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RWANDA AREA DEVELOPMENT RECONNAISSANCE SURVEY

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Kigali, Rwanda
June 23, 1978

RWANDA

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SUMMARY OF RECOMMENDATIONS

The following is a brief summary of the major recommendations made by the Area Development Reconnaissance Team, for studies and projects for the Zaire-Nile Crest region and the Nyabarongo valley basin. No attempt has been made to limit them geographically since some involve both areas of the basin.

Watershed Protection

The most important long-term need of Rwanda is the protection of its watersheds from the extensive widespread erosion that is causing a gradually accelerating general degradation of the soils as the protective forests and other vegetative cover is removed. If permitted to continue unchecked, agricultural production will decline to the point where the soils will become unproductive or will be unable to produce the amount of food required to feed a rapidly expanding population whose pressure is already causing serious problems in some regions.

The introduction and general acceptance of a coordinated agricultural development program embodying the latest improved cultural techniques, high-yielding adapted varieties of seeds, soil building legumes and green manure crops, stable manure, fertilizers, and disease and pest control; will be able only to provide temporary relief if soil erosion is not effectively controlled.

AID should explore with the Government of Rwanda and the various other international aid organizations, in particular those already engaged in various aspects of reforestation and soil conservation, ways and means through which it could make a positive contribution toward the development of an effective and coordinated national program of reforestation and soil conservation.

Ecological and Environmental Impact Study

Prior to initiating a development project in the lower Nyabarongo valley an ecological and environmental impact study should be undertaken in view of its possible impact on the project. Such a study should include the entire basin, with special emphasis on the lower valley.

In the upper and central reaches of the basin the serious problem of pollution caused by the uncontrolled dumping of water carrying a heavy sediment load resulting from washing tin ores at the mines in the valley, should be examined and alternative solutions determined. The deposition of heavy sediment loads in downstream reservoirs and flood control structures will

shorten their useful life.

Also, in the lower valley, water storage reservoirs and flood control structures constructed in the proposed project area, as well as the drainage of swamps for land reclamation for agriculture will have a major effect on the ecology of the affected areas. The swamps are the habitat of a rich variety of plant, bird and animal life, some of which might be endangered as a result of the proposed project. Furthermore, the population in the area depends on the swamps for their water supply and this should be protected.

Study of River Stability and Morphology

This study is needed in the proposed lower Nyabarongo river project area to assemble and analyze sediment load and transport capacity information. Foremost among the unanswered questions is that concerning morphological changes that may be expected in the river due to the alteration in its natural regime. Both the Nyabarongo and the Akanyaru rivers will be changed substantially. In the project area the Nyabarongo would have a reduced discharge much of the year and will no longer carry its former flood peaks. Sediment load and sediment carrying capacity will be changed.

The river's erosive capacity will be altered during much of the year. There is need to determine whether the changes in the river will lead to accelerated downcutting of the channel bottom, erosion of banks, or rapid changes in meander pattern. One, or all such effects may be experienced and must be analyzed in order that counter-measures can be devised.

Soil Capability Classification(including irrigability)

In the development of new irrigation and drainage systems technical constraints are substantial and require the thoughtful applications of modern irrigation science and engineering. Progress in soil science makes it possible to predict chemical and physical reactions and long-term compatability of water with soil can be established before an irrigation decision is made. However, this is not sufficient. Groundwater must be under control, otherwise the root zone may be too wet for cropping. What is necessary are field and laboratory measurements of appropriate parameters of soil and geology for classifying land for irrigation and crop suitability. A projection of soil-water interaction over a long term is necessary to provide assurance that an irrigation project can have an unlimited useful life.

This is not the sole factor determining a project decision but without a competent classification of the land a sound basis for a decision is missing. Therefore, a team experienced in

irrigability classification should survey the proposed project lands and classify them as to suitability for irrigation and for specific crops, such as foodcrops, rice, etc.

Roads and Bridges

The topography of the country makes for very difficult communications. The absence of adequate roads and bridges hinders both commercial exchanges and administrative contact wit much of the population. It also inhibits the ability of extension programs to reach farmers, the communication of ideas and the distribution of goods.

A survey is proposed to determine the most likely area in the basin for developing a secondary road network, taking into account density of population to be served, agricultural production of the region, and the mineral and other resources available. The active interest of the people concerned must be determined.

Apart from the need for secondary roads, high priority is assigned to the improvement of the Kigali/Gitarama/Kibuye trunk road.

Agricultural Cooperatives and Credit

The Cooperative movement in Rwanda is weak and needs suppor Agricultural credit is extremely limited. This lack of credit, even though the credit needs of subsistence farmers are usually not large, acts as a brake on development on the agricultural sector.

A study of the cooperative movement is proposed along with an analysis of the requirements for credit. In addition to evaluating their present status, as area would be selected where the interest and needs of the rural population indicate a basis exists for establishing a pilot project which would provide appropriate training and guidance in cooperative organization and management and credit procedures for both staff and farmer members.

Foundation Seed Project

It is recommended that a foundation seed program be established as a first step in the development of an overall seed program. One of the major impediments of agricultural developme is an inadequate supply of good quality seed.

The project would provide facilities, long-term rechnical supervisory services, and training of personnel for the multiplication, processing, treatment, storage and distribution of

genetically pure high-quality seed which has been tested for adaptability to the soils and climate of the area where it will be used.

RWANDA AREA DEVELOPMENT RECONNAISSANCE SURVEY

I. Background

Rwanda is a land-locked country located in the heart of Africa. It borders on Zaire, Uganda, Tanzania and Burundi. The area of Rwanda is 25,595 sqkm. or slightly smaller than the state of Maryland. The capital, Kigali, has a population estimated in excess of 95,000 and growing rapidly. Rwanda is also Africa's most densely populated country with 350 persons per square mile of arable land and with an estimated total population of 4.4 million in 1976, growing at a rate of about 2.8 percent per annum.

Rwanda is listed in the 1976 World Bank Atlas as one of the five poorest nations in the world. Over 95 percent of the population derive a living from the rural sector, where the average per capita income level is approximately $ 65, as compared with $ 80 per capita nationwide and about $ 120 in urban areas, as of 1976. Also, rural income distribution is skewed, with almost two-thirds of the population earning less than $ 65 per capita. Rwanda is included in the United Nations list of the "25 least developed countries", and has also been designated "most seriously affected" by recent economic developments.

II. Land Resource Base

The topography of Rwanda is dominated by rolling hills, with rapidly diminishing forests on the crests, marshy valley

floors, and intensively cultivated slopes, with fragmented fields and ubiquitous banana groves. The climate is equatorial, with temperatures ranging between 15° and 25° C(59° and 77° F). Two rainy seasons(October to December and January to May)provide relatively high rainfall, generally well distributed throughout the year. However, rainfall tends to be irregular, varying significantly from one year to another.

Four natural regions of the country may be distinguished, which vary in altitude and rainfall: (a) the eastern plains, with low hills and broad valleys, relatively dry (700-1000mm. rainfall annually); (b) the central plateau (1500-2000mm.), the principal agricultural area, which is deeply dissected by numerous steep valleys with marshy bottoms (1000-1200mm. rainfall annually); (c) the western divide, with high hills and mountains, which forms the Zaire-Nile watershed (2000-2500m.), with a rainfall of 1200-1400mm.; (d) the northern highlands (2500-4500m.) with volcanoes and lava plateaus and the heaviest rainfall (1400-1800mm.).

About two-thirds of Rwanda's land area is suitable for agriculture, with the remainder covered by lakes, forests and marshes. Of total land area, about 38 percent is natural pasture. Because of population pressure, marginal lands are being brought under cultivation in many areas. The Ministry of Agriculture has estimated that total land use for agriculture and livestock

increased from 890.000 hectares in 1966 to some 1,140,000 ha. in 1974 and the trend is continuing. With uncultivated land being occupied at such an alarming rate, some prefectures have no more land available. It is likely that all land suitable for farming will be entirely occupied within the next few years, leaving no alternative but intensification of existing farms and settling of land that can at best be descrobed as marginal for agriculture, such as forest soils, marsh lands, steep slopes, etc. The high population density has also led to more continuous cultivation of the soils, which are not allowed sufficient time to lie fallow. This is leading to a decline in soil fertility, with consequent decreases in crop yields.

About 95 percent of cultivated land is used for the production of foodcrops, with the remainder devoted to cash crops, such as coffee, tea and pyrethrum, which are primarily destined for export. Agricultural products contributed 65 percent of Rwanda's total exports between 1970-74. However, the production of foodcrops was inadequate. The population as a whole receives only 80to 85percent of the minimum daily requirement of calories and 90 to 95 percent of that of protein. Deficiency in animal protein and fats is, however, much higher and more widespread.

III. The Rural Economy

1. Agriculture

The tradition of small family farms is firmly established in Rwanda. Landholdings are typically small and fragmented, and

average about 1 hectare per family for an estimated 800,000 farm families. There are almost no large-scale farmers, and farm size varies primarily with natural conditions, with larger farms in less productive areas. Regional disparities in soil quality, steepness of slopes, and above all, altitudes, affecting temperatures and rainfall, are all very significant factors contributing to heterogeneity.

Farming is on a family basis, with little hired labor. Income distribution in rural areas is considered to be relatively even, and regional disparities in wealth are not pronounced. The urban population is small, and urban incomes remain relatively low at about $ 120 per capita. Rural income, by contrast, is estimated at about $ 65 per capita. The rural population is thus almost universally poor, and the dominant activity of the rural sector is production for subsistence. On most farms, however, production is relatively diversified, with farm families producing a wide range of crops for food and cash, in addition to raising livestock, fishing, bee keeping, and engaging in rural industries(primarily beer brewing)and handicrafts.

Foodcrop production dominates the agricultural sector; the principal crops are bananas and sorghum(used largely for traditional beer brewing), beans, peas, maize, cassava and sweet potatoes. Cultivation techniques are rudimentary, the hoe being the principal tool. Mineral fertilizers are not used except experimentally, or on a limited scale for certain cash crops,

because the cost is prohibitive. Organic fertilizers are used for household crops only. Fields are commonly interplanted as a hedge against crop failure. Despite steep slopes in most parts of the country, soil conservation measures are seldom used, and this, combined with the decreasing use of fallow, has contributed to erosion and to the deterioration of soil fertility in many areas. There are generally two harvests of foodcrops annually in most parts of Rwanda.

Significant increases in productivity for foodcrops are possible and techniques have been demonstrated on research stations, in paysannats, and in pilot programs. Improvements include new seed varieties, better rotation, anti-erosion measures application of manure and green manure, and improved cultivation techniques.

Most farmers grow some crops for cash. Coffee is the principal commercial and export crop, and is grown by an estimated half of all farmers. In 1976 there were an estimated 49 million coffee trees in Rwanda. Coffee production fluctuates considerably from year to year, due to poor maintenance of trees and sensitivity of output to climatic conditions. Rwanda re-exports considerable quantities of coffee brought in from Uganda, Zaire and Burundi (about 13,500 tons in 1974). The value of coffee production in 1976 was US $ 20 million. The Government has sought for some time to diversify away from coffee in order to reduce the country's heavy reliance on a single volatile export crop.

The principal new commercial crops are tea and pyrethrum. In 1976 tea production was estimated at 4,975 tons, up from 1,200 tons in 1972, and is still increasing rapidly as new plantings come into production. Tea and pyrethrum now account for about 10 percent of export earnings. Cinchona (quinine) is also grown as a commercial crop. Oilseed crops, notably peanuts and soybeans; tobacco, rice, sugar, vegetables and fruits are being grown increasingly as cash crops in parts of Rwanda. Finally, bananas and sorghum, brewed as traditional beer, probably provide over 50 percent of rural cash income.

2. Livestock

Animal husbandry is an important activity throughout Rwanda, and while the overall cattle population is declining, livestock production contributed about 5 percent of GDP in 1975. Livestock production has not been integrated with cropping activity to any great extent, although many farmers raise crops and also keep cattle and small ruminants. In 1976 the total national cattle herd was estimated at about 650,000 head. Almost all animals are long-horn humpless Ankole types, grazing on an estimated 900,000 hectares. Cattle are individually owned but herded collectively on communal pastures, generally on non-arable hilltops and valley bottoms. Herd productivity is low due to poor nutrition and disease. Since cattle are considered to be a store of wealth, meat and milk production is low, and many cattle are sterile. The size of the total herd has been declining by about 5 percent per year largely because of diminishing pastures as land is

brought into cultivation, and degeneration of pastures due to overgrazing.

