout the country.

Agrarian organization began on the hill tops where the first houses were built and perennial food crops cultivated (banana trees and gardens). This year-round residential nucleus was surrounded by a halo of seasonal crops. Fields further down the slope were communal pasture lands. As population growth spurred changes, three distinct phases are evident in the development of the lands:

- While the number of people living on the hills was still relatively small, the convex headlands were left in pasture. Only the choice heads of the lateral valleys were used for crop land.
- As the population grew, cropped fields radiated further outward and the halo of seasonal crops took over convex hilltops.
- In the final stage of development, all hill slope land was in use. Fields were subdivided every generation among the sons of each family, and individual holdings became widely scattered. At this stage, the marais were attacked by a pioneer front of farmers seeking land to make up for the deficit of hill fields.

In this context, the development of the marais can be viewed in two ways. The first is to see the conquest as a stop gap solution to an immediate problem, temporarily fending off a crisis situation. This kind of development occurred without a rational plan, but was a willy-nilly exploitation of a new ecosystem. Seen in this light, the development of the

marais is a simple survival mechanism, not the beginning of a new era in agriculture.

A more optimistic interpretation views marais development as a deliberate and rational choice on the part of the peasant. In this case, the conquest can be viewed as a creative solution, chosen by an innovator anxious to stay abreast of ever changing agriculture.

In fact the marais were not spontaneously and completely cultivated once the hill land was all gone, but rather development moved in fits and starts. It would be interesting to know why the Rwandan peasants and public officials were so late in developing these alluvial zones, which are initially more fertile than the hill land. Three reasons seem to explain this situation. First, gradual early population growth encouraged the use of those lands that required the least investment of inputs (labor and capital) to cultivate; the hills. It was only later that the peasants began to consider the marais. First, peasants had to have a relatively secure lifestyle before they would want to invest scarce inputs into the cultivation of potentially more risky areas. The clearing of the marsh, the construction of raised beds, etc. is difficult, and there were no models for a peasant developer to copy. Finally, cooperation at the national level for the control of the marais water through adequate drainage was only recently established. It was not until then that the marais could be developed on a larger scale. Now the competition for appropriation of these lands has begun among peasants, farmer associations, and entrepreneurs.

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CHAPTER SIX

SOILS OF THE SMALL MARAIS

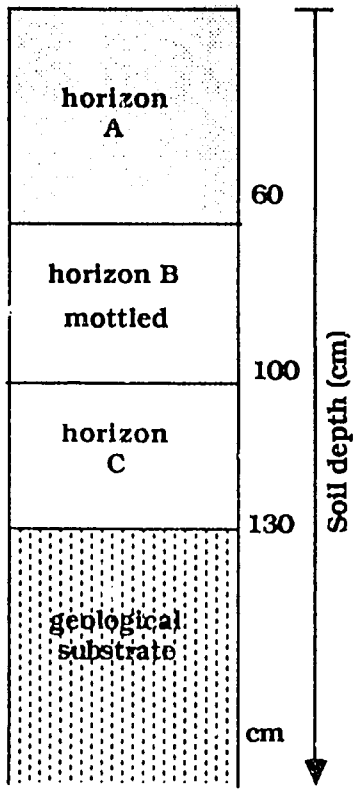
AREA AND GEOMORPHOLOGY OF THE SMALL MARAIS

The small marais vary in size, and this, along with location, are important factors in their classification. They are generally separated from the hills that border them by a band of transition soils whose extent depends on the location of the marais. These transition soils are intermediate between hill soils and marais soils, with a smaller concentration of rich alluvial material, a larger percentage of colluvium, and better drainage qualities than in the marais.

Parent Material

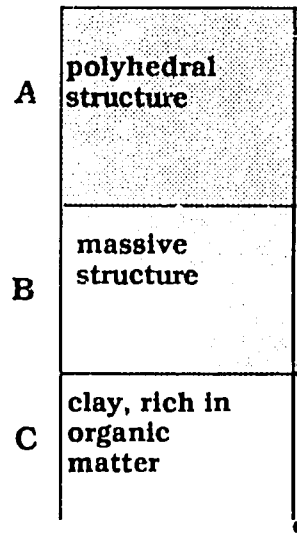
Parent material varies according to the location of the marais. Very small marais often are fairly steeply sloped. Consequently, the original soil material was generally made up of colluvium transported from the adjacent hills. Alluvium is more often found in the lower lying marais. Organic soils may be present, but their extent or importance to cultivated agriculture is generally less well known. Profile type is AC or ABC (Figure 6.1). The C horizon is a sticky, pliable clay in some places and sand in others, both of which could be used for construction purposes.

In the small marais, which are narrow, the parent material is generally a mixture of alluvium and colluvium, and transition soils can make up a large portion of the total. Organic soils are found along rivers. Sticky, pliable clay, as well as sand quarries may be present.



The A, B, and C horizons, each of which can have variants, make up the classic soil profile. If the soils are organic, the strata are called 01, 02, etc. When the A horizon is cultivated, it becomes an AP horizon. In the marais, the AP horizon may extend deeply into the raised beds, and soils may become hydromorphic, the A horizon rests on a B layer of variable depth, which generally has little organic matter and may or may not exhibit hydromorphic characteristics. The B horizon may be absent in some cases in the marais. Beneath B lies horizon C, which may be a hydromorphic including sandy, or sticky and pliable clay materials, or buried organic matter.

Figure 6.1 A Profile of a Typical Marais Soil (Mutwewingabo and Rutunga, 1987).



Horizon	Diagnostic criteria	%C	pH	CEC	% clay	% base sat.
A	dark brown some mottling	2.9	3.9	12	60	4
B	dark brown strongly mottled	1.7	4.1	14	66	3
C		3.0	4.5	7	36	4

Figure 6.2 Profile of an Aquept in Mwogo (Mutwewingabo and Rutunga, 1987).

In the small marais which are relatively wide, parent materials are colluvium, alluvium, and organic matter, and the resulting topsoils are a mixture of these materials. Profile type is AC, ABC, or O. Organic soils, when present, are shallow or are covered by a mineral horizon. Transition soils are less important. Sand or sticky, pliable clays are occasionally present.

SOIL CHARACTERISTICS AND THE CLIMATE

Water availability and air temperature play a primary role in the evolution and use of the soils. Papyrus and Typha vegetation, for example, retain water in the soil and regulate temperatures, thereby creating a favorable microclimate for the formation of organic soils.

In the east and in the west around Bugarama, where the climate is ustic[1], mineral soils (alluvial/colluvial origins) in the marais generally have a high CEC and often exhibit the characteristics of a vertisol. The pH is at least 5 or higher, and soils are dark colored. During periods of rapid evaporation in the dry season, salts can precipitate on the surface. In general, the agricultural potential of these soils is good, but water management may be difficult because of the large cracks that may form during wetting and drying. Excessive sodium may be limiting in some areas.

In the plateau and hill zone (1400 - 2000 m), where many small marais are found (Jones and Egli, 1984) and the climate is isothermic[2] udic[3], soils

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[1]Ustic - humid regime in which the 18-50 cm soil layer is dry for 90 or more days per year but never more than 180 cumulative days.

[2]Isothermic - thermal regime in which the average annual temperature at 50 cm deep is between 15-22°C and the difference between the coldest and hottest months is less than 5°C.

[3]Udic - humid regime in which the 18-50 cm soil layer is dry for 60 consecutive days or 90 cumulative days.

can have an organic or mineral base that is moderately to very acidic and have a relatively poor CEC. The mineral soils are less dark, and the agricultural potential of these is variable. The physical properties of organic soils and clay soils rich in iron make them prone to irreversible desiccation.

In the high altitude zone (> 2000 m) where the climate is isomeric[4] perudic[5], organic soils predominate over mineral ones. All of the soils are generally very acidic and have a poor CEC. Their potential for agriculture is therefore low to moderate, and altitude further limits what crops can be grown. The physical properties are, however, very good, and the climate is less likely to cause desiccation.

SOIL CLASSIFICATION

The classification system used in this chapter conforms with USDA specifications (USDA, 1975). The principal orders, sub-orders, and great groups of soils in the small marais are listed in Table 6.1. In this section, we describe in detail the characteristics of the most important soil sub-orders found in the small marais. Figures 6.2-6.8 illustrate a typical profile of some of the soil types.

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[4]Isomeric - thermal regime in which the average annual temperature at 50 cm is between 8-15°C and the difference between the hottest and coldest months is less than 5°C.

[5]Perudic - humid regime in which precipitation exceeds evaporation during every month of the year.

Table 6.1. **Orders, Sub-orders and Great Groups of Soils in the Small Marais.**

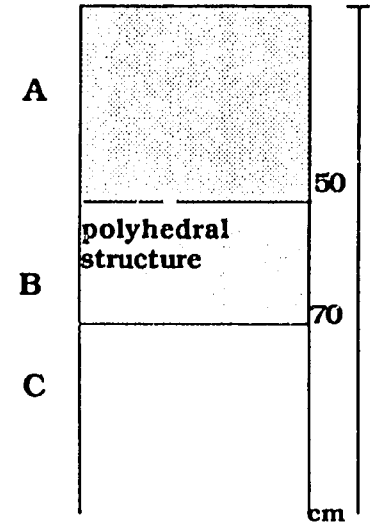
	Orders	Sub-orders	Great Groups
Mineral	Oxisol	Aquox	Plinthaquox
			Ochraquox
			Umbraquox
	Vertisol	Ustert	Chromustert
			Pellustert
	Ultisol	Aquult	Plinthaquult
			Paleaquult
			Tropaquult
		Humult	Palehumult
			Plinthohumult
			Tropohumult
	Alfisol	Aqualf	Plinthaqualf
			Natraqualf
			Tropaqualf
		Ustalf	Durustalf
			Plinthustalf
			Natrustalf
			Paleustalf
			Rhodustalf
			Haplustalf
	Inceptisol	Aquept	Haplaquept
			Plinthaquept
			Tropaquept
		Tropept	Humitropept
			Ustropept
	Entisol	Aquent	Hydraquent
			Fluvaquent
			Tropaquent
Organic	Histosol	Fibrist	Borofibrist
			Tropofibrist
		Hemist	Sulfihemist
			Luvihemist
			Borohemist
			Tropohemist
		Saprist	Borosaprist
			Troposaprist

The soils of small marais are classified in seven orders, twelve sub-orders, and thirty-six great groups. Variability is enormous, and each soil requires a different type of management.

Aquepts (Figure 6.2): These younger mineral soils are developed in deposits of alluvial and colluvial materials, with some minerals not fully weathered. They always exhibit hydromorphic characteristics (mottling). Color, texture, pH, and chemical composition (richness) are very variable. Some soils are rich in sodium at the surface and are cracked because of variations in moisture content caused by the alternating dry and rainy seasons. In the east and in Bugarama, some Aquepts are black and rich in montmorillonite clay, with Vertisol-like characteristics.

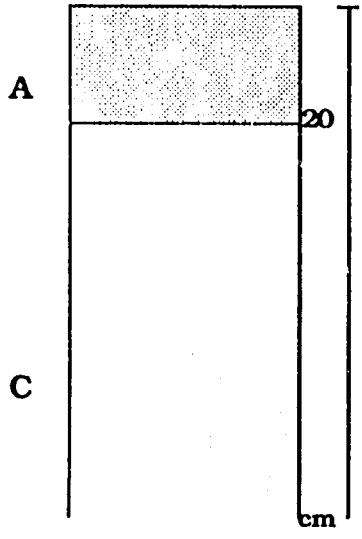
Tropepts: These soils are frequently found in the transitional areas and are distinguished from the Aquepts by the absence of signs of a high water table in the top 50 cm of the profile. At a depth of 100 cm, some Tropepts exhibit secondary properties similar to Oxisols or Vertisols. Base saturation and percent carbon are very variable and depend on the type of parent material and climate. These values are relatively high in the dry climates (Bugarama) and low in the areas of greater rainfall (the Zaïre/Nile divide). These soils are found in the marais throughout the country.

Aquox (Figure 6.3): These soils are distinguished from the Aquepts by the absence of unweathered minerals in the upper 2 m of the profile, or by the presence of cracks in the top 30 cm. The soil also does not exhibit



Horizon	Diagnostic criteria	% C	pH	CEC meq/100 gm soil	% clay	% base sat.
A	dark brown with some mottling	1.2	4.5	3.9	29	25
B	dark brown with a lot of mottling < 16 meq/100 g of soil	1.4	4.5	4.6	31	20
C						

Figure 6.3 Profile of an Aquox in Mwogo (Mutwewingabo and Rutunga, 1987).



Horizon	Diagnostic criteria	% C	pH	CEC	% clay	% base sat.
A	clayey - brown	2.4	4.7	22	45	22
C	sandy-clay, brown, mottling	1.5	4.6	15	36	27

Figure 6.4 Profile of an Aquent in Rwondo (Neel, 1971).

secondary Vertisol-like characteristics and is mottled due to the high water table in the rainy season. The A horizon is uchric or umbric. The pH and natural fertility of this soil are variable but generally low. These soils are rare in the marais of Rwanda.

Aquents (Figure 6.4): These soils do not have well defined horizons, apart from the upper ochric surface layer. They are more or less permanently water-logged, and the parent material is essentially unchanged, with a stratified profile. Color, texture, and amount of carbon are variable. Sometimes, Aquents are rich in clay and at the same time behave like a Vertisol. These soils are found throughout the marais in Rwanda.

Aquults (Figure 6.5): These soils are seasonably inundated in their natural state and must be artificially drained when cultivated. At the surface, they show signs of water-logging, the minerals are unweathered, and the soil has Oxisol-like characteristics. The profile has a low base saturation and is rich in clay silicates. Stone fragments are present. The B horizon has a polyhedral structure and contains more clay than the A horizon. The fractures are strongest below the argillic horizon. The texture of these soils is variable, and the epipedon is ochric or umbric. The natural fertility is, in general, poor. These soils are occasionally found in the marais in Rwanda between 900 and 1800 m altitude.

Humults: These soils are distinguished from the Aquults by the absence of signs of water logging near the surface and by the generally high amount of organic carbon. Some of these soils have secondary hydromorphic character-

Horizon		Diagnostic criteria	% C	pH	CEC	% Clay	%base sat.
A	crumb like structure		1.5	5.6	6.5	21	57
	37						
B	polyhedral structure	more clay than in horizon A, base saturation less than 35%, mottled, numerous stone fragments	1.1	5.4	11.6	40	29
	115						
C	clay rich in organic material		2.9	5.0	12.0	43	21
	cm						

Figure 6.5 Profile of an Aquult in Makera (Rutunga and Sebahutu, in press).

Horizon		Diagnostic criteria	% C	pH	CEC	% Clay	%base sat.
A	crumb like structure	black, rich in bases, hard and dry	2.5	7.8	24	29	very high
	32						
B	polyhedral structure	more clay than in horizon A, base saturation greater than 35%, mottling stone fragments	1.6	8.4	22	38	very high
	76						
C	gravel and pebble deposits		0.6	8.7	8	23	very high
	cm						

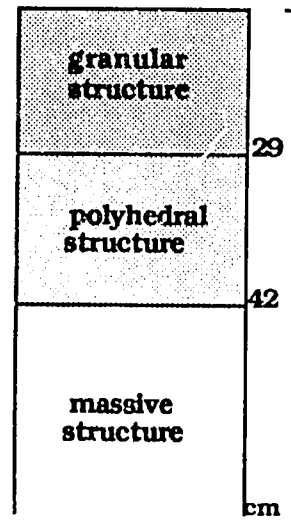
Figure 6.6 Profile of an Aqualf in Bugurama (Neel, 1967).

istics below a depth of 75 cm. Humults are only sporadically found in the marais.

Usterts (Figure 6.7): These soils range from clay to sandy-clay texture, and are dominated by montmorillonite and kaolinite clays. If the soil dries out in the dry season, shrinkage can occur, along with the development of wide cracks. Soil particles below horizon A (between 25 and 100 cm) aggregate into large prism-like blocks. When dry, the aggregates form large hard clots, which are difficult to work; when wet, they are highly plastic and equally difficult to till. The color is generally dark but with small amounts of carbon, and base saturation and depth are variable. In eastern Rwanda in the small marais, the fractures that form when the soil dries out remain at least three months. These soils are dominant in the east around Bugesera and Bugarama.

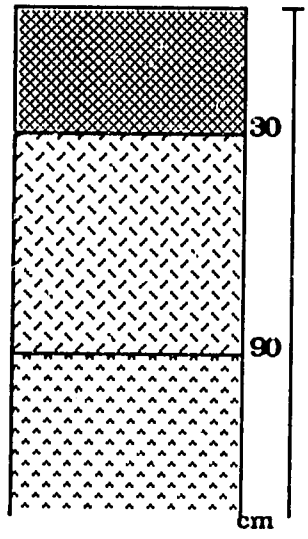
Aqualfs (Figure 6.6): These soils are distinguished from the Aquults by the presence of unweathered minerals (>10 percent in the clay horizon), and by a base saturation that is greater then 35 percent. These soils have an ochric and umbric epipedon, and their natural fertility is high. They may contain fractures between 30 and 125 cm, have Vertisol-like characteristics, or have a sodium or magnesium rich horizon. These soils are very rare and are only found in the marais near Bugarama, Bugesera, and in the east.

Ustalfs: These soils are distinguished from the Aqualfs by the absence of signs of water logging and by the presence of a calcium-rich horizon 1.5 m deep in the profile or in the lower 50 cm of the clay horizon. These soils are found in ustic or udic climates, such as in the Masangano region.



Horizon	Diagnostic criteria	%C	pH	CEC	% clay	% base sat.
A	fractured in the dry season	3.9	5.4	14	31	84
B	marbled dark brown slickensides cracks	0.3	5.0	21	58	64
C	marbled dark brown slickensides	0.2	4.7	21	61	71

Figure 6.7 Profile of an Ustert in Mutara (Drolet, et al., 1985).



Horizon	Diagnostic criteria	%C	pH	CEC	% clay	% base sat.
O1	histic layer dominated by Ca	23	4.1	99.7	nd	47
O2	sapric layer, dark brown, dominated by Ca and Mg	30	4.6	124.8	nd	64
O3	sapric material, dark brown, dominated by Ca and Mg	34	4.9	141.5	nd	60

nd = not determined

Figure 6.8 Profile of a Saprist in Nyasoge-Rutare (Touchet, et al., 1983).

Secondary characteristics include the presence of a fractured hardpan, of a sodium-rich horizon, and of aquic, vertic, ultic, arenic, oxic, or mollic qualities. These soils are relatively rare in the marais in Rwanda and are only found in Masangano (junction of Mukungwa-Nyabarongo), Buagasera, Bugarama, and in the east.

Fibrists: These soils are formed from organic matter and are made up of peats and mucks. Bulk density is very low, and the carbon concentration is greater than 20 percent of the weight when unsaturated. In the natural state, these soils are flooded, and if cultivated, drainage must be installed. In the peats in this sub-order, three-fourths of the exposed surface area is made up of only slightly decomposed fibers. Sulfuric or sulfidic materials are absent and the pH is variable. Secondary characteristics include the presence of strata of mineral soils and of hemic or sapric materials.

Hemists: These soils contain a higher percentage of decomposed materials than the Fibrists. Sulfuric material may be present in the top 50 cm. The pH is generally low and difficult to correct because of a high CEC. Secondary characteristics include sapric or fibric qualities.

Saprists (Figure 6.8): These soils have the highest percentage of decomposed materials, and sulfuric material is absent. The pH and nutrient-supplying power are variable. Some secondary characteristics are the presence of strata of mineral soils or of fibric or hemic materials.

The organic soils are found throughout the country, although Fibrists and Hemists dominate in altitudes higher then 1800 m.

SOIL PRODUCTIVITY

The productivity of the soil is dependent on a wide range of intrinsic as well as external factors. The degree of slope and surface drainage characteristics represent external factors, while physical, chemical, and biological properties of the soil itself are internal components. All of these factors in combination with the climate determine the productivity of a soil.

Generally, because marais are relatively flat, slope is not a handicap to development nor a limiting factor for crop growth. In the lowest lying part of the marais, groundwater is close to the surface, and the soil profile remains wet during the rainy season. Proper water management is one of the most troublesome aspects in cultivating marais soils. In the same marais, some areas can be over drained, while nearby the soil is water logged. On top of this, small marais have a large watershed causing floods during heavy rainfalls. Soils most affected by inundation are the Aquents, Aquepts, Usterts, Aqualfs, Aquults, Aquox, and Histosols.

Soil morphology in the small marais is very variable. Some soils have a deep permeable profile, with uniform texture that is medium to fine (clayey-sand, limey-sand, sandy-clay, sand-clay-lime). Others are too permeable or are too compacted. In the latter case, the agricultural value is further reduced when the surface layers are compacted. The organic soils have extremely low bulk densities. Plants growing in fibrist and hemist soils cannot easily form sturdy root systems.

Almost all of the soils in the marais, once overly drained and dry, readily suffer irreversible desiccation. This is because of the high concentrations of iron and smectite clays that become very hard when dried. In peats, desiccation occurs because of polymerization of organic matter. After drying, the soil structure is destroyed, and it cannot successfully be used for agricultural purposes.

Ranges of values for various elements and ratios important to plant growth in Rwanda are listed in Table 6.2. These are used as a basis against which to compare the relative nutrient-supplying power of various marais soils.

According to previous studies, it appears that the Aquults, Humults, Aquepts, Tropepts, Aquox, and Histosols of the udic and perudic zones are the most deficient in nutritive elements, the most acidic, and the richest in exchangeable aluminum. Furthermore, the top 50 cm of Hemist soils are saturated with sulfur and are toxic to several crops. A few rare Aqualfs and Ustalfs have high concentrations of sodium and/or magnesium.

In a single marais, one can find numerous types of soils, and there can be enormous variability in physical and chemical properties in a single soil (Annex C, Table C.1) type. Therefore, marais soils are not readily typified in a brief report. Further, more detailed soils research will be required to construct an adequate typology.

TECHNIQUES FOR OPTIMAL SOIL MANAGEMENT

Before proposing changes in soil management systems in the marais, it is very important to consider the ultimate consequences. Some management systems will provide short-term gains in productivity, but will promote long-term environmental decay. Others may look good on paper, but produce

Table 6.2 Some Important Elemental Soil Availability Parameters in Rwanda.

Element or ratio	Value	Meaning
Ca	0.8 meq/100 g of soil 1.5-2.0 meq/100 g of soil	depletion threshold deficiency threshold
Mg	0.1 - 0.2 meq/100 g of soil 0.5 meq/100 g of soil	depletion threshold deficiency threshold
K	0.15 - 0.20 meq/100 g of soil	deficiency threshold
Ca/Mg	< 1 1 to 10 > 10	deficiency in Ca optimum deficient in Mg
Mg/K	< 2 2 to 20 > 20	deficient in Mg optimum deficient in K
(Ca+Mg)/K	< 12 12 to 30 > 30	insufficient Ca + Mg optimum deficient in K
K / sum of exchangeable bases	< 0.02	K depletion
C / N	9-12	optimum level for mineralization
Phosphorus (Bray I)	< 20-50 ppm	deficient in P
CEC (measured in acetate)	< 10-25 meq/100 g of soil	weak
Al	< 2 meq/100 g of soil rate of saturation < 0.3	acceptable level
sum of cation exchange capacity	> 3-10 meq/100 g of soil	acceptable level
pH (measured in H_2O)	5.5 - 6.5	optimum
carbon	≥ 1.5-2.0 percent	sufficient

negative results in the field. In the following sections, we consider various management techniques. However, our overview is necessarily general because research on appropriate management methods is still in its infancy, and few concrete recommendations can be safely proposed.

Improvements Relative to External Factors

To eliminate problems of flooding and water-logging in the marais, a first thought might be to install a contour canal to limit inflow of water from the surrounding hill slope land. The canal could help to control flow and double as an irrigation canal in the dry season. However, there are several problems associated with this system. A small surface area coupled with a long canal could make the system difficult to install. Also, if hill water is eliminated or reduced, marais soil texture or nutrient-supplying capacity may be changed, and a large water source is required to supply the irrigation canal with water during the dry season.

For transition soils and those in micro-depressions of the marais, a drainage-irrigation canal will not be helpful unless the terrain is levelled. Levelling ensures sure that all soils have an equal depth to ground water and that no part of the marais will be either too dry or too wet. Levelling operations are expensive, and nutrient rich top soil may be covered by infertile subsoil.

It is traditional to construct raised beds in the marais for all food and some feed crops. This technique probably is most appropriate where the groundwater is close to the surface. Where groundwater is relatively deep, such as in the eastern part of the country, it is necessary to construct large, relatively low beds with narrow ditches to minimize loss of

cultivable area. The decision to construct beds parallel or perpendicular to inflow varies with the particular circumstance.

Some marais are so low that it is impossible to avoid flooding. These could be fallowed in the rainy season and used in the dry season. Alternatively, crops such as paddy rice, which tolerates flooding, could be grown.

Improvements Relative to Intrinsic Factors

First of all, we need to emphasize that without proper water management, it is useless to attempt to modify soil characteristics. In general, material eroded from the hill slopes is quite weathered and consequently is rich in oxides. These may tie up certain nutrients, lowering the fertility of the soil. Maintenance of adequate levels of organic matter is extremely important to ensure both rapid mineralization and the protection of leachable cations.

Special strategies should be used to develop and manage different-textured marais soils. Because of their inability to hold cations, the sandy-textured soils currently have limited agricultural uses. However, with the addition of fertilizer, these soils could outperform more clayey ones. Also tuberous-rooted crops, such as sweet potatoes, can produce a satisfactory crop without fertilizer. The land could also be used for extensive grazing or as a sand quarry. When the sand is exhausted, fish ponds could be installed, or the plots could be reclaimed. In the case of clay-textured soils, green manure crops should first be grown to improve the soil tilth. If the ecology permits, floating rices could also be planted. Little is known about suitable methods to develop organic soils (Fibrists or Hemists), but tea culture could be attempted if markets were available.

Some problems, such as those detailed by Unger (1978), might make tea production unfeasible in some situations.

The correction of nutritional deficiencies is easy for some elements and impractical for others. Acidic mineral soils that are rich in aluminum can be treated with lime and/or manure. Acidic sapric and hemic organic soils with high levels of aluminum can also be limed. For organic, hemic soils that are rich in sulfur, however, lime only temporarily corrects the problems. All of the acidic soils, mineral and organic, generally lack phosphorous, potassium, magnesium, and nitrogen. Lime alone cannot neutralize all of the available aluminum and allow the other beneficial cations to enter solution for plant uptake. The deficient nutrients must be supplied in a readily available form in manures and/or chemical fertilizers (Annex C, Tables C.3-C.6). Aquox, Aquult, Humult, and certain Tropept, Aquept, Aquent, Saprist, and Hemist soils all are acidic and suffer nutritive deficiencies. In contrast to the acidic soils, some soils have excess salts (sodium and/or magnesium). These include certain Usterts, Saprists, and rarely Aqualfs or Ustalfs. Theoretically, gypsum could be applied or the soil could be flushed with excess drainage water. Practically, it is probably better if these soils are reserved for halophilic plants.

AGRICULTURAL POTENTIAL OF THE MARAIS

The agricultural potential of a soil is determined by the limitations to production in a given environment. The enormous climatic and soil variability found in the marais means that the type of culture practiced and yields achieved are also very variable. More precise information on

various cultural requirements for crops grown in Central Africa may be found in Van den Put (1981).

Sweet potatoes are the most widely grown crop in the marais, particularly in the dry season. This is likely because the sweet potato is drought resistant, requires few or no added inputs, takes only small amounts of labor, and tolerates adverse soil conditions (Acland, 1971). Because many marais soils suffer from degradation and poor water management, farmers find the sweet potato to be the most reliable crop, even though yields may be low.

In spite of all of the problems, very few small marais remain uncultivated. Some have been specially developed to grow rice or as tea plantations. Crop rotations, if used in farmer-managed marais, include sorghum or corn in the rainy season, followed by sweet potatoes in the dry season. When left fallow, the marais may be grazed because they are usually overrun with rhizomatous grasses, such as *Digitaria*. Of course, some farmers practice monoculture, usually rice to the detriment of the soils. These farmers would have much better yields and long-term soil quality if they practiced rotations that included legumes. Table 6.3 links crops to appropriate ecological zones and soils found in the Rwandan marais. Most suggested crops are already cultivated there, but others would be worth growing on a larger scale.

OTHER USES FOR THE MARAIS

Since many of the marais have serious limitations to intensified agricultural production, it is worth investigating other possibly more profitable uses. However, it is extremely important that all parties

Table 6.3. Crops Appropriate for Various Ecological Zones and Soil Types in the Marais.

Ecological zone	Soil type	Suggested crops
Low altitude (<1400 m)	Usterts, Aquepts	Rice, soybeans, sorghum, corn.
	Tropepts, Aqualfs	Beans, sugar cane, legumes.
	Ustalfs, Saprists	Sweet potatoes (except in Usterts or other soils with surface clay), pasture (except on saprists), forage crops.
	Aquents	Sweet potatoes, legumes, pasture.
	Fibrists	Legumes, potatoes, beans, forage crops.
Plateau and hills (1400-2000 m)	Aquox, Aquepts	Rice (<1700m), soy beans, sorghum.
	Aquults, Humults	Corn, beans, sweet potatoes.
	Tropepts, Saprists	Sugar cane, legumes, tea, forage crops (except on saprists).
	Aquents	Sweet potatoes, forage crops, legumes, colocase, pasture.
	Fibrists	Legumes, tea, forage crops.
	Hemists	Tea, legumes.
High altitude (> 2000 m)	Aquepts, Aquults	Sweet potatoes, potatoes.
	Tropepts, Humults	Corn, legumes, tea.
	Saprists	Forage crops.
	Fibrists	Potatoes, tea, legumes.
	Hemists	Tea, pasture.
	Aquents	Potatoes, legumes, tea, forage crops.

involved with development, from farmer to engineer to Government, work together to minimize risk and safeguard the interests of each.