Rwanda is free of rinderpest, pleuropneumonia and foot-and-mouth disease. The main cattle health hazards are tick-borne diseases(principally East Coast Fever), typanosomiasis(sleeping sickness transmitted by the Tsetse fly), brucellosis, and internal parasites.

The potential for improving traditional extensive livestock is limited. Some improvement in quality of pastures and of animals can be achieved by improved herd management and by upgrading extension and veterinary services. However, in many areas destocking is essential since large numbers of animals are unproductive and pastures are severely overgrazed. One potential technique for destocking is the establishment of fattening ranches where young steers would be finished for market on a commercial basis. Such operations would require competent continuing management if they are to be economically successful. The most hopeful prospect for livestock development is the integration of livestock and cropping. Research stations have demonstrated successful farming patterns where farmers keep a cow permanently on the farm, stall-fed with fodder crops, which also may serve as anti-erosion hedges. The cow provides milk for her calf, the family, and for sale, and manure for crops. Estimated milk production with a half-bred Ankole-Sahiwal cow is 1.300 liters per year. Five to ten tons of composted manure

can also be produced annually, more than doubling crop yields on demonstration farms. However, transporting manure to the field often presents problems. Calves may be sold or reared for income. The principal problem is the acceptability of these techniques to farmers. While stall-feeding has not been widely adopted, limited experience in paysannats and in the vicinity of research stations indicates that farmers may accept stall-feeding if their farms are large enough to grow adequate forage and still provide for family food requirements. Because of the pressing need to intensify farming, promotion of stall-feeding techniques is being accorded high priority by the Government.

3. Marketing and Processing

Crop and livestock marketing and processing: virtually all commercial crops and about one-third of foodcrop production enter commercial marketing channels. Coffee is purchased green or partially processed from farmers by traders at prices fixed by Government. Tea and pyrethrum are marketed independently by individual factories. Other crops are sold at traditional periodic markets, where transactions are almost exclusively in the hands of private traders. Marketable surpluses are sold by farmers on a cash basis, generally immediately after harvest when prices are usually depressed. Prices vary considerably among regions. The Government is seeking to lessen the impact of price fluctuation by encouraging the development of producer cooperatives. These have met with some success. In addition,

a USAID-financed food storage project is aimed primarily at price stabilization by ensuring more regular supplies of food ly season and among regions.

Cattle are sold at periodic markets which are operated by communal authorities. Traders, who are often the butchers, buy cattle for slaughter or move them on the hoof to other markets. The movement of cattle is generally west towards Zaire and into Kigali. The live cattle trade is not organized, prices are not controlled, and there are no organized stock routes or holding grounds in the country. An estimated 95,000 head of cattle were produced in 1974, and of these about 75,000 were consumed in Rwanda. The average weight at sale is estimated at 240 kgs, producing 120 kgs of meat. Domestic demand for low quality meat is limited by the low purchasing power of the population. Milk production available for consumption in 1974 was estimated at 25 million liters. Only about 5 percent of total milk is marketed commercially at relatively high prices and there appears to be a significant unsatisfied demand for milk in most parts of the country.

IV Socio-Political Features

What follows constitutes only a brief overview of the most relevant points of significance for this survey. Further information may be found in the Rwanda DAP of October 1977 and the literature cited there.

1. Ethnic Groups

Apart from the remnants of the nomadic and pastoral Hima (less than 1,000) living in the northern part of the Akagera National Park, Rwandan society is composed of the Hutu (almost 90%), the Tutsi (close to 10%), and the Twa (less than 1%). No accurate figures are available, however. The first full-scale census is only underway and even that will probably not be very exact.

There are characteristic physical differences between the three groups, but considerable mixing has taken place, particularly between the Hutu and the Tutsi. The latter are typically tall and thin (ave. ± 5ft. 9in.), the former are shorter and heavier (ave. ± 5ft. 6in.). The Twa actually consist of two groups, one pygmoid in stature and features and the other resembling rather the Bushmen of Southwest Africa.

Until the revolution of 1959-62 the dominant group was that of the Tutsi, nomadic cattle herders of Hamitic origin who first appeared around the 12th century and gradually extended their control over the country. They kept political, military, and economic power in their hands largely through a system of client-

ship (ubuhake) which made the Hutu dependent on and subservient to them.

Sometime before the beginning of this era the agricultural and goat-herding Bantu-speaking Hutu appeared and gradually cleared much of the forest. Their language, and to a certain extent, their social and political institutions formed the basis for modern Rwandan society.

The first occupants of the land would seem to have been the Twa. The pygmoid type are essentially hunters living in the Nyungwe forest, whereas the Bushman type are potters and live among the rest of the population. During the Tutsi domination many lived in or near the court, both as potters and servants. They are distinguished linguistically by the use of only two tones as opposed to the three in the standard Rwandan language.

Before the revolution the Tutsi lived primarily in the central plateau region, but since then they have tended to live near the borders of the country, apparently in fear of the Hutu. Formerly they received more education than the other groups and occupied all administrative posts above that of district sub-chiefs. Now they are restricted to a percentage of all jobs according to their proportion of the population. Some are primarily herders, some farm, others are unemployed. In some small regions they constitute the majority of the population, but normally they are a small minority. All Rwandans carry identification cards which state their ethnic group, and Hutu,

Twa and Tutsi are given preference for work in that order.

While few Hutu were educated before the revolution, the situation is changing in their favor. However, 1970 figures show an average of 77% illiterates for all groups in Rwanda.

Although relations between the Hutu and the Tutsi have improved since 1962 and the official policy of the Government is to treat all groups fairly, dislike, distrust and fear still exist and cannot be ignored. The census underway, for example, has led many Tutsi to believe that one purpose of it is to enable the Government to carry out forced emigration of the Tutsi as a solution to population pressures.

On the other hand, more serious for the future may be the relations between the Hutus of the north who were never completely dominated by the Tutsi, and those of the center and south. The first President came from the region of Gitarama in the center, and the present Government, created by the coup d'etat of 1973, is dominated by northerners.

2. Settlement Patterns

The overall high rural population densities vary considerably, depending primarily on the type and quality of the soil and rainfall. The eastern prefectures of Byumba and Kibungo receive less rainfall and have been traditional grazing areas. The same was true of the Mayaga and Bugesera regions south of Kigali. The other central and northern regions benefit from greater rainfall

and except for forested parts of the Congo-Nile watershed, support higher population densities.

Characteristic of settlement patterns everywhere, except in the north, have been the absence of villages and the occupation of hillsides as opposed to valleys. Recent population pressures, however, have brought important changes. People have been migrating away from exhausted and crowded lands in the center and west of the country to the traditional pasture areas of Mayaga and Bugesera in the south and Kibungo and Byumba in the east. They have also increasingly cultivated the valley bottoms which had been used until 1973 for pastures or held in reserve. As one result, the number of cattle in the country, once estimated in excess of 900,000 head, has been declining steadily. The ownership of these animals is quite unevenly distributed. A study of a region in the north showed that 65% of the cattle were owned by strangers to it, whereas there was only one cow per 3 or 4.6 peasant families, depending on the altitude.

Traditionally private property has been recognized in land cleared from the forest and maintained under cultivation. On the other hand, abandoned lands and pastures, found mostly on high slopes and on valley bottoms, except in the drier regions, has been regarded as communal property. People have been increasingly occupying these lands for cultivation, but the communal government retains control over them.

No clear national land tenure policy has been adopted, though the feudal system prevailing under the Tutsis has been abolished, and no system of land titling has been established. Land has traditionally been held by patrilineages (see below under Family Organization) and approval of male family members and the local Burgomaster are required for the sale or transfer of property. The pressure on land has resulted in increasing fragmentation, with the result that about one-third of the individual families hold less than half a hectare, one-third between one-half and one hectare, whereas "rich" peasants hold about two and three-quarters hectares on the average. These holdings, furthermore, are frequently scattered. Generally speaking it would seem that most peasants farm their own land, but renting of land, wage labor, and the sale and concentration of land holdings would appear to be on the increase.

Although rural settlement is, in most regions, in the form of scattered family homesteads, the latter are linked by numerous regional market centers, the number of which and frequency of operation are regulated by the Government.

The World Bank (1976: Annex I, p. 5) estimates that one-third of foodcrop production enters commercial markets. However, this estimate seems high and misleading in the sense that variations with respect both to crops and regions are great. A 1972 study of two communes in the north (Minagri 1975(March): 12)(28) showed that only 1% of foodcrops, varying from 13% for potatoes to 16.6% for

manioc, entered the market. National figures for 1976 (Minagri 1976: 13) give an overall average of 31.3% commercialization, with above average figures for peanuts (46%), soybeans (33%), sorghum (37%), wheat (40%), rice (75%), sweet potatoes (32%), potatoes (40%) and manioc (34%).

3. Political and Administrative Structures

These are dominated by the President and other officers of the National Guard since the coup d'etat of 1973. Instead of a political party as such, a National Revolutionary Development Movement was created in 1975 containing government officials at the national and local levels. The country is divided into prefectures (10), communes (143 , including the towns of Kigali and Butare), sectors (1600) and collines ("hills", of which there are 16,000). All officials from Ministers of National Ministries through prefects and the burgomasters who head the communes are appointed. At the local levels the burgomaster is assisted by an elected council and the chairmen of sectors and "chefs de collines" are elected.

Although authority is highly centralized, attempts have been made to base development at the local level by giving communes a degree of independence of action and supporting it by allocating them the proceeds of head taxes (400RF) and animal taxes. Furthermore, national service in the form of umuganda, consisting one day a week unpaid work for the country, is organized by the commune for its benefit. This may involve such projects as road

maintenance or the cultivation of communal fields, the proceeds from whose harvests go to the commune.

4. Family Organization

Traditionally both Hutu and Tutsi have recognized a series of patrilineal descent groups. The largest of these were thirteen fixed and geographically dispersed ubwoko, or clans. Of greater significance as corporate groups were the inzu, or patrilineages, rarely exceeding six generations in depth. They were important in affairs of ritual, marriage, mutual aid, and blood feud. Intermediate were the umulyango which came into existence when the inzu divided and whose life span rarely exceeded theirs. Each of the latter two had heads and both groups were exogamous (Maquet; 1961, ch. 2)(34).

At present the significance of these groups seems to have declined(except perhaps in the north)and the primary social unit is that of the nuclear family with incidental attachments of other relatives. The virilocal homesteads(sing. rugo), consisting of a collection of a small number of round huts(or more commonly now of rectangular mud-brick, tile-roofed houses)surrounded by a hedge, are scattered over the sides and occasionally tops of the hills. Though kinship may link many of the homesteads on a single hill, there has been no common organization of what constitute neighborhoods rather than villages. Even such cooperative activities as mutual aid in harvesting are declining with the size of fields cultivated. All observers seem to agree that in

most sections of the country families are highly independent, suspicious of others, and little inclined to cooperate with them. Cooperative organizations, therefore, tend to be concerned with sales and purchase rather than production.

Marriage (that with father's sister's daughter is preferred) involves the payment of a bride price, the amount and constituent parts of which vary from region to region, but include such things as animals, beer and hoes.

Polygyny, once estimated to characterize 30% of all marriages has been outlawed since the mid-sixties and now survives only among some seven to ten percent of married men.

Rwandan society is very much male oriented and women are supposed to serve men. Not only do wives serve their husbands, but so do sisters their brothers. All family members are supposed to share the work in the fields, but women do the larger share in addition to their household work. One study (Ubonabenshi, 1977: 46 bis) (12) showed that out of a 12-hour day women devoted 33.8% of their time to agriculture, 20% to household duties, 2.4% to animals, 34.4% to "non-productive occupations", and 9.4% to various other. Men, on the other hand, devoted only 23.1% to agriculture and related activities, 14.1% to animals, 3.9% to household activities, 41.7% to "non-productive occupations", and 17.2% to various others. This is reflected in the attitude of women that they are the agricultural experts and not the men.

Yet women have no rights to land. All a man's property, including land, cattle, trees, huts, and household implements, are divided upon his death among his sons, or, failing these, his closest male agnates. Wives and daughters receive nothing, though the former may continue to live in the household until they die. In theory sons are supposed to share equally in the inheritance, but sometimes a major share is given to one son. As a consequence of the pressure on land, there is frequently not only not enough land to leave a worthwhile portion to each son, or to set him up in marriage, but even not enough to keep parents and young children occupied. Hence many sons do not work on the land at all and are becoming not only unskilled but increasingly alienated from farming.

The system of relationships between family members is a complex one determined by a variety of factors too numerous to enter into here (Maquet; 1961: ch. 2). They may be summarized by saying that a male tends to have formal or strained relations with his father, mother's brother, and brothers, whereas relations are easier or even affectionate with his mother (and to a lesser extent her sister), father's brother, father's sister, sisters, and grandparents. For women the most difficult relationship tends to be that between married sisters.

5. Religion

Probably the majority of Rwanda's population are at least

nominally Christian and the great majority of these Catholic. Other Christian sects represented are Presbytarians, Anglicans, Seventh Day Adventists, Jehovah's Witnesses, and Conservative Baptists. Islam is alsoattracting increasing numbers to it, particularly in towns and among commercial people. The rest remain attached to their traditional religion, which though it conceives of a dominant and benevolent god, is concerned particularly with malevolant ghosts and possibly benevolent ancestors. Diviners and sorcerers had particular powers enabling them to deal with the supernatural, but while few of the former would appear to be consulted nowadays, socerers are still supposedly active and feared and their services are available for hire against enemies.

V. Development Constraints

1. Population Growth and Land Resources

Economic and social development in Rwanda presents some special problems and challenges. Population pressure on land is increasing, technical and managerial manpower is very scarce, institutions are not well established, the level of resources for investment is low, and the country is far from international markets.

The most important constraint which Rwanda faces is the balance between population and the land resources of the country. The annual growth rate of approximately 2.8 percent presents a grave problem and there is little likelihood that this rate of growth will be reduced in the near future. From the present estimated population of 4.4 million people, the GOR projects that by the year 2000 there will be 8.2 million Rwandans. Despite this, no definitive steps have been taken towards the initiation of an effective family planning program.

The increase in population density has resulted in the occupation of almost all good land and an intensification of food crop production. The almost universal pattern of agricultural holdings is the traditional small family farm. Land holdings are typically small and fragmented, averaging one hectare per family. In view of the small size and limited growth prospects of the modern sector, it is certain agriculture will continue to dominate in the economy, and the small family farm will remain the major farm type to the extent that further land is available for their growing number.

The high population density is leading to more continuous cultivation of the soils and resultant reduction in the time the land lies fallow. Since only a limited amount of manure is used, soils are being exhausted. Only

through a change in cultivation practices will a continuing decline in soil fertility be prevented. Soil erosion is also a problem. Much of the cultivable land is located on slopes and the soil retention and conservation measures undertaken thus far have not succeeded in preventing the erosion of topsoils in many areas. While crop yields in general are declining, there is considerable scope for improvement. More efficient extension services and improved cultural practices, along with improved adapted seed varieties and the increased use of animal manure and green manure crops, could lead to significantly increased yields.

2. Absorptive Capacity

Despite the urgent need to increase agricultural productivity and raise living standards in rural areas, investment in agriculture remains low. While AID Agencies are offering, or are willing to offer substantial financial assistance to Rwanda, planning mechanisms and project implementation capacity are not adequate to enable maximum use of the assistance offered. This is largely due to the inadequacy of appropriate educational standards. While 25 percent of the adult population can claim literacy not more than 2 percent have received a secondary education. Another serious problem is that primary education does not provide training in the practical skills, especially in agriculture, which would be most useful to primary school leavers in their working life.

The management of technical assistance programs in past years has not been conducted on a systematic basis related to requirements or availabilities of scarce human and material resources. This policy has been at the expense of long-term development objectives. As more skilled and educated Rwandans become available the country needs to be more selective in its utilization of foreign technicians. It is time to reconsider and coordinate technical

assistance policies to assure the proper use of nationals. A survey of present and future manpower requirements is urgently needed along with a determination of the types and levels of training required to provide the necessary qualified administrative and technical personnel.

Government policy is now directed toward an integrated rural development strategy. It is essential that the new 5-Year Plan clearly defines the country's development priorities, outlines the specific policies that will be required in various sectors, and presents an investment plan. Coordination among the various departments of the Ministry of Plan and the technical Ministries must be close and of a continuing nature if an acceptable, effective development program is to be the end result.

3. Geographical Isolation

Rwanda's landlocked position presents a development constraint. It is obliged to rely on expensive international land transport and shipment via foreign ports for its imports and exports. Apart from the difficulties of distance, Rwanda also suffers as a result of occasional political rifts between the adjacent countries.

The distance from markets raises the price of Rwanda's imports substantically and lowers its earnings from exports. The increases in fuel prices and transport costs since 1974 have been particularly important in adversely affecting the country's terms of trade.

Geographical isolation has adversely affected the profitability of exports and probably the rate of growth of exports. Fuel price increases in particular, have reduced the profitability of export crops production. Producer prices for the major export crops have risen, but less rapidly than the corresponding international commodity market prices. On the other hand, the high transport costs afford a natural protection for domestic

industry to the extent that these have a high local share of value added. Government policy should be to continue to promote export crop production but must realize that Rwanda's competitive position has been reduced, and accordingly place increased emphasis on production for the domestic market, substituting for imports where possible.

VI. Development Objectives

Rwanda's future development alternatives are few, if any, since her assets are limited while the constraints as outlined above, are formidable.

The noticeable unity of its population is perhaps Rwanda's most valuable asset. The social conflicts of the 1950's have been resolved and harmony among racial groups is more assured. Income and wealth distribution is remarkably even for a developing country. Probably less than elsewhere, development policies will not have to be implemented in the face of the opposing interests of a powerful minority.

Secondly, Rwanda's development need not be beset with the administrative difficulties that larger countries frequently incounter. Communications problems are reduced. The country's small size has advantages in permitting policies to be evolved which do not bring into conflict the interests of different regions.

Rwanda's third asset lies in its soil, which is relatively fertile where erosion is not a serious problem. Overpopulation has led to overgrazing and soil depletion in some areas. The hilly nature of the landscape makes soil erosion on hill tops a problem. Despite these difficulties, the heavy soil and abundant rainfall of most areas offer potential for high agricultural yields.

This resource endowment leaves few options and dictates that the most important policy directives should be a very broad and integrated approach

to development in the rural areas. Government policies seek both an integrated and a balanced approach that will not destroy the cohesive nature of the population, but rather reinforce it. In so doing the Government hopes to lay a solid basis for its overall economic program.

The principal objectives of the Government's development program as set out in various planning documents are :

1. to assure intensification of foodcrop production so that the entire population can be fed;
2. to create meaningful and diversified employment opportunities in rural areas through modernization of agriculture, the promotion of artisanal manufacturing, the expansion of crop processing facilities for commercial crops, and programs of public works in such priority matters as irrigation and drainage, anti-erosion structures, rural roads and water supply;
3. improvement of rural incomes to protect farmers against consumer price increases through higher producer prices for export crops and more stable prices for domestically consumed foodcrops;
4. construction of basic infrastructure including improved access to international transport links, better communications, and the upgrading and extension of social infrastructure;
5. training of managers and skilled workers at all levels and in all sectors of the economy, with priority given to the skills necessary for the rural development efforts.

The above objectives rightly give priority to food crop production and to promoting an even distribution of income growth and the benefits of development as the best long-term development policy. Government is looking beyond short-term advantage in its development policy, and this has an important bearing on the choice of development strategy to reach its objectives.

VII. Development Strategy 1977 - 1981

The objectives of Rwandan development strategy are :

1. to satisfy the need of the population for food;
2. to promote better utlization of human resources;
3. to improve the collective and individual standard of living of the population;
4. to improve the position of Rwanda vis-a-vis other countries.

Development strategy at the level of the rural sector is :

1. to intensify and diversify agriculture with the obligation of rapidly developing the production of foodcrops;
2. training, extension and organization of farmers at the commune level with a rural emphasis, and the creation of development centers and permanent training;
3. to attempt to specialize at the level of different agricultural zones of the country;
4. to improve the country's storage system and the marketing of agricultural production;
5. to initiate a sound system of agricultural credit.

Priority will be given to integrated rural development projects with economic crops, which link agriculture and livestock and which facilitate the development of artisanat, and which bear directly on the social improvement of the population and help most of all, the poorest rural elements.

VIII. Description of the Nyabarongo River Basin

The Nyabarongo river and its tributaries drain an area of about 16,500 km^2, of which approximately 2,000 km^2 is located in Burundi. The Nyabarongo is by far the largest drainage basin in Rwanda. The 14,500 km^2 of the basin which lies in this country represents about half its total area.

The river basin on the west reaches the Congo-Nile crest which extends along lake Kivu at a distance of 15-20 km. It is the watershed which divides the waters between the Congo river basin on the west and the Nile basin on the east, of which the Nyabarongo is a part. The Nyabarongo river rises at the foot of the Congo-Nile crest in southwestern Rwanda and is formed by the union of three main tributaries; 1) the Birurume which drains the steepest part of the basin with numerous deep narrow valleys. It is a sparsely populated region difficult of access; 2) the Lukarara which furnishes the most important flow to the river, and whose origins are said to be the farthest from the Nile; 3) the Mwogo, which drains the region northwest of Butare. This area is flatter and heavily populated.

The Nyabarongo basin extends northward to the Zaire-Ugandan frontiers and the Rugezi swamps south of Nyanda and then turns to the southeast, passing west and south of Kigali and is lost in the swampy areas north of lake Rugwero. From its beginning for about 60 km. the Nyabarongo flows north in a narrow V-shaped valley to Gatumba. From that point the valley has narrow alluvial

plains which are not swampy but frequently inundated. In this stretch there are many torrential tributaries. At Ngaru, where it is joined by the Mukungwe, the river makes a sharp turn to the southeast and becomes narrower although it has a narrow alluvial plain, also flooded but not swampy. There are rapids but no appreciable falls.

Two large tributaries, the Base and the Bakokwe, add large flows to the Nyabarongo. The valley is always very narrow but below the confluence of the Bakckwe the valley widens and its aspect changes. The alluvial plain is now 4-600 meters wide and and the river develops very tight meanderings. The land is inundated during certain months but is not swampy. The swampy areas begin about 8 km. above the confluence of the Nyabugogo at Kigali. This is manifested by fields of papyrus of varying size covering zones which are almost constantly covered with water. A large proportion of the valley dries out, however, after the rainy season and is put under cultivation or used as pasture. This aspect of the river changes little up to the confluence of the Akanyaru. It is at this point we have the upper limit of the valley area which it is desired to develop.

From the confluence of the Akanyaru to Rwinzoka the valley of the Nyabarongo varies in width from 700 meters at Gatare to 2,500 meters in the area around Mwogo. The land is swampy and covered with papyrus but there is always a certain proportion of the land which dries out after the rainy season and is culti-

vated or used as pasture. Below Rwinzoka the aspect of the land changes greatly. In the first place the valley widens considerably from about 1,500 meters at Tabarasi to 6,000 meters at Kalenge. It is a veritable lake of papyrus in which the winding course of the Nyabarongo forms a network of channels without importance. At Nganka and Kwitalie the valley narrows abruptly to 1,500 meters and it is at this point we have the lower limit of the valley studied.

IX. Description of the Nile Crest Region

The Congo-Nile crest in Kivu region of western Rwanda separates the drainage basins of two important African river systems. The watershed runs north and south at a distance of 15-25 km. from lake Kivu which forms the boundary with Zaire. The short streams of steep gradient on the western slopes of the watershed flow into the Congo river system. On the eastern slopes the numerous streams flow into the main tributaries which form part of the Nile basin. The major river draining the eastern slopes of the Congo-Nile watershed, is the Nyabarongo. It's drainage basin covers approximately half of the area of Rwanda.

In general, the topography of Rwanda slopes from west to east. Altitudes in the Nile crest region range from 1,300-2,500 meters, with areas around the chain of volcanoes in the north reaching an altitude of 3,000 meters. Along lake Kivu and in the southwest area, elevations are near 1,500 meters. The great variation in altitude results in a wide range of temperatures

and of rainfall. These play an important part in determining the choice of agricultural crops for specific regions.