Marais rich in sand should be exploited for construction purposes. Similarly, marais containing the right kind of clay could be used for the production of bricks, tile, and pots. Peat can be extracted for fuel from organic deposits.

Once the soils are removed, farmers can rejuvenate the remaining earth for agricultural purposes. If regeneration is planned, soil that is excavated should be stored at the site. Other possible uses are as fish ponds or to collect water for other purposes.

FURTHER WORK AND RESEARCH

Although we have formulated a few recommendations for marais management, we have skipped over many areas where little is known. These areas require further study before progress can be made. Existing institutions that have the necessary infrastructure to undertake this research are MINAGRI, UNR and ISAR, which could work in collaboration with agricultural development projects. Six specific areas of work are suggested.

Inventory the Small Marais

There are numerous, scattered small marais, and their individual and total surface areas are unknown. An inventory based on aerial photographs as well as land-based observations would be very helpful. We recommend that specific details be collected for each marais, such as soil type, clay or sand deposits, crops planted, use of manure, problems connected with water, etc. These investigations could be entrusted to a district agricultural

agent. This information would aid in determining which marais have the greatest development potential given available resources.

Management of Surface and Internal Water in the Soil Profiles

Various crops have different water requirements and tolerate varying degrees of water logging. Rice can grow in flooded soils, while corn, sorghum, and sugar cane require the groundwater to be at least 30 cm deep in the profile, and sweet potatoes, potatoes and young tea require 40-50 cm to water. Seasonal fluctuations in groundwater levels further complicate management.

In order to facilitate the development of the marais, it is necessary to assure compatibility of development programs with hydrological conditions. Research to identify the most appropriate cultivation techniques (size and height of raised beds) is necessary (see also Chapter 7). When it is impossible to avoid temporary flooding, one could imagine, for example, paddy rice could be substituted for other crops or the beds could be fallowed. In each case, we need to determine if the agronomist or the hydrologist should tackle the problem first.

Improvement of Soil Physical and Morphological Properties

Important soil physical and morphological properties include texture, structure, depth, bulk density, permeability, and gradient. Research on the efficacy of the use of techniques to correct soil problems is very important because large capital investments in marginal soils may not always yield correspondingly large yield increases. Soil texture is difficult to change, but improvements can be achieved by the incorporation of copious quantities of organic matter (manure, green manure crops). Some examples of common

textural problems include sand-textured and clay-textured soils. A sandy texture is very permeable, and water will not be retained in the profile (ex. when the groundwater is close to the surface). In contrast, a clay texture inhibits infiltration of water, leading to stagnant pools. Sands and clays can also be removed and used for other purposes prior to agricultural development.

Shallow soils can be improved by cultivation techniques such as mounding and the construction of raised beds. Micro-depressions, which collect surface runoff, can be removed by levelling, but only at the risk of burying fertile horizons.

Improvement of Soil Chemical Properties

Marais soils are often acidic and/or have low levels of organic matter and a poor natural fertility. Thus, the application of lime and/or organic matter may not always give the expected yield responses. In order to determine how to develop guidelines on amounts to be applied, yield response trials need to be run on many soils. Because most marais soils are progressively deteriorating, amendment will be necessary to maintain long-term sustainable agricultural systems.

In the case of peat marais that are rich in sulfur, research needs to be carried out to determine how best to make them usable for agricultural production. Gypsum (calcium sulfate) could be applied, or the soils could be flushed with fresh water, but these corrections are expensive and logistically difficult to carry out.

Cultivation Techniques

The best crop rotations and other developments for improving productivity and agricultural potential of the small marais need to be identified. We need to evaluate land-shaping techniques (raised beds, flat, mounds, etc.), which tend to have the biggest immediate effect on yields in the marais. A study to determine the effects of various cultivation techniques on different crops would be helpful. We also need to research to find the optimal water table depth for each crop and the interactions among the various operations (raised beds, fertilization, planting, etc.) involved in crop production.

Vegetable and Animal Crops

Research on the species or varieties of plants best adapted to the microclimate and soil types of the small marais is essential. We need to identify species or varieties that tolerate temporary flooding (rice) in the rainy season and that can endure low temperatures at night in the dry season. Perennial trees and shrubs that can grow in stagnant water could help to improve fruit and forage production or soil fertility, as well as protect banks from water erosion.

The best way to integrate animals and plants in the marais has yet to be determined. Should aquaculture be practiced with pigs and ducks or alone? And, how should we integrate rice culture with fish production?

Finally, it is important to point out that these six research points are clearly intertwined, and integration will obviously be required. The results of an agronomical field study carried out by the team in Ilibunga and Nyarutovu marais (Butare) clearly illustrate this point (Annex C).

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CHAPTER SEVEN

HYDROLOGY AND WATER MANAGEMENT OF THE MARAIS

INTRODUCTION

Studies of hydro-agricultural management in the marais of Rwanda have the general goal of augmenting agricultural production by improved water control (PNUD/FAO, 1984). However, technical intervention by donors in the marais has not always led to an increase in agricultural output. Partly to blame is the unique, poorly understood hydrological conditions of the marais. The objective of this chapter is to explore the interaction of climate, soils, and hillsides on water flow in the marais, and based on this analysis, formulate sensible strategies to aid in the advancement of water management. In particular, we will consider:

- general hydrology of the **collines** (hillsides) and marais and the establishment of interflow values, which help to determine water availability for irrigation in the dry season;
- changes in the water table and water balance in the marais; and
- current irrigation and drainage practices used in crop production that impact on water availability.

RIVER FLOWS IN RWANDA

River flow is generally described in Chapter 2. In this section we compare annual flow with precipitation, estimating the percent of precipitation that becomes stream flow and ultimately leaves Rwanda in the form of surface runoff. The portion of precipitation that does not run off is lost by evapotranspiration.

The annual runoff for various stations and watersheds is shown in tables 7.1 and 7.2. River runoff accounts for approximately 10 to 20 percent of the total annual precipitation. Runoff begins to increase in the middle or at the end of March and decreases at the end of May. Rivers rise again during October or November but do not reach the same height as during the long rainy period.

Table 7.1. **Stream Flow Data for Mwogo Watershed at Nyabisindu, 1974 - 1981.**

Average annual outflow	252 mm/year
Maximum annual outflow	400 mm/year
Minimum annual outflow	145 mm/year

Source: Meulenberghs (1986).

Table 7.2. **Average Yearly Fluxes in m^3/sec and in cm/year (1983 - 1985) for Four Stream Flow Stations, Rwanda.**

	Area km^2	Average annual flux 1983		1984		1985	
		m^3/sec	cm/yr	m^3/sec	cm/yr	m^3/sec	cm/yr
Akagera - Kagitumba	40.450	208	16	n.a.		203	16
Akagera - Rusumo	30.200	209	22	181	19	222	23
Kagitumba - Kagitumba	2.800	n.a		9.6	11	10.	312
Nyabarongo - Kigali	8.900	84	30	76	27	82	29

The runoff peaks are not extreme and indicate the capacity of the marais to buffer seasonal fluctuations in flow. They also indicate that direct overland flow is of minor importance compared to interflow and base flow components.

Hydrology of the Marais and Collines

Our discussion of water movement is limited to the Central Plateau because our research was located in this important agricultural region, and time constraints prevented further work. However, our data and conclusions can be applied to other areas in Rwanda because of similar hydrological and agricultural conditions. The Central Plateau (1500 - 1900 m) covers more than half of the country and is about 80 km across. It consists of convex hills with deep valleys, which are filled with sediment eroded from the hillsides. Slopes of 10 to 45 percent are the norm and are routinely cultivated.

The marais and surrounding hills form a delicate ecological system with many different patterns of water availability. Limitations include the fact that bottom lands flood periodically, while the hilltops cannot support agricultural production during the dry part of the year.

To characterize water flow to the marais, we need to make a distinction between physical attributes of the hillsides surrounding the marais and the marais itself. In each, we need to distinguish a zone where roots penetrate and a non-root zone because evapotranspiration only occurs in the root zone.

Collines. Generally the hill soils are Oxisols or Ultisols, with high saturated conductivities (7-23 cm/hr; Sanchez, 1976) and low water-holding capacities (10-15 percent; Sanchez, 1976). Because of both the high conductivities (associated high infiltration rates) and stable aggregates (a crust does not form), only the most severe thunderstorms will cause direct surface runoff. In all, there is very little erosion compared to similar hill slopes in other countries.

During the long rainy season, precipitation exceeds potential evaporation. Because there is very little runoff, water in excess of the evaporative demand percolates below the root zone. During this time, there is sufficient moisture to grow field crops such as beans, potatoes, and sorghum on the hillsides.

During the long dry season, the soil near the surface desiccates to the wilting point. Annual crops cannot be grown, but perennial tree crops survive the dry period because their roots cover a larger soil volume from which they can extract water. During the short dry and wet periods, the same processes occur as during their longer counterparts, but magnitude is decreased.

The excess water that percolates through the soil profile during the rainy periods saturates the subsoil, and then moves downward until it reaches a fragipan. The impermeable fragipan deflects the downward movement of the water, causing it to flow along the hardpan. This is called interflow, and the water may move in a saturated or unsaturated state down the hill until it reaches the groundwater in the marais. This is a rather slow process, and it may take years for a water molecule to move from the top of the hill to the marais. Two important attributes of this flow contribute to water availability in the marais. First, the further down the hill, the larger the volume of interflow (i.e., a larger portion of the hill slope contributes water) and the higher the moisture content of the subsoil. Second, as the slope decreases, flow declines, and the soil is wetter (the extreme is the marais where the soil is saturated). The soil's moisture content determines which crops can be grown. Near the bottom of the hill, where the soil is wettest, sorghum and beans are produced in the rainy seasons. Farther uphill, homestead sites and banana trees are interplanted

with beans, sweet potatoes, and other vegetables, which are grown during the wet season. Further uphill, where the soil is driest, there are meadows and coffee plantations, and at the top of the hill, reforestation efforts. Typical cropping patterns by elevation during the rainy season for the Central Plateau are shown in Figure 7.1. Cropping patterns for the eastern portion of Rwanda are shown for purposes of contrast in Figure 7.2. Because of lower rainfall in the east, the hilltops are covered by drought-resistant grasslands.

Marais. Water that flows through the soil down the hill slope ultimately reaches the marais, where it is added to the groundwater. To determine the magnitude of the interflow from the hill slope and to understand water movement within the marais, we installed several rows of piezometers across and one row of piezometers in the longitudinal direction of two marais 6 km east of Butare. We also measured the water leaving one marais. The Ilibunga and Rwandore marais where the flow measurements were made, is underlain by an argillic horizon. In the Ilibunga marais the depth to the argillic horizon is 1 m and the topsoil ranges from a well structured clay to a sandy texture. The Rwandorere marais argillic horizon is at a slightly deeper depth of approximately 1.5 m. In this marais, 2 ha are organic soils, while the remaining 18 ha are well-structured mineral soils.

The initial results of the hydraulic measurements indicate that the water table closely mimics the level of water in the ditch bottoms during the dry season. This is partly because of sub-irrigation but also because of water flowing from the hillsides. As can be seen in Figures 7.3 and 7.4, the water table actually flows uphill near the hill slope. Below the argillic horizon, the water is under pressure. One piezometer in a seepage

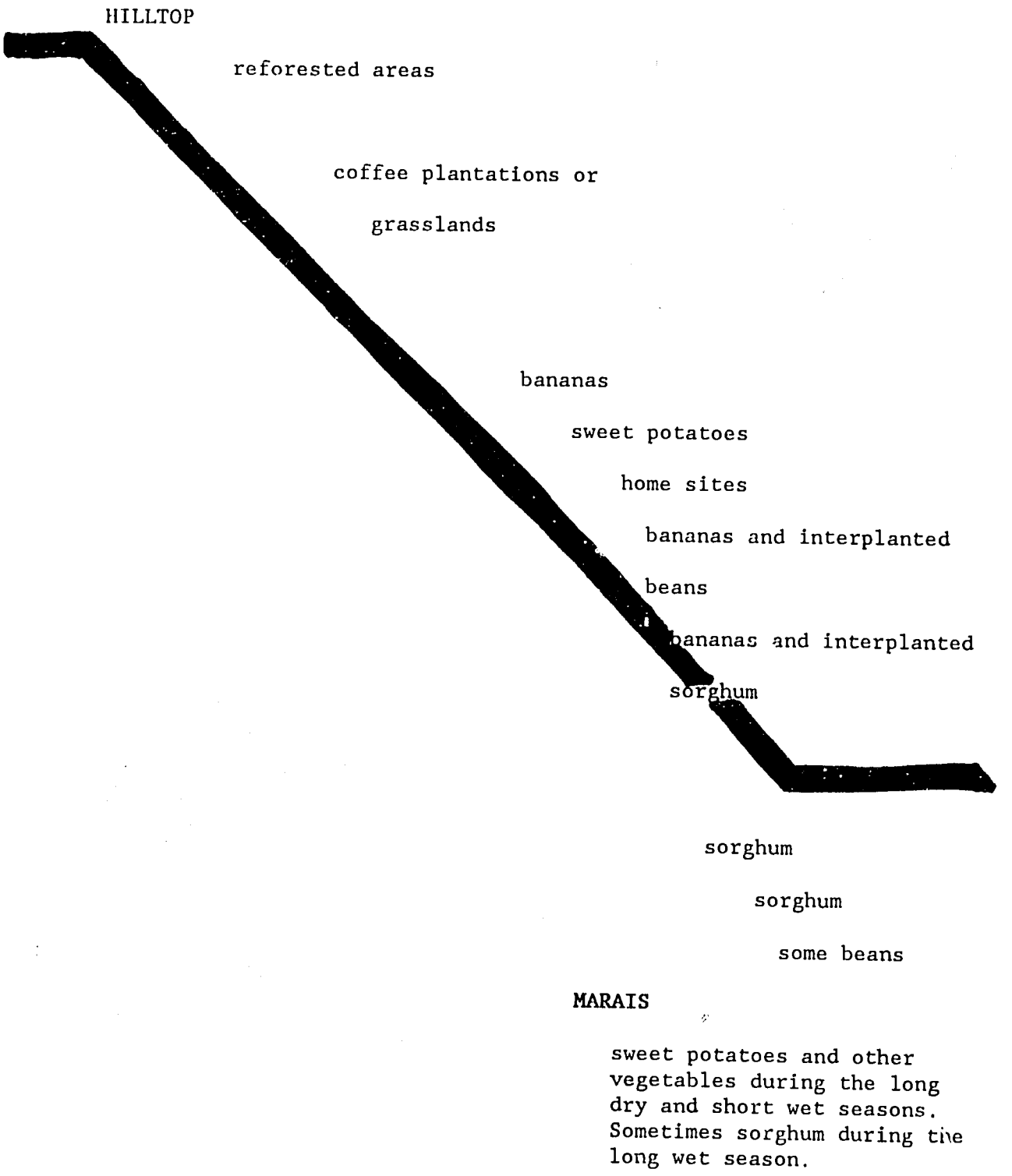

Figure 7.1. A Typical Cropping Sequence in the Central Plateau by Elevation Hillsides are not planted during the long dry season, except near the marais where sorghum is sometimes grown.

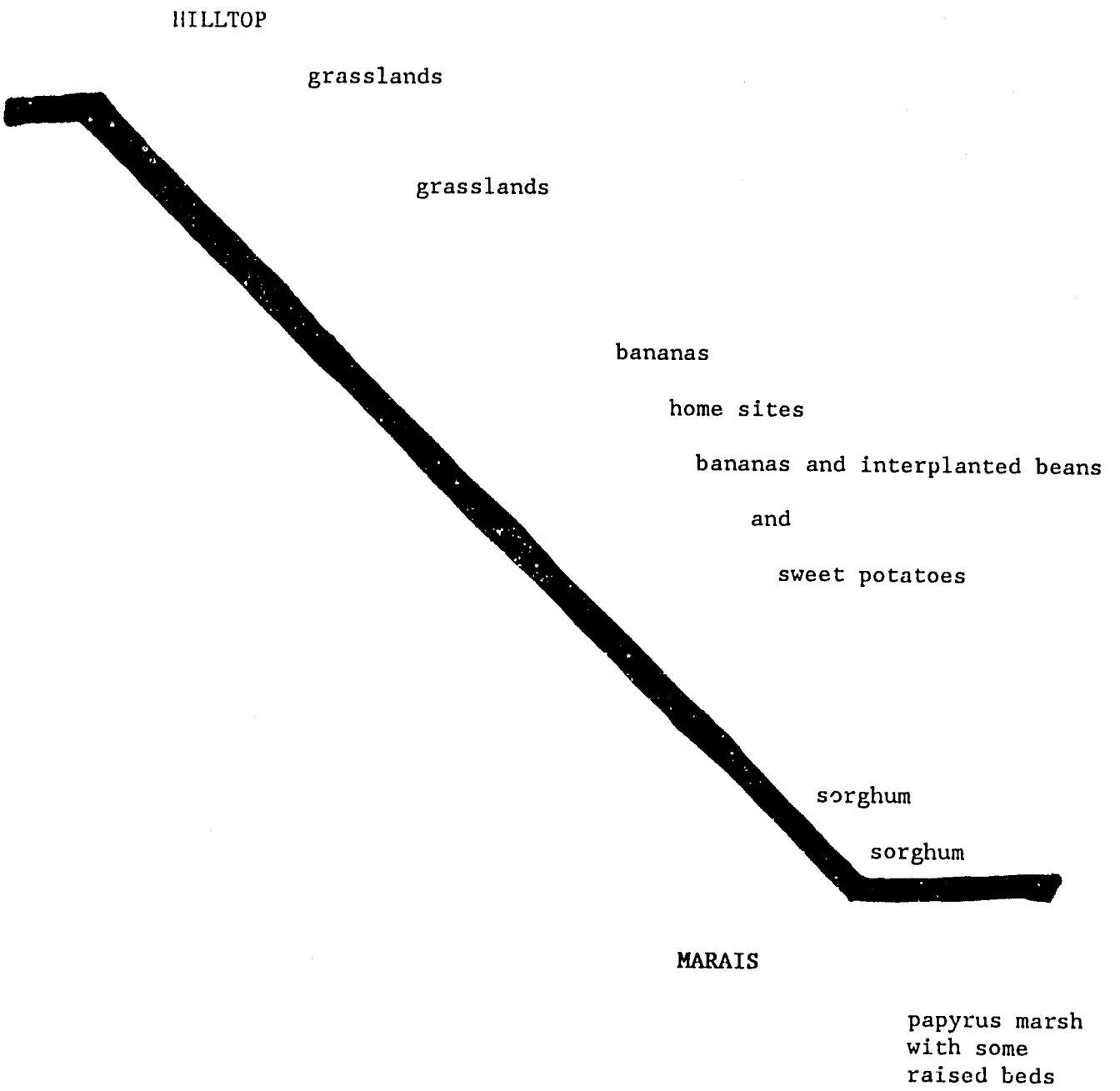

Figure 7.2. A Typical Cropping Sequence in East Rwanda by Elevation. Hill sides are not planted during the long dry season.

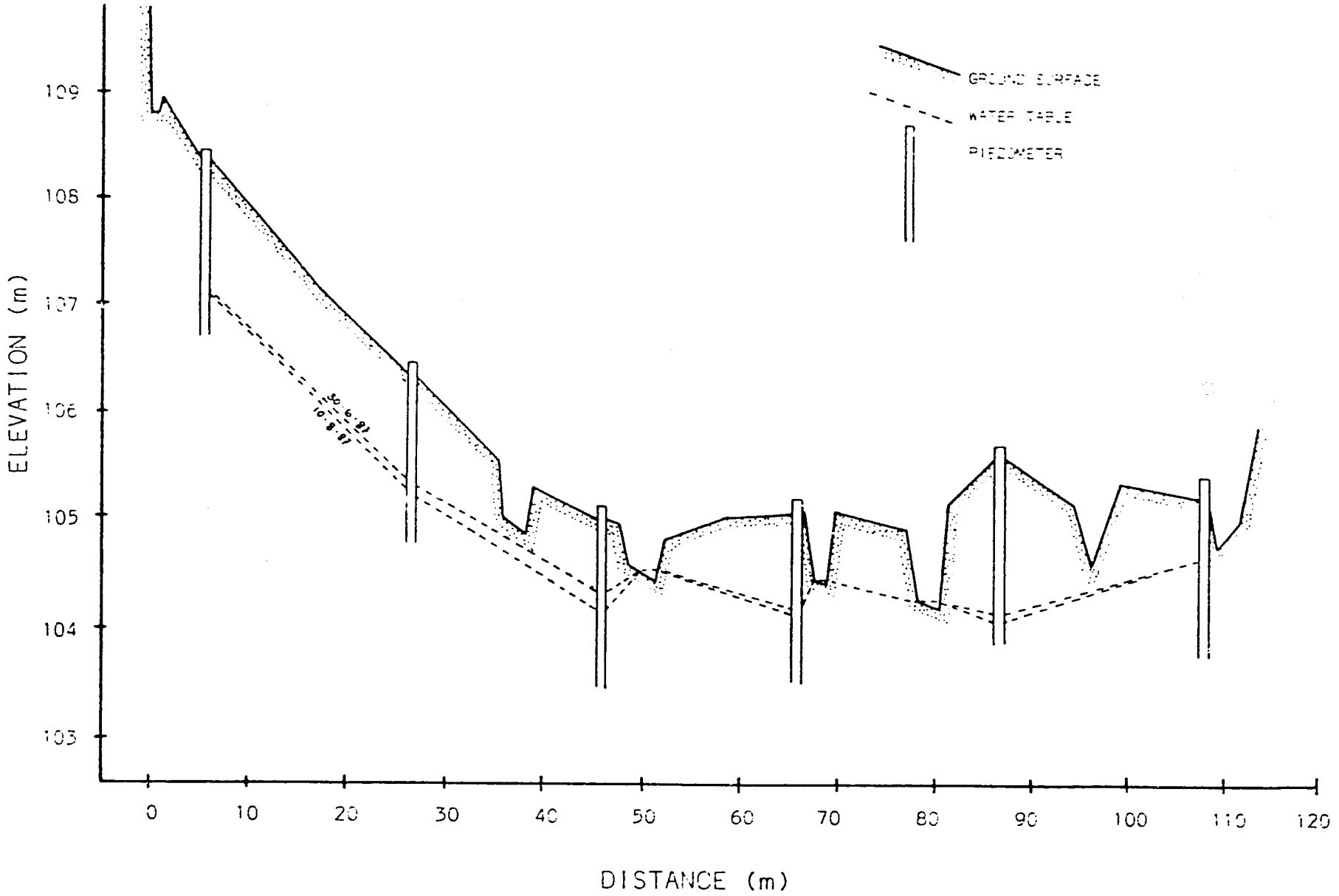

Figure 7.3. Water Table Cross Section Rwandorere Marais.

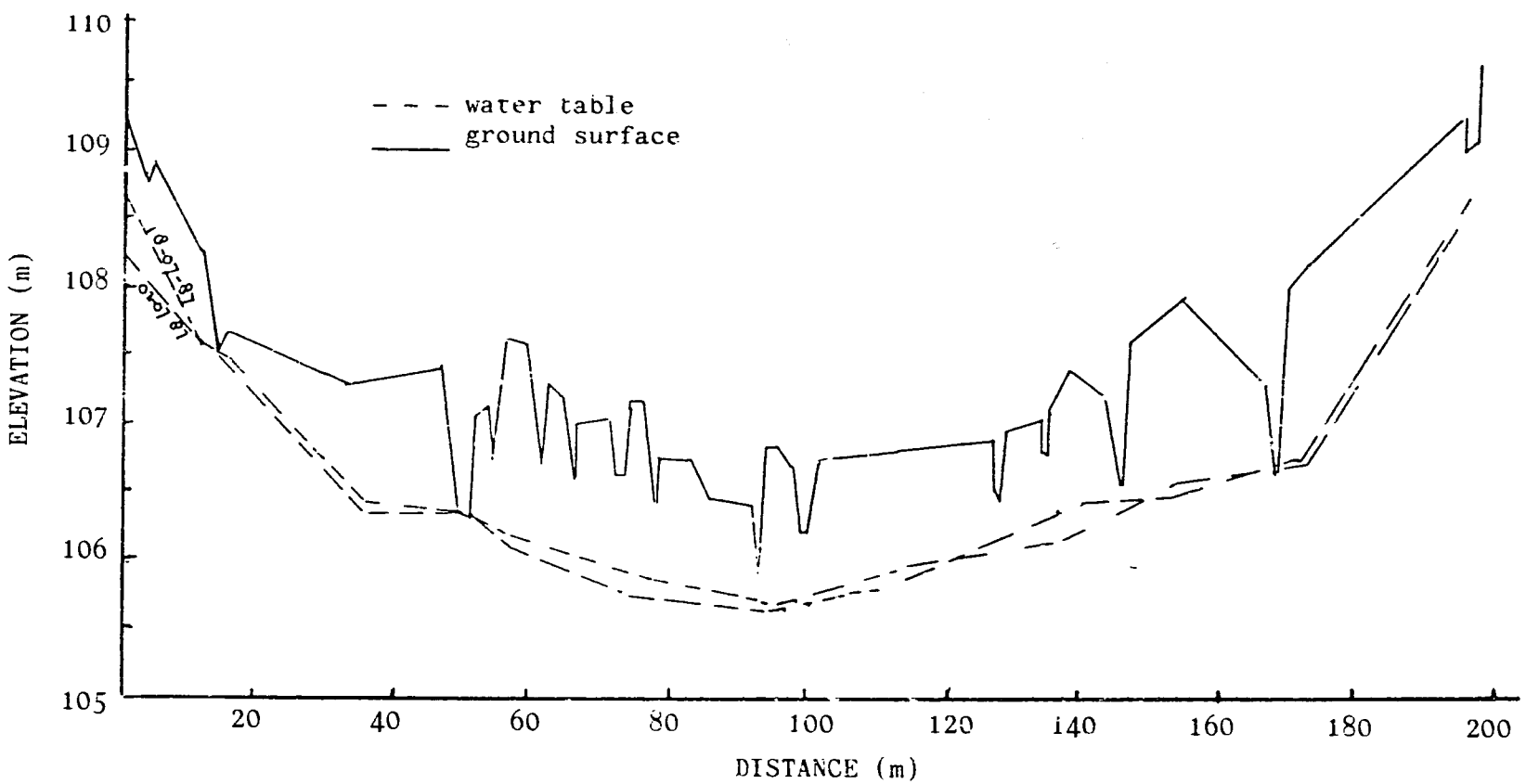

Figure 7.4. Water Table Cross Section, Ilibunga Marais.

area indicated that the hydraulic pressure in the soil below the argillic horizon was 80 cm more than that above the argillic horizon.

Our measurements show that the total amount of water stored in the ground in the marais during the dry season does not significantly change, even when water is flowing out of the marais. Since outflow is always balanced by inflow, inflow must equal outflow plus evaporation in the marais. For the 20 ha Ilibunga marais, with a 180 ha drainage area, outflow is a more or less constant 6 l/sec, in the dry season. However, this does not mean that the marais do not play an active role in the local hydrology. First, farmer-installed drainage and irrigation facilities maintain the water table parallel to the surface. If farmers did not sub-irrigate in some parts of the marais, the water table would drop. If the main drainage canal eroded until it intersected water-bearing layers, the water table would significantly drop, and most of the seepage spots would disappear. When this happened, plants could no longer be grown. Above all, our measurements indicate the importance of interflow moving down the hillsides to stream flow. Especially significant is dry season interflow, which maintains base flow in the river.

In one effort to further characterize hill slope flow, we constructed a model. We used the Thornthwaite Mather procedure (T-M procedure) (Steenhuis and van der Molen, 1986) in combination with a hill slope model developed by Steenhuis, et. al, 1987.

In most applications, the T-M procedure uses monthly or daily sums of potential evaporation and cumulative precipitation. The moisture status of the soil depends on the accumulated potential water loss (APWL). The APWL is calculated using two different methods depending on whether the potential evaporation is greater than or less than the cumulative precipitation. For

months that the potential evaporation is in excess of the precipitation (i.e., the soil is drying out), the APWL is incremented by the difference between potential evaporation (ΣPET) and precipitation (ΣP):

$$APWL_t = APWL_{t-\Delta t} + (\Sigma PET - \Sigma P) \quad (1)$$

$APWL_t$ = the accumulated potential water loss at time t (cm);

$APWL_{t-\Delta t}$ = the accumulated potential water loss at time $t - \Delta t$

ΣPET = cumulative evaporation over time period Δt (cm); and

ΣP = cumulative precipitation over time Δt (cm).

With this method, the relationship between APWL and the amount of water stored in the root zone is expressed as

$$ST_t = ST_f \, [\exp(-APWL_t/ST_f)] \quad (2)$$

ST_t = the available water stored in the root zone at time t (cm); and

ST_f = the available water stored at field capacity in the root zone (cm).

For months that the potential evaporation is less than precipitation (i.e., moisture content increases and/or percolation occurs), the storage in the soil is incremented by the difference between the potential evaporation and precipitation.

$$ST_t = ST_{t-\Delta t} + \Sigma P - \Sigma PET \quad (3)$$

If the storage ST_t at time t is higher than field capacity, then percolation ($Rech_t$) is simply calculated:

$$Rech_t = (ST_f - ST_{t-\Delta t}) + \Sigma P - \Sigma PET \quad (4)$$

and the accumulated potential water loss (APWL) is set equal to zero. If, on the other hand, the moisture content in the root zone does not reach field capacity, then the APWL may be found by combining the first and second equations:

$$APWL_t = ST_f \ln [(ST_{t-\Delta t} + \Sigma P - \Sigma PET)/ST_f] \quad (5)$$

and no percolation will occur.

We began by applying the T-M procedure to data for the Rwandorere and Ilibunga marais using a monthly and daily time step relevant for the period of our study (May 1986 - September 1987). The precipitation record used was that for Butare. The average root zone depth was equal to that of hoe cultivation (30 cm), and the amount of water available in the root zone at field capacity, was 13 cm^3/cm^3 and the potential evaporation was 0.45 mm/day. No other input data were used. A monthly time step was found to be too coarse (i.e., could not capture changes in moisture content over time). However, a daily step (Table 7.3) yielded good results.

Percolation was 23.8 cm between June 1, 1986 and May 31, 1987 in a year with slightly below average precipitation. The amount percolated compared favorably with runoff observed in the Mwogo watershed near Butare, where the average was 25.2 cm (Table 7.1).

The advantage of the T-M procedure is that results can be obtained over a short time period. The T-M procedure probably yields more realistic results than the Curve Number Method, which is currently used in Rwanda.

The T-M procedure only predicts the amount of water that percolates past the root zone, and as is expected, is only equal to the flow out of a watershed over an extended time. To obtain predictions with a higher time resolution, a hill slope model, such as that recently developed by Steenhuis et al, 1987, needs to be used. The stream flow column in Table 7.3 is calculated using a modified hill slope model as presented in Steenhuis and van der Molen (1986). The contibuton of the hillside to the stream flow for the year was 26.1 cm. More precise predictions will be attempted in follow up studies, which include evaporation and precipitation in the marais itself.

Table 7.3. **Precipitation, Percolation, and Runoff for Rwandorere and Ilibunga Marais.**

		Precipitation cm/month	Percolation below root zone cm/month	Contribution of hillside to stream flow** cm
1986	May	8.4	1.4	6.0
	June	0.3	0.0	4.3
	July	0.0	0.0	3.4
	August	6.2	1.7	3.1
	September	3.9	0.0	2.5
	October	13.9	0.8	2.2
	November	9.3	1.4	2.1
	December	7.8	0.1	1.9
1987	January	13.1	3.1	1.8
	February	10.8	0.9	1.8
	March	16.3	4.2	2.0
	April	17.3	4.6	2.2
	May	15.8	5.6	3.1
	June	0.0*	0.0	2.7
	July	0.7*	0.0	2.3
	August	4.7*	0.0	2.0
	September	14.5*	3.5	1.8
	October	9.8*	0.4	1.9
	November	26.2*	15.4	3.2
	December	11.7*	6.7	4.5

*Precipitation measured at the Ilibunga Marais 6 km. west of Butare

**Actual Stream flow obtained by subtracting the evaporation and adding the precipitation in the marais area.

WATER MANAGEMENT - THEORETICAL ASPECTS

The objective of irrigation and drainage practices is to provide optimal moisture levels in the root zone of the cultivated crop to ensure maximum yield. This means that, for most crops, there is a best depth to the unsaturated zone, depending on crop type. A further objective is to prevent the accumulation of salts in the root zone by leaching them out of the profile with added water.

Water Table Considerations

The relationship between water table depth and plant yield was clearly shown by our experiments. Because there is an optimum depth to the water table under the bed area, and this is impacted by bed construction, we need to know something about how the water moves through the soil. To find the shape of the water table under a bed, we need to balance rainfall and (upward) seepage against evaporation. Also, depth to the impermeable layer and conductivity of the soil are important. The simplest approach is to consider steady state groundwater conditions.

The steady state drainage equation for finding the height of the water table at the midpoint between the ditches is

$$L^2 = \frac{4K(2d+\Delta H)\Delta H}{q} \qquad (6)$$

L = distance between the drains or bed width (m)

K = saturated hydraulic conductivity (m/day)

ΔH = height of the water table in the middle of the bed above the water level in the ditch (m)

q = net recharge (m/day)

d = effective depth of the saturated zone and may be estimated by

$$d = \frac{L}{(L - 1.4\ D)^2/(D\ L) + 2.55\ \ln\ (D/0.7W)} \qquad (7)$$

D = the depth from the water level in the ditch to the impermeable layer (m)

W = the width of the ditch (m)

Finally, $q = P + S - E$ (8)

P = precipitation per day, (m/day)

S = seepage (i.e., upward flow) (m/day)

E = evaporation per day (m/day)

In figures 7.5 and 7.6 the different terms are schematically shown. The net recharge term q may be either positive or negative and is determined from long-term average climatic parameters or by using other drainage equations in tandem with long-term daily data. When q is positive ($(P + S) > E_p$), then ΔH is positive (i.e., the water level in the middle of the bed is higher than the water in the ditches), and when q is negative (sub-irrigation), then the water table in the bed is lower than the ditch level (i.e., H is negative). The use of potential evaporation as an approximation for actual evaporation is warranted because the water table is close enough to the root zone that plants do not wilt.

Drainage and sub-irrigation calculations depend on the height of the water table in the middle of the bed. However, the actual shape of the water table under steady state conditions can be accurately calculated as follows:

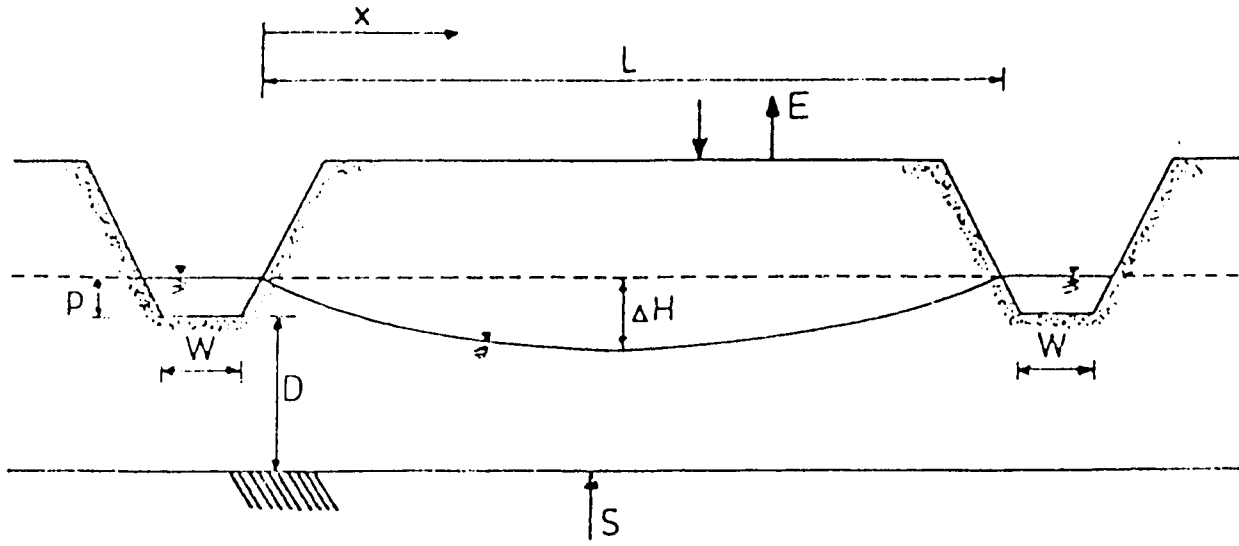

Figure 7.5. Water Table Profile When P + S < E.

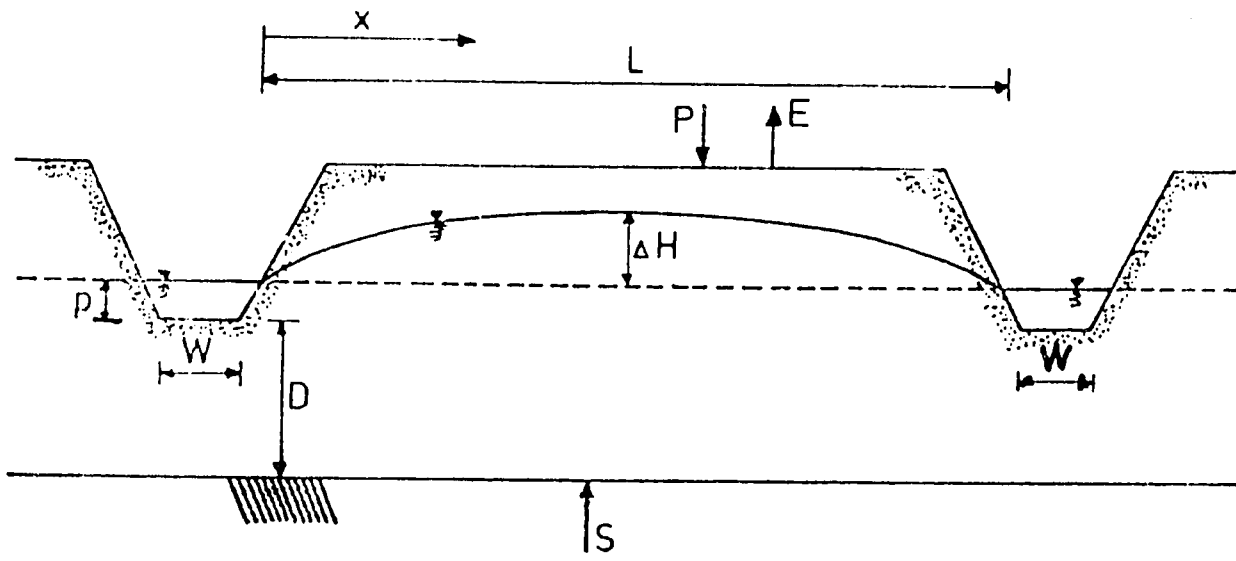

Figure 7.6. Water Table Height When P + S > E.

$$h^2 = d^2 + q\ x\ (L-x) \qquad (9)$$

h = height above ditch level

x = distance from the ditch

Depth to the impermeable layer and saturated hydraulic conductivity are properties related to a particular soil profile and are only minimally alterable by the farmer. However, it should be noted that the traditional method of deep tillage to the water table (70 - 100 cm) destroys layering in the soil, thereby significantly increasing upward movement of water to plant roots.

The depth to the water table from the soil surface (critical drainage depth) and the width of the bed can be changed by the farmer to obtain a groundwater level optimal for plant growth. The best critical drainage depth depends on many factors. **Agronomic**: each crop has an optimum depth to groundwater for maximum yields. Table 7.4 lists critical drainage depths for various crops and soil textures in a temperate climate where drainage is not a concern; **soil structure**: the height of capillary rise is a fixed function of soil structure and cannot be changed by the farmer; **socioeconomic**: the condition of the bed, a function of farmer effort, affects depth to the water table.

Table 7.4. Recommended Depth to Groundwater Under Temperate Conditions.

Soil texture	Optimal depth	
	grass	field crops
Sand	0.3 - 0.6 m	0.6 - 0.9 m
Silt	0.6 - 0.9 m	0.9 - 1.2 m
Clay	0.6 - 0.9 m	1.2 - 1.5 m

Source: J. Kesler, 1973.

Note that critical drainage depth, h_c, refers to the groundwater level relative to the ditch water level, while the symbol ΔH represents the depth of the water table above the ditch water level.

Thus:

$$H_c = H - \Delta H + P \tag{10}$$

H = vertical distance between the bed height in the middle of the plot and the ditch bottom.

P = water table height in the ditch.

To further illustrate the steady state equations, an example is helpful. Calculations shown here are for a typical bed during the summer when rainfall is at a minimum. The potential evaporation averages 5 mm/day (Table 1.2). The conductivity of the top soil is 0.8 m/day, (average in field trial measurements), and the distance to the impermeable layer is 1.8 meter below the top of the bed. The depth of the water is 10 cm in a ditch 30 cm wide. The bed has a width of 6 m and a height of 80 cm above the ditch bottom. We calculate the water table height at the middle of the bed under conditions of sub-irrigation and drainage in an area with seepage rates of 5, 10 and 15 mm/day, respectively.

The effective depth to the saturated layer is calculated using equation 2 and the following parameters.

$D = 1.8 - 0.8 = 1.0$ m

$W = 0.30$ m

$L = 6$ m

we find that

$$d = \frac{6}{(6 - 1.4 * 1)^2/1 * 6 + 2.55 * \ln (1/(0.7 * 0.3))}$$

$d = 0.80$ m

Thus, when the impermeable layer is close to the surface, the effective depth value expressed in equation 2 can safely be neglected.

The net recharge can be calculated using equation 3. With seepage rates of 0, 5, and 15 mm/day, net recharge is -5, 0.5 and 10 mm/day, respectively.

The midpoint height between the canals may be obtained with equation (4). Assuming $x = 3$, for the -5 mm/day net recharge rate, the height is

$$h = \sqrt{(0.8)^2 + 0(-0.005 * 3(6-3))}$$

$h = 0.77$

and ΔH is $0.77 - 0.80 = 0.03$ m

Similarly, we find that when

$q = 0$ mm/day, $\Delta H = 0$

$q = +5$ mm/day, $\Delta H = 3$ cm

$q = +10$ mm/day, $\Delta H = 5$ cm

When the bed size is increased to 20 m, heights are

$q = -5$ mm/day, $\Delta H = -32$ cm

$q = 0$ mm/day, $\Delta H = 0$ cm

$q = +5$ mm/day, $\Delta H = +24$ cm

$q = +10$ mm/day, $\Delta H = +43$ cm

During the rainy season for a precipitation rate of 5 cm/day, we find that $\Delta H = 24$ cm for the 6 m wide beds and 114 cm for the 20 m wide beds.

This clearly inundates the beds and also shows that 20 m wide beds as proposed by some projects will cause water logged conditions.

Water management in the Rwandan marais is extremely complex. Generally, there is excess water during the long rainy season from March through May, requiring drainage, and a severe water shortage during the summer dry period, requiring irrigation. This is, however, something of an over simplification of a complex situation. For example, in some marais, flash floods occur during periods of extended rainfall. Also, not all fields require irrigation during the long dry period. Those located near the hillsides in recharge areas (i.e., spring-fed) actually require drainage year around.

Traditionally, in small marais farmers' fields consist of raised beds 50-80 cm high, 3-8 cm wide, and 10-25 m long. Drainage discharge and irrigation supply is by means of open ditches throughout the marais between the beds. The dual use of ditches for sub-irrigation and drainage requires considerable management expertise on the part of farmers.

Salinity Considerations

In areas where potential annual evaporation is larger than precipitation, salts may buildup in the soil in areas where the groundwater is continuously or seasonally fed by an underground flow from higher areas (Kesler, 1973). In the marais, salt buildup can be a problem because average potential evaporation is approximately 1650 mm/year (Ndoruhirwe, 1984, Table 7.1), while average annual precipitation is only 1500 mm (west) to 1000 mm (east) (Agrar-Und Hydrotechnik GMBH, 1986). In areas where there are Vertisols that readily develop large cracks into the soil profile when dried, such as in the Imbo agro-ecological region (Delepiere, 1973), some of

the rainfall bypasses the soil matrix completely. This rainfall does not help leach out salts, further enhancing chances of buildup.

In the western and middle parts of the country, despite annual precipitation that is smaller than potential evaporation, there is little or no problem with salt buildup because of the favorable distribution of rainfall. Excess rainfall during the monsoon period is sufficient to leach salt (accumulated during the dry season) out of the beds and into the ditches. This movement is encouraged by the relatively small horizontal travel distance in the beds. There is a possibility, that if the bed width was significantly enlarged, salts might not be leached out in one rainy season. More calculations are, however, required to verify this hypothesis.

We should note that when the seepage at a particular spot is high and bed size relatively small, excess salts are carried with the seepage water to the ditches. Thus, if there is a salt problem, we will find it in areas with sub-irrigation.

Field Observations

Specific water management practices used by farmers are not well documented. Statements such as *An estimated 1/3 to 1/5 of the cropped area is devoted to drainage (bed-ditch system)* shows a lack of understanding of the complex irrigation and drainage practices in the marais. Jones and Egli (1984:23) write about the development of the marais:

> *the empirical techniques (by the farmers) of developing the marais are effective and require no public intervention, in sharp contrast to the disastrous attempts to develop several marshes in southern Rwanda and northern Burundi with technical and financial assistance from France. These modern techniques, using heavy machinery led to the desiccation of the marais . . . . . .*

In other words, the failure of some of the donor agencies to consider the dual role of the beds for irrigation and drainage led to disaster.

The following description of water management practices is based mainly on field visits made to marais throughout the country and on detailed observations made in the Ilibunga and the Rwandorere marais. Although our observations are anecdotal and are not based on rigorous research, they do provide an initial glimpse at a complicated, unresearched, and fascinating agricultural system.

Drainage and Irrigation Practices. In farmer-managed systems in the marais, the central canal is used for both irrigation and drainage. In areas where there is excess water (i.e., seepage areas), it is delivered to the canal. In areas with water shortages, the central drain is used to replenish the aquifer with sub-irrigation. This dual use of the same canal for irrigation and drainage is facilitated by the longitudinal slope of the marais soils, which varies from 0.01 percent of the large rivers to 1 - 2 percent in the upland areas. Figure 7.7 shows a traditional irrigation and drainage channel layout of a typical marais, Ilibunga, with a 1 percent longitudinal slope. The irrigation canals are only used during the middle and at the end of the dry season. During the rainy season, the same canals are used for drainage. The conversion from drainage channels to irrigation canals is accomplished by redigging some of the canals to slightly change the grade and by installing some small earthen obstructions, 20 - 30 cm high in the 50 - 100 cm wide canals. A more detailed look at the dual irrigation and drainage systems is shown in Figure 7.8. Here, drainage and irrigation take place in adjacent plots at the same time. In the irrigated bed, farmers plant beans and want to establish the root system. In the next plot

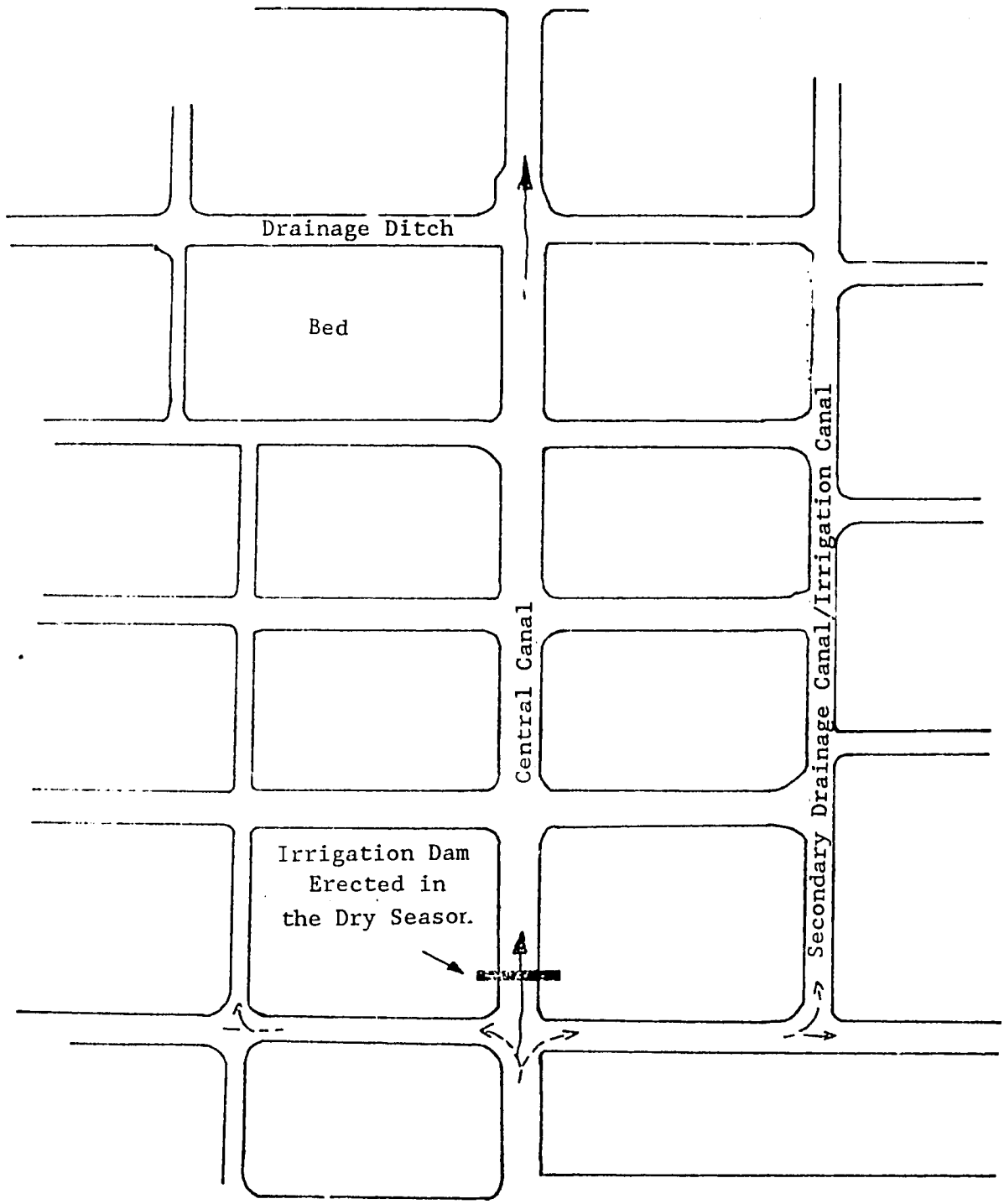

Figure 7.7. Ilibunga Scheme.

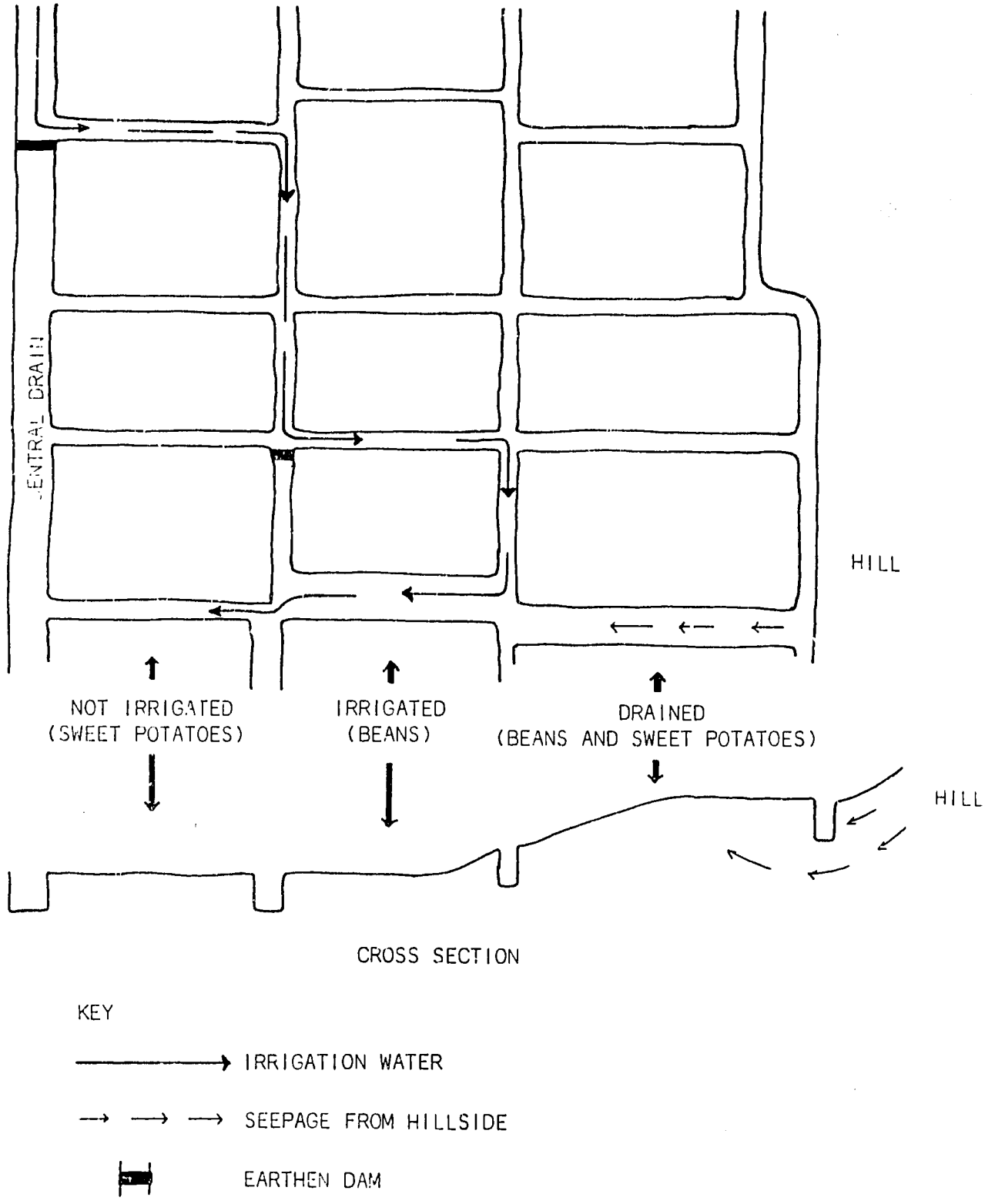

Figure 7.8. Detail of Ilibunga Simultaneous Irrigation and Drainage Practices.

sweet potatoes are grown and the excess seepage water is discharged into the ditch between the beds. The irrigation water originates from the main drainage ditch 30 m upstream and is conducted to the bed through various small (drainage) ditches. To obtain enough head for the water to flow in the irrigation canal, the main drainage canal is dammed up with a 30 cm high earthen obstruction. Small earthen obstructions are also found between the beds in the drainage ditches through which the irrigation water is conducted to guide the water to the desired location.

Less than 200 m downstream from the 30 cm high earthen dam, another small obstruction in the main drain is used for sub-irrigating a relatively large 3 to 4 ha area with sandy soils on both sides of the stream. The water is rotated between the two sides by slightly reshaping the earthen dam in the main canal.

Raised Beds. The use of optimum bed shapes and sizes is an integral part of the irrigation and drainage practices employed by farmers. The farmer-made beds are typically 5 to 7 meters wide in mineral soils containing some clay, and 10 - 16 m in organic and sandy soils. Grasslands have a minimum width of 10 m. Beds are 50 to 80 cm above the ditch bottoms. Water height in the canals varies from 0 to 10 cm. Beds up to 1 meter high, with an almost rectangular cross sectional shape, are found in areas where there is upward seepage of water. Side slope varies from 45 to 60 degrees. The length of the bed is from 10 to 25 m and is probably determined both by the amount of land allotted to the farmer and by "right of way" of other farmers to drain or irrigate their land. The width of the ditch is 0.25 to 0.50 cm, occasionally up to 1.25 m.

Beds near the hillside are located at right angles to it. Near the main drain, beds might be either parallel or perpendicular to the stream. Beds are commonly slightly graded in the lengthwise direction, and have steeper grades near the hill, especially in seepage areas. In foreign-assisted projects many exceptions and variations are found to the above. However, in farmer-built and-managed systems, beds usually resemble our description, although there is some variation in depth of the ditches. In the north, depth of the "ditches" between beds is approximately 50 cm, while in the south, beds are slightly more elevated above the ditch bottom.

Changes in bed size by farmers are always made in rough accordance with drainage theory based on practical experience. For example in the Ilibunga and Rwandorere marais in high conductivity soils (sand and organic soils), bed size is larger than in soils containing more clay. In a cross section of the Ilibunga marais in the 4 ha irrigated area, the soil type changes from sand to clay and then back to sand again. In the sandy areas, bed size is 15 - 20 m, and in the clay area, bed size decreases to a characteristic 5 - 7 m, and then increases to approximately 12 m (Figure 7.9). Also in the Rwandorere marais in the organic soil area, bed sizes of up to 13 m can be found, while just outside the organic soil area, bed sizes are only 5 - 7 m.

In the Rwandorere marais, we saw a bed that was converted from grassland to sweet potato production. The 15 m grassland bed was halved to 7 meters by digging a ditch down the middle. In the part that was not halved, potatoes were only grown at distance of 4 meters from the ditch (Figure 7.10). Farmers know how to optimally manage water for the best returns with different crops.