Rainfall in the western region generally ranges between 1,200-1,400mm., with up to 1,800mm. in the higher volcanic plateaus of the north and in the Nyungwe forest area of the southwest. At these higher elevations the dry season is less severe and shorter, permitting two crops annually of many food-crops on the same land.

The vegetative cover of the region varies widely due to type of soils, and particularly to differences in temperatures and rainfall. The variations from one zone to another are quite marked and represent three main vegetative associations: 1) virgin mountain forest areas and the forest areas which have been cleared in recent years; 2) higher pasture areas at higher altitudes(1,800-2,500 meters); 3) pastures at medium and lower altitudes.

In the higher forest zones the soils are not well adapted to agriculture due to the extremely steep slopes. As deforestation takes place, rapid loss of humus occurs and serious erosion begins. Tea culture is possible in those areas with less steep slopes but is less suited to the greater part of this zone. It is in this zone that extensive soil erosion control measures and soil building practices are required along with large-scale reforestation with

commercial species such as pine, podocarpus, grevillea, cedar. Eucalyptus is the tree usually planted by the peasants since it is fast growing and provides wood for construction, as well as firewood and charcoal for cooking.

The lands in the vicinity of the volcanoes at an altitude above 2,400 meters represent a zone defined more by the properties of the volcanic soils than by altitude and other climatological factors. The land is steep and broken by numerous escarpments and rocky outcrops, with the slopes becoming less steep to the south and west. These diverse soils have a high agricultural value. In the north where the soils are less developed the most suitable crops are bananas, pyrethrum, tobacco and vegetables. On the other soils of this zone, coffee and tea provide good yields.

The higher pasture zone is full of steep narrow valleys which have been recently cleared of forest. Rapid erosion on the steep slopes has resulted in acid soils of low fertility and low water retention capacity, as manifested by the poor vegetation. Apart from controlled pasturing, this zone should be reforested, especially the more rocky sections.

The large lower zone of pasture areas between 1,500-2,000 meters, known as the piedmont, represents the western end of the central Rwandan plateau. Its ferrisols have a very variable value for agriculture. The hills have numerous rock outcroppings

and are often eroded. The climate is semi-equatorial, with a severe dry season of three months duration. Pasture is mostly Eragrostis boehmii, which has limited nutritive for livestock.

The southwestern zone around Cyangugu and Bugarama is suitable for a variety of commercial and foodcrops: bananas, coffee, tea, rice, cotton, quinine.

The cattle population in the Nile crest region represents about 15 percent of the national herd. This number is steadily diminishing in favor of sheep and goats as population pressures on the land in many areas increase, resulting in more intensive cropping, with consequent reduction of the areas lying fallow between crops and available for pasturing livestock.

RECONNAISSANCE SURVEY

X. Scope of Work

The purpose of the present reconnaissance pre-feasibility study is to identify and analyze rural areas of Rwanda to determine whether a reasonable basis exists for implementing a development project, and to identify the essential elements, efforts and resources necessary for successful implementation.

Two specific areas of Rwanda had been selected for investigation prior to the arrival of the study team: the Nyabarongo valley and the Zaire-Nile crest area. On-site investigations of the two areas were to be made. Development constraints were to be identified and ranked according to their relative importance. The team was to develop recommendations identifying what further studies or efforts would be required to prepare a project proposal and what assistance, together with estimated costs, would best alleviate identified constraints.

The team was to develop and prepare this analysis into a final report to be submitted to the AAO/Kigali and REDSO/EA.

XI. WATER RESOURCES

The Republic of Rwanda does not lack in its total water supply although there are wet and dry seasons and a substantial range of annual rainfall increasing from 800 mm. in the southeast to nearly 1,800 mm. in the northwest. Dry seasons occur in general during Dec.-Jan. and Jun.-July-Aug.-Sept., the latter being more severe.

The following summary of available water resource information suggests that water is not a limiting resource to the future economic development of the country. Its development and management in the Nyabarongo River Basin may help achieve important national and regional objectives.

We have reviewed two major reports prepared for the GOR listed as references (4) and (5) together with climatological statistics supplied by the Director General, Genie Rural, the Ministry of Agriculture and Soil Conservation (Mr. Alfred U. Musema).

1. PRECIPITATION ON PROJECT AREA

Statistical analysis was performed on monthly precipitation data for two stations in the area of the Nyabarongo project -- Kigali at the upper end and Karama at the lower end. Tables 1 and 2 summarize the results.

Mean annual precipitation at Kigali is 998.56 mm.; at Karama it is only 861.70. Comparing precipitation with evaporation (at Karama, the only data available) shown in Table 2, it can be seen that mean annual evaporation of 1,532 mm. is substantially higher than mean annual precipitation of 862 mm. Potential evapotranspiration may be estimated roughly as 70% of evaporation, which is 1072 mm. Again this figure exceeds precipitation suggesting that a moisture deficit probably would affect cultivated crop yields in the project area.

Monthly data are more informative than annual means because they show the distribution of precipitation compared with evapotranspiration during the growing season. Referring again to Table 2, we note that potential evapotranspiration exceeds precipitation during 5 out of 12 months. The differences are substantial during the months of June, July, August, September and October. Evidently crops growing during this period would depend heavily upon moisture stored in the soil and it is likely that they would suffer moisture stress unless supplemental moisture were supplied by irrigation.

Irrigation at the Experiment Station at Karama appears to confirm the conclusion that crops respond to supplemental water. However, we did not observe check plots there without irrigation so a visual comparison could not be made and this information could not be obtained either at the Station (the Director was absent) or from the Ministry of Agriculture.

We should caution however that the Karama site is above the water table level of the Nyabarongo valley floor by perhaps 1 or 2 meters and the soil is relatively light textured on the surface, at least. It is likely, then, that little moisture is supplied to crops from capillary rise of ground water. It is possible that on the valley floor, the water table would supply some of the seasonal moisture deficit. This would vary with site conditions and soil type. Light textured soils overlying gravel with rapid drainage to the river would not be expected to be supplied substantially in that way.

From scanty information available, there is a significant amount of land in the project area having the foregoing characteristics. A detailed land suitability classification should be accomplished to identify and map soil and site conditions as to suitability for specific crops and responsiveness

to irrigation (among other things).

Finally, we should note that the monthly precipitation characteristic given by the standard deviation (σ) shows substantial variability year by year in monthly amount. In the long term for a given month, about 70% of precipitation observations would be within the range of: Mean $\pm$ Standard Deviation. For example, from Table 1, (Kigali) for January, precipitation in 70% of years ought to be between 40.64 mm. and 115.36 mm. With an equal chance of any one year being below the mean as being above it. A significant number of years will be dryer during a given month than indicated by the mean; on the other hand some will be wetter.

Table I -- Precipitation Characteristics at Kigali

13 - years, 1961 - 1972 (data in millimeters)

Month	Range	Sum	Standard Deviation σ_n	σ_{n-1}	Mean
Jan	27-161	1,014	35.89	37.36	78.00
Feb	48-361	1,741	97.93	101.93	133.92
Mar	49-262	1,500	49.23	51.24	115.38
April	61-247	2,031	54.22	56.43	156.23
May	33-179	1,336	45.82	47.69	102.77
Jun	0- 89	322	28.37	29.53	24.77
July	0- 28	66	9.40	9.78	5.08
Aug	0- 53	261	15.76	16.40	20.08
Sept	3-118	786	33.64	35.00	60.46
Oct	44-248	1,346	49.89	51.93	103.54
Nov	70-168	1,509	34.43	35.84	116.08
Dec	39-127	1,074	27.06	28.16	82.23
Annual					998.56

Table 2 -- Precipitation Characteristics at Karama

10 - years, 1961 - 1970 (data in millimeters)

Month	Range	Sum	Standard Deviation σ_n	σ_{n-1}	Mean	Evaporation	Est. ET_p
Jan	30-212	801	50.32	53.04	80.10	107	75
Feb	24-228	857	55.69	58.70	85.70	88	62
Mar	41-189	1,057	45.18	47.62	105.70	87	61
April	80-250	1,410	56.60	59.66	141.00	77	54
May	14-188	885	56.18	59.22	88.50	100	70
Jun	1- 45	175	15.38	16.21	17.50	150	105
July	0- 23	37	6.74	7.10	3.70	207	145
Aug	0- 38	127	13.02	13.72	12.70	225	158
Sept	14- 93	413	21.42	22.57	41.30	180	126
Oct	30-108	789	23.47	24.74	78.90	130	91
Nov	60-236	1,328	63.30	66.72	132.80	83	58
Dec	15-124	738	35.24	37.14	73.80	98	69
Annual					861.70	1,532	1,072

Table 3 -- Mean Annual Precipitation in Watershed and Project Area, mm.

Year	Upper Watershed					Project Area		
	Rubona	Ruhengeri	Kibeho	Gitarama	Rwerere	Kigali	Rwamagana	Karama
1956	1,012.8	1,320.1	1,207.8			976.4	895.2	-
57	1,375.8	1,253.9	1,673.0			1,239.3	-	-
58	1,326.2	1,260.9	-			906.9	-	-
59	1,336.1	1.165.3	-			1,159.4	-	-
60	968.2	1,120.1	1,312.0			-	-	-
61	1,459.9	1,406.2	1,515.0		1,112.0	867.5	-	-
62	1,447.2	1,440.3	-		1,189.7	1,033.3	-	867.5
63	1,324.1	1,801.1	-		1,539.1	1,926.8	1,236.7	940.5
64	1,405.6	1,398.6	-		1,138.2	1,026.2	1,091.3	943.0
65	1,149.6	1,308.5	1,310.1	1,047.0	1,246.4	1,168.0	1,132.5	996.1
66	1,333.4	1,344.8	-	1,111.7	1,093.0	762.4	959.3	728.0
67	1,128.8	1,278.4	1,267.6	1,459.3	1,258.2	948.7	935.2	780.9
68	1,299.2	1,453.0	-	1,232.6	1,143.3	1,149.4	1,246.6	1,144.7
69	1,131.7	1,692.5	1,328.0	823.9	1,071.8	799.8	879.0	692.6
70	1,202.9	1,282.0	1,284.8	923.3	1,169.9	985.9	1,088.1	817.6
71	1,285.6	1,763.5	-	1,105.8	1,307.6	961.8	890.3	860.5
72	1,086.0	1,557.5	1,572.2	1.014.8	1,357.3	1,270.0	1,268.6	916.8

2. PRECIPITATION ON WATERSHED

The watershed of the Nyabarongo covers 14,500 km^2 occupying around half the land area of Rwanda. Precipitation over the total area of the watershed averages 1,220 mm. annually. Its distribution over the watershed is highest in the west, corresponding with the higher land surface elevations where it reaches around 1,400-1,500 mm. In the eastern part of the basin, where the proposed land reclamation project is located, the annual precipitation is around 800-1,000 mm. Table 3 displays available precipitation data for eight stations, five of which are in the upper watershed contributing most of the runoff.

Statistical analysis of precipitation records by the Genie Rural et de l'Hydrologie produced a frequency distribution of low and high precipitation around the mean indicating that the low annual mean over the watershed to be expected once in 100 years is 1,000mm. and the high annual mean expected once in 100 years is 1,460 mm. These results along with the expected corresponding runoff are displayed in Table 5.

3. RUNOFF

The drainage pattern of the watershed is densely dendritic with two major rivers collecting all the runoff from the upper basin. The Nyabarongo is the larger of the two and is the main stem flowing out of the basin at Lake Ragwero on the Burundi boundary. The Akanyaru joins the Nyabarongo near Kigali.

Valleys have been sharply downcut so that they have very steep sides and narrow floors. The river channels have well-developed meander patterns throughout their lengths due to very low gradients of the valley floors. In the upper basin the gradient is uniformly around 0.21%; this reduces in the last 70 km through the project area to 0.1% or less.

The relief is sharp over the entire basin, the western half of which is best described as spectacular. Valley walls rising at 45°-60° angles to heights of 800 meters above floors which are typically around 500 meters wide create a unique scene.