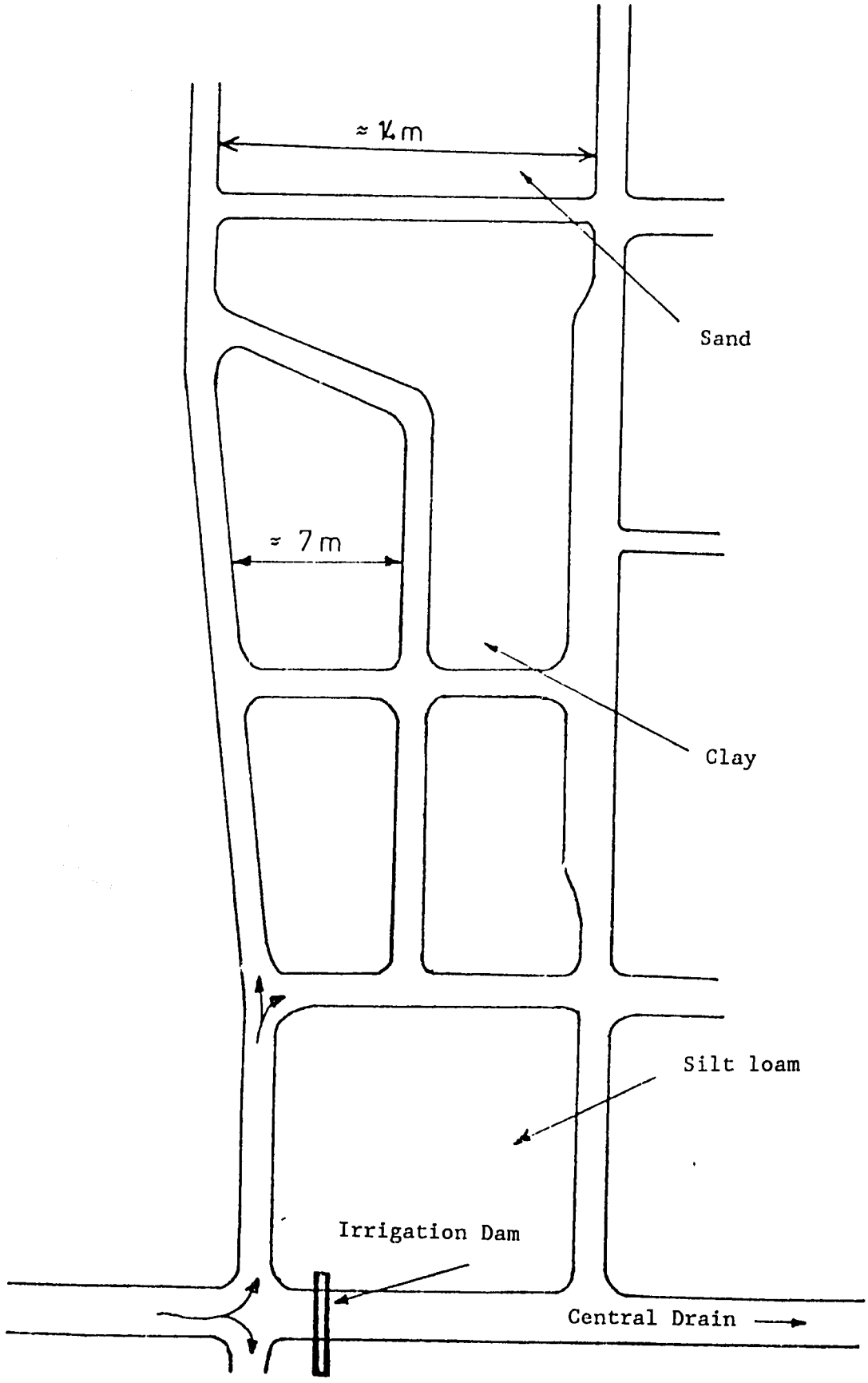

Figure 7.9. Bed Size as a Function of Soil Type.

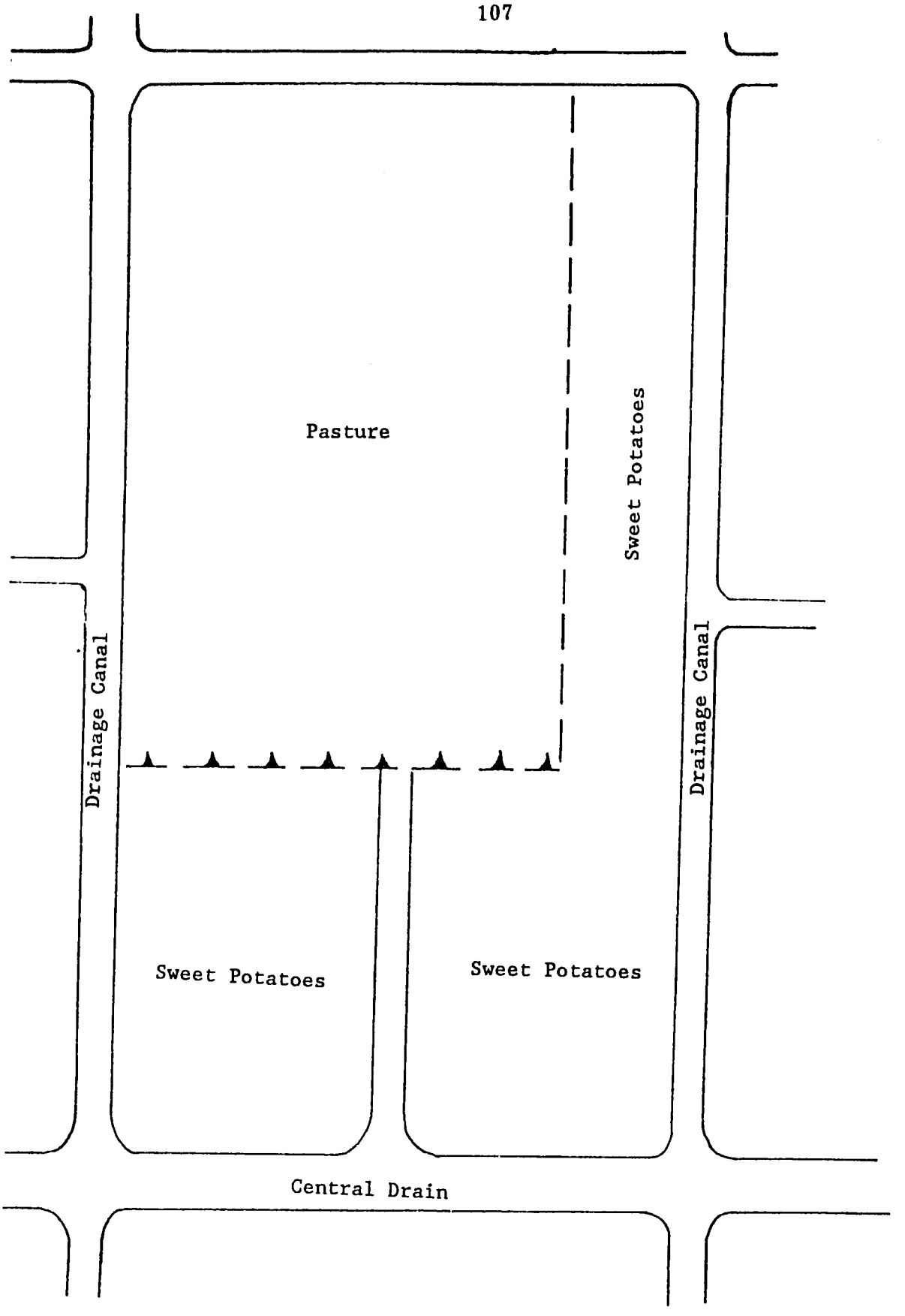

Figure 7.10. Bed With Grassland Being Converted to Sweet Potatoes.

The ability of Rwandan farmers to successfully integrate knowledge about variability in drainage properties of soils and water needs of different crops in the planning of irrigation and drainage canals, is impressive and beyond the immediate capabilities of most outside designers.

MARAIS CONSTRUCTED WITH DONOR OR GOVERNMENTAL ASSISTANCE

Gohini Rice Perimeter (Commune Kayonza, East Rwanda)

The farmer practice of diverting drainage water to irrigate crops is used in the Gohini rice perimeter. This approximately 150 ha system, which is part of the Rwamanaga Rice Development Project, was constructed with Chinese technical assistance. Diversion structures are built across the valley at regular intervals to conduct water from the main drain to the irrigation canals along the fringes of the perimeter. At the most upstream end of the project, there is a reservoir (which is almost empty at the end of the rainy season), probably for flood control purposes. Despite the fact that no water is released from the reservoir, there is more than enough in the main drain to supply all of the fields on a rotational basis. The water originates from springs along the boundary of the 10 km marais. From a hydrological standpoint this is a good project. Since there are many heads and tails within the same perimeter, water wasted in one area provides extra supply for a downstream sub-perimeter. However, it is possible that after the Chinese consultants depart, the rotation schedule will be difficult to maintain.

Farmers report yields of up to 5 tons of paddy per ha. It is unlikely, however, that such yields can be maintained over the long run without added fertilizer. This year, small amounts of fertilizer were used, but farmers did not know how much or what type.

The irrigation system is designed for rice only, as with other modern, donor-installed irrigation systems in Bugarama, Cyili, Mutara, Kubuge, etc. A first in the Gohini system is the introduction of crop rotation. Designers hope to use one block out of four for another crop. However, this will require considerable additional land shaping.

Development Projects in the Nyabugogo Valley (Central Rwanda)

Not surprisingly, some of the oldest marais developments projects are found close to Kigali, the capital. In the Nyabugogo Valley north of the capital, three large-scale projects were built.

- the Kabuye system, a 300 ha rice perimeter built with Chinese assistance
- a sugar cane plantation
- a 120 ha perimeter for intensive vegetable production

In the rice perimeter, typical of other rice development projects, expensive intervention was carried out without farmer input. The government, even after completion of the construction twenty years ago, still remains heavily involved in system management. In spite of this, rice yields declined steadily over time, probably because soil fertility is not maintained with added fertilizers.

Sugar cane is well adapted to the wet marais environment, but must be cultivated on a large-scale estate basis because of the necessity of proximate processing facilities. Sugar cane area cannot be further enlarged unless more factories are built.

Vegetable production is well adapted to marais cultivation, and high market values economically justify the costs of drainage and irrigation. Marketing is a problem in Rwanda, and the government formed a cooperative to

sell vegetables to Europe. Because of poor management, the European market was lost, and vegetable production is in a state of disarray. The government is contemplating large-scale forage production for feed for milk cows and doing away with the rights of the small vegetable cultivators in this perimeter.

Giterama Perimeter (South Central Rwanda)

In early 1960, several small marais in the Giterama Prefecture were drained with French bilateral aid. At that time, there was little practical experience with marais improvements, and drainage was the main goal. Since, several reports pinpoint these marais as failures because of over drainage (Jones and Egli, 1984; Willardson, 1986). At the time we visited them at the end of the dry season, they certainly could not be classified as failures but did not appear superior in any way to well-managed farmer marais. If significant errors in design were made by the French, farmers must have corrected them.

Rwasave Marais (West of Butare)

In this marais, designers straightened and dug out the main drain below the field level and installed an irrigation perimeter channel at the marais boundary. Since the valley is quite narrow, a significant portion of the area is lost to canal infrastructure. Because of the extensive drainage system, however, it was possible to grow sorghum during the wet part of the year. The marais was not fully utilized (80 percent), and some fields were heavily infested with weeds. Fields outside of the irrigation perimeter had just as good or better crops than those inside. At some points, farmers were already transforming the drainage infrastructure into an irrigation

network during the dry season. There was a reservoir at the head of the system, but it was almost empty and not finished at the time of our inspection. It is rumored that a donor agency will supply funds to finish the dam and rehabilitate the canals. The design of the system is severely flawed. The only way to improve the water management of this site is to fundamentally change the design itself. A farmer-type of irrigation system, similar to the Chinese schemes, that distributes water from the main drainage canal in irrigation channels should be installed.

Development of the Gikongoro Marais (West of Butare)

Under the guidance of the FAO, agronomists are experimenting with intensifying crop production in a marais in Gikongoro Prefecture. Field widths were increased to 20 m. The fields were smoothed, and an irrigation canal was installed at the outside boundary of the marais. Also, the parcel layout was changed to a neat block pattern. In some parts of the marais, smoothing and levelling the land brought the subsoil to the surface, an argellic material that hardened when dried. In other parts, where the subsoil was sandier, leveling, did not have a detrimental effect on the soil structure. At the end of the wet season, we found a trial sorghum field that was in excellent shape. The crop was fertilized and the drainage ditches were at least 1 meter deep. Close by, where drainage was insufficient, the borders of the plot were only able to produce one crop. Also, in the beginning of the wet season, we again found a trial with a fertilized maize field (300 hg/ha) that produced a good crop.

Trials in the Bahima Marais

The Bahima marais project, although well intended, was poorly conceived and executed. This marais is subject to severe flooding, but despite this is intensively cultivated. Last year, the dry season sweet potato crop was lost after the first rainfall. In November, the entire marais was flooded several times. An area of about 3 ha was set aside for a demonstration project of an improved marais model. Fifty cm deep drainage/irrigation ditches were dug at intervals of 20 m, and raised beds were levelled. We visited the project site twice. In February, a soybean crop with poor yields was harvested. In August, the perimeter seemed to be abandoned, despite the fact that there was sufficient water for irrigation.[1] Interviews with farmers revealed that they were happy not to be included in the project and disappointed in the quality of the government work.

Thus, there is clearly a mixed record of successes and failures by donor and government projects in the marais. Rice marais are hydrologically well designed but economically less feasible. When donor agencies intervene in marais where traditional cropping patterns are used, the results are no better than those in farmer-managed marais. It should be kept in mind that we studied only small marais development, and that work with larger marais is clearly beyond the capability of single farmers.

WATER MANAGEMENT ALTERNATIVES

Intensification of marais cultivation has been recommended as a development strategy for Rwanda. Typically, an estimated one-third to one-

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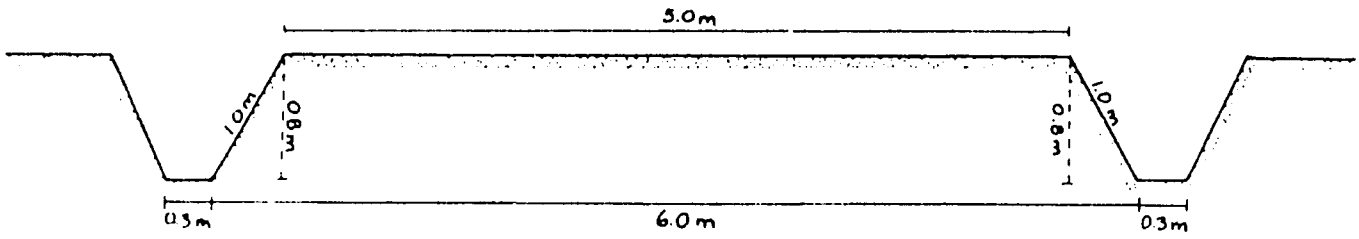
[1]In September, the test site was replanted, but water-logging was evident throughout the fields. Traditionally, farmers do not crop fields in the marais in the rainy season.

fifth of the cropped area is devoted to drainage (bed-ditch system), and the marais are generally left fallow during the long rainy season (Cambrezy, 1981). However, the assumption that farmer beds waste more space than flat wide beds is not necessarily true. For example, when ditches are 30 cm wide, beds are 80 cm high, and side slope 60 degrees. A simple calculation shows that the total area not under water is 10 percent larger than if the land was flat with no ditches (Figure 7.11).

The cultivation of sweet potatoes and beans on the same bed is another example of the intensive use of marais land. During the small rainy season in the fall in the Ilibunga marais, sweet potatoes are grown on the steeper part of the bed near the ditch and beans on the flatter middle part of the bed. According to female farmers (women plant), sweet potatoes need more water than beans, and we know that good drainage is critical for optimum growth (Jones and Egli, 1984). When sweet potatoes are grown on or near the drain, not only is the soil well drained, but because of capillary action, significant quantities of water are also supplied to the plant. This is clearly an intensive and optimum use of marais land.

Thus, in the farmer-managed marais, we find that practices are adapted to local variations in drainage and soil properties. Because of the complexity of detail necessary to accurately plan parcel size and bed height, outside design efforts made without farmer participation will be hard pressed to match the better farmer-managed marais. Moreover, we are limited by inadequate knowledge of water management parameters in the marais. Appropriate long-term research to measure basic hydrologic parameters, such as drainage coefficients, bed widths, saturated hydraulic conductivities, etc., should be continued.



Level land available for crop growth is equal to the bed widith plus the ditch width which is 6 + 0.3 = 6.3 m.

For a bed system the amount of land available is 1 + 5 + 1 = 7 m.

Figure 7.11. Comparison of Amount of Land Available to Grow Crops in Beds (80 cm high, and 6 m wide, ditch width 30 cm) versus on Level Land.

In light of the less than successful intervention by donor agencies in existing small marais, we should not automatically assume that farmer practices are inefficient and less than optimal. Farmers should only be encouraged to alter their practices when there is clear evidence that a better method exists for cultivating crops in the marais. It should be noted that we did not examine larger marais, but because of the amount of work required to develop these, donor involvement could be quite helpful.

RECOMMENDATIONS

1. Small marais (together with collines) act as a buffer for river flow, forming an integrated link in the hydrology of the whole country. Therefore, any program constructed to aid development of the small marais should also consider the effect of proposed changes on the overall hydraulic framework.

2. Marais development should be approached on a watershed-wide basis. The hiring of a watershed manager for each river basin could serve to guide government and donor intervention in the water sector.

3. Currently, farmers control the water table depth by alternating between irrigation and drainage according to the season. Limited field measurements carried out during the present study show that current farmer practices are both environmentally sound and provide optimum water management control. Unless information exists to the contrary, farmers should not be encouraged to change their management strategies.

4. Planners of water management improvement projects in the marais should consider both drainage and irrigation. When the focus is on drainage alone (as was the case in some donor projects), over drainage during the dry

season can occur, resulting in water shortages. A good management strategy is to plant water tolerant crops such as rice during the rainy season.

5. Outlet improvement (i.e., removing excess water due to downstream blockage) may increase stream flow velocity in the main drainage canal, resulting in gradual erosion of the main drain. This leads to excessive draw down of the water table, and consequent water shortages during the dry season. For this reason erosion control practices and outlet improvement should go hand-in-hand in project design.

6. Most crops can be grown in the marais, each needing an optimum water table height. These particular crop requirements should be considered in project design.

7. Knowledge of water management parameters in the marais is so limited that sound engineering design is greatly hampered. Perimeters constructed using expensive "hi-tech" irrigation and drainage techniques are, therefore, on the average, no more successful than farmer-constructed systems. (Possible exceptions to this are the rice irrigation perimeters). To improve the success rate of technical interventions, appropriate long-term research on water management practices in the marais should be carried out under the general guidance of the UNR and/or MINAGRI to obtain basic hydrologic parameters (drainage coefficients, bed widths, saturated hydraulic conductivities, etc.).

8. The failure of many governments to satisfactorily manage small systems in other countries, the high cost of construction, maintenance and operation, and the ability of farmers and farmers' organizations to adequately manage small marais is a good indication that the highest probability of success lies in obtaining farmer participation. Field testing should be made to find out how to obtain the largest farmer

involvement possible. We speculate that farmer participation will assure that variabilities in soil properties are taken into account during planning and construction phases. It also means that traditional land and water rights are maintained.

9. A national survey of the marais should not only collect soil classification data, but should also measure parameters required to complete irrigation and drainage design such as saturated conductivity, water content at saturation, 0.1 bar (field capacity), and 4.2 bar (wilting point).

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CHAPTER EIGHT

THE SOCIOECONOMIC SITUATION

In this chapter, we will describe the general socioeconomic situation in the Rwandan marais. The discussion will be focused on two important aspects:

- The particular sociological characteristics of the Rwandan farmer as a user, not only of the marais, but also of hill lands.
- The economic importance of the small marais with respect to overall agricultural production in Rwanda, and in particular, how natural resources peculiar to the marais interact with sociological characteristics to determine economic performance at the local level.

SOCIOLOGICAL CHARACTERISTICS

A study of sociological characteristics of inhabitants of the small marais requires the precise identification of the social conditions in which farmers operate, and an understanding of how farmers make decisions about what to produce for home use vs. what to produce for sale. Thus, we need to observe and describe the farmer's behavior, based on the fundamental objective which we take to be the maximally efficient use of inputs (purchased and own), whether the farmer is using hill or marais lands and subject to technical, financial, socioeconomic, and institutional constraints. Conscious or unconscious goals and outside constraints generally determine the farmer's actions, rational or not, in the marais.

Social Conditions of Agricultural Production

Until recently, researchers viewed traditional agriculturalists in underdeveloped economies as inefficient, especially when they used primitive techniques in place of modern technology. After researchers carefully studied peasant societies, they realized that peasants were quite efficient, given the resources available, optimizing use of inputs so as to achieve specific goals, particularly as regards income. Hence, socioeconomic analysis no longer treats peasants as antediluvian remnants left far behind economically modern society.

The main difference between the traditional peasant and producers in other so-called "modern" sectors is that the peasant directly consumes (as a household) a rather large part of his own production. His consumption function is thus directly linked to his production function. Optimal use of all inputs within the context of the household and as a consumer therefore occurs when the peasant achieves his production objectives. This symbiotic tie between production and consumption, present in all primitive societies, is still dominant in present-day Rwandan agriculture (Rainelli, 1975: 53). Unfortunately, agricultural production, unlike industrial production or service industries, is extremely dependent on erratic climatic conditions and other natural hazards.

Having said this, let us suppose, like Winkelman (1972), that a traditional, peasant-farmer maximizes his efficiency (U). This efficiency depends on the goods and services represented by his income (Y), his labor (M), and his spare-time activities (L). Indeed, the amount of time worked influences work efficiency in two ways: directly, but also indirectly through the income that it creates.

Let us acknowledge that free time (H) is divided between work and spare-time activities. A mathematic representation of the behavior of such a peasant is expressed thus:

$$U = u(Y,L,M) \quad (1)$$

$$Y = y(M) \quad (2)$$

$$H = M + L \quad (3)$$

and its Langrangian is

$$F = u(Y,L,M) + \lambda*[H-L-M] + \beta*[Y-y(M)] \quad (4)$$

The differentiation of (4) in relation to income (Y), to part-time activities (L), and to labor (M), the setting of the derivative equal to zero, and the elimination of the Langrange multiplicators leads to the fundamental relationship that, at equilibrium is:

$$(\delta U/\delta Y)\ (\delta Y/\delta M) = \delta U/\delta L - \delta U/\delta M \quad (5)$$

> *The peasant maximizes his efficiency when he divides his time between work and part-time activities in such a way that the marginal efficiency of work through the intermediary of the income he procures (term on the left) is equal to the marginal efficiency of part-time activities plus the* <u>*disutility*</u> *of work as such* (Winkelman, 1972).

This mathematical behavioral model requires some additional information in the case of a traditional Rwandan peasant-farmer, whose situation differs little from that of the Ougandan peasants from Kintende and Amwona that Hamdani (1986) describes. To achieve equilibrium, we must divide the income (Y), into subsistence income in kind (Ya) and monetary income (Ym) from the sale of products. The ratio between Ya and Ym depends on both the amount and price received for agricultural products sold by the peasant. When marketed products include food crops, quantity sold, although dependent on price, is also limited by the farmer's desire to first satisfy the basic food needs of his family. These are generally determined not only by the

caloric requirements of the particular family, but also by its social status. Local food habits must also be taken into account.

The relative size of the farm operation also plays a significant role in Rwanda. At a given level of technology on a small farm, the peasant will farm intensively, increasing the productivity of the land. This situation does not necessarily result in an increase in labor productivity because of present familial structures in Rwanda. Indeed, the rapid population growth currently occurring tends instead to worsen the family food situation. On the other hand, the low fertility of the land and lack of additional land nearby means that child labor cannot be efficiently used for highest returns. This, combined with the weak development of the non- agricultural sectors, results in large quantities of under utilized manpower.

Since Winkelman's model is valid even in the context of hidden unemployment, its use is still legitimate for the situation in Rwanda. In a case where the possibilities for increasing production per family member are progressively limited and the framework for product allocation is based on average subsistence production and not on marginal productivity of labor, a low price tends to progressively push producers further into a poor subsistence economy. Monetary income (Ym) thus tends to diminish in favor of "food" income (Ya), even if the principle of maximization of income (Y) is still important to the peasant. Given the present situation, conflict between crops grown for personal consumption and for income-production means that acreage sown with crops for personal consumption increases relative to that grown to cash crops, which have become relatively unprofitable. Normally, as a consequence, export potential decreases while imports, as opposed to food-relief shipments, increase. It should be pointed out that, if the size of the farming operation could be progressively increased, this

problem would not occur. Instead, the tendency would be to increase monetary income (Ym) by putting new land into cultivation, even when the prices of cash crops appeared to be falling. In such cases, the supply side function and the production function are aberrant because, with a drop in price, the traditional peasant would normally respond by increasing the quantity offered. Educational level of the peasants can play a major role here.

Although ideally it is always possible to increase harvests by using new methods and additional labor *in a more suitable selection and use of seeds, and in the intensification of weeding, tilling, planting, mulching, etc* (Vinier, 1972), in reality, peasant activities are dictated by long tradition and custom. Because many newer cultural methods that could increase output are not part of the peasant's tradition, he ignores them due to a lack of appropriate education and information. We should therefore realize that constraints caused by custom and tradition do inhibit the peasant's output. But the peasant remains no less rational in his outlook. When he gets persuasive advice from extension personnel it doesn't take him long to make use of it. Finally, lack of suitable storage facilities often forces him to sell at less than optimum times. For a household in Rwanda, the decision as to when to sell (before, during or after the harvest) also depends on how well the husband and wife communicate with each other (Damez, 1986).

It would therefore be erroneous to assume that the traditional peasant-farmer is insensitive to the social context in which he produces, consumes and sells, inasmuch as he reacts to market conditions, which may be determined by government intervention. His production function generally adjusts itself to his utility function, which he maximizes through the

satisfaction of his needs, food and money. Thus, the traditional peasant mirrors common desires and needs expressed by the society in which he lives.

"Social" Coordination of Individual Production

We saw that the production function of the traditional peasant-farmer is linked to his consumption function. Furthermore, most of the needs that the peasant seeks to satisfy are common to the society in which he lives. This means that his choice of what to produce is more or less determined by society's needs. This is true for his own preferences as well as for those of the community in which he lives and with which he carries on trade. If he intends his farming enterprise to provide him with a monetary income, he must exchange a portion of what he grows, the product of his labor, for money, which he can convert into different amounts of other goods and services. It is as if his hours of labor were only a fraction of the total working hours that society asks him to allocate to the production of food, because output is insufficient to meet society's needs.

Social division of labor is thus, very significant in allowing the needs of both the producer and society to be met through trade. Increasingly, the traditional peasant-farmer of Rwanda is becoming involved in the market economy, contributing in this sense to his own and society's well-being.

Certain technical constraints with social aspects (technosocial constraints) do limit the producer's freedom. In fact, when land parcels are very small and widely scattered, the choice of crops to plant depends to a large extent on what the adjacent farmers plant. Thus, a peasant risks a substantial reduction or complete loss of his harvest due to pests if he

decides to grow beans on his small plot of land, while other farmers around him grow fodder or weed-infested crops, such as wheat or sweet potatoes.

Observation, therefore, indicates that the traditional peasant who farms fragmented plots chooses his crops based on what his neighbors do in order to get the best return from his land given his circumstances. He is not "sovereign" or "free" in this matter. The same is true with respect to sowing dates. Quite often, he must conform to his neighbors' timetable for the same reasons. The Rwandan peasant cannot escape these collective constraints, especially when grazing is integrated with agriculture or the farmer's plots are distant from his homesite, as is generally the case in the marais.

The Peasant's Production Plan and Preferences

In an ideal situation, the peasant produces, consumes, and sells strictly according to his individual preferences. In reality, many other factors outside the peasant's control impinge upon his choices and the results, these include agroclimatic, technical, financial, and subsistence constraints. These constraints can be grouped into three broad categories:

- temporal aspects
- spatial aspects
- socioeconomic aspects

Temporal Aspects. Plant growth is markedly affected by weather patterns, which are made up of varied combinations of temperature, rainfall, duration, etc. These along with location and altitude determine the type of climate. It is the climate in combination with the soil that determines the type of crop favorable to the particular environment, as well as its yield. Some crops, moreover, only develop some of their nutritive, alimentary, or

medicinal properties under specific climatic regimes (length and intensity of solar radiation, for example), and in specific soil types. Plant growth is tied to the rhythm of the seasons. Similarly, crops that man grows to satisfy food or industrial needs are dependent on specific ecological conditions to produce a high yield.

Spatial Aspects. In an area where all cultivable land is in use, the intensity with which it is improved and used is directly related to the amount of area cultivated per person. When area cultivated per person progressively declines, production possibilities dwindle unless new more intensive cultural techniques or conditions are introduced. In every ecosystem appropriated for agricultural exploitation, special plant and animal species are deliberately selected or tolerated by man. The criterion for selecting these species over others is, therefore, their ability to satisfy (directly or indirectly) human needs. Since humans must eat throughout the year, farming methods must also be perfected that allow a year round food supply from this limited area.

For the community to survive, the necessity to sustain productivity while maintaining the ecosystem results in the formation of an agrarian system characterized by various types of suitable crop rotations and associations, as well as by integrated livestock and cropping systems. Rural religions that maintain the social continuity of the community also arise.

Socioeconomic Aspects. Faced with the need to supply his family with food throughout the year, the peasant producer sometimes adjusts the planting of certain crops to match requirements. Thus, he decides when to

plant sweet potatoes in accordance with when they will be needed by his family. When and what portion of the crop will be marketed for cash also affects planting plans. In fact, market structure may sharply narrow choices open to producers. Let us imagine the case of the traditional peasant who is forced to sell all of his rice to the factory or project that maintains the drainage or irrigation works on the rice perimeter where he has one or more plots. This sort of situation is very widespread in Rwanda.