In spite of extremely steep sloping sides, the soil is capable of relatively high infiltration rates and absorbs substantial rainfall. Runoff is moderated therefore and the flood peaks are not as sharp nor as high as might be expected otherwise. Flood stage on the Nyabarongo at Kigali is typically about two meters above base level. The peak lasts less than one month during the major wet season of Feb-May. Valley floors are inundated for relatively short periods during peak runoff.

Table 4 shows annual runoff in the Nyabarongo river at Kigali above the confluence with the Akanyaru and at Kanzenze below the confluence. The difference can be attributed to the Akanyaru river discharge. About 67% of the total volume is supplied by the upper Nyabarongo basin. The total runoff volume averages 3.144×10^9 cubic meters annually (2.55×10^6 Acre-feet).

Table 4 -- Annual Discharge of Nyabarongo River

Year	at Kigali		at Kanzenze	
	$m^3 \times 10^9$	Acre ft $\times 10^6$	$m^3 \times 10^9$	Acre ft $\times 10^6$
1956	1.793	1.410	2.669	2.165
57	2.276	1.845	3.125	2.534
58	1.922	1.559	(2.734)	2.217
59	(1.858)	1.507	2.680	2.173
60	1.928	1.564	2.872	2.329
61	1.875	1.521	2.564	2.079
62	-	-	4.307	3.493
63	3.595	2.911	(4.601)	3.731
64	-	-	3.786	3.070
65	-	-	-	-
66	-	-	3.300	2.676
67	2.911	2.361	2.919	2.367
68	3.301	2.677	-	-
69	-	-	3.279	2.659
70	-	-	3.332	2.702
71	-	-	-	-
72	2.545	2.064	3.487	2.828

Table 5 -- Statistical Characteristics of Rainfall and Runoff

Return Period years	Basin Annual Precipitation mm	Annual Runoff at Kigali billion cu. meters	Annual Runoff at Kanzenze billion cu meters
100 dry	1,000	1.35	2.20
50 dry	1,030	1.48	2.44
10 dry	1,100	1.78	2.66
mean	1,220	2.29	3.20
10 wet	1,350	2.80	3.74
50 wet	1,430	3.18	4.15
100 wet	1,460	3.31	4.30
		Peak Daily Discharge cu. meter per second	
mean		225	258
40		335	365
50		430	455

4. WATER QUALITY

Data are lacking on water quality parameters. The Genie Rural is now beginning to take data on suspended sediment concentrations.

Qualitative observations reported in (4) are that the Akanyaru river has a moderate sediment load in its upper reach but that much of it is dropped in the swampy final 70 km section before it joins the Nyabarongo. The Nyabarongo sediment load is principally supplied from the tributary Nyabugogo river which has a considerably steeper gradient. A bed load of sand is generated in the upper watershed near Gatumba where tin mining has disturbed surface soils and severe gully erosion is occuring. Sand beds and dunes are observed throughout the length of the river.

No data are available concerning water pollutants which may be associated with mining and processing operations which, although concentrated near Gatumba, are found throughout the upper basin.

5. LAND RESOURCES OF THE LOWER NYABARONGO VALLEY

A. Topography. -- The valley downstream from Kigali is somewhat wider than that upstream and the valley floor has a lower gradient. Aggradation is evidently occuring although it is thought that a state of near-equilibrium exists in the river channel. The suspended sediment load at Rusumo downstream is estimated the aame as that at Kanzenze in the upper end of the project area. Local scour occurs at bends, as well as local deposition, and slow changes in meander pattern have been seen during the past 16 years. Aerial photos show two loops to have closed during that time. Stream bank protection with rock gabions may be desirable at selected sharp bends.

The floor of the valley widens in the proposed project area, ranging from 700 meters to 2,500 meters. From the confluence with the Akanyaru river the length of the project area is about 130 km. Preliminary estimates are that 7,700 Ha. of land can be reclaimed in this project (5).

The topography of the valley floor is irregular, with some low, swampy areas generally near the edges. The river has built up its banks above the general level of the valley floor to an irregular height of one to two meters. This is thought to be a result of a dense growth of papyrus throughout the valley floor which slows the flood water as it overflows the bank and lets part of the sediment load be deposited there.

B. SOILS

Valley floor soils are alluvial deposits transported from the watershed. They are mixed deposits consisting of irregular bodies of like-textured materials somewhat stratified. A typical profile consists of about 2.5 meters of clay (including both light and heavy clays) overlying 1½ meters or more of fine sands, coarse sands and sand-gravel mixtures as follows :

Depth m.	Material
0 -0.5	light or heavy clay
0.5-1.0	light or heavy clay
1.0-1.5	heavy clay
1.5-2.0	heavy clay
2.0-2.5	light or heavy clay
2.5-3.0	fine sand or coarse sand
3.0-4.0	fine sand or coarse sand with gravel

Although information is not available on the physical and chemical properties of these soils, the clays are probably composed of 1:1 type minerals including kaolinite and halloysite. Some silt is very likely present even though none was identified in the report (4). Like similar soils elsewhere in the country, they are probably workable for tillage and should be good agricultural soils.

The underlying sandy materials should permit good drainage if an outlet is provided. Further, the heavy clay at shallow depth would suggest land adaptable for rice culture.

Permeability of the soil materials is recorded as follows :

	Permeability Range meter/24 hr.
light clay	1.20 - 0.20
heavy clay	0.70 - 0.15
fine sand	1.5
coarse sand	15.
sand with gravel	35.

These permeabilities are comparable to many ferrallitic soils of Africa reported in literature and indicate that they are manageable so far as drainage or irrigation is concerned. Again, the low permeability of the heavier clay would be an asset for rice culture. However, it probably does not occur in the profile throughout the valley but only in certain places.

6. AVAILABILITY OF CONSTRUCTION MATERIALS

Rwanda is favored with an abundance of sand, gravel and soil materials suitable for earth dam or dike construction. Extensive sampling and laboratory testing was reported in reference (4) showing adequate deposits of these materials at each proposed construction site.

Limestone is known to occur for cement manufacture and it is understood that a plant is being planned at Cyangugu in the southwest.

7. RECLAMATION OF NYABARONGO VALLEY

Two preliminary studies have been done to assess possibilities for reclaiming land for food production in the valley. The first, beginning in 1959 by a consulting firm SOCINCO S.A., produced five alternative schemes for flood control and land development. Cooperation with Burundi was assumed so no attempt was made in the plans to avoid impacts across the border.

Comprehensive topographic data in the valley was collected, preliminary designs were made for engineering works, foundation investigations were made at proposed dam sites, and cost estimates were made for five alternatives.

However negotiations between Rwanda and Burundi during 1973 on the preferred alternative failed to produce agreement so a sixth alternative was sketched out in a study made in 1974-75 by Louis Berger International Inc., that would involve no international agreement. In conception it is like the third SOCINCO alternative and is based almost entirely on data collected in the first study.

A. INITIAL ALTERNATIVES

The five alternatives advanced by SOCINCO are as follows :

a. Plan No. 1. -- A dam just downstream from the confluence of the Akanyaru which would raise the water surface in the Nyabarongo three meters above the average water surface in Lake Cyohoho South to force some of the discharge from the Nyabarongo and all the discharge from the Akanyaru into the lake from which it would flow through a tunnel 2140 meters long and into Lake Ragwero. The bypass works and tunnel would be within Burundi. The bypass capacity would be 65 m^3/sec.

The dam would impound 600 x 10^6 m^3 temporarity to permit a limited

release of 60 m^3/sec downstream into the valley. In this way, there would be no flooding in the valley and drainage of marsh areas could be done by gravity ditches.

Land would be inundated for sustained time upstream from the dam in the Nyabarongo and the entire 70 km of the Akanyaru would be ponded and flow reversed.

b. Plan No. 2. -- The same dam and the same bypass system would be used but 125 m^3/sec would be released downstream. Minor diking along the banks of the Nyabarongo would be necessary to contain the release within the channel. Marsh areas would have to be drained by "polderizing" and pumping out. Six pumping stations would be required.

c. Plan No. 3. -- The same dam and bypass system and the same release of 125 m^3/sec would be used. However to avoid the necessity of a dike at Lake Ragwera to restrain the encroachment of the lake northward into the project area, the flow of the river would be diverted into Lake Sake then into Cyahafi swamp through a 350 meter tunnel. A second dike would be needed downstream from Cyahafi swamp to prevent the flow from going back into Lake Ragwero. Five marsh drainage pumps are needed.

d. Plan No. 4. -- No dam or storage would be used and no bypass system either. The flood flow would be contained within the channel of the Nyabarongo by extensive diking of the banks. The dike north of Lake Ragwero would again be needed because all the discharge would go into the lake. Six marsh drainage pumps are needed.

e. Plan No. 5. -- This is the minimum plan which would not attempt to reduce the flood peak nor to contain the flood flow within the channel banks but would allow annual flooding of the valley floor. Drainage ditches would be constructed to provide rapid relief following the flooding period.

Cost estimates for the five alternatives in 1962 were as follows:

Plan No.	Total Cost capitalized over 20 years	Reclaimed area	Cost per Hectare
1	RwF. 342,000,000	9,800 Ha.	RwF. 35,000
2	376,000,000	8,700	43,300
3	351,900,000	8,700	40,400
4	413,900,000	8,700	47,600
5	75,500,000	5,000	15,100

Plan No. 1 was chosen as preferred but as indicated earlier, agreement could not be reached in 1973 with Burundi and the further work on the plan was discontinued. By that time, the cost estimate was RwF. 450,000,000 or 45,918 per Hectare.

f. Plan No. 6. -- Another conceptual plan was outlined subsequently which would include a dam on the Nyabarongo about 37 km downstream from the Bakokwe river confluence. It would be about 30 meters high and store up 250 x 10^3 m3, sufficient to permit restricted release of 200 m^3/sec during the flood season. The rest of the plan would be like Plan No. 3 except the flow in the river in the project area would be diverted into Lake Mugesera, then by tunnel into Lake Sake, and finally by tunnel into Cyahafi marsh and thence to the Akagera river. No cost estimate or preliminary plans were made.

B. CURRENT PROPOSAL

The Berger organization was employed in 1974 to re-examine the previous alternatives and others in order to find the best plan for reclaiming the valley land. Constraints applied were that no modification be made in

hydraulic regimes of lakes or rivers outside Rwanda; that flood flow be controlled except for extreme events to minimize inundation of the valley lands below the confluence with the Akanyaru; that marshes between the Akanyaru and Karama be drained and reclaimed; and that the irrigation be provided if necessary; that low areas in the valley floor be filled, if possible by alluviation.

The plan also ought to allow for future developments ancillary to the land reclamation project such as improvement of the Akanyaru valley, drying and filling certain small lakes in the lower basin, and future possibilities for irrigating plateau lands around the valley by storage and pumping.

This proposal that was developed includes a dam downstream from the Akanyaru confluence but lower than that of Plan No. 1. Such that backwater in the Akanyaru would not reach Burundi. Storage of 170 x 10^6 cubicmeters would allow the controlled release of 200 m^3/sec into the valley during flood season. Backwater from the dam would extend 25 km up the Akanyaru and 16 km up the Nyabarongo. The smaller dam (6 meter height) would control the estimated 50-year return period flood.

Channel capacity through the valley would be increased by raising banks where they are low; channel cross section improvement to create a minimum width of 40 meter and depth of 4 meters (capacity 160 m^3/sec); and possibly remove some loops that are nearly closed (with care not to increase the hydraulic gradient of the river).

The consultant did not have enough detail of the river topography to confirm the extent to which the channel capacity can be improved but it was an opinion that at least 175 m^3/sec could be handled without overflow.

In order to reduce the controlled discharge to 175 m^3/sec, a second dam

and reservoir could be built 16 km upstream from the confluence of the Nyabugogo to hold 230 x 10^6 cubic meters. This would be operated in conjunction with the lower dam downstream to permit the controlled discharge that could be contained within the banks through the valley.

The dam is estimated to require about 320,000 cubic meters of earth fill material, readily available, at a cost of about RwF. 320,000,000 (1975).

This site is evidently a good choice since the width of the valley is only about 200 meters and valley walls are extremely steep and rocky. Relatively little arable land would be lost in the reservoir.