If the price offered by the factory is lower than that on the open market, the normal tendency is to divert a portion of the harvest to the highest bidder on the open market. Thus, for a given harvest of rice, the peasant will thus tend to try to increase the price as much as possible. That is, if the price offered by the project is lower than that on the open market, it will not be in the peasant's best interests to sell to the factory, and the peasants objectives will diverge from that of the project.

Let us now examine the same peasant as he allocates his lands among cash and food crops, of which rice is a cash crop. If the price of rice is low, the peasant will tend to plant more area to food crops. On the other hand, when the price of rice increases, or holds steady, the peasant may then begin to obtain more of his food crop needs from neighboring or local markets. This, of course, is conditional on the regular and reliable availability of suitable foodstuffs. If this is not the case, the peasant will revert to subsistence cultivation. Thus, the price offered to the producer will markedly affect his production plans.

Property Rights: One of the Factors of Production

Production consists of a combination of different factors (inputs) undertaken with the aim of acquiring a product (output) capable of

satisfying a need of one or more members of society. In order to produce the required quantity, the peasant begins with a two-fold plan: the search for an optimal production system; and the search for an optimal scale of production, which permits maximization of profit (income).

Given the above, economists tend to oversimplify the situation by retaining only three production factors: capital, labor, and land. Actually, there are others, which, depending on circumstances, can be equally important. Some of these are seeds, fertilizer, chemicals, and land-use rights.

Property rights are all the more relevant in the case of agriculture because the owners of land or those with guaranteed land-use rights control whether or not land is used for agricultural production. Similarly, land transfer allows the owner to shift his rights of production to a new owner. Hence, property (usufructuary) rights are a source of income through rent or transfer. Land use is, therefore, explicitly brought about by access to property rights. Uncertainty about guaranteed availability or rights results in a sense of insecurity for the producer, with many harmful consequences such as poor upkeep of lands, unwillingness to make improvements, etc.

The unsettled and sometimes murky conditions associated with property rights to land are an impediment to the optimization of production. The precariousness of this right causes producers to modify their production plans, sometimes decreasing the area of certain crops to the advantage of others, which are not necessarily more profitable. If land-use rights were legally secure, however, many benefits would accrue to society and the producer; for example the planting of many trees. This explains the reason for deforestation in the marais at the moment. In a similar vein, the

average Rwandan farmer plants banana trees around his homesite as a sign of his ownership of the land.

We should explain that leasing of the marais land by the State to farmers will initially tend to increase selling prices. At the same time, the rental income collected by the State could contribute to the development of other public activities. The farmer, however, would need to be guaranteed, preferably with a lease or contract, the right to use plots for a sufficiently long period of time so that he could make land improvements to increase production to make up for the loss of rental income. Thus, such a situation contributes two-fold to production efficiency because not only would the farmer no longer live in a state of uncertainty, but also the State obtains a new source of revenue. We will return to this subject in the following section.

Application to the Rwandan Marais

In the preceding sections, we explained the socioeconomic behavior of the Rwandan farmer. The rather recent agricultural exploitation of the Rwandan marais spontaneously occurred as a consequence of increasing population pressure and insufficient cultivable land in the hills.

When there is sufficient land, such as in in the Upper Valley of Kagera where the average farm size is quite large, the intensity of cultivation is low and exploitation of the marais has scarcely begun. On the other land, when population pressure is high, marais land is rapidly cleared and tubers are substituted for more nutritive crops. When the man/land ratio reaches a critical level, without corresponding changes in farming methods, farm operations naturally expand into the marais. However,

farm work is clearly more difficult there because marais soils are heavier and more likely to be inundated by water than those in the hills.

In order for it to be worthwhile for peasants to open marais lands, the income that they receive must be greater than that that would be generated by similar labor in the hills. Peasant labor required to clear drains and farm the marais is, therefore, extra effort that must be expended over normal agricultural work in the hills. Thus, an equilibrium can only be achieved when, in addition, the amount of work is *such that the sum of the marginal utility of the outlay through the intermediary of the income it creates and its marginal disutility as such is zero* (Winkelman, 1972:40). This approach to labor in the marais is seen, according to Jones and Egli (1984:93), during the dry season, when the marginal cost of agricultural manpower is usually the lowest[1], and the hard heavy work required to develop and cultivate the wetlands is undertaken.

An acceleration of development of the marais stems from the fact that they are initially at least more fertile, even if the soils are water-logged. When the marais are drained, yields are much higher than in the hills because marais soils are rich in organic matter derived from alluvial deposits eroded down the slopes of the surrounding hillside (Sirven, et al., 1974).

For many small hill farm operators, labor surpluses could easily be used to cultivate the marais. Moreover, if more manpower were required for the production of financially profitable cash crops (for example, rice in Cyili, Rwamagana, etc.), any possible deficiency in family labor could be made up by hiring outside workers.

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[1]The personal economic cost of farm labor in the hills relative to that in the marais can be considered to be variable during the course of the growing year.

Let us now see how the Rwandan peasant divides his marais holdings among different agricultural enterprises. As was outlined previously, when farmers allocate marais plots among subsistence and cash crops, they take into account not only the relative profitability of the various crops but also household food security. This means that any operation that does not satisfy this two-fold requirement runs the risk of failure. Hence, in a area where use of marais lands helps farm families resolve food shortages, obligatory cash crops should either be able to be alternated with another food crop or be very lucrative for the peasant. If not, farmers will be inclined to abandon State-planned crops, or to do a poor job of caring for required crops; that is, there must be incentive for the peasant before he will be persuaded to participate. For example, the number of weedings can be reduced by peasants, thereby resulting in a yield decline. Similarly, fertilizer applications can be omitted!

We noticed a widespread satisfaction among the peasant-rice farmers of Cyili, who were happy to be able to alternate food plants such as beans with rice, even if this rotation was imposed by shortfalls in irrigation water.

It is evident, therefore, that in the context of the marais the peasant's behavior is one of maximizing his personal income, which is made up of subsistence food products and monetary revenue, both being dependent on the size and composition of the family. If possible, maximization is brought about by adding value to the raw product through processing of one sort or another. Sale of further processed products on the open market allows the peasant to substantially increase the monetary portion of his income. It is in the peasant's personal interest with respect to his rice crop for example, that he not sell all of it in paddy form (at 25 RwFr/kg presently), but convert at least some to brown husked rice (50 RwFr/kg). If

this is not possible, the he should be compensated for the obligatory delivery of all of his production at the low price by offering him financial equity or stock in the company, which would give the peasant-supplier the right to share in any profits.

However, this reasoning does not account for one important factor in the developed marais. In these, maintenance costs remain the obligation of the Rwandan State, which indubitably increases the cost of the final product. Put another way, the cost to the individual per unit of production is only a fraction of the total cost, the remainder of which is borne by the State. Up to now, the State covered amortization and maintenance costs by obliging peasants to deliver all of their rice or tea production to the factory or to the State project and at a relatively low "administered" price.

We have shown how, under these conditions, when a free market situation also exists, evasions occur. In a way, State investments directly profit those individuals who succeed in acquiring peasant production subsidized by the State on the open market. These individuals thereby directly compete with the conversion and marketing units belonging to the State.

Because the marais belong to the State, freedom should be given to the farmers to allow them to market their goods in any way they please, while requiring rent in return for use of marais plots. We have observed numerous marais plots that were rented by their official grantees to others, who develop them and sell in the renter's name. The farmers who rent the land still manage to realize a good profit Land rent paid the "phony farmers" can go as high as 2500 RwFr/year and by units of 12.5 ares of rice. This indicates that the State could ask for rent from all plot grantees, which it could allocate for recurring costs associated with operations already in

place. The government factory would then be able to compete price-wise with the private sector with respect to offering good prices for raw materials (paddy rice, green tea, etc.) and marketing finished products.

The Role and Consequences of State Involvement

In the marais, the State's involvement is major and multifaceted. It ranges from simple instruction provided by agricultural, veterinary or fish-breeding extension staff to the construction of governmental production units within the framework of projects or development companies. In any event, since the Rwandan State is the ultimate owner of the marais (large and small), farmers can be evicted at any time to allow the State to undertake projects. Farmers can also be required by the State to convert to crops judged to be more useful to the State. Generally, those who cultivate "obligatory" crops, most often export crops, are advised by government agencies. In this way, the State plays a role at every stage of production. Unfortunately, this role is sometimes altered by the context of involvement. Hence, when there is a disparity between the unsatisfied food or cash needs of the farmers, needs which caused them to exploit the marais, and the objectives pursued by the State, farmers will always pursue their own best interests.

Under these circumstances, the State is regarded as an expropriator, and its role misunderstood, even by those who in theory are the project's target population. This also occurs every time a development project is established in a marais area where demographic pressure on the land is too large. In the eyes of the peasants, the project appears to be a competitor. State officials find that they cannot impart advice or suggest agricultural techniques and have them adopted. The entire area rejects all aspects of

government involvement. Unable to overcome local resistance, the project fails and beneficial activities associated with it also disappear because they cannot survive without outside assistance. This attitude on the part of the farmers should be viewed as normal, after all, in their view, the State is infringing on their ability to generate the highest profits. The managers of well planned projects should seek to integrate their objectives with those of the general population rather than opposing them. Planners should realize that if farmers did not defend what they perceive as their rights, they would have a difficult time supporting their families.

What has to be kept in mind is that State involvement in the marais, is actually desired by farmers searching for a way to survive, and should be planned so as to respond best to the expectations of the population. If expectations are not met, beneficial aspects of the projects are ignored by the farmers, and the project's image is often irreversibly "tarnished". Thus, instead of becoming directly involved in production, thereby "expropriating" small farmers, the State should limit its involvement in some cases to coordination, assistance, and technical advice.

THE ECONOMIC IMPORTANCE OF THE SMALL MARAIS

The demographic factor is probably responsible for the development of more difficult to work, water logged marais than all other factors put together (Jones and Egli, 1984, point 2.20). Demographic pressure, in tandem with the introduction of new crops and integration into a market economy, are some of the most important factors that contributed to the deterioration of the ecosystem and to the distortion of traditional agricultural systems. As a consequence, consumption was lowered over time in quality as well as in quantity. Thus it is that, contrary to what

should be the case, crops with high nutritive values are progressively replaced by higher yielding plants that tolerate the deteriorating soils.

The ongoing decline is explained by the progressive dwindling of farm size as population explodes. Fertility on small plots cannot be maintained because there is insufficient land to allow some to remain fallow or to support animal systems that could provide precious manure. Peasants survive by adopting new plants, mainly tubers, such as cassava, potatoes, and sweet potatoes. Tubers have clearly displaced cereals and vegetables. It is this process that Geertz labels "agricultural regression," because there is a continuous deterioration of the population's food conditions. In the struggle against this regression, hill slope lands were first overtaxed, aggravating erosion and, consequently, productivity on hill lands declines. This was followed by reclamation of valleys at the food of the hills, the marais. By exploring the role that the marais play in the traditional systems of crop rotation, in agricultural production, peasant diet, and other income-producing activities (tiles, brick builders, sand, etc.), we will come to appreciate their socioeconomic importance.

An average crop rotation in the hills has the following components: tubers (sweet potatoes or cassava) followed successively by weeded, nitrogen fixing beans, and then cereals (sorghum or corn). The rotation may continue with a vegetable (beans) planting, and then another cereal planting, such as sorghum or corn. When the farm is large enough, limited fallowing is practiced after this cycle, which can last for up to three years. If this is not done, the long-term fertility will decline. This explains why traditional small-scale agricultural systems are deteriorating under the pressure of population growth. In fact, the development of the marais actually serves to mask the acuteness of the population crisis. The new

marais lands help farm families to make up deficiencies in production and allow some limited fallowing of hill lands, especially in the dry season. The marais also have the advantage that they can be cultivated during the dry season, provided that water management tertiaries are installed, when a significant portion of the agricultural work force is not active in the hills.

As we emphasized earlier, marais soils are generally water-logged and difficult to work. Nevertheless, Rwandan farmers cultivate them; some have even tried to use the organic soils in the large valleys, but lack of water control has seriously limited their use. However, marais soils do support a number of cultivated plants, including sweet potatoes, rice, etc., which, if grown in the hills during the dry season, would have low yields of poor quality material. The marais thus allow agricultural work to continue year round, even during the traditionally slow dry season. They also serve to employ an agricultural labor force that would normally be idle in the off season. The extra income that this generates can be used for other agricultural purposes or simply to improve rural well-being.

The Marais and Peasant Diet

Produce from the marais also makes a very valuable addition to rural diets, especially between planting seasons in the hills. Quite a bit of food - sweet potatoes, potatoes, cabbage, eggplant, etc. - comes from marais fields, some in the off-season, which allows members of many farm families to subsist until the next harvest. The fresh fodder contributions made by the marais during the dry season also cannot be ignored, because they allow livestock to subsist until the rainy season begins.

The integration of the Rwandan peasant into a market economy has forced him to cultivate commercial perennial crops, such as coffee trees, tea plants, etc., depending on the region. Banana trees (which are used for wine production), along with the other perennial crops, play a major role in determining the evolution of land use on the hill tops. Currently, an increasing portion of this land is being devoted to perennial crops and this *"has only been made possible because the new valley lands have largely taken over food production"* (Atlas du Rwanda, Plate XXII/II.3). Give the settlement patterns, **hilltop land has taken on an increasingly residential character, with homesites surrounded by banana, coffee and tea plantations, and woodlands, while food production is concentrated in the marais in the valleys.**

Maintenance of the dietary "vegetable-cereal-tuber" equilibrium in the production of vegetable protein and energy was possible therefore, only through the exploitation of the marais. If the whole range of crops that are grown in the marais are considered, marais lands in the Upper Plateau grow up to 18 percent of food energy, 22 percent of protein, and 15 percent of fat. Yet, the marais account for only 9 percent of the hectare/months of use of the land. On the other hand, crops cultivated in the hill lands, which make up the remainder of the arable land, only produce 82 percent, 78 percent, and 85 percent, respectively, of these nutritive elements.

With respect to the peasant diet, the marais therefore make up part of the food deficiency and also supply basic and quality nourishment to farm families. Without the marais lands, the need for food imports would surely climb in Rwanda. Even if imports were made, the neediest families would not be able to pay for food unless it were distributed as food aid free of

charge. The same families, with minimal assistance, can grow the necessary food in marais lands.

The Marais and Other Income Producing Activities

The marais have long provided natural resources for the Rwandan rural craft industry. Because of the special clay deposits, the pottery industry developed, which helped launch a lively barter trade for food products. The marais likewise supported the growth of basket making, which uses marsh plants found in swamp lands.

Today, along with these domestic uses, the marais also support non-agricultural, commercial activities related to tile and brick manufacture. This has fueled improvements in rural housing and has contributed to rural well-being through the generation of additional rural income.

Certain marais clays are even used as a substitute for modern house paints by innovative peasants. Moreover, the development of urban centers, and consequently the building sector, has brought about the growth of sand and gravel excavation activities in the marais along streams. Other profitable, industrial activities in the marais include the cultivation of papyrus for the manufacture of paper or cardboard and the extraction of peat to be burned as heating fuel or to be used as fertilizer for agricultural use.

Marais lands can profitably be used for a wide variety of activities and, if rationally exploited, could markedly add not only to the income and well being of the individual, but also generate profits for the State. One important aspect not yet mentioned is that the marais are located in relatively undeveloped rural zones. Exploitation of the marais can thus

contribute to the development of urban-rural trade and help to halt the growth of poverty in rural areas.

The development potential of each individual marais should be examined and appropriate industrial activities chosen based on the natural resource inventory and location. After considering the needs of the local inhabitants, several activities could be selected, preferably including some that contribute to improving the dietary conditions of the small peasant. These agricultural activities should include acquaculture, which is particularly appropriate in Rwanda.

Finally, it is important to note that when an income-producing activity is chosen for a marais, appropriate distribution and marketing facilities should also be simultaneously put in place or developed.

Constraints on Marais Production

In addition to agriculturally-based constraints to development of the marais, including those affiliated with social conditions - the distance of the marais holdings from the farmer's homesite, (which can increase risk of human theft and animal predation on harvests) and uncertainty regarding land use rights - competition from non-agricultural activities, such as tile and brick manufacturing, can have a marked impact on the local agricultural economy. Certain local communal directives tend to favor non-agricultural activities to the detriment of agricultural and grazing operations, inasmuch as they are sources of communal income because of the taxes that they pay.

Depending on the situation, agricultural activities may therefore be pushed aside in favor of non-agricultural activities. Although such industries are important to healthy growth of overall marais development, it is important that, given the pressing food needs of Rwanda, their superior

economic and social profitability be amply proven before hand. Increases in communal finances alone should not be used as the basis for allowing industry to supplant agriculture. Finally, as already mentioned, support for distribution and marketing services is necessary. For optimal development of the marais, various improvements and continual upkeep will be necessary; some of the work may be too costly for peasants to support alone, requiring State assistance in some form.

CONCLUSION: THE RWANDAN FARMER - MARAIS INTERACTION

In this chapter, we have described how the Rwandan farmer learned to thwart the tendency toward Geertzian agricultural regression after the crisis of crop rotation in the hill tops. In the process, new plants were introduced or plantings were intensified, responding not only to food but also money needs of the traditional peasant, who was increasingly integrated into the market economy. It is in this context of maximization of utility, through the maximization of a mixed income - i.e., monetary but constrained by food security - that the Rwanda peasant began to clear and cultivate the marais.

To survive, the farmer learned how to preserve foods or plant special crops to get through the off-season period, to multiply and conserve certain seeds in the marais, and to fallow lands in the hills for at least a short period of time during the dry season. The maintenance of soil fertility on hill tops became an important priority as farm size shrank because of population pressure, and each unit of land had to produce more food.

In addition to traditional artisanal industries in the marais, the Rwandan learned to excavate sand, to make bricks and tiles, etc., activities that have raised Rwanda to first place in improvement in rural

housing in Central Africa. Moreover, the exploitation of the marais for agricultural uses has partially reabsorbed disguised unemployment and served as a source for the development of non-agricultural activities, a significant source of income in the rural areas.

Finally, one cannot ignore changes in dietary habits of the Rwandan rural population. The marais make marked contributions to the improved availability of nutritious food for the rural populace. This in turn promotes good health and a higher sense of satisfaction. Thus, the best economic and social use of the marais is a goal well worth pursuing.

Hence, even if the State chooses to remain the owner of all marais land, access to this land should be secured by a lease or contract defined for a specified period between the State and the lessee. Rights and obligations would ensue for both contracting parties. The State, for example, would have the right to evict the farmer if the terms of the contract were violated, while the farmer would agree to do a good job cultivating the land allotted him and to pay rent to the State. The rent should be set in accordance with the development possibilities and agricultural value of the plots. Likewise, in perimeters operated by the State, drainage and/or irrigation works should be maintained by the State or even better handed over to the farmers and financed by the marais users.

When the State decides to reclaim marais lands from users for production purposes, a profitability analysis is necessary. This should account for the needs of the neighboring population, particularly when the avowed aim of the project is to improve conditions for the local population. We feel, based on our research in four marais, that decentralized management at the communal level should be systematically put in place on the small marais. Also, certain maintenance and water control work in the marais

should be carried out by users within the framework of community work projects.

Lastly, it should be kept in mind that: (1) an increasing man-land ratio caused by rapid population growth implies that the marais will play a growing role in providing food for farmers and in contributing to stabilization of hill lands by removing some pressure for constant cropping. (2) in spite of the generally low educational level of the Rwandan farmers, they are ingenious and rational. Thus, numerous desirable changes could be achieved simply by improving knowledge, and (3) the present system of inheritance contributes to the dwindling of plot sizes and must not be continued in the marais.

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CHAPTER NINE

DIVERSITY IN THE DEVELOPMENT OF THE SMALL MARAIS

For some time, Rwanda has faced a serious shortage of hill slope land, and plot size per household has gradually shrunk. Soon farmers will become gardeners and will no longer be self-sufficient in food production. Since increases in production on hill slope lands are limited by physical constraints, the development of the marais could provide farmers with much needed additional land. Thus, development initiated now will have a profound effect on future productivity.

SUBSISTENCE FARMING

Since independence, the peasants have resolutely worked to overcome obstacles to the development of the marais.

Occupation and Development of the Marais

Whatever the type of marais, they are mainly cultivated during low-water periods, especially in the dry season, July-August. In general, the stream or river that cuts through the marais forms a natural landmark, dividing the area into two communities or administrative sectors. The marais, which is located in both communities, is viewed as a transitional space, but also as a place for contact among the peoples of the two communities who cultivate it. Each community implicitly understands which land it has the right to cultivate. When development work begins, each farmer occupies as much land as his available labor allows.

At the start of development work, raised beds are used to facilitate drainage and to get the soil surface above the groundwater table. The amount of physical work required to construct a raised bed explains, in part, why it has taken so long to intensively cultivate the marais and why each person can only manage a very small area.

The raised beds alternate with small drainage canals. Aquatic and marsh plants grow in the ditches between the raised beds, capturing nutrients that are eroding from hills. They also help hold soil from the beds in place. The plants are used fresh as a green manure fertilizer on the beds.

The two current land appropriation situations do not permit improvements in agricultural production. In the first case, perhaps most common today, individuals permanently appropriate the land. Land that a peasant occupies can be transmitted by the head of the family to sons. If he has more children than fields, beds will be subdivided into several plots so that each will have a part. As the years pass, the beds become a veritable maze of tiny plots, not large enough to support families. This prohibits the use of technological innovations and cooperative ventures. The scene is dominated by minuscule fields growing sweet potatoes, sorghum, and beans for personal consumption, with no extra left for sale in the marketplace.

In the second case, individuals temporarily appropriate marais lands. Communal authorities redistribute the plots to the peasants each year. After the harvest, the land returns to communal ownership. It is a rare situation to receive the same plot each year because the number of farmers requiring subplots noticeably increases. Under these conditions, it is easy to understand why no farmer wants to make long-term investments in the land.

This tenurial arrangement perpetrates a system based on land exploitation without concern for the long-term consequences.

At present, there is no general development plan for the marais, and each farmer can situate his raised bed however he wishes, draining or holding water as he pleases. The results are chaotic, making it impossible for anyone to manage water precisely for improved productivity. Cooperatively maintained structures such as canals, that could direct water to the fields in times of extraordinary dryness, for example, do not exist. Further, as demographic pressure increases on the land, the alternate construction of raised beds and ditches begins to disappear.

Division of water and aquatic plants among users is ad hoc, occasionally resulting in quarrels between neighboring bed-users. Sometimes one farmer will take all of the organic matter from the ditches and put it onto his bed without sharing, depriving the other of the only source of fertilizer. The disgruntled neighbor then decreases the height of his bed, lowering the water table in the dry season, and condemning the neighbor's field to poor productivity because of the lack of sufficient water. Absence of rules for the equitable division of water and available organic matter is a principal factor in the degradation of the marais soils. Because animal wastes are seldom carried to the beds, water and plant material are the only resources the farmer has at his disposal to improve output.

Organization of Work

Any given individual subsistence farmer in the marais may have several ways that he organizes his available labor. Usually, he, along with his wife and/or children, completes all of the required labor from bed preparation to the harvest. Plot size is generally so small that no non-

family labor is required. The tendency among young people, however, is to work cooperatively in each others' fields.

The advantages of this approach are that because the fields are worked and seeded in a short period of time, the plants all mature together, meaning easier harvest; secondly working together encourages each individual to do the best that he can. Another labor management method is **ubudehe**, working together, with liquor as remuneration for all. This is disappearing because fields are too small for large groups to work together. The advantages are the same as the former situation, but work quality may be lower, reducing chances for a successful harvest.

Socioeconomic and Environmental Consequences of Subsistence Agriculture

Subsistence agriculture does not allow farmers to realize the optimum agricultural potential of the land for two main reasons. First, competition among neighboring farmers to gain access to surrounding plots favors their division into successively smaller lots. This makes it impossible for practice optimal water management or to gain the use of improved tools or techniques. Second, each individual can cultivate where, when, and what he wishes. This does not favor the best use of the marais.

Group effort is almost nonexistent, and each farmer is left alone to manage as best he can. Since there is little or no surplus left after the family's needs are satisfied, the farmer has nothing to sell for cash, and thus cannot invest in inputs that could improve productivity, nor can he afford to practice environmentally sound agriculture.

Individual exploitation of the marais is perhaps environmentally most damaging. Continuous cropping of fields without fallow periods or green

manure crops leads to the loss of organic matter, to soil erosion, to damaged soil structure, and to the disappearance of natural fertility.

Younger farmers have already noted the disadvantages inherent in individual ownership of land and are directing their activities toward collective development of the soil.

PRODUCTION GROUPS AND COOPERATIVES

The movement to form agricultural cooperatives gained impetus with the advent of the Second Republic, especially with State encouragement to extension personnel. *Agricultural production would increase if government farm services interested themselves more in the young to help create agricultural and livestock cooperatives.* (Message to the Nation, July 1, 1975.)

The first experiments with agricultural collectivization were carried out in the marais because this territory is state property. The State, therefore, could recover the land from individuals and redistribute it among cooperatives.

Occupation and Development of the Marais

In general, land is allocated by a communal council following a technical plan created by the counselor of the sector of the particular marais. If the land is fallow, it is first cleared, then a development plan is executed. In contrast, if the land previously belonged to several individuals, infrastructure is constructed to allow best use of the land. This includes the digging of drainage canals, the creation of larger plots[1]

[1]In Chapter 7, we was pointed out that "improved" practices should only be introduced if they are consistent with the farmer's cultivation practices. Also drainage canals should be able to serve as irrigation canals during the dry season.

(several small raised beds are joined together), and the levelling of sand and clay pits.

Organization of Work

There are four types of farmer organizations for communal agricultural production in the marais.

a) Youths under twenty-five years old who are managed by a community supervisor.
b) Cooperating workers over twenty-five years old managed by a community supervisor.
c) Pre-cooperatives, groups of farmers working together using provisional statutes while waiting for the development of competent agencies.
d) The cooperatives are farmer organizations composed of at least seven persons freely working together, but legally and officially recognized as a single entity.

All of these groups are unique in their method of organization and in their legal recognition although the processes for land allocation, land use, and work organization are similar.

The General Assembly in each cooperative plans the overall development direction and elects the Development Committee (President, Secretary, and Treasurer), which is responsible for the individual development of the assigned plots.

Depending on the sizes of the assigned plots, the cooperators decide the number of days per week that each will work. By working together,

larger development projects can be accomplished, and agricultural activities like land preparation, planting, and harvesting can be completed in a more timely manner. Those members who do not appear on planned work days must pay the equivalent of one days salary for each absence to the collective. This method of motivating and constraining the cooperators is consistent with program goals established by communal agreement.

Innovations in Land Use and Technology

In the cooperative state of land management, the importance of the legal rights to own property dims before the security of enjoying the fruits of one's labor. It is this security that motivates the cooperators to work together and divide tasks amongst themselves. Plot sizes are fixed by cooperatives and farmers' groups in an equitable fashion, providing a real opportunity to make progress in initiating agrarian reforms that distribute shares of available cultivable area among all farmers. Some of the technological innovations found in group situations include

- fertilization of the marais with animal manure;
- seeds planted in rows, and spaced correctly for the appropriate crop;
- irrigation with watering cans;
- construction and maintenance of distribution canals and the proper discharge of water; and
- planting and harvesting of a large area in a timely fashion.

All cooperatives forbid farmers from changing the division of plots in any way, and nowhere is the situation different. At worst, when a group disintegrates for some reason, their land is removed from production with

eventual compensation for any investments made. The land is then given to another, more viable group. Similarly, when a cooperative member retires or dies, his legitimate heirs present a single successor who replaces him. Therefore, the ratio of manpower to usable area is optimally maintained. This is not the case on the family farms in the hills.

Distribution of Output

Agricultural cooperatives generally produce surpluses to sell in the market place. Consequently, marketing research is necessary before new crops are planted. Market polls indicate that the most popular items are a variety of cabbages, eggplants, onions, leeks, and fish. Other food crops such as sweet potatoes, kidney beans, potatoes, colocases, etc. would probably also be popular in the marketplace.

Cooperators normally divide the proceeds from the sale of crops by saving one-third for the cooperative and distributing the remaining two-thirds among the members. Large cooperatives sometimes retain all profits from crop sales, distributing dividends at the end of the year.

Socioeconomic Evaluation of the Cooperatives

There are at least two more advantages to the cooperative approach. First, each individual member has savings in the form of cooperative assets. Even more important, the land is neatly laid out, and everyone takes pride in their job. Financial matters are handled by a competent group chosen by cooperative members. This engenders confidence in the financial sector, which may invest in basic agricultural infrastructure. This in turn frees up cooperative assets for use in the purchase of genetic material and new tools and techniques. The surplus generated by the cooperative must be sold

in the marketplace, hastening the passage of the agricultural sector into the modern economy. Finally, agriculture as an enterprise takes on new meaning in the eyes of the farmers and in the public view.

However, the cooperative movement has suffered several defeats since its inception. Farmers viewed the cooperatives simply as secondary activities, contributing minimal resources because land was still available and anyone could ignore the cooperative and survive. Today things have changed because of the scarcity of farm land, particularly for the young. Cooperatives can now be the sole source of revenue for members. Such farmers are bound for better or worse to their production organization because they will only receive profits in proportion to the work they contribute. Under such conditions, cooperators take the enterprise seriously, organizing themselves so as to avoid failure.

At present, only a very small part of the marais land is organized into cooperatives, in spite of the advantages. Clearly, farmers still need further education about the success of this agrarian reform. It is very important not to force people to enter the cooperatives against their will, however, because if the group does not work together, failure is predictable. Development of the small marais offers an opportunity to organize land and society in a new way to better preserve the environment. Such activities are easier for a group to coordinate and manage than for a single individual.

PRIVATE AGRICULTURAL ENTERPRISES

In certain places (Mwogo, Bistenyi, Rumirabahashyi, etc.), the state has allocated marais land to private entrepreneurs for development. Allocations range from 20 to 100 ha and account for a sizeable portion of

developable land in some areas. This form of land development is not popular with anyone except high officials and big businessmen.

Organization of the Land and Distribution of Products

Once the land grant is made, the agricultural entrepreneur seriously studies how to develop the marais in order to make a profit. Some activities include construction of small dams for retaining water, building central drainage canals, creation of lateral and contour canals for irrigation, and division of the land into optimum size plots. For development and organizational work, the entrepreneur may convert the independent farmers to land laborers. From then on, the farmer-businessman concerns himself with the profitable production of crops. Development of the land proceeds in the same fashion as in the cooperatives: improvement of fertility by hauling manure, use of more modern agricultural equipment, etc. Products are normally sold through traditional market networks - local and foreign.

Socioeconomic Consequences

From an economic viewpoint, it is undeniable that private businessmen make more efficient use of the marais than isolated farmers on minuscule plots. However, those that view agribusiness as the best way to organize agricultural production also rate economic growth in isolation as the most important indicator of progress. They give little or no thought to the less tangible, but equally important general condition of the populace. The principal fault of such an approach is the belief that profitable commercial enterprises alone assure all workers of a decent wage along with increased production. In reality, this is seldom the case.

The production cooperatives, on the other hand, have the advantage of directly involving the greatest possible number of people in the production process, while using their knowledge of water management and crop production and maintaining traditional ties to the land. This is very important in a society where demographic pressure is making it more difficult for new farmers to obtain the use of sufficient land to make a living. The cooperatives also ensure a more equitable division of resources among all people throughout the country. Also, the organizational structure of the cooperatives permits the inclusion of more environmentally sound land management plans.

Given almost equal production records, it is best to choose that form of land management in the marais that benefits both the interests of the State (diversification of agricultural production) and those of the greatest number of citizens - the cooperative.

STATE PROJECTS

State-run projects for development of the marais compete for land and human resources with cooperative land management. Therefore, State projects need to be compared and contrasted with the alternate cooperative method of land development.

Land Management in State Projects

The state is involved in hydro-agricultural development of three marais types:

- Small marais already cultivated, but in an unsatisfactory manner.
- Small marais, not yet cultivated because of technical difficulties.

- Large marais not yet cultivated and beyond the ability of individuals to develop.

In all three cases, the State first makes a detailed study of the area in question, formulating recommendations before construction begins. The objectives in the planning stage are to outline a work plan, to estimate labor and time required to complete the plan, and to propose a cultivation plan. In the development program, they try to take into account the complex hydrological problems and sociological, agronomic, and economic questions.

Given the twin objectives of economic profitability needed to repay the investment and of self-sufficiency for farm families bordering the marais, the State uses three methods to allocate land and to control agricultural production.

- The State manages large farms, requiring workers to plant crops (often tea); profits are used to repay the investment.
- The State allocates land to farmers who are obligated to raise specific cash crops (tea) or to limit themselves to food crops (rice), according to State mandate.
- The State allocates land to farmers without particular directions for the practice of traditional subsistence agriculture.

In each case, there is a corresponding method to organize agricultural work and distribute products.

Organization of Work and Distribution of Products

State-managed land development requires an extensive administrative cadre from the director to the manager at the work site. Labor is hired locally to complete necessary work. The State oversees marketing of raw products and occasionally constructs processing facilities to add further value to crops. These are paid for by deducting a portion from the sale price the farmer receives for the raw product. A positive attribute of this system is that farmers still enjoy their accustomed lifestyle while making efficient use of the marais.

Each farmer develops a management plan according to the program established by State project directors, including an agricultural calendar, plans for land improvement by irrigation, also procurement of materials and establishment of rules for product quality, etc. Farmers basically control production factors and are the first to benefit from their own superior management. Some good examples are tea plantations in Cyohoha-Rukeli and rice production in Rwamagana.

This was not the case at first in all State-developed marais. In some, land was equally distributed among a great number of farmers, who were free to cultivate it in any manner that they wished. Because farmers did not foresee the possibility of selling surplus, they only grew enough to satisfy their own needs. The agricultural potential of the marais was not developed for optimal profitability under this system. An example of this kind of project is Rugeramigozi marais near Gitarama.

Socioeconomic and Environmental Evaluation

As with collective development, State development of the marais encourages sensible land use policies and helps fund the construction of

appropriate infrastructure, including the installation of water control structures that permit the recovery of large agricultural areas. Plots are laid out in a rational manner, supplying farmers with adequate land while still following a development plan. Farmers are not allowed to subdivide or exchange plots. Although relatives may inherit the land, only one child may replace the farmer, preventing indiscriminate subdivision of the land into progressively smaller parcels. The head of a farm family knows that he must prepare his successor in advance. Thus, land is rationally passed from one generation to the next.

It is undeniable that collectivization of the population contributes to the use of improved cultivation methods (spreading manure, irrigation, etc.) and to the processing of more agricultural products by growers or growers groups. Rwanda's last untapped land reserves, the marais, must be carefully developed in order to feed as many people as possible while maintaining the delicate ecosystem. Organizational arrangements that promote efficient production and investment in land improvements through fertilization and irrigation constitute the preliminary steps in this process of agricultural development. State projects, in so far as they are concerned with physical management issues in the marais, are more successful at achieving these goals than individuals. The creation of a general center to assist in policy formation for the development of the marais and to monitor future progress would be helpful.

These are, however, several problems with the current organizational structure. Those who are chosen to receive a land allotment should have no other source of revenue. All farmers who border a project area should be invited to tour the area and discuss opportunities available to them. Plot sizes should be based on the farmer or groups' labor availability as well

as on rational ecological division of the land. The basic unit of land should never be any smaller than the plot. It is the State's role to insure that all farmers conform with these directives, as is the case in state-managed rice and tea plantations. That way individuals need not worry about establishing rules among themselves. A land tax should also be established, proportional to the land area held. This tax would provide a fiscal basis for infrastructure maintenance. The State should also agree to buy farmers' products at fixed or predetermined prices.

In a word, all development efforts should follow three sequential steps. First, effort needs to be spent in developing a rational plan taking all aspects, from human to environmental, into consideration. Next, the people chosen to participate in the project should be motivated to the fullest extent possible. Finally, crop choices should be carefully made to maximize agricultural productivity, give peasants a profitable return, and ecologically sound and sustainable.

OTHER NON-AGRICULTURAL ACTIVITIES

The principle economic activity in the marais today is agriculture. However, there are other competing uses that can complement or interfere with its agricultural uses. Some marais lands are used for pasture for cattle. Other uses include building sites for homes or agricultural processing facilities. Clay is extracted from some sites for tiles and bricks. Others provide sand for construction purposes.

Without a rational plan, there is a risk that indiscriminate development for a variety of purposes will compromise the agricultural sustainability of the marais. Each zone of every marais should be classified and a best use assigned to it. There should be plenty of

flexibility in this document to allow reassignment of class, but a formal process would help inject some coherent organization. Also, marginal areas should be reserved for the creation of improved pastures.

CONCLUSIONS AND RECOMMENDATIONS

Because the marais are the last undeveloped lands in Rwanda, a diversity of users are competing to control them. As we have seen, different managerial strategies yield varying results. Initial division of marais lands was made on an ad hoc basis, with no special planning. This resulted in excessive fragmentation of plots and the stagnation of agriculture at low levels of productivity with little or no surplus and a decaying land base. Individuals could not make the necessary infrastructural investments in water control or land shaping, and soil fertility declined. This is now the most common way to use the marais lands. In order to overcome these problems, some form of cooperative management is needed. We described cooperatives and State-run projects. To reintalize the rural economy, youth in particular, should be established in cooperative agricultural ventures throughout the country. Because the marais is the only land left that is not developed, the formation of cooperatives and the opening of these lands must occur in sociological and ecological harmony.

CHAPTER TEN

THE ROLE OF THE STATE

In our overview of the development of the small marais, we must also consider important institutional aspects as well. Because the State, owns all marais lands, it has the opportunity to play a critical role in assuring their future optimal development. Thus, government bodies must take needed action to ensure that this process occurs in the most efficacious manner possible.

In this chapter, we present an overview of the history of State intervention in the small marais, as well as summarizing current systems of operation. We consider deficiencies in present government structures and formulate recommendations to (a) aid in the achievement of smooth progress in development activities in the small marais and (b) improve coordination among different State offices and funding sources.

HISTORY AND EVALUATION OF GOVERNMENT INTERVENTION IN THE MARAIS

Since independence (1962), State structures were constantly readjusted. By trial and error, the government hoped to adapt these organs into a comprehensive management system for development of the marais.

Government Representation in the Marais

From the beginning, the Rural Engineering Board had the most important role in the development of the marais. From 1962 to 1972, the Rural Engineering Service (Service du Génie Rural) was part of the Agricultural Production Board (Direction Générale de la Production Agricole), which

included four sections; hydrology and climatology, land management and rural hydraulics, agricultural industry, rural construction and topography. In 1972, the Rural Engineering Service was reorganized into two closely allied divisions: the Rural Engineering Branch (Division du Génie Rural) and Hydrology Branch (Division de l'Hydrologie). In 1974, a third branch, Soil Protection (Division de la Protection des Sols), was added. By presidential decree number 69/09, June 30, 1976, the Rural Engineering and Soil Conservation Board (Direction Générale du Génie Rural et de la Conservation des Sols) was formalized. Finally, in February 1984, a fifth reorganization occurred, which remains in effect to this day. The Direction Générale is now made up of two departments: the Rural Engineering Department (Direction du Génie Rural) and the Department of Soil Conservation (Direction de la Conservation des Sols) (Figure 10.1). The 1984 reorganization, decree number 173/06, clearly identified responsibilities of the various ministries, offices and departments of the government.

In addition to the Rural Engineering Department, other ministries and services are responsible for separate activities in the marais: Ministry of Public Affairs and Professional Training (MINIMART) (Ministère de la Fonction Publique et de la Formation Professionelle) extracts building materials and harvests papyrus, for the paper industry; and the Ministry of Public Works and Energy (MINITRAPE) (Ministère des Travaux Publics and de l'Énergie) uses the marais as a place to store water, removes peat and compresses papyrus for energy needs. Ministry of Youth and the Cooperative Movement (MIJEUCOOP) (Ministère de la Jeunesse et du Movement Coopérative) is active in the organization of cooperatives and other farmers' groups. The communities, administered by the Ministry of the Interior and Community Development (MININTER) (Ministère de l'Intérieur et du Développement

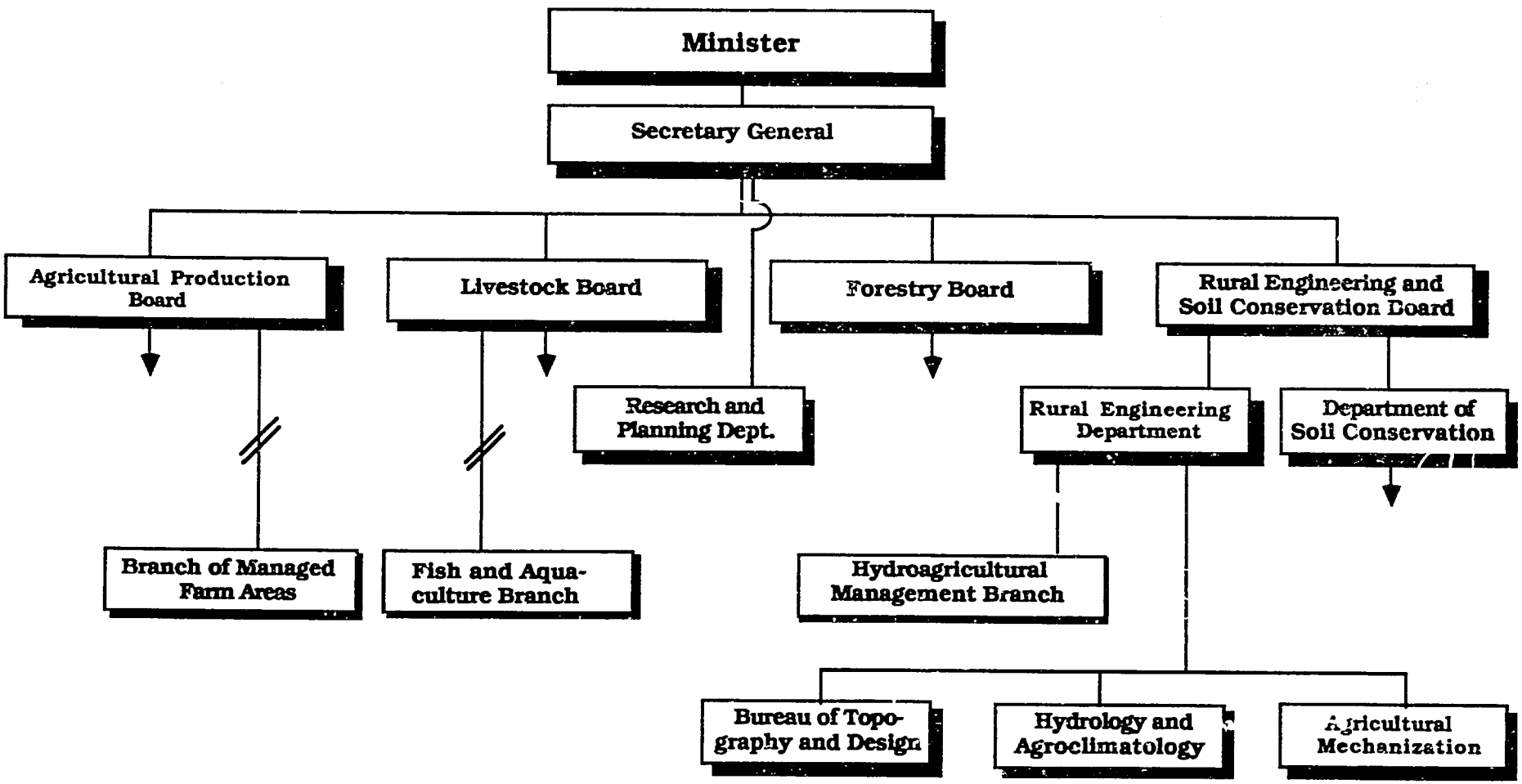

Figure 10.1 Organizational Structure of the Ministry of Agriculture, Animal Husbandry, and Forests, Rwanda.

Communal), are also involved in marais management. The Rwandan Bureau for Tourism and National Parks (ORPTN) (L'Office Rwandais du Tourisme et de Parcs Nationaux) work in the marais to protect the fauna and flora. Under the Ministry of Agriculture, Livestock and Forestry (MINAGRI) (Ministère de l'Agriculture, de l'Élevage et des Forêts), the Livestock Board (Direction Générale de l'Élevage) carries on livestock and fish culture projects in the marais, while the Agricultural Production Board (Direction Générale de la Production Agricole) also manages development activities there. The Rural Engineering Board (Direction du Génié Rural) has never had agents at the community or district level. Because the Rural Engineering Board has no official local representation, local authorities (district heads and/or bourgmestres) must assume responsibility for management of the marais.

ORGANIZATION OF STATE OPERATIONS IN THE MARAIS

Services are provided by numerous State agencies at all levels (national, district, and community) in the small marais. In this section, we will outline some of the areas where the State is active, what they do, and who carries out the work. Important sectoral areas include agriculture, animal husbandry, fish culture, extraction of building materials, removal of peat, papyrus, etc. Besides the government presence, cooperatives are also very active in the marais.

Agriculture

Of all the sectors, agriculture occupies the most attention of the Ministry of Agriculture, Livestock, and Forestry. Four modes of government operation are presently in use:

- No direct intervention
- Provision of extension services
- Special management and development activities
- Specific projects

There is *no direct intervention* by MINAGRI in most of the small marais, which are managed by the peasants themselves. Normally, agronomy extension agents in the communities tend to limit their activities to the hills, and the use of the marais is left completely up to the farmers. Unfortunately, some abuse this freedom, planting inappropriate perennial crops, such as bananas and timber trees. To halt these practices, since 1985 MINAGRI has undertaken a campaign to get farmers to remove all unauthorized perennial crops in the marais.

The service mode that is the most direct and likely to last the longest is that of *specific projects*. These projects usually involve the actual construction of special infrastructure and the administration of design, planning, and other activities. Some examples are tea, rice, and sugar cane projects.

Management and development activities of the small marais are the joint responsibility of two sections within MINAGRI: The Research and Planning Department (Direction d'Études et Planification), and the Rural Engineering Department (Figure 10.1). Table 10.1 lists some moderate-sized marais managed by the Rural Engineering Board. Another project not listed in Table 10.1, funded from the regular budget, is the development of 2000 ha of the Nyabarongo and Akanyaru river marais for crop production during the dry season.

Table 10.1 Some Marais Managed by the Rural Engineering Board.

Marais (Prefecture)	Area (ha)	Cost per hectare (Frw)	Description	Problems
Kamiranzovu (Ruhengeri)	652	102,000	1983-85 (Japan) drainage canals, individual plots, 7.5 are/family, two crops per year, worked by hand (shovels,hoes, picks, machetes).	lack of appropriate materials, shortage of qualified personnel.
Mwogo (Butare, Gikongoro and Gitarama)	200 complete; 400 incomplete	130,000+	1978;1982-85 (Germany) drainage canals completed in part, individual plots, 2 are/family, hand labor with mechanical support.	work not finished,lack of detailed studies, insufficient funds, end of donor funding.
Rwasave (Butare)	270	260,000 Frw	Financing by Germany/Belgium drainage and irrigation canals, individual plots, 5 are/family, two crops per year, worked by hand with machinery support.	work not finished, lack of funds, lack of sufficient study.
Ntende (Byumba)	50	-	work continuing since 1985, worked by hand	

Source: MINAGRI, Project for the Development of the Small Lowlands of Rwanda, 1986.

Livestock

Livestock is considered to be a marginal activity in the small marais. In Chapter 5 we saw that in earlier years, marais were reserved for pastures during the long dry season when grasses in the hills dried up. However,

presently this activity competes with crop planting and can only be found in regions where demographic pressure is lower.

A few individuals have received grants to intensively grow forage crops in the marais for dairying, for example in the Murogo Valley. Otherwise, only isolated pastures are found among the cultivated plots. Often, they are on higher lands, which are too dry for crops during the dry season.

A principal handicap that discourages the development of forage crops in the marais is the distance between the marais plot and the family homesite, where the animals are kept. It is difficult to transport both the forage to the animals and the manure to the plots.

Fish Culture

Although fish culture was in use in the marais before independence, it was neglected in the 1960s and 1970s. In the last seven years, fish culture has assumed new importance, notably because of the **National Fish Culture Project (PPN) (Projet Pisciculture Nationale)**, which benefits from financial and technical assistance provided by USAID. In 1986, the total surface area of fish ponds in the project zones covered 62 ha with 52 technicians who were responsible for 58 communities. Fish culture has the possibility of using land unsuitable for agriculture, while yields are competitive with those derived from other forms of agriculture.

Mining of Sand, Gravel, and Clay

The extraction of soil aggregates (sand, gravel, clay) is, along with the removal of peat and papyrus, a non-agricultural economic activity that generates income in the small marais. Mining of sand, gravel, or clay requires an authorization permit from MINIMART. The contractor must deposit

4,000 to 5,000 Frw in the public treasury in order to remove clay. The permit lasts for four years and is renewable. Clay quarries are not always in compatible with agricultural activities. According to farmers in the Rugeramigoyi Marais (near Kubgayi, Gitarama Prefecture), plots located in the old quarries recover their fertility after a few seasons of planting. It is predicted that demand for various aggregates will continue to increase over the next few years.

Removal of Peat

The only peat quarries actually in use are found in the Akanyaru Valley. Under MINITRAPE, peat "briquettes" are manufactured for fuel. However, the peat industry is still in its infancy. It is possible that peat removal will increase in importance in the future because of the lack of other available fuels. In fact, experiments using peat to replace charcoal as an energy source have already begun. Peat reserves in the large marais of Rwanda are much more important than in the small marais.

Removal of Papyrus

Papyrus is traditionally used for the construction of huts and buildings. The dry trunks are used as framing material and for ceilings. When the pith is removed, the trunks can also be used for rope. The upper part of the papyrus (brush) is used in the traditional preparation of banana (**urwagwa**) wine. Papyrus is also used by artisans to make chairs, baskets, and other small ornamental objects. Finally, papyrus is used by various industries, particularly the paper industry, for the manufacture of cartons and ceiling tiles. This industry could become even more important in the future as locally produced items are substituted for expensive imports.

DEFICIENCIES AT THE STATE LEVEL IN MARAIS MANAGEMENT

Coordination of Activities

As we saw in this and previous chapters, many different ministries are responsible for various aspects of marais development. Unfortunately, the different agencies do not coordinate their efforts and their activities may overlap or leave large gaps, resulting in poor overall management. Another major problem in marais development is that no skilled personnel are available. This is exemplified by the staffing problems at the Rural Engineering Department, which is quite involved in marais development.

The Rural Engineering Department includes five units: one board direction), one division (division), and three bureaus (Figure 10.1). The number of cadre working in the five units at the present time are listed in Table 10.2. Four of the level AO functionaries perform essentially administrative tasks. Staff of the Rural Engineering Board and the Hydroagricultural Management Department are not properly trained to carry out the tasks that they are expected to complete. To meet current responsibilities alone, this department needs many more skilled workers and more or less double the current number of staff. A listing of the necessary personnel is given in Table 10.3.

The three bureaus of the Rural Engineering Department also have a serious lack of experts. For example, it is difficult to imagine how the Bureau of Hydrology and Agro-climatology can fulfill its responsibilities-studies of flow patterns, sedimentology, climatological analysis, etc. - with the personnel at their disposal today. As a result, even when studies are finished, the data are unreliable as found at the Mwogo stations. Similar problems with unreliable research occurred in the course of planning for the management and development of the Nyabarongo Valley.

Table 10.2 Current Personnel in the Rural Engineering Board.

Bureaucracy	A0	A1	A2	A3	Total
Branch of Hydroagricultural Management	2+1*	-	-	-	3
Bureau of Agricultural Mechanization	1+2**	1	1	1	6
Bureau of Hydrology and Agroclimatology	1	-	2	1	4
Bureau of Topography and Design	-	-	2	-	2
Total Dec. 1987	8	1	5	2	16

*For several years, the Branch benefitted from the assistance of an Egyptian engineer (bilateral Rwanda-Egyptian cooperation).
**Two engineers in the Bureau of Agricultural Mechanization are habitually used in the Branch of Hydroagricultural Management.

Table 10.3 **Personnel Needed by the Division of Hydroagricultural Management Carry Out Current Responsibilities.**

Function and Tasks	Level	Number
Division Chief	A0	1
Engineer (liason with district agents)	A0	1
Engineer (research & plan of action)	A0	2
Engineer (research & appropriate technology)	A0	1
Engineer (follow consultants & projects of third parties)	A0	1
Field Supervisor (administrative and by third parties)	A2	2
Documents/Librarian	A2	1
Work Supervisor/Administrative Work	A3	2+

Funding, which is currently at a very low level, is another serious problem. An examination of the allocations to the Rural Engineering and Soil Conservation Board (Table 10.4) shows that they remained more or less constant on a percentage basis, but that purchasing power significantly diminished. After the budget revision in 1987, following the strong drop in

coffee revenues, the budget of the Rural Engineering Department was sharply decreased. It is expected, however, that once organizational and personnel constraints are resolved (these actions of course also require cash), outside funding will become available when donors and lenders gain confidence in the ability of the bureaucracy to successfully plan and complete projects.

Table 10.4 MINAGRI Annual Budgets, 1984-1987 in millions of Francs Rwandais (1 US $ = 180 FRw).

Office	1984		1985		1986		1987(org)		1987(mod)		
	FRw	%	FRw	%	FRw	%	FRw	%	FRw	%	-%
Secr. Général	90	11	94	10	167	17	195	19	182	19	-7
Agr. Prod. Board	317	37	335	37	321	32	307	29	292	31	-5
Livestock Board	185	21	198	22	229	23	238	23	211	23	-11
Forestry Board	123	14	130	15	121	12	131	13	116	12	-11
Rural Eng. + Soil Con. Board	149	17	145	16	167	16	168	16	135	14	-20
Total	865	100	902	100	1004	100	1039	100	936	100	-10

1987 (org) = initial budget for the year 1987
1987 (mod) = revised budget for the year 1987
Sources: Official journals of the République Rwandaise, 1984-1987.

A lack of appropriate available equipment is also a major bottleneck in the marais. The only heavy equipment that Rural Engineering actually owns is one truck. It is difficult to imagine personnel being able to commence new work or even to maintain regular maintenance schedules with such a handicap. Also, they lack essential materials to carry out necessary surveys.

In summary, a few personnel are responsible for a tremendous territory with little or no funding or equipment. As we have already seen, the marais

is very important for Rwanda. Nonetheless little has been invested in facilities and infrastructure in the marais. If development in the marais is to proceed in a logical forthright manner, helping to feed and provide work for the most people while preserving the environment, more careful investments in personnel, equipment, and facilities must be made.

SUGGESTIONS FOR IMPROVEMENT

After having described deficiencies in current government intervention in the small marais, in this section we present an alternative approach. Clearly, at the national level, a first step is to improve coordination and cooperation among the different ministries, along with correcting the personnel shortages. Our suggestions are based on extensive user participation in marais development, because without local assistance and enthusiasm, no progress will be possible.

Large and Small Marais

From the outset, we must distinguish between large and small marais, because management style is completely different in the two. Large marais must be developed (and protected) by special national authorities and remain the direct responsibility of the national office charged with their development. This is because the large marais are environmentally very complex and further, their scale means that local authorities would not be able to muster the resources to complete their development. Communities on their banks however, must fully participate as partners in all development and management work. There are actually not that many large marais. Only primary and secondary order river valleys are included, about one-half of the total marais area (Chapter 2).

All other marais in Rwanda are classified as small marais. For these, users and communities are the principal players in development and administrative decision making. Therefore, we propose to look at the question of how to develop and manage the small marais "from the bottom up," that is to say, to place the greatest possible freedom of action and decision making at the local level, but within an established national framework. Figure 10.2 shows how various official actors involved in the marais might interact, including appropriate areas of responsibility and channels of communication. Note that large marais are clearly distinguished from small.

Organization at the User Level

As already indicated in Chapter 9, marais user organizations (cooperatives and local groups) are the best way to promote improved agricultural production and development of the marais lands. These user organizations are equally indispensable in promoting the adoption of appropriate technology and in encouraging farmers to consider the production of high-value, commercial crops. Therefore, the formation of cooperatives and local groups should be given highest priority. Because these groups are primarily users' organizations, their main focus should be on the defense of users' interests. Agents of MIJEUCOOP or other service organizations could offer assistance in the creation of users' groups, but must always respect and encourage the independence of each group.

The Communities

In our organizational framework, the communities would have, among all other bureaucracies, the most important role in the development and

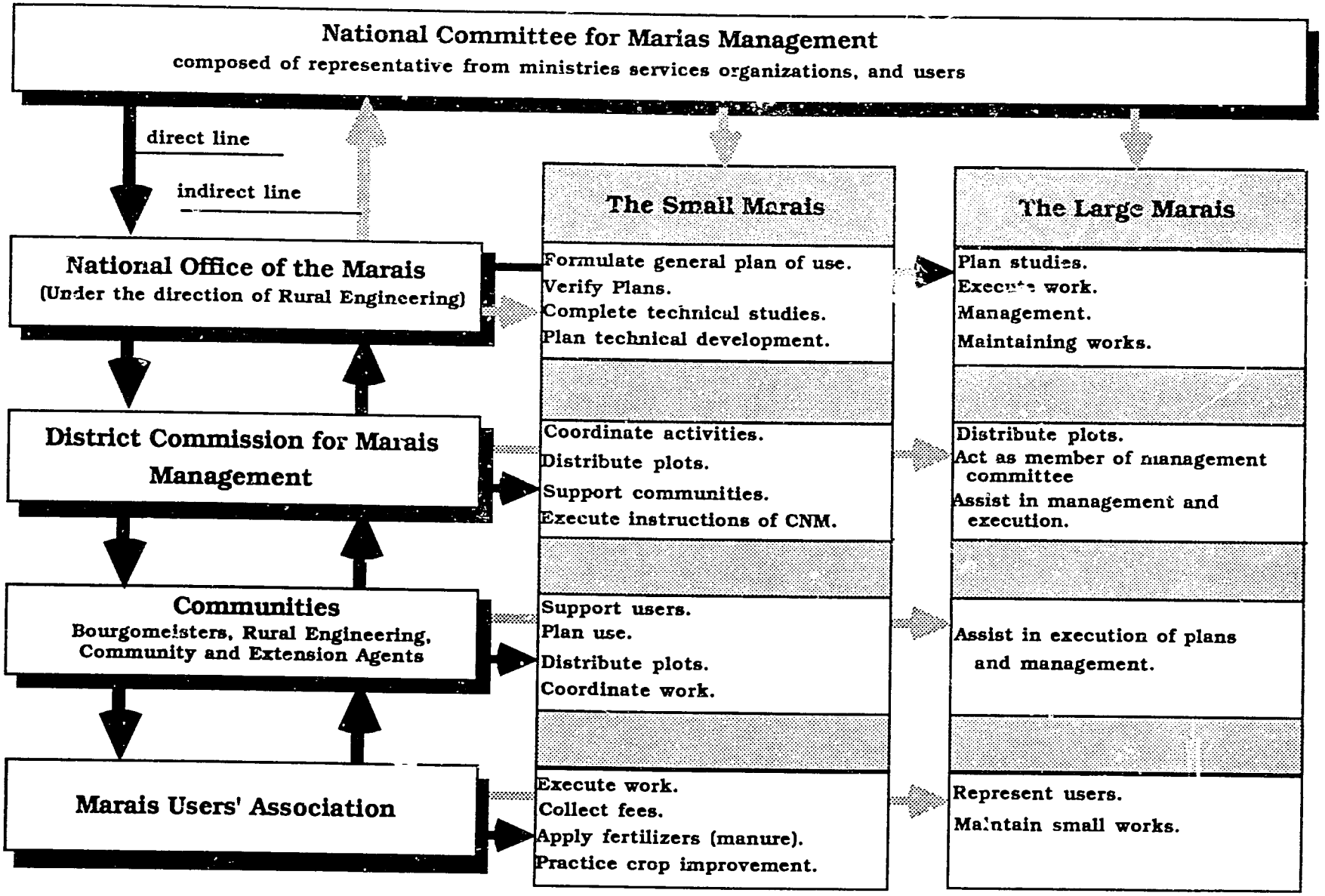

Figure 10.2 Proposed Areas of Responsibility and Channels of Communication for Official Actors Involved in Marais Management.

management of the small marais. They would be responsible for motivating and encouraging marais users to organize. Marais user groups, on the other hand, would be charged with following the instructions of the District Commission and the technical directives issued at the national level for marais management. In effect, the community administration would be the executive organ of the District Commission.