Other alternatives exist for managing the restricted discharge of 200 m^3/sec from the low dam to minimize flooding damage in the valley, including higher levels along the channel (at least 0.6 m) and a more extensive drainage system. No firm conclusion was reached by the Berger organization as to the optimum plan because of the need for more detailed topographic data on the project area.

CONVERSION FACTORS

1 m^3/sec = 20.57 cu.ft./sec

1 Hectare = 10,000 sq. meter = 2.47 acre = 1 hectare

1 sq. kilometer = 100×10^4 sq. meter = 247.1 acre = 100 ha.

1 billion m^3 = 810,710 acre-feet

1 km. = 0.621 mile

1 mile = 1.61 km

1 cu.ft./sec. = 28.75 liter/sec

8. ASSESSMENT OF PROJECT

The work done by SOCINCO and Louis Berger International is competant for the level of preliminary identification of alternatives. However, the major effort to date has been invested in the initial scheme assuming an international cooperative project with Burundi. Failure to reach agreement has forced consideration of alternatives for which less hard data are available. Nevertheless the evaluations of possible alternatives is considered adequate to establish the possibility of the land reclamation project.

Physical information now available is sufficient to scope the possible alternatives but not sufficient to find the optimum plan or combination. The Berger concept is based on objectives and constraints with which we agree. They are considered correct for the circumstances which exist. In particular it does not foreclose future options for further water resource development such as reclamation of small lakes and irrigation of plateau lands.

We agree with the strategy of controlled flood release combined with minor channel improvement. The optimum combination needs to be identified in feasibility studies for which more physical facts will be needed.

Reservoir sites are very limited in Rwanda because of the low gradients of valley floors and intensive cultivation on floors and sides throughout the country. The site identified 16 km upstream from the confluence of the Nyabugogo on the Nyabarongo is probably the best selection but further study should be given to find all possible alternatives. Multiple small dams on tributaries could be a possibility although doubtful because of intensive agriculture on valley floors and side slopes.

We believe the two-dam strategy is desirable because it creates options

for future related development, for example, low-head peaking power and water storage for supplementary irrigation, possibly on the plateau lands between Kigali and Karama. Such a development could be integrated with new hydropower projects which would supply necessary energy for pumping.

The strategy of river channel modification is hazardous because rivers tend to defeat the efforts of man to make large changes in their natural regime. Some "training" can be done but it should be minimized. Here the need for more data in the morphologic characteristics of the rivers is urgent. A pre-feasibility study is recommended to assemble and analyze sediment load and transport capacity information.

Drainage plans for the valley lands are feasible. A drainage network can be designed which will effectively control ground water and remove excess precipitation. The main drain should be excavated into underlying coarse sand and gravel in order to capitalize on them for efficient ground water removal.

Irrigation will probably be necessary for some of the reclaimed valley lands having surface soils of light sandy texture which would tend to dry during the dry season and which might not be supplied by ground water. A land capability classification is essential prior to preliminary project design so that the irrigation needs can be identified. This is recommended as a high priority task.

If irrigation is needed, the most simple water distribution system should be designed. It should be operated and maintained by a farmers cooperative association for which substantial technical advisory services will be needed.

9. SPECIAL STUDIES NEEDED
(pre-feasibility)

Several issues need to be resolved early in further feasibility investigations. They are therefore in the nature of temporary constraints to be resolved. The following sections outline these studies.

A. RIVER STABILITY AND MORPHOLOGY

A unique plan is proposed for reclamation of 7,700 Ha on the floor of the Nyabarongo river southeast of Kigali. A dam on the Nyabarongo river will raise the elevation of water surface at its confluence with the Akanyaru river about 3 meters, sufficient to back water into the Akanyaru. Flood peaks in the Nyabarongo will be partially removed through this small reservoir; a flow of about 175 m^3/sec will be permitted to continue through the project area confined within banks of the river channel (built up where necessary).

Heavy growths of papyrus will be cleared (by hand labor); excessively low areas in the valley floor will be filled up 1 to 2 meters by sedimentation using sediment carried in river water; drainage and irrigation distribution ditches will be dug (preferrably by hand labor). The land thus reclaimed would be brought into food production in sections (lots) staged over a 10-year project construction period.

The scheme is highly imaginative and physically possible. Whether or not it is physically feasible involves several questions not fully settled as yet because certain data are not available or because necessary analyses have not been made. Foremost among the unanswered questions is that concerning morphological changes that may be expected in the river due to alterations in

its natural regime. Both the Nyabarongo and the Akanyaru will be changed substantially.

The Nyabarongo through the project area will have a reduced discharge much of the year and will no longer carry the former flood peaks. Sediment load and sediment carrying capacity will both thereby be changed. Its erosive capacity will be altered substantially, at least during much of the year. Whether or not its new character will lead to accelerated downcutting of the channel bottom, erosion of banks, or rapid changes in meander pattern remains to be analyzed. There is a strong possibility that one or all of these effects may be experienced. If so, appropriate counter-measures would have to be devised.

These potential problems are amenable to analysis and ought to be settled before large investments are made in project planning. It is recommended that a qualified consultant be engaged to design a plan of study (probably one year) specifying necessary field data collection and analytical methods to be used to forecast river changes including those outlined above.

Data collection for the study can be done by the Genie Rural et de la Conservation des Sols which already is beginning to take limited measurements of suspended sediment loads. The expert consultant would be responsible for interpreting the data and analysis at the end of the study. (Note: the writer can recommend several qualified experts for this work). Estimated consultant cost is :

Design of study	
1 man-month on site	$ 10,000
1 man-month USA	7,000
Travel	
3 trips to Rwanda	3,600
Per Diem	3,000

Data Interpretation

1 man-month on site	10,000
	$ 33,000

B. SOIL CAPABILITY CLASSIFICATION (including irrigability)

Technical constraints are substantial in all new irrigation projects but particularly so in any area not previously irrigated. Expanding an existing, successful irrigated area is usually a straightforward transfer of proven practices. On the other hand, opening up a new project challenges the most thoughtful applications of modern irrigation science and engineering. Water, the universal solvent, is to be combined with soil, an aggregation of complex chemically active constituents. What happens cannot be left to chance; success or disaster hinges on the reaction. History is filled with evidence of this fact yet modern man has failed often to take notice.

Soil science has progressed in the past two decades so that chemical and physical reactions can be predicted; long term compatibility of water with soil can be established before an irrigation decision is made.

But this alone is not sufficient to insure success. Ground water must be under control; otherwise the root zone may be too wet for cropping. In some situations, soluble salts accumulate in the soil, a residue from evapotranspiration. If natural drainage is not adequate, artificial measures can be taken.

Drainage engineering is capable of assessing the capacity for drainage of project lands before the irrigation project decision is made. What is necessary are field and laboratory measurements of appropriate parameters of soil and geology.

The foregoing described technologies constitute the tools for classifying

land for irrigation and crop suitability. They enable a projection to be made of soil-water interaction over a long term. Clearly no irrigation project should be initiated without assurance that it can have an unlimited useful life.

This is not to say that the project decision rests alone on the physical irrigability of the land; other questions will be added such as economic costs and returns, national objectives for regional development, population redistribution, quality of life for rural poor and the like. But without a competent classification of the land, a sound basis for a decision is missing. It is recommended that a team experienced in irrigability classification be employed to survey the proposed project lands and classify them as to suitability for irrigation and moreover for specific crops, e.g rice, sugar cane, sorghum, etc.

An estimate of cost for this work is very difficult and uncertain. It is estimated that about 8 months time will be required with a team as follows :

	Number	Man-Mos		Cost
Senior Classifier	1	8	US $	64,000
Irrigation and Drainage Engineer	1	8		64,000
Soil Surveyor (Supervisor)	1	8		64,000
Soil Surveyor	2	16		6,400
Chemist	3	24		4,800
Soil Survey Aides	3	24		4,800
Engineer Aide	1	8		1,600
Laboratory Assistant	3	24		4,800
Driver	2	16		3,600
Draftsman	1	8		1,600
Skilled labor	8	64		1,100
			$	225,500

Services/Logistic	88,000
Materials	69,000
Total	$ 382,500

10. ENVIRONMENTAL IMPACTS

Environmental health may be the first consideration but other environmental elements, including natural resource conservation, should not be overlooked. Malaria and schistosomiasis may become health problems in a new irrigated area because of numerous shallow water bodies. On the other hand reclamation and drainage of the swampy-boggy floor of Nyabarongo valley ought to be an environmental health improvement by reducing the incidence of these and possible other human health factors.

Clearing of the land now covered with a dense cover of papyrus will create a substantially different environment in the entire valley floor through the project area (70 km). To the extent that the dense brush-like growth shelters wild animals and birds, the impact will be adverse to those uses. Nothing is known about this potential impact and it is recommended that a study be done to inventory and characterize the wild life populations in the valley with particular attention to species which may be endangered.

The new river regime to be created in the valley by control of the flow and reduction of the flood peak may have impacts on the aquatic life in the river channel and on the flood plain. Changes in the sediment load which may result can also effect biota of the river channel. Since there is presently no information on aquatic life and biota of the channel and flood plain, it is recommended that an iventory be taken and that a projection be made of impacts due to the project. This study must be coordinated with that recommended elsewhere on sediment load changes to be complete and meaningful. Morphological impacts on the river channel due to changes in flow and sediment load may also be expected. These have been described in another section and constitute one of the most serious considerations yet

to be made in determining physical feasibility of the project. Channel deggradation and aggredation, accelerating meanders and sedimentation of certain sections of the river behind dams or in the Akanyaru river are possible environmental impacts.

11. NOTES ON PROJECT EVALUATION

This section is presented as a framework for future guidance in evaluating the Nyabarongo project. Time and information constraints permit no more than this. Some principles that seem to be relevant to this project follow.

The reason for national interest in water resources and related land development projects is not solely to meet present and future requirements that will produce substantial contributions to the flow of national income as well as contributions to other objectives.

Farmers coming into the project would need about 2 Ha of land per family to make a living. If for example, current land development costs experienced in the Senegal River basin of US $ 6,000 per Hectare, are applicable as well in Rwanda, the initial investment cost per farm would be US $ 12,000.[1] With a per capita farm income around US $ 65.00 and an average of seven members per family this development investment would be about 25 times the per capita income. The function of project evaluation is to assess total benefits in relation to all the objectives which the country may define for such an investment.

The principle for project evaluation is that benefits and costs have meaning which can only be identified when directly related to objectives.

1) Preliminary estimate of design and construction cost for the Nyabarongo project made in 1974 by Louis Berger International Inc. is US $ 3,000 per hectare which may be inflated to around US $ 6,000 per hectare in 1978 suggesting that this estimate is reasonable

This means that clear and thoughtful definition of objectives must preceed any consideration of benefits, and that all relevant types of benefits should be identified. Too often only one objective is considered -- national income increase -- and only the primary benefit is identified, that being direct consumption of goods and services produced by the project.

There may be benefits assignable to one or more of several objectives such as, for example :

a. National Income Increase

b. Regional Development

c. Environmental Protection and Natural Resource Conservation

d. Citizen well-being

These are not mutually exclusive objectives so benefits that are assigned to each should not be double counted in assessing the grand total of benefits, yet by identifying all objectives and their associated benefits, full credit can be given to those benefits related to objectives which are priority in national policy for development. A water resource project evaluated on a single objective, such as National Income, probably will be under-valued because of failure to identify other objectives and to evaluate benefits associated with them.

Benefit is defined as :

> Increase, net of associated and induced costs, in the value of goods and services which result from the project as compared to their value without the project. Benefits include tangibles and intangibles.

In this definition particular attention should be given to three parts: (1) identifying all beneficial contributions; (2) the "with project" and "without project" principle; and (3) associated and induced costs.

For example beneficial contributions in addition to the primary benefits of direct consumption of goods and services produced by the project should include secondary effects in terms of employment of other production factors such as labor, productivity gains in the land resource and capital. Benefits should be counted regardless of where they occur in the economic system. Indirect benefits tend to be ignored because they are not obvious, or because the analytical tools are not available for their assessment. It is entirely possible that they might exceed the direct benefits. If the objective is national income increase, the benefit value to be measured is the total increase in national income.

In attributing benefits to a project, care must be taken to count only gains that would accrue as a result of the project, not counting as project benefits those gains that would be realized without the project. This is not a "before" and "after" assessment, but rather a measure of additional gains that are expected as a result of the project.