The responsibilities of each community would include:

- Prepare a rational plan for use of all the small marais resources in their zone of action;
- Establish and keep on schedule plans for various marais plots;
- Execute management operations in the small marais;
- Prepare proposals for the assignment of plots in the marais;
- Collect user fees for marais plots;
- Manage funds put at their disposition for the improvement of the marais under their jurisdiction.
- Complete an annual report containing information on productivity, problems, and advances in activities in the small marais; and
- Act on decisions handed down by the District Commission.

The communities, as organized at this time, are not equipped to fulfill these tasks. This is why they must be reinforced with aid from technicians who, in cooperation with extension and cooperative agents, should directly assist users in the improvement of their marais. In the hierarchy, these agents perform their responsibilities under the authority of the bourgmestre. They also have channels for consultation with the District Commissioner and specialized technical services at the national level.

In Rwanda, boundaries between administrative units follow, in general, the lowest common denominator in the country. As a consequence, sometimes

marais are split between two or more communities. In this case, it is recommended that a single users' group be created for each marais.

The Districts

The actions of the communities should be supervised and coordinated directly by a District Commission for Marais Management. The commission would include among its members: the prefect (or his representative), the district agronomy extension agent, the district technician(s) (for example: an engineer specifically responsible for the development of the marais or other natural resources), and representatives from the technical ministries (MIJEUCOOP, MINITRAPE, etc.).

The District Commission would have the following responsibilities in the small marais:

- Supervise the communities in their activities for the improvement of the small marais;
- Give the communities instructions on management techniques relating to the small marais;
- Intervene in instances where arbitration is necessary;
- Assign plots in the small marais;
- Help implement proposals formulated by the authorities and users groups;
- Act on the instructions of the National Office of the Marais.

The District Commission's role is very important because it possesses the power to assign and distribute land in the small marais. It also coordinates actions for marais development and management. The Commission would be guided by an A1 technician and by a secretary when necessary. The

community agents (Rural Engineering technicians, agronomists, and the agents of the cooperatives) form the true work force.

National Office of the Marais

It is imperative that a central office coordinate all marais activities and have final responsibility for overseeing all marais efforts. There are two possible options:

- Assign this responsibility to an existing group
- Create a new group for all Rwandan marais.

Earlier, we showed that there is a chronic lack of qualified personnel and funding for marais work. Thus, it seems contradictory to discuss the creation of yet another understaffed office when well enough placed, but under-used government organizations already exist. The Rural Engineering Department, for example, is organizationally well equipped to handle the task of coordination. This choice might seem arbitrary, but this office plays the most important role in the marais at this time.

We propose to first reinforce all existing offices. Later, we suggest the creation of an autonomous, specialized office. The Rural Engineering Department, which we will call the National Office of the Marais should be beefed up. Work for the National Office includes two primary areas of responsibility:

a. Coordinate activities and provide a general outline for development of the small marais; and

b. Intervene directly in the large marais.

As far as the second activity is concerned, the National Office is responsible for the elaboration and execution of research projects and

management. This office also must maintain management of projects already underway in the large marais or delegate responsibility to another branch.

In the case of the small marais, the role of the National Office will be much less direct. Users' groups, communities, and District Commissions for Marais Management will be the primary operators. The National Office should provide general direction, which is only logical given the great number of small marais found throughout the country.

The specific tasks of a National Office pertaining to the small marais are:

- Outline general development of the small marais;
- Verify and approve plans for the use of small marais resources prepared by each community;
- Coordinate the actions of the District Commissions;
- Provide technical support for improvement projects where such support is solicited;
- Prepare technical (hydrologic, agronomic, etc.) and socioeconomic studies for important enterprises in the small marais;
- Develop appropriate techniques and crops in collaboration with research institutions such as the ISAR, the UNR, etc.;
- Secure (affirm) the National Committee for Marais Management.
- Implement the instructions of the National Committee.

The National Office of the Marais will, therefore, be responsible for overall management of all of the marais in Rwanda. Recalling that the marais cover 7.5 percent of the national territory, it is an enormous responsibility, requiring a multidisciplinary approach. This is why the National Office must be reinforced by the addition of various experts in the fields of ecology, environment, agronomy, socioeconomics, etc.

The National Committee for Marais Management

From the start, the office that is chosen to oversee marais development (we proposed Rural Engineering) will affect policy formation the most. But, as previously stated, a large number of other ministries and offices also operate in the marais. In order to ensure that coordination and cooperation among the diverse departments is improved, we propose the establishment of a National Committee (inter-ministerial) for Marais Management. All of the ministries and offices involved in the marais must be represented on this Committee, as well as all groups involved in marais development and, of course, the users and their various groups.

In the long run, we propose that the National Office of the Maris become an executive office of this Committee. The best time to detach the National Office from the technical ministry would be when self-financing is assured. Such a situation would allow, in the end, a more balanced inter-disciplinary and inter-ministerial approach.

OTHER FACTORS NECESSARY FOR OPTIMAL DEVELOPMENT OF THE MARAIS

In the following pages, we will review in some detail other factors, besides the organizational ones just covered, that will be important in the development of marais resources.

Education of Rural Engineering Technicians

Given the almost complete absence of technicians in Rural Engineering, a first priority should be to further educate those already employed, particularly level A2 and A3. For example, in Burundi the École des Travaux Publics (School of Public Works) in Gitega provided training for Rural

Engineering technicians (as well as topographers, and bridge and dike technicians).

In our scenario, every community will eventually have one or more Rural Engineering technicians. Their primary task will be to help the user organizations improve their marais, then to give management assistance and aid in the maintenance of hydraulic works. In the beginning, this will be a full-time job, but after a few years, the technicians could also assist with rural construction, road maintenance, and small-scale public works. They will thus truly become "community technicians."

A rather large number of new technicians (level A2) need to be trained. For each community to have one technician, 143 would be necessary. Another sixty are needed for the national offices and other services. This brings the total to about 200 people. According to our estimate, this demand needs to be satisfied in less than ten years. Twenty to 25 Rural Engineers and 10-15 hydrologists would be needed as well. This is why a minimum of twenty new technicians, two new engineers, and one hydrologist must be trained every year.

A scheme for recruitment of advanced technicians, engineers, and experts should be included in a national plan of action. A precise evaluation of the number of upper-level managers and skilled workers required is an urgent necessity. The Ministry of Public Affairs and Professional Training (MINIFOP) (Ministère de la Fonction Publique et de la Formation Professionelle) must help to assure the future availability of these specially trained workers. Also, the government needs to help prevent the transfer of these experts into services that have no relationship to marais development. For example in August 1987, the Rural Engineering

Department lost its three hydraulic engineers when they were transferred to district administration.

Self-Financing

The establishment of new government structures like the ones described earlier will have an impact on the State budget. The recruitment of personnel alone entails considerable extra expense. Thus, a national strategy for the marais must include financial planning which, in the long run, will lead to self-financing. Ideally, fees collected from marais users should cover all of the costs of administering the National Organization for the Management of the Marais. The advantages of such a situation are:

a. The National Office of the Marais will be required to design economically viable programs.

b. The performance of a national office will be measured in terms of their success in achieving the goal of self-financing.

c. Projects will be designed in the most efficient manner possible and will not cost the State additional funds.

d. The office will be directly responsible for its actions and expenditures.

The introduction of required fees (users pay a small sum for the use of marais plots) must be implemented in successive phases with a certain measure of prudence. Users need to understand that the fee is not an arbitrary tax, but designed to fund programs and staff that will improve the productivity of the very marais plots that they cultivate. In some areas, users are already accustomed to paying for the use of agricultural lands in the marais. In the rice paddies, farmers are obliged to sell their output for a lower than free-market price. Thus, from one hectare the government

can net between 12,500 frw (2.5 t/ha, 30 frw/kg free market) and 50,000 frw (5 t/ha, 35 frw/kg in the free market) in hidden taxes. In the Ngoma and Mbanyi (Butare) communities, marais users pay a duty of 100 Frw (Cambrezy, 1981).

It would take too long to present a thorough analysis of the economic and financial consequences of the general introduction of fees. Nonetheless, if we estimate the surface area of the marais lands actually cultivated at 90,000 ha (Chapter 2), a fee of 25 frw/are/year would yield an annual revenue of 225 million francs, a doubling of the current budgetary allocation of the Rural Engineering Department.

Lending institutions, national as well as foreign, remain (for the moment) indispensable in the procurement of funds for direct investments in the marais including: (a) construction of drainage and irrigation infrastructure and access routes; (b) ready availability of farm credit; (c) major studies and research programs; and (d) technical assistance. An expansion of the number of government personnel as well as bureaucratic restructuring, and the introduction of a national marais strategy may cause an increased need for contributions from lending institutions.

All of the lenders, and in particular the World Bank and the PNUD, consider education to be the key to development. They rarely refuse loan requests for the creation of centers such as the one proposed earlier for training of technicians or for efforts to improve other areas of education and training as required. Therefore, it will be possible to solicit and obtain financial assistance for either the creation of a training center or for advanced training for agency personnel.

Evaluation

There is an urgent need to prepare and implement a national strategy for the marais. But, as the preceding chapters have demonstrated, many facets of the marais are still too poorly understood to allow formulation of precise recommendations. This is why considerable effort is needed to develop a strategy with the flexibility to provide solutions to current problems, while allowing for future developments resulting from increased understanding of the natural environment of the marais.

In order to ensure the advancement of work in the marais and continued protection of its resources, the national strategy must be evaluated on a regular basis. If carried out every five years for example, the assessment would conform with quinquennal plans for development. The appraisal process should be initiated by the National Committee of the Marais, with special attention given to regularly submitted activity reports.

Participation of the Private Sector

We already emphasized how deeply the State is involved in marais management from basic research studies to organizing users' groups at the local level. At the present time, the high cost of running marais operations would rapidly discourage private involvement. There are a few private concerns that have recently begun to invest in management work, but for most, the risk is still too high. Thus, government actions, particularly in the agronomic context, are quite helpful, although the costs (construction, transport, personnel, budget, etc.) have been made on too large a scale. In fact, the tremendous capital investment that the Government made in the rice-growing irrigation schemes (Rwamagana, Cyili, Bugarama, Kabuye, Mukunguri, and Mutara) oblige them to force the users to

sell all of their paddy harvest to State factories at below market prices (see also chapters 8 and 9). Of course, rice growers prefer to sell their harvest on the free market just as consumers would rather buy rice there than from State-run stores. Given this situation, it is only logical that the State cease processing and selling rice, leaving those activities in private hands. However, the State (or the project) would still need to maintain large-scale projects and carry on agricultural organizing work. Funds to support these activities could be garnered from simply renting out the plots for a set fee and charging for the use of hydro-agricultural facilities. In the cases where a private enterprise does its own managerial work and doesn't use government support services, a lower rent fee could be charged.

Users will probably not oppose official payment of a set rent fee for the use of specified plots. There are already many who pay rent fees by the seasonal for use of plots to other users who have received extra or unwanted allotments of marais land from the government. In Bugarama, a plot of 15 ares is easily rented out for 2500 frw/season.

In general, the State should progressively withdraw financial and managerial support from certain areas that interest the private sector, but only if the same operations will continue at a similar quality, but for a lower price. The State should be prepared to assume the role of overseer, rather than carrying out all activities itself.

Guarantee of User Rights in the Marais

The marais lands, as well as that of the hills belong to the State. Unlike the situation with hill land, however, marais users can lose their rental rights if they do not use their plots during several successive

seasons (in some places a single season of non-use is sufficient) and, what is worse, if the land is expropriated for public use, they receive no indemnity for improvements made if no written contract is established between the State and the user. Uncertainty about rights to use marais lands discourages farmers from participating in efforts to improve land through fertilization or the use of new management techniques.

To encourage users to invest in fundamental and necessary improvements of marais lands, it is absolutely necessary that renters be guaranteed by the State their rights to use marais land. To do this, a written contract must be established between the user and the National Office of the Marais, perhaps by delegating this task to the District Commission for Marais Management. The contract should give the user the right to an indemnity for all land improvements if the contract is terminated by the State. Similarly, the user may not rent or sell the use of his plot nor may his right of use be transferred via inheritance without the express permission of the State.

High-value Commercial Crops

Management is very costly for the State. If the State is to recoup its large investments in infrastructure and management and farmers are to make cash profits, users should be encouraged to grow high-value commercial crops such as rice, sugar cane, vegetables, legumes, etc. If the farmer only plants crops for his own use, he might not have sufficient cash to cover his plot rent fee, and if the State collected no fees, it would not be able to afford to continue providing the same level of services.

The cultivation of high-value crops also has several other added bonuses, such as monetarization of the rural community, the creation of jobs

(rice farmers often employ a salaried workman for certain kinds of work such as weeding and harvesting), the use of modern cultivation techniques, etc.

Meanwhile, in order to avoid the attendant losses of fertility associated with monoculture, the State should allow farmers to practice crop rotations that include food crops. To encourage intensification of cropping, the State could also authorize the cultivation of commercial crops in association with food crops.

Formation of Cooperatives

The development of managed irrigation schemes is very difficult. Users, who are not used to working cooperatively must work together to construct a cultivation calendar, collaborate in the maintenance of canals, choose an equitable policy for water management, etc. However, if the farmers are grouped together in cooperatives, they have a better chance of completing tasks in a timely fashion. A second reason justifying the formation of cooperatives is that individuals alone have no power to influence the formation of policy or to affect contracts, however an organized, coherent group of users presents a different face to the world. Cooperators would have the ability to:

- Solicit favorable credit terms or construct an owner-held farm credit system;
- Maintain a cooperative store where bulk supplies are sold at low prices;
- Establish a cooperative marketing organization to sell their crops at a profitable price.
- Sign contracts as organizations for the delivery of special services, such as schools, prisons, the army, etc.;

- Invite agronomists or other experts to present special training workshops;
- Organize field trips to visit other cooperatives;
- And sometimes cooperatively purchase a vehicle to transport crops to urban areas where the prices are higher and demand is stronger.

For a long time, the government has worked to encourage the formation of cooperatives, particularly farm cooperatives. In 1984, they created a special ministry, MIJEUCOOP (Ministry of Youth and Cooperatives) and hired a cooperative organizer for each district and community. However, one of the biggest problems with this approach is that the government directly intervened in organization activities. This worked to stifle the spirit of individual initiative, which characterizes all successful cooperatives. Extensive legislation works to further dampen collective enthusiasm. This strategy must be changed to allow people to freely choose to group themselves at their own initiative. Recently, a Center for Training and Cooperative Research was established (CFRC). The State should entrust the cooperatives to this center.

As far as private individuals who have signed a rental contract with the State goes, it would be best if they too regrouped into cooperatives to provide themselves with sufficient financial backing to undertake necessary projects. They would then have enough power to influence decision making and hire services at the best price in a similar manner to the cooperatives.

Agricultural Loans

As we alluded earlier, farmers' cooperatives theoretically benefit from better access to credit sources. But the two financial institutions in

Rwanda that grant this credit--theBanques Populaires (Popular Bank) and the Banque Rwandaise de Développement (the Rwandan Development Bank) do not specialize in agricultural loans. Consequently, both farm cooperatives and individuals encounter difficulties in obtaining farm loans. This is because:

- Farm loans are often monetarily insignificant in relation to those granted to other non-agricultural activities.
- Banks are less interested in agricultural loans because extra work is required to process and maintain the loans, the loans are less profitable, and are likely to be more risky for the bank.
- Cooperative find it difficult to furnish sufficient collateral or guarantees; and
- Applying for a loan involves complicated procedures. Many cooperators cannot read or write.

As we have already seen , improving productivity in the marais absolutely requires the use of inputs, most of which must be purchased (manure, chemical fertilizers, selected seeds, plant protection products, etc.). Thus, it is imperative that access to farm loans be improved immediately. This could be accomplished by:

(a) Creating programs for special loans for the agricultural sector within existing banking institutions, or by establishing a new banking institution especially for the agricultural sector; and

(b) Improving farmer access to loan officers by setting up a regular schedule of stops for bank representatives down to the sector level.

Encouragement of Agro-food Industries

The government, disappointed by the results of cooperative projects and farms, has begun to encourage private entrepreneurs to undertake marais development. In fact, a good number of private entrepreneurs are quite interested in developing the marais lands for cash cropping or intensive animal husbandry. Products from these projects are marketed locally or sometimes sent to a processing plant (Chapter 9). However, as more cash crops are produced for sale on marais lands, markets further afield must be found, and the products must be transported there. In this context, the government should promote the development of alternative markets.

The government could actively facilitate the creation of further processing plants for agricultural products, agro-industries. The advantage of this is that it offers the possibility of simultaneous benefit for many economic sectors. First, a guaranteed market for the agricultural products of the marais is created. Because farmers are directly remunerated, they would be willing to invest more inputs (manure, labor, etc.) in cash crops for sale. Then, in a chain-like fashion, industry and private enterprise will be able to create profitable businesses. Finally, the national economy will benefit from reduced imports and increased exports.

Therefore, the government should direct and encourage entrepreneurs in the promotion of agro-industrial units before increasing basic production. This could be done by:

- Furnishing preferential, low-interest loans to agribusiness.
- Partially subsidizing investments in start-up operations;
- Supporting commercial loans with partial guarantees;
- Providing assistance in management and organization of businesses;

- Establishing lending facilities for the import of necessary machines and replacement parts;
- Discouraging competitive imports; and
- Facilitating export procedures for finished products.

RECOMMENDATIONS

The following is a summary of the most important recommendations made in this chapter.

1. The community should be the administrative nucleus for development of the small marais. To accomplish this, Rural Engineering technicians need to be placed at the community level. They should have sufficient resources at their disposal.
2. All of the marais users (cooperatives, groups, individuals and various small businesses) should be strongly encouraged to form a single group for each marais, which will directly represent their interests. These groups could also undertake responsibility for management of each marais.
3. Plots should be distributed by the District Commissions for Marais Management. These Commissions would also coordinate community activities.
4. Coordination and cooperation among different government institutions would be improved by creating a National Committee of the Marais. It would include representatives from the various ministries, offices, and organizations concerned, as well as representatives for marais users.
5. In the first phase, the Department of Rural Engineering would be reinforced with more personnel. In the second stage, a National Bureau

of the Marais would be created. This service would ultimately become the executive branch of the National Committee of Marais Management.

6. A Center for Training and Advancement for Rural Engineering technicians (level A2) must be established. It would be capable of training at least twenty new students each year and would also provide workshops and seminars as needed.

7. In order to assure that fully trained personnel are available when needed, planning relating to future needs for personnel must be completed.

8. To facilitate evaluation of progress in the small marais, the National Committee on Marais Management must regularly prepare reports on the progress of various activities.

9. The National Strategy for the Marais must ultimately be self-financed. Beneficiaries should pay a percent of earned profits to support the infrastructure. These fees would help fund the development and management of marais resources.

10. In general, the State must progressively withdraw from activities in the marais, whenever the private sector can provide similar services at a lower cost. The State should only play the role of economic regulator.

11. To encourage users to invest in fundamental improvements in the marais, it is absolutely necessary that they are guaranteed by the government of their right to use the land. To do this, a contract must be established between the user and the National Bureau of the Marais or the District Commission for the Management of the Marais. The contract should confer indemnity rights to the beneficiary equal to the worth of

any improvements made if the State should choose to reclaim the land for any reason.

12. To repay investments made in the construction of hydro-agricultural infrastructure and justify the intensive use of marais lands, the State should strongly encourage users to grow high-value commercial crops such as rice, sugar cane, vegetables, etc.

13. With the goal of improving the efficacy of the cooperatives, the State must entrust follow-up work to the Center for Training and Cooperative Research. Also, it would be best if private parties who have signed contracts to use marais plots would reorganize into management groups.

14. It is absolutely imperative that farm loans become easier to acquire. This could be accomplished by:

    (a) The establishment of programs for special loans specifically destined for the agricultural sector, either within the existing banking institutions or through the creation of a new banking institution, primarily concerned with the agricultural sector.

    (b) The improved accessibility of loan officers, notably by bank representation at the "sector" level (for example: by the presence of a bank agent once a week), could ease problems farmers have in obtaining loans in a timely fashion.

15. The Government must actively facilitate the creation of further processing units for agricultural products. This policy would simultaneously offer advantages to many economic sectors such as agriculture, industry, and transportation.

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CHAPTER ELEVEN

SUMMARY AND RECOMMENDATIONS

In the preceding chapters, a detailed analysis of the various components required to improve use of the small marais was presented. Inadequacies resulting from past failures in development and management of small marais in Rwanda were also reviewed. Practical solutions were proposed in accordance with the study's principal objective (Planning of Actions, 02/1987), stated as follows:

Provide the Rwandan Government with a concrete answer to problems associated with the development, enhancement and management of small marais in view of the most comprehensive rational and efficient utilization that is possible. [...]. The outcome of the study should constitute for the Rwandan Government a reference capable of guiding it through a better development and management of the country's small marais.

This chapter contains a synthesis of all of the recommendations couched in terms of the national strategy for the development of the small marais. Justifications for most of the recommendations cited below were already discussed in the preceding chapters.

The recommendations are grouped into seven main sections:

- National strategy for the marais
- Hydrology and physical designs
- Pedology and agronomy
- Socioeconomy and management of the small marais
- Organization of State intervention

- **Applied research**
- **Direct field actions and practical recommendations**

A NATIONAL STRATEGY FOR THE MARAIS

Marais are extremely important in Rwanda. They occupy about 7.5 percent of the national territory and represent the only land resource for which a substantial increase in agricultural productivity is still possible. The marais and associated waterways also contain the country's drainage system. Marais physiology determines forms and dimensions of rivers, peak flows, and erosion capacities. Thus, the marais play an environmentally critical role.

Serious interest in land clearing and cultivation of the marais began about three decades ago, and growth has continued unabated since then. According to our estimates, nearly all small marais, which constitute about one-half of the surface area of the valley bottoms, are already occupied by farmers. Even though the marais were being developed, the Government never set forth a national policy or planning strategy. This naturally led to the present chaotic state, and the formulation of a national strategy is pressing matter. Strategy formulators must consider on the one hand, the agricultural potential of the marais and attendant pressures to develop them, and on the other, the fragile ecology of the valleys and the necessity to protect them from irreversible damage.

1. The formulation of a national strategy for the marais is an urgent issue. It is possible, following an exchange of ideas at the national level, that a strategy could be adopted in 1988. The strategy should highlight priorities on which the government should concentrate:

- Put in place necessary coordinating structures;
- Protect the environment;
- Optimize agricultural production and develop alternatives;
- Define rights and obligations of users; and
- Apply the law on marais development.

2. To ensure that the national strategy is publicized in the most efficient and thoughtful manner, it is advised that a national dialogue on marais development be initiated through conferences and seminars.

3. The national strategy must be included in a ministerial decree, which indicates the attributions, intervention practices, rights and obligations of users, State, and non-government organizations.

4. Short- and medium-term intervention plans should be prepared based on the national strategy and the law for marais development. To be included <u>in the immediate future</u>:

   - Reinforcement of the Rural Engineering Department;
   - Creation of a center to train Rural Engineering technicians;
   - Inventory of marais resources;
   - Establishment of a marais development fund;
   - Introduction of a fee system;
   - Implementation of the law on marais development;
   - Institution of an applied research program.

<u>in the medium term</u>:

- Formation of marais users' groups;
- Creation of a national marais service;

- Development of a master plan for the development of the small marais;
- Implementation of actions to support communities and prefectures;
- Pursuit of investors for the agro-industrial sector.

5. It is important that procedures to evaluate improvements made in the small marais be established to ensure that appropriate actions are taken.

The physical properties of the marais are very variable. Classifications and typologies can be constructed based on physical, geographic, and evolutionary characteristics, among others. A classification system that accounts for all of these aspects could be developed, but its worth would be dubious because of the extreme diversity found there. The priority at this point should be to inventory marais lands and their individual resources. A typological study might then be possible.

6. An inventory of all of the marais in Rwanda is urgently needed. Not only must the inventory assemble statistical data (site, boundaries, surface area, altitude, watershed, use, etc.), but it should also provide information on physical constituents (soils, hydrology, etc.). For this purpose, a detailed list of all important factors must be established. Following the inventory, data should be analyzed to provide a summary of marais land availability, use, and resources according to the selected criteria.

7. Once the inventory project is complete, a master plan for the development of small marais in Rwanda should be designed.

Farmers reclaimed the small marais in Rwanda using local techniques. This level of technology will not allow proper development of the large marais because the hydrologic, agronomic, and socioeconomic problems are much more complex and on a larger scale. There is clearly a need to formulate a classification that distinguishes between large and small marais.

8. Using the framework of the national strategy for the small marais as a basis, a simple classification could be set up as follows:

   I. Large marais: larger river valleys and flood plains;

   II. Small marais: all other marais with small and medium surface areas; and

   III. Special marais: marais located in national parks or those protected from agricultural use.

9. Marais classification should be the object of a government decree, which establishes the legality of communal authority over class II marais.

HYDROLOGY AND PHYSICAL DESIGNS

10. Small marais in association with hill slopes act as buffer zones to accumulate water, which directly affects flow rates for all rivers and waterways in Rwanda. This affiliation constitutes the basis of Rwanda's hydrology system. Any improvement or changes in water management infrastructure in the small marais should be evaluated in terms of its impact on the overall hydraulic framework, especially downstream.

11. Marais development should be approached on a watershed-wide basis (as opposed to random segments). The establishment of a master

plan (for example, Mutara and Nyaborongo) for each watershed could guide both government and donor agencies in their work in the marais. These plans could be more technical and contain greater elaboration than the command plans mentioned earlier.

12. Current water management practices in the marais consist of careful water table control by alternating irrigation and drainage between the seasons. These traditional practices are environmentally and technically sound. Therefore, caution should be exercised in attempting to replace these with modern systems, which have not yet been proven to be better.

13. Hydraulic infrastructure in the small marais must contain both drainage and irrigation components, as well as provide for outlet improvement and erosion control (especially for the main drain). In the simplest form, improvements can consist of dredging a 'belt' canal, a task easily achieved by farmers themselves.

Outlet improvement removes downstream blockages, which allows excess water to exit the marais more rapidly (i.e., diminishes flood risk). If planning is poor, hydrologic conditions downstream of the improved marais may be damaged. Also, risks of drought in the dry season worsen. As a preventive measure, detailed studies should be made prior to initiating any improvements.

The purpose of erosion control is to maintain flow velocity in the main drain below a non-destructive level, by constructing a flume, or protecting the river banks. Otherwise, restructuring of the main drain results in greater flow velocity and increased erosion capacity of the drain. In cases where erosion control works were omitted from the design or were poorly

built, the bed will need to be progressively redug, resulting in a lower water table and subsequent water shortages during the dry season.

14. To prevent problems associated with excess drainage (too large, too deep, or too dense a drainage network), crops adapted to wetland conditions (rice, sugar cane) are recommended in the rainy season.

However, rice monoculture is not advised (i.e., two crops/year). Instead, a dry season legume should be included in the annual crop cycle rotation.

15. Technically, most crops can be grown in the marais, but each crop has special requirements for water table height and moisture content. These requirements should form the basis of any water management planning.

16. Participation of users in development projects and management decision making in the small marais will ensure a greater probability of success. Pilot projects should be initiated to determine the best approach to use to obtain the fullest participation of the local users.

17. When the marais are inventoried, water parameters needed to formulate a sound technical design for drainage and irrigation systems should be collected - saturated conductivity, water holding capacity, field capacity [0.1 bar], wilting point [4.2 bar], etc.

The failure of the governments of other countries to efficiently manage small irrigation systems and the high costs incurred by them for construction and maintenance should serve as a object lesson for Rwanda.

18. From the outset, the government should involve marais land users in all phases of development from conceptual design to construction and maintenance work, to management activities.