Finally, associated and induced costs should not be overlooked on the cost side of the project evaluation. Associated costs are those needed to make the products and services produced by the project available for use or sale. Induced costs are those such as for example increased cost of government service due to the project and increased public transportation costs.

XII. AGRONOMY

1. GENERAL

The agronomic studies carried out during the course of the present reconnaissance survey while fairly general in nature, were made in the two potential project areas; the lower Nyabarongo river basin and the Nile Crest region of western Rwanda. Thus, the following section of this report discusses the agronomic potentials and limitations of the two areas as related to soils characteristics and potential, liming and its effect on productivity, land use patterns and production practices, and cropping schemes.

2. SOILS CHARACTERISTICS AND POTENTIAL

The soils of Rwanda, like the climatic conditions of the tropical zone, have a great amount of diversity with several of the great soil groups being represented throughout the country. The most dominant soils are the laterites, now reclassified under a new soil order known as the "Oxisols". These soils, formed under forest and savannah vegetation, are generally strongly weathered and leached, usually to great depths. Actually, the laterites are the most strongly weathered soils in the world.

Despite the deep, strongly weathered regoliths, most of the soils lack distinct horizons, except for a darkened surface layer or A_1 horizon. Below this the profile may remain unchanged for many feet.

Red and yellow profile colors are common to laterites because of the large amounts of iron oxides formed through intensive weathering. The varying shades of red, yellow or grey do not necessarily indicate a higher iron content in the deeper red-colored soils. Iron in hydrated form in yellow soils may exceed the iron content of red soils. Color change

an indication of the degree of hydration.

Most of the soils, except alluvial deposits in valleys and river bottoms, have a low organic matter content and a low cation exchange capacity. Supplies of weatherable minerals are generally low, and their capacity to fix phosphorus in unavailable forms is high; they have a high degree of aggregate stability and the appearance of some red color.

The clay content of oxisols is frequently high, but the low activity of the clay contributes to the development of a desirable granular condition which permits rapid infiltration of water and permits cultivation shortly after heavy rains. These factors account for the need of frequent heavy applications of fertilizer for sustained crop production.

In the absence of fertilizers, periods of extended fallow are necessary for soil rejuvenation. Shifting cultivation is commonly practiced in some countries where cultivable land is available. In Rwanda, however, this system of cultivation is not possible because of the population pressure on the available arable land. Most of the desirable soils are presently occupied, and only a very limited amount of marginal soils remain uncultivated. Because of the critical man-land ratio, periods of fallow are being drastically shortened or disappearing. Farming on steep slopes, shortening of the fallow period, depletion of organic matter and lack of erosion control will all contribute in the long run to the exhaustion of many soils.

Between the youngest soils of Rwanda, located on rather recent volcanic ash, and the oldest soils, there exists a wide range of soil properties. Soils in the lake Kivu, northwestern and southwestern regions of the country possess characteristics of the Eutrophic Brown soils on volcanic ash. These are considered to be relatively young soils. They often have a high organic matter content in the A_1 horizon and a high cation exchange capacity. Their

reserve of weatherable minerals is usually large, and they are generally well structured and very permeable. At high altitudes they are suited for intensive cultivation, comparable to that in use in humid temperate regions.

Older soils are found throughout the country in most areas not occupied by the volcanic soils. These represent soils with varying properties, among which are the ferrallitic soils which reflect the final stages of weathering and leaching, wherein only the least mobile and least weatherable constituents remain. These are fairly deep soils with slightly differentiated horizons but containing little or no reserve of weatherable minerals. Their agricultural value varies but frequently is relatively low.

Many of the yellow and red ferrallitic soils carry forests or savannah. An important part of the mineral reserve is concentrated in the vegetation and in the superficial soil layers where plant materials are continually added and decomposed. After these lands are cleared, the accumulated reserves are quickly exhausted by annual crops and by the rapid decomposition of organic matter. Restoration can only be accomplished by long fallow. In the forest regions the perennial crops like coffee can be maintained economically for several years. Generally the agriculture potential of forest soils is greater than that of soils under savannah.

The humic ferrisols (classified among the Ultisols) are also found in Rwanda. Like the eutropic brown soils, the ferrisols are a transitional group which are evolving under a hot and humid climate and whose normal development is retarded compared with that of neighboring soils. The ferrisols, just like the eutrophic brown soils, are distinguished from neighboring soils by their higher exchangeable base content, better structure, higher biological activity and, therefore, higher fertility.

Although these soils are higher in plant nutrients than ferrallitic soils, they appear to be relatively poor as compared to the eutrophic brown soils which have developed on similar parent material. When climate, land-form and altitude permit, they are suited for coffee, tea, cinchona and possibly others.

Soil textures range from fine sands to heavy clays. I.S.A.R. experiment station reports indicate that the soil reaction (pH) ranges from less than 5.0 to 6.8 in lower and medium altitudes and up to 8.0 in the higher elevations. The soil reaction (acid-neutral-alkaline) has a pronounced effect on the availability of plant nutrients present in the soil. Many of the soils are deficient in phosphorous, potassium and calcium. Although the pH levels may appear to be within the tolerable range for many crops, they could not be considered optimum, especially when values fall below 5.5. The pH usually reflects the percentage base saturation, and the above values suggest lower than desired levels of basic elements needed for optimum production.

Because of the many physiological factors involved, it is difficult to associate, with any high degree of accuracy, the optimum growth of crops with the pH of mineral soils. With some crops it is known that abundant calcium is essential, and if it is supplied in adequate amounts, the crop will perform well even at a relatively low pH. Most crops grow well on slightly to moderately acid soils.

The intensity of acidity which plants will tolerate is also influenced by the supply of available nutrients and moisture. When other conditions are favorable for the growth of a plant it will thrive in a much more acid soil than it would if the nutrient or moisture supply were limited. Therefore, if soil depletion in Rwanda continues unabated, adverse effects on crop

yields can be expected to intensify on moderately to strongly acid soils. Crops like maize, millet, sorghum and tobacco, all grown in Rwanda, are highly tolerant to acidity and can be expected to perform satisfactorily in moderately acid soils, if other conditions are favorable. However, when other production factors such as nutrient supply, moisture, physical structure and tilth are not favorable, less than optimum yields can be expected on moderately to highly acid soils.

Cotton, soybeans and wheat are moderately tolerant but beans, cabbage and lettuce are especially sensitive to soil acidity.

The Louis Berger study (5) shows there are several soil types represented in the proposed project area of the Nyabarongo river valley possessing a rather wide range of production capabilities. In order to fully evaluate the productive potential of the valley area, a land-use classification will be required.

At the foot of the hills are the colluvial soils which are for the most part the richer soils and are presently producing bananas, beans and other vegetables. These soils are rarely under water, permeable and easy to work but make up only a small portion of the total area.

Black tropical (margalitic) soils found in the valley derive their color from humus-montmorillonite clay complexes although they do not have a high organic matter content. They are coarse, well-drained soils which are rarely inundated but sensitive to drought, and for this reason, are not desirable for cultivated crops but are adapted for forage production. However, if these soils are drained so that the water table can be controlled, they would be suitable for the production of seasonal crops.

Along the river banks are the young soils of light and heavy texture, relatively rich, permeable and easy to work. Most of these are dry throughout

the year in the northern part of the proposed project area but become gradually more subject to flooding as you progress southward in the valley.

Recent alluvial deposits, generally of heavier texture, are found at a greater distance from the river banks. The light textured silty soils are usually located at an intermediate distance between the river banks and the extreme limits of the alluvial deposits. Most of these soils are covered with water for the greater part of the year. The peat soils in low depressed areas usually remain permanently flooded and are difficult to drain.

Drainage of the proposed Nyabarongo valley project area would permit the production of rice, sugar cane, vegetables and other crops on a significant portion of the 7,700 hectares involved. With the exception of rice, it may be possible to grow most of these crops without irrigation, if the level of the water table level can be regulated to provide an adequate sub-surface moisture supply. The establishment of an extensive irrigation system would involve a complex system of agriculture which would require a long period of time to effectuate. Further studies would be required to determine the possible benefits and water requirements for selected crops. Production increases derived from an irrigation system, based strictly on a cost-benefit analysis, may be difficult to justify.

3. LIMING AND ITS EFFECT ON PRODUCTIVITY

Liming, an important practice in soil management, needs research attention to evaluate practical and economical aspects of improving degraded soils. Frequently soil fertility is regarded chiefly as a matter of supply of nitrogen, phosphorous and potassium, and insufficient emphasis is placed on lime, which performs many indispensable functions in plant growth

and in modifying soil conditions.

Liming of acid soils in Rwanda could make a significant contribution to agricultural productivity and should be given careful consideration along with further studies and evaluation. Research workers at the I.S.A.R. station at Rubona conducted a number of trials with the use of lime on several crops. All tests showed positive yield responses, especially when lime was applied in conjunction with chemical fertilizers. Agronomists at the Swiss Agricultural and Forestry School in Kibuye also reported excellent yield increases in liming trials conducted in high altitude soils.

Research in other tropical countries has shown that differences in response to lime among soils of the humid tropics are as great as between soils of the tropical and temperate regions. In general, however, liming is basic to their effective use. Although many tropical crops evolved under acid soil conditions and may be tolerant of soil acidity, few, if any, are immune to all the factors of acid soil infertility.

Relatively low rates of application are usually adequate for maximum crop production. In many cases lime seems to be effective chiefly as a source of calcium and magnesium as nutrients. Maximum yield has usually been reached with the first increment of lime, even when it was very low. Soils of humid tropical regions are usually highly resistant to pH change above 5.5 and any attempt to lime them to conventional pH levels, such as 6.5 to 7.0, is inadvisable.

Soil pH per se is a less dependable criterion of lime need in soils of the tropics than in those of temperate regions. In the tropics, maximum crop yields often are made at pH levels that would be intolerable in less weathered soils.

Much has been said in past years about the dangers of using lime on tropical soils. Recent studies have shown that overliming injury of crops on soils of the humid tropics seems to have been overemphasized. The cost and availability of lime in most tropical areas automatically prevent the use of more than minimal rates, and yield depression seems to be less frequent than formerly believed and tends to be restricted to certain crops. Cereals, soybeans, sugar cane, beans, cowpeas, peanuts, and cotton have generally been responsive to liming in the humid tropics. Since the effects of lime are dissipated more rapidly in tropical than in temperate regions, it is logical to make more frequent and lighter applications in the tropics.

Lime deposits, found in different parts of Rwanda, could provide a supply of calcium and dolomitic limestone, thus eliminating the need for importing these materials. The Geological Service division of the Ministry of Agriculture and Economic Affairs reports limestone deposits, both calcium and dolomitic, at Kibuye, Kariba, Kamanyola, Mushao, Mashyuza, and other locations.

4. LAND USE PATTERNS AND PRODUCTION PRACTICES

With a total land area of less than 26,000 square kilometers, Rwanda has approximately 350 inhabitants per square kilometer of arable land. The gradual increase in population density has been accompanied by diminishing farm size which is now estimated to be about one hectare as compared to 1.5 hectare in 1953.

Rwanda's topography offers a wide range of crop alternatives because of its varying altitude and temperature. Most of the land is devoted to the production of food crops including bananas, beans, cassava, maize, millet, peanuts, potatoes, peas, rice, sorghum, soybeans, sweet potatoes and

sugar cane. The remaining land is occupied by the commercial crops - coffee, tea, pyrethrum and cinchona. Coffee is the principal commercial and export crop. Recently, fruits, vegetables, peanuts and soybeans have been grown increasingly as cash crops.

Data provided by the Ministry of Plan show that in 1974, 504,000 hectares were devoted to food crops as compared to 42,000 hectares to cash-crops. Of the total land area planted to foodcrops, (1975) beans were grown on 191,000 hectares and bananas occupied 190,000 hectares. Sorghum ranked third and was followed by sweet potatoes with 133,000 and 87,000 hectares, respectively. (Tables 1 and 2)

Most of the land is farmed on a family basis using almost exclusively traditional methods. Cultivation practices and techniques are primitive and few tools are available. The hoe and sickle are the principal tools, and animal power for land preparation, cultivation and transportation is non-existent. Most crops are interplanted, and generally, plant spacing and population densities are ignored. Seedbed preparation is usually inadequate because hoeing does not provide the means for deep cultivation and proper pulverization of the soil. Usually the time for land preparation is limited because farmers wait for the first rain following the dry season to soften the soil before cultivating. Weed problems are common and contribute further to reductions in yield. Some manure is used on farms where livestock is kept, but chemical fertilizers and pesticides are used only on demonstration farms and some of the larger commercial farms. Many of the varieties used are poorly adapted and low yielding.