Such an approach will require less outside financing and debt because works built by users themselves will be less costly. Since farmers understand agro-hydrologic and soil conditions in the marais best, their active participation will allow planners to choose reasonable goals. In addition, traditional land and water rights will be respected.

PEDOLOGY AND AGRONOMY

19. As part of the small marais inventory, reconnaissance studies in the form of agro-pedology surveys should be undertaken. These would include the following information for each marais: soil type (mineral or organic), soil texture (sand or clay), cropping systems, best adapted crops, manure and fertilizer practices, and special problems related to water management. These studies would permit planners to select those marais with the higher potential for development.

20. To facilitate marais development, research should be carried out to identify the best cultural practices (height and width of beds, water table adjustments according to crops and seasons). In cases where temporary flooding is anticipated, rainfed rice or grazing fallow is a possibility. Close communication with hydrologists is a necessary component of these research activities.

21. Soil texture (excess sand or heavy clay) is difficult to change, but can be improved through the addition of organic matter (farmyard manure, green manure). Alternatively, clay and sand

deposits can be mined prior to the introduction of cropping. Shallow soils can be improved using cultural techniques such as mounding or bedding. Micro-depressions, which prevent the regular flow of water, can be levelled, but with the risk of burying fertile surface horizons. Investigations into the possibility of improving soil physical conditions are warranted, because productivity on such soils will tend to remain marginal, despite heavy investments in amendments and water management. On heavy clay soils, however, rice can be grown at altitudes below 1700 m using a soil-improving legume rotation. The addition of organic matter to marais mineral soils is essential.

22. In view of the progressing degradation of marais soils, the introduction of sustainable cropping systems will not be possible without the addition of inputs. Fertilizer trails are needed to assess the magnitude of response to various inputs (organic and chemical) on different soils, and to formulate recommendations on rates and types.

23. In the case of the sulfur-rich peats, the most appropriate land use patterns must be identified through research on different alternatives.

24. Sustainable cropping systems that improve productivity and agricultural potential of the small marais soils should be tested. Synchronization of the crop calendar with seasonal water fluctuations needs to be perfected. Land preparation techniques that promote the optimal growth of different crops (i.e., raised beds, mounds, flat beds) need to be developed.

25. The cultural requirements of individual crops under marais conditions should be determined. In particular, research is needed to define the optimal water table depth for various crops. The interactions between the diverse operations (land preparation, sowing, fertilization, water table) are also important considerations for agronomy research.

26. Further research is also required to identify plant species or varieties specially adapted to marais conditions. Those that tolerate wet conditions (rice) would be suited to the rainy season, while tolerance to lower temperatures would be a required asset for dry season crops.

27. Agroforestry systems capable of withstanding wet conditions should be worked out. These perennial crops could produce forages or fruits, improve soil fertility, and protect waterway banks against erosion.

28. Animal agriculture in all its diversity (for example, fish culture, ducks, cattle), alone or in combination with cropping systems (for example, rice/fish culture, forage crops), should be integrated into research programs.

29. Because rice culture appears to be well adapted to marais conditions and is easily undertaken by farmers' cooperatives, groups or individuals, it is recommended that:

    (a) Rice culture be introduced to small marais farmers. A special program is needed to persuade farmers outside of State rice perimeters to try it.

(b) Research be initiated to develop varieties that yield well above 1700 m. Collaboration with ISABU or other research institutions is advised.

(c) A good crop to rotate with rice be identified, such as a legume, in order to optimize use of marais land and ensure sustained soil fertility.

SOCIOECONOMY AND MANAGEMENT OF THE SMALL MARAIS

30. Because the State retains ownership of marais land, users' rights should be secured with a contract with the State valid for a set period of time.

31. In marais perimeters that are part of State projects, drainage and/or irrigation works should be maintained with user financing.

32. When the State reclaims a marais, the needs of the local population and of previous users must be considered and appropriate alternatives proposed to them.

33. The current system of inheritance, which tends to fragment upland homesteads, should not be extended to the small marais.

34. Reclaimed or more productive marais land can help provide jobs for the burgeoning population, which cannot readily find employment in other sectors. For this reason, State and/or private enterprise should not retain absolute control over the use of these lands, with the peasants reduced to simple farm laborers.

In the event that some of the land is delegated to private entrepreneurs, they should be encouraged to develop non-agricultural employment opportunities (cottage industries, employment in the new enterprise, etc.) for the local populace. The remaining farmers could then

be incorporated into viable cooperatives, which could perform similar functions in the agricultural sector.

35. Manpower and finances should be channeled into hydro-agricultural developments in the marais down to the commune level. Only then can marais land be distributed to individuals or cooperatives.

36. Production should be diversified within cooperatives. Some possibilities for both home consumption and industrial/export purposes include:

- products that substitute for items now imported
- products that are widely consumed
- products that can be further processed
- products with a commercial value
- products produced by animals

37. Agricultural reform should be carefully and consistently introduced to the marais lands.

38. Other activities (brick and tile-making, recreation, etc.) in the marais should, in general, be subordinated to agricultural uses unless the benefits for the majority of the population outweigh those derived from agricultural uses.

ORGANIZATION OF STATE INTERVENTIONS

39. The community must become the administrative nucleus for the development of the small marais. Rural Engineering technicians will need to be assigned to communities, and they should have adequate materials at their disposal to carry out needed planning studies. Land-use schemes for the marais should be individually established by each community.

40. All marais users (cooperatives, groups, individuals, and small enterprises) should be encouraged to regroup into marais societies, which will take over managerial responsibilities in each marais and defend the interests of the respective users.

41. Prefectural commissions for marais management will have the responsibility of plot allocation. These commissions should also coordinate community actions.

42. Communication and cooperation among Ministries, government services, and non-government organizations will benefit from the creation of a National Marais Committee. It should include representatives from the ministries, services, and other organizations, as well as the marais users.

43. First, personnel should be added to the Rural Engineering Department. Then, a National Service for the Marais should be created within that section concerned with the marais. The National Service for the Marais should ultimately provide executive service for the National Marais Committee.

44. A center to train level A2 technicians needs to be created. The center should be able to train at least twenty new technicians per year and should have the capacity to present periodic seminars and provide additional training opportunities as needed.

45. To ensure that appropriately trained personnel are available when needed, future personnel requirements should be calculated now.

46. To facilitate evaluation of projects in the small marais, the National Marais Committee should be required to prepare regular progress reports.

47. The National Strategy for the Marais should be based on self-financing, such that users will pay fees for benefits. The funds should be employed to develop and manage marais resources.

48. In general, the State should progressively retire from certain activities in the marais when these can be conducted at a lesser cost by the private sector. The State's role would then become that of an economic regulator.

49. To induce users to invest in improvement of marais lands, they should receive a written guarantee of their right to use the land in the form of a contract. The contract should be made between the user and the National Service for the Marais or the Prefectural Commission for Marais Management. This contract should give the user the right to an indemnity for all improvements made during the tenure period.

50. The State should encourage users to cultivate high-value crops such as rice, sugar cane, and vegetables.

51. The State should allow the Center for the Formation of Cooperatives to handle cooperative affairs. Private individuals that have signed contracts with the State to use the same marais should regroup into management societies.

52. It is imperative that a more efficient and accessible agricultural credit system be installed by establishing special credit programs uniquely designed for the agricultural sector within existing banking institutions, or by creating new banks orientated toward the agricultural sector.

53. The government should encourage the growth of further processing for agricultural products. Other economic sectors would also

benefit from growth in the processing industries (agriculture, industry, transport, national economy, etc.).

APPLIED RESEARCH

Up to now, very little research has been conducted on marais characteristics and physical parameters, and past projects were only partially successful. Most of these 'failures' can be attributed to a general lack of knowledge about marais properties and environment. Design and planning methods imported from elsewhere are generally poorly adapted to Rwandan conditions and often lack a firm scientific basis.

54. An applied research program should be established as soon as possible. This program should be directly tied into work at the Rwandan Institute for Agricultural Research (ISAR).

ISAR should hire personnel to conduct research on drainage and irrigation practices. There is now no person specifically assigned to the hydrology sector.

55. The applied research program for the marais must include the <u>active</u> participation of: (a) the Rural Engineering Dept., and later the future Marais Service and (b) the National University of Rwanda (UNR), when personnel and logistical constraints are overcome.

56. Basic goals for the applied research program should be formulated by the National Marais Committee. This committee should also be responsible for: (a) overall coordination among the different sub-programs; (b) administration of the research program's funding; (c) monitoring of progress (d) evaluation and (e) publication of results in cooperation with other institutions.

57. The applied research program must include the following aspects:

- The hydrology of small watersheds and small marais to establish norms and give practical advice for design (drainage and irrigation);
- Establish hydraulic parameters: drainage coefficients, water availability during the dry season, optimal bed size, saturated conductivity, etc.
- National hydrology, analysis of characteristics of large rivers and the effects of drainage works (in small marais) upstream
- Soil science (properties, fertility, crop adaptability) to allow the formulation of appropriate guidelines for soil and crop improvement
- Changes of traditional cropping systems in the marais, for example rice in high altitude marais.
- It is believed that marais resources are underutilized, but to what extent? The true potential of the marais need to be determined.

Marais development projects, organized and financed by the State, are very costly. For example, the price per hectare of a simple drainage and irrigation project can amount to 100,000 frw/ha or more. Even when a more appropriate technology is available, the administration will never be capable of developing all marais.

58. Thus, technology applicable to users themselves is urgently needed. Rural Engineering technicians and/or regular agriculture extension agents could help implement this technology.

DIRECT FIELD ACTIONS AND PRACTICAL RECOMMENDATIONS

In Chapter 3, we mentioned that three main groups of constraints prevent intensified use of marais lands.

(1) Uncertainty on the part of the user regarding land rental rights.

(2) Lack of a market for commercial products.

(3) Lack of local and internal organization.

59. In the immediate future, users of small marais should be encouraged to organize themselves into marais societies. The procedures for the formation of cooperatives should be improved.

60. Commercial outlets for marais products need to be developed without delay. The government should encourage, guide, and help the private sector to better organize itself.

A practical example: it is often difficult for aquaculturists to find markets for their fish. However, at the same time fish is almost never found at the market, although there is clearly a demand for it. The main problem is irregularity of supply. This could easily be solved by organizing a regular harvest of one pond per week at the local community level.

61. As we await the passage of the law on the development of the small marais, the State should begin now, wherever possible, establishing contracts with users (especially cooperatives) to guarantee them land rental rights in the small marais. Simultaneously, the government should begin a national campaign to inform land users what its intentions are in the marais.

ANNEX A

PARTICIPANTS

This report was prepared by Rwandan and American experts. They worked closely together during several months in the summer of 1987 on joint field visits and working sessions.

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ANNEX B

REPORTS AND PUBLICATIONS OF THE STUDY

Résultats d'essais de recherche agronomique
Marie Pierre LefranÇois
Cornell University, Ithaca 1988

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Mr. Venant Rutunga, Head, Department of the Environment and Production Systems, Rwandan Institute of Agronomy (ISAR); soil science expert.

Mr. Roelof Sikkens, Research Associate and Coordinator Small Marais Development Study, Butare; irrigation and drainage expert.

Mr. Tammo Steenhuis, Associate Professor of Agricultural Engineering, Cornell University; water management expert and hydrologist.

Mrs. Catherine M. Tardif-Douglin, Research Assistant, Department of Rural Sociology, Cornell University; socioeconomic research.

ANNEX C

AGRONOMIC FIELD STUDIES

Agronomic research activities were undertaken in the two small marais of Nyarutovu and Ilibunga (Butare Prefecture) from early July to mid-November 1987. The purpose was to assess the agronomic characteristics of the two sites in particular. No attempt was made to form generalizations. The research program included a soil characterization, a study of the traditional cropping system, a soil map of Ilibunga and fertilizer trials with four different crops. The field activities as well as the general results are described in the following pages.

PHYSICAL AND CHEMICAL CHARACTERIZATION OF THE SOILS

Preliminary observations in the marais revealed that the soils were almost exclusively mineral, the exception being a small, localized pocket of peat in the Nyarutovu marais. The peat was not carefully analyzed, but we noted that it supported the most intensive and varied production of both marais.

To characterize the mineral soils, 50 soil samples representative of the existing variability throughout both marais were retrieved to a depth of about 30 cm. The samples were submitted to the soil laboratory of the Agronomy Department of the UNR. The following tests were performed: pH (dry and moist soil), exchangeable acidity, exch. aluminum (Al), percent organic matter, exch. cations (Ca, Mg, Na, K), effective cation exchange capacity, and bulk density. Table C-1 summarizes results of the soil analyses for both marais.

Table C-1. Results of Soil Analyses.

Soil test	Nyarutovu marais			Ilibunga marais		
	mean	range	CV**	mean	range	CV*
pH-dry soil	3.8	3.2-4.5	9%	4.1	3.5-5.1	9%
pH-moist soil	4.33	.7-5.1	9%	4.8	4.2-6.5	8%
Acidity (mcg/100g)	2.72	0.83-6.23	51%	1.71	0.25-4.18	59%
Al (mcg/100g)	2.15	0.55-5.18	57%	1.35	0.10-3.35	66%
% Org. Mat.	2.7	1.5-6.2	57%	2.0	0.7-3.8	41%
K (mcg/100g)	0.11	0.08-0.18	28%	0.12	0.05-0.21	35%
Ca (mcg/100g)	0.81	0.16-1.68	59%	1.23	0.12-3.52	65%
Mg (mcg/100g)	0.30	0.05-0.66	65%	0.51	0.07-1.37	58%
CEC (mcg/100g)	3.96	2.45-6.76	32%	3.56	1.43-7.10	41%
Bulk density (g/cm^3)	1.38	1.07-1.60	10%	1.46	1.29-1.67	8%
P	traces (limit of detection)					

**Coefficient of variability

In general, tested soils had a poor nutrient status and high acidity for both marais, although conditions in the Ilibunga marais were slightly better. Thus, the assumption that marais soils are much more fertile than hill slope soils did not prove to be valid in this case. In fact, Van der Zaag, et al. (1984) reported higher pH (5.8) and exchangeable bases (Ca: 7.7, K: 0.54, Mg: 1.72 mcg/100g) values for a survey of Butare soils than was found in this study. This seems to indicate a greater desaturation of the exchange complex in the marais than elsewhere. However, bulk density values and field observations indicated good physical structure of the soils, except where heavy clay reached the surface in the Ilibunga marais.

Another interesting facet of the tests results was the difference between dry and moist pH values. This was attributed to the hydromorphic character of marais soils, and notably to the reduction reactions in wet soils, which tend to decrease exch. acidity and Al levels, as well as increase the availability of certain nutrients. This process is similar to what occurs in rice soils (Sanchez, 1976), although is less pronounced

because soils are not completely flooded. Finally, the values for the CV (coefficient of variability) confirmed that spatial variability was very high even, within a marais.

SOIL MAP FOR THE LLIBUNGA MARAIS

A student from the Agronomy Department of the UNR, M. Ngoga Télèsphore, mapped the soils of the Ilibunga marais as the subject of his thesis. A dozen soil profiles were prepared throughout the marais, and soil samples were collected for analysis. The map, which will be completed in 1988, is based upon the USDA soil taxonomy.

Mr. Rutunga, the student's advisor, found that the soils of the Ilibunga marais were derived from hill slope colluvium overlying a heavy clay, gleyed, alluvial subsoil. Hydromorphic features (mottles, gley) were present at different depths throughout the marais. We noted few pure sand and heavy clay out crops, confirming high textural variability within small distances. Soil analyses are anticipated to definitely classify the soils. The reader should refer to the *Projet Carte Pédologique* du Rwanda for further details on the classification of small marais soils in Rwanda.

STUDY OF THE TRADITIONAL CROPPING SYSTEM

Sweet potatoes on raised beds are the predominant cropping system in the small marais of Rwanda. This is probably because the sweet potato tolerates low fertility levels and drought. Data were collected to evaluate the performance of this system. Yield measurements were recorded from raised beds that were planted to sweet potatoes by the farmers during the long rainy season (February to June). For the 50 positions in the marais

where soils were sampled, sweet potato vine and tuber yields were measured in $1m^2$ areas and converted to mt/ha. Yields are summarized in Table C.2

Table C.2. Sweet Potato Yields (Vines and Tubers).

Marais	Measure	Vines(mt/ha)	Tubers(mt/ha)
Nyarutovu	mean	14.4	6.6
	range	4-31	2-11
	CV	59%	42%
Ilibunga	mean	18.5	11.5
	range	3-54	0.2-22
	CV	75%	58%

As Table C.2 indicates, yields of sweet potato were variable in both marais, ranging from very poor to good. Tuber yields were on average almost twice as high in the Ilibunga marais as in the Nyarutovu marais, but soil fertility levels were also higher in the Ilibunga marais. In both marais, however, vine production exceeded tuber production. This is difficult to explain, and despite the economic value of vines as planting material, is not a desirable attribute. As a basis for comparison, MINAGRI(1978) reports 7-8 mt/ha of tubers as the national average, although a more optimistic value of 12 mt/ha is cited by (Alvarez and Ndamage (1985). At ISAR, the country's research institute, 20 mt/ha are obtained on average (MINAGRI, 1978).

In order to explain the yield variability throughout the marais, we attempted to relate yields to soil fertility and depth to the water table (measured from piezometers installed by Sikkens). The following tendencies were noted: yields seem to have been more influenced by soil fertility than by depth to the water table. In particular, tuber yields were positively correlated with moist soil pH and negatively correlated with bulk density.

The greater effect of moist pH as opposed to dry pH or sum of cations could be because of a more accurate reflection of field chemical conditions especially ongoing oxide-reduction processes by the former measure. As for bulk density, it is well documented that sweet potatoes prefer friable soil (Acland, 1971; Purseglove, 1968).

The influence of depth to the water table was clear on tubers planted in the early part of the rainy season (February - March). Tuber yields for these plantings were negatively affected by the high water table. This relationship did not hold for later plantings, where we expected yield declines because of the low water table. However, other researchers report that sweet potatoes are intolerant of water logging, but withstand drought stress (Acland, 1971; Purseglove, 1968). This also correlates with the farmers' practice of planting sweet potatoes near the ditches (where water losses will not occur) in the small rainy season.

FERTILIZER TRIALS

To link the soil test results to crop productivity and to gain a better understanding of soil constraints in the marais, fertilizer trials were conducted with four different crops on available land in the Nyarutovu marais. The four crops in the trials were potatoes, cabbage, sweet potatoes, and soybeans. Land preparation and crop field operations were performed with the help of local labor, and all planting material was obtained through local channels (no varietal information). The trials involved various combinations of nitrogen (N), phosphorus (P) and potassium (K) fertilizers obtained through the FAO fertilizer project in Butare. In addition, farmyard manure was added to all crops except sweet potatoes, in

order to conform to local practices. Results and a general description of each trial are outlined in the following paragraphs.

Potatoes

The trial was designed as a randomized complete block, with five treatments replicated in three blocks. The treatments were (1) control (2) 150N-50P-50K (3) 50P-50K (4) 50N-50P (5) 50N-50K expressed as kg/ha of nutrient. Each treatment plot measured 20 m^2, for a total 100 m^2/block. The seed potatoes were planted in rows, 40 cm apart, 60 cm between seed pieces and according to local practice, manure was placed near the seed pieces. Fertilizer treatments were broadcast directly after planting. Plants were watered regularly in the first few weeks, and after 3.5 months of vegetative growth, the tubers were harvested and yields measured. Treatment means are displayed in Table C.3.

Table C.3. Potato Tuber Yields - Mean of Three Blocks.

Treatment	Tuber yields (mt/ha)
Control	5.7
150N-50P-50K	10.5
50P-50K	5.7
50N-50P	9.7
50N-50K	9.1

Yields were rather poor for this crop, considering that on volcanic soils in the north of the country 20-25 mt/ha are easily achieved without fertilizer (Joseph, 1982). The maximum yield obtained in this trial was 15 mt/ha for one of the plots treated with 150N-50P-50K. The low yields were attributed to a high incidence of disease, probably bacterial wilt, the most serious pest of potatoes in Rwanda (Joseph, 1982).

The disease probably confused the effects of the different fertilizer applications, but yields were increased by N treatments. The application of 150 kg/ha N led to a 4.1 mt/ha increase in tuber yields on average. Thus, manure was insufficient to fulfill the N requirements of the crop. It should be mentioned that depth to the water table, which varied between 30 and 70 cm, did not appear to affect yields.

Cabbage

Cabbage seed was first sown under a heavily manured thatched nursery, then seedlings were transplanted into the trial plots following one month of growth. The trial was designed to test the effects of a complete N-P-K treatment on three different soils: two mineral and one organic. For each soil, there were two replicates of the fertilizer treatment and control, giving a total of twelve plots each measuring 12 m^2. After 3.5 months of vegetative growth, twenty-five individual heads were harvested from each plot and weighed. Results are displayed in Table C.4.

Table C.4. **Average Weight of Cabbage Heads.**

	Mineral soil 1 (gm/head)	Mineral soil 2 (gm/head)	Organic soil (gm/head)
Control	345	310	1410
150N-50P-50K	1050	670	1305

The results show that fertilizer greatly improved yields on the mineral soils but not on the organic soils, which produced the highest yields. Organic soils hold a storehouse of nutrients, which are liberated as the organic matter decomposes (Lucas, 1982). It is worth mentioning that the

water table was very close to the surface on the organic soils, and this may have had a positive effect during the dry season months. Applications of insecticide powder were essential to control aphids and other insects.

Sweet Potatoes

The sweet potato trial was designed like the potato trial, with the exception that 80 kg/ha of N was applied instead of 150. This was because of the known sensitivity of sweet potatoes to excess N, favoring vine production relative to tubers (IITA, 1977; IRRI, 1973).

Local vine material, consisting of a mixture of clones, was planted in mid-July and fertilized two weeks later to allow proper rooting. Unlike the other crops, sweet potatoes were not manured or watered in their early growth period. The trial plots were harvested after four months of vegetative growth, although prematurely due to time constraints (normal growing period is six months in Rwanda). Yields are reported in Table C.5 for the various treatments.

Table C.5. **Sweet Potato Vine and Tuber Yields (mean of three blocks).**

Treatment	Vine yields (t/ha)	Tuber yields (t/ha)
Control	16.6	4.8
80N-50P-50K	22.7	2.8
50P-50K	16.9	6.3
80N-50P	25.5	3.2
80N-50K	25.3	5.2

As expected, the early harvest led to low yields of tubers. However, vine production was very high, especially among those treatments that received N. Tuber yields did not increase with fertilization. Earlier studies demonstrated the response of sweet potatoes to mineral fertilizers

in Rwanda (FAO, 1984). Ndamage and Rutunga (1987) observed that manure had more beneficial effects than mineral fertilizers. Nyabyenda and Rutunga (1985) recommended combining both sources of fertilizer to optimize production. The literature also listed many contradictory results while reporting that the poorest yields were found in those areas with the most limiting factors. We noticed that the highest yielding plots (9 mt/ha) in our trials were those bordering the ditches, indicating that the crop was suffering from a lack of water. Furthermore, the least productive block had a greater percentage of heavy clay, and thus higher bulk density. In these trials, other limiting factors appear to have had more effect on changes in yields than fertilizer,

Soybeans

The soybean trial was designed to evaluate the effects of a rhizobium inoculation combined with P and K fertilizers. For this, a split-plot design was used, with inoculation as the main factor and fertilizer as a sub-factor. Three fertilizer treatments were tested: control, 50P-50K, and 50K (kg/ha). With three blocks, this gave a total of eighteen plots, each measuring 12 m^2.

Soybean seed was densely planted in rows 40 cm apart. Prior to sowing, half the seed within each block was inoculated with rhizobium. Fertilizer treatments were directly broadcast onto plots after planting. Plots were watered regularly for the first few weeks of growth and weeded a few times throughout the season. After 4.5 months of vegetative growth, the trial was harvested and dry seed weights recorded and converted to kg/ha. Results appear in Table C.6.

Table C.6. Soybean Dry Seed Yields (mean of three blocks).

Treatment	Seed yield (kg/ha)	
	Non-inoculated	Inoculated
control	1867	2363
50P-50K	1725	2384
50K	1672	2033

Yields were well within the range of those obtained by the national research station (ISAR) in its trials throughout the country. In fact, once emergence was complete, there was a vigorous uniform stand of soybeans on all three blocks, and deficiency symptoms on unfertilized or uninoculated checks were not obvious. Despite this, inoculation with rhizobium increased yields by 505 kg/ha or 30 percent on average. The crop did not respond to P and K fertilization. In addition, depth to the water table, which varied between 30 and 70 cm, did not influence yields or plant growth. On the whole, the study showed that soybeans can be grown in the marais, even without the addition of P and K.

Benefit Cost Analysis

Simplified benefit cost calculations were made to determine the economic feasibility of using mineral fertilizers on cabbage and potatoes. The calculations were not carried out for the crops that did not respond to the fertilizers: sweet potatoes, soybeans, and cabbage on organic soils. Results are summarized in Table C.7. The preliminary nature of this trial did not justify a more elaborate analysis.

Table C.7. Benefit Cost Calculations for Fertilizer Use-Potatoes and Cabbage.

	Potatoes	Cabbage (mineral soil)
Fertilizer quantity (N-PK)	680 kg/ha	680 kg/ha
Cost per fertilizer unit	40 Frw/kg	40 Frw/kg
Total cost (fertilizer)	27,200 Frw/ha	27,200 Frw/ha
Additional yield	5,000 kg/ha	*11,000 kg/ha
Market price**	12 Frw/kg	15 Frw/kg
Total value (benefit)	60,000 Frw/ha	165,000 Frw/ha
Benefit cost ratio	2.2	6.1

* assuming 20,800 cabbage heads/ha and an average increase of 0.53 kg/head (Table C.4)
** local market and cooperative (COVEPABU)

According to FAO (1984), fertilizer use is profitable when the benefit cost ratio exceeds 2. Therefore, the use of mineral fertilizers was profitable for both crops in this study, although more so for cabbage. In the absence of disease, it is likely that this ratio would have been much higher for potatoes.

SUMMARY REMARKS

The agronomic studies conducted in the two small marais of Nyarutovu and Ilibunga allow us to make certain conclusions. Although our field trials were limited to these marais, we can still gain some insight into the behavior of soils and crops in the overall small marais ecosystem.

(1) Soils of the Nyarutovu and Ilibunga marais have a low fertility, perhaps more so than hill slope soils that receive regular applications of manure. Soils are highly deficient in exchangeable cations and phosphorus, have a low cation exchange capacity, and high acidity and aluminum levels. Apparently, reduction processes in the

marais contribute toward a higher pH reading in wet soils compared to air-dry soils, a positive aspect for fertility. Though the marais are in close proximity to each other, they have different soil properties. Variability within each marais is also high.

(2) Low soil fertility is translated into poor yields of sweet potatoes in the farmers' plots. The Ilibunga marais, with better native fertility, produces higher yields.

(3) The fertilizer trials demonstrate the possibility of growing crops besides sweet potatoes in the marais. Although recommendations cannot be formulated from these limited studies, the fertilizers did lead to economic yield increases for certain crops. In addition, the importance of adequate plant protection measures for fertilizer effectiveness was realized.

(4) The peat area of Nyarutovu seems to support a more productive and varied agriculture than elsewhere in the marais. This is most likely because of the ability of peat to supply nutrients, as well as a higher water table.

(5) The influence of depth to the water table on crop growth and yields is not clear and requires more investigation.

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ANNEX D

LIST OF ACRONYMS FOR

IMPORTANT GOVERNMENT BUREAUCRACIES

Direction Générale des Forêts	Forestry Board
Direction Générale de l'Élevage	Livestock Board
Direction Générale du Génie Rural	Rural Engineering Board
Direction Générale de la Production Agricole	Agricultural Production Board
Direction Générale du Génie Rural et de la Conservation des Sols	Rural Engineering and Soil Conservation Board
Direction de la Conservation des Sols	Department of Soil Conservation
Direction d'Études et Planification	Research and Planning Department
Direction du Génie Rural	Rural Engineering Department
Division du Génie Rural	Rural Engineering Branch
Division de l'Hydrologie	Hydrology Branch
Division de la Protection des Sols	Soil Protection Branch
ISAR	Rwandan Institute for Agricultural Research
Ministère de la Jeunesse et du Mouvement Coopérative (MIJEUCOOP)	Ministry of Youth and Cooperative Movement
Ministère de l'Agriculture, de l'Élevage et des Forêts (MINAGRI)	Ministry of Agriculture, Livestock and Forestry
Ministère de la Fonction Publique et de la Formation Professionelle (MINIFOP)	Ministry of Public Affairs and Professional Training
Ministère de l'Industrie et de l'Artisan (MINIMART)	Ministry of Industry and Trades

Ministère de l'Intérieur et du Développement Communal (MININTER)	Ministry of the Interior and Community Development
Ministère des Travaux Publics et de l'Énergie (MINITRAPE)	Ministry of Public Works and Energy
L'Office Rwandais du Tourisme et des Parcs Nationaux (ORPTN)	Rwandan Bureau for Tourism and National Parks
Projet Pisiculture Nationale (PPN)	National Fish Culture Project
MINEPRISEC	Ministry of Primary and Secondary Education
MINISUPES	Ministry of Higher Education and Scientific Research
Service du Génie Rural	Rural Engineering Service
UNR	National University of Rwanda
Comité National des Marais	National Marais Committee
Service National des Marais	National Service for the Marais
Centre de Formation et de Recherche Coopératif (CFRC)	Center for Training and Cooperative Research