The constantly increasing pressure on arable land has led to continuous cultivation of the soil with resultant shortening of fallow periods, and, in some cases, complete elimination of fallow. This, combined with the

TABLE I AREA PLANTED UNDER FOODCROPS (in thousand hectares)

Crop	1975 Year
Beans	191
Bananas	190
Sorghum	133
Sweet Potatoes	87
Peas	72
Maize	63
Cassava	32
Potatoes	23
Peanuts	15
Millet	5
Rice	1

Source: Ministry of Agriculture

TABLE II

LAND USE AND AVAILABILITY
(in thousand hectares)

	1974
AGRICULTURAL LAND	1,250
Foodcrops	504
Fallow	177
Paysannats	72
Cashcrops	42
Pasture	353
Uncultivated	102
LAND NOT SUITED TO AGRICULTURE	526
UNUSABLE LAND	784
Lakes	128
Forests	164
Marshes	84
National Parks/Hunting Area	347
Urban and Other	61
Total	2,560

Source: Ministry of Plan

limited use of chemical fertilizers, cultivation on steep slopes without proper soil conservation measures, and the absence of soil building practices, has led to the serious exhaustion of soils in some areas. If present practices remain unchanged for an extended period, further serious deterioration of soils will occur in most areas of the country. It seems unlikely that Rwanda, faced with the urgent priority of producing an adequate food supply for its growing population, within the constraints of its land resources, can significantly increase its agricultural productivity without the introduction and adoption of innovative technology. The use of chemical fertilizers, the introduction of leguminous green manures, new adapted varieties, improved cultural practices, adoption of soil conservation measures and plant protection techniques could make major contributions to augmenting agricultural production.

The limited amount of reliable data available on yields of foodcrops indicate room for improvement. Generally, yields achieved at I.S.A.R. experiment stations are double or triple the national average. These data suggest that significant increases in productivity for foodcrops are attainable with the use of chemical fertilizers, manure, crop rotation, improved varieties and more effective extensions services. (Table 3).

Once the technological base has been established, an effective educational delivery system will be required to disseminate the information and carry out the adoption of improved methods. The quality and effectiveness of the extension service has been at a low level and needs improvement and expansion. Agents will require training in extension methods and philosophy and further knowledge of the agricultural sciences.

TABLE III FOODCROP YIELDS UNDER RESEARCH CONDITIONS AND THE NATIONAL AVERAGE (1969-1970 data)

Crop	Research Station I.S.A.R.	National Average
	(tons per hectare)	
Beans	2.6	0.9
Pea	1.5	0.8
Peanuts	3.4	0.8
Maize	5.4	0.8
Sorghum	5.0	1.2
Potatoes	25.0	6.5
Sweet Potatoes	15.0	8.0
Cassava	22.0	6.8
Bananas	27.5	12.0

Source: Ministry of Agriculture

5. CROPPING SCHEMES

The major cropping scheme in the traditional food crops is that of "mixed cropping" or "intercropping" where two or more crops are grown simultaneously. Technically speaking, in "mixed cropping" there is no systematic arrangement of rows. In "intercropping" the crops are grown in definite row patterns. Mixed cropping or intercropping, as it evolved in traditional agriculture, under a low level of technology and a long period of time, was practiced mainly to reduce risk and optimize production. The planting of two or more crops together introduces genetic diversity and reduces the spread of insect vectors and diseases and lowers the probability of a complete crop failure.

The intercropping concept has been abandoned in developed countries where harvesting is done mechanically. In Rwanda like other under-developed countries, intercropping does not pose a serious problem because crops are hand harvested.

Most of the foodcrops are intermixed in numerous combinations in addition to being sometimes grown in pure cultures. Beans (Phaseolus vulgaris) are frequently interplanted with maize, bananas, cassava and sometimes in three-way mixtures with maize and bananas. Sorghum and sweet potatoes are commonly interplanted with bananas and cassava.

Irish potatoes are often mixed with peanuts and bananas. Maize, peanuts and cassava are grown in various combinations with most foodcrops. Yams (Dioscorea alata) and colocase (taro-colocasia esculenta) exist mostly as interplanted crops that vary the diet of the population but are ususally not marketed. Research conducted by the I.S.A.R. stations in 1976 shows no convincing evidence that superior yields were obtained when crops were grown in pure cultures as compared to mixed cropping schemes.

One of the common rotational procedures is to plant beans in September at the beginning of the rainy season. These are harvested in December and followed with a sorghum crop. Sweet potatoes usually follow sorghum with plantings commencing in June immediately following the sorghum harvest. Normally, in the past, the land would then be allowed to remain fallow for a year or more. However, in recent years the increasing scarcity of cultivable land, has necessitated shorter fallow periods, and even elimination of fallowing. Some variations in the rotational systems may occur among farmers and the different altitude regions.

Among the commercial crops, coffee and tea are grown in pure cultures. Pyrethrum, which behaves as a perennial, is usually replanted every third year and is grown in pure culture. Cinchona trees, for quinine production, are usually interplanted with cassava while they are young, but often after a few years interplanting is discontinued, and the trees are maintained in pure culture.

6. FOODCROPS

A. Bananas, (musa spp.) grown on most low and medium altitude farms in Rwanda occupy 190,000 hectares of land and are used primarily for traditional beer brewing. It is estimated that approximately 90% of the production is made into beer and sold to bars and neighboring farmers. Thirty percent of total production is marketed or traded. It is also reported that there is a substantial clandestine export of bananas from the Cyangugu region to Burundi and Zaire. Gros Michel is a very popular and widely grown variety although other varieties are grown on a lesser scale. The cooking banana or plantain (Muca paradisiaca) is also grown in most areas.

Ministry of Agriculture data show that the national average yield of bananas (Table 4) was 12,625 kgs per hectare at lower elevations and slightly lower at medium altitudes, ranking second only to cassava in total yield per unit of land. Bananas give the highest return per man day of labor compared to other crops grown in Rwanda.

Although bananas rank high in total production per hectare among the traditional food crops, yields are considered low, and the nutritional value of banana beer is low. Since bananas are grown on such a large portion of the cultivated land and play such an important part in the economy, more attention should be given to increasing their productivity and nutritional value. This may be accomplished by the collection and testing of imported varieties and conducting a plant breeding program to develop more nutritious, high yielding disease resistant varieties.

B. Beans (Phaseolus vulgaris), the staple food of the Rwandese diet, are planted on approximately 191,000 hectares of land, slightly more than the area occupied by bananas. Approximately 23% of the crop in marketed or traded. Latest research data show that the national average yield is 875 kilograms per hectare. Test trials conducted at the I.S.A.R. produced yields of up to 2.6 tons per hectare, indicating the potential for substantially greater production when grown under improved practices. Research data also indicate no significant differences in bean yield when grown at low, medium and high altitudes.

The Louis Berger report states that yields of 900 kgs per hectare were produced in the Nyabarongo valley area which compares favorably to the national average. Although this report does not provide conclusive evidence of the proposed project area's bean producing capability, it does furnish some indication of the possible potential.

TABLE IV CROPS OF RWANDA - YIELD DATA FOR 1976 (Kilograms per Hectare)

Foodcrops	Low * Altitude	Medium ** Altitude	High*** Altitude
Beans	875	860	860
Peas	-	-	900
Colecase (Taro)	4,900	3,600	-
Yams (Dioscorea)	6,250	-	-
Cassava	17,500	14,300	-
Sweet Potatoes	7,875	7,900	6,500
Potatoes	4,760	5,830	8,500
Wheat	-	-	850
Maize	1,000	1,070	1,100
Rice	3,527	2,534	561
Sorghum	1,375	1,200	1,000
Peanuts	1,100	820	-
Soybeans	833	830	-
Bananas	12,625	11,250	-

* Region of Imbo, Gisaka, Mutara

** Region of Bugesera, Mayaga, Icyanya

*** Region of Bugoyi, Mulera

Source: Ministry of Agriculture

C. Cassava (Manihot utilissima) also called tapioca, yuca or manioc was introduced in Rwanda after the 1943 and 1945 famines. The crop has gained gradual acceptance during recent years and consumption has been on the increase. Cassava is adapted to low and medium altitudes, and government publications report national average yields to be 17,500 kilograms per hectare at low altitudes and 14,300 at medium altitudes. It ranks sixth among the foodcrops in total planted area with 32,000 hectares devoted to its culture. About 20% of the crop is either marketed or traded, and an unknown quantity moves secretly into Burundi and Zaire.

In vew of its growing importance as a staple food, cassava should receive more attention by research scientists. The crop is well adapted to the edaphic and climatic conditions of the country and possesses the capacity for producing large amounts of food calories in the form of carbohydrates per land unit. Besides, the culture of cassava is relatively easy, labor requirements and investment costs are low and it has the ability to grow in the sub-optimal soils of the area. Cassava competes well with weeds and possesses resistance to many deseases and insect pests.

Production data from the cassava producing countries of the world indicate that with minimal effort and poor conditions, yields may be as low as 7,500 kgs per hectare, while under better conditions, yields may increase to 50,000 kgs per hectare. This may rank cassava first in production capacity compared to potatoes, yams and taro, and it surpasses the yield of any cereal crop. As in the case of other crops, there are usually wide ranges of productivity among varieties, and responses to fertilization and other factors vary considerably. Cassava is quite drought resistant and seldom irrigated. Where irrigation has been used, yields were substantially increased.

D. Maize (Zea mays) is one of the major food crops grown in Rwanda. Ranking sixth in total area planted, 1975 Ministry of Agriculture data indicated maize was grown on 63,000 hectares. Grown frequently as a catch or cover crop, it is mostly consumed fresh on the farm, and only recently has it entered urban markets in sizeable quantities. About 20% of total production is marketed.

Yields have been traditionally low (averaging less than 1,100 kgs/ha), due mainly to the relatively infertile status of the soil, over-intensive cultivation, low yielding varieties, poor seed quality and the complete absence of fertilizer usage. There is a definite need for an intensified variety breeding program to provide well adapted, higher yielding, more nutritious varieties. Hybrids, which are frequently higher yielding, would not be recommended under present conditions because of the problem of multiplying and maintaining an adequate supply of first-generation seed which must be planted each year.

Because of the absence of a commercial seed industry in the private sector, and limited government facilities for producing, processing and distributing large volumes of hybrid seed, it would seem prudent, for the immediate future, to concentrate on the development of locally adapted synthetic and open-pollinated varieties. Seed of these varieties can be selected and replanted by the farmer for a number of years. This simplifies seed distribution because the annual demand for large volumes of genetically pure seed is greatly reduced.

Information taken from the Berger study of the Nyabarongo valley indicated maize yields of four tons per hectare in the study area, considerably higher than the national average yield of slightly under 1,100 kgs/ha.

E. Peanuts (Arachis hypogaea) are grown on 15,000 hectares of land. The average national yield per acre (1976 data) in the low altitude region was 1,100 kilograms (in the shell) per hectare and 820 kilograms at medium altitudes. The crop is not adapted to high altitude culture. Yields of up to 3.4 tons per hectare were obtained in experiments conducted by I.S.A.R. stations, indicating the potential for significant production increases under improved conditions. The Berger study reports yields of 1,500 kilograms per hectare in the Nyabarongo valley and states that peanuts should perform well on the lighter soils of the valley.

Peanuts are very nutritious, being high in protein and oil content. The nuts contain 40 to 48 percent oil and 25 to 30 percent protein. Vines have approximately seven percent protein and may be utilized as livestock feed. The crop cannot compete well with weeds and they must be controlled effectively or yields will be greatly reduced. Peanuts generally respond well to lime applications in calcium deficient soils but show less response to the other major elements.

Although yields have been low, this crop does have a potential for increased production if cultural practices are improved, higher yielding disease resistant varieties are introduced or developed and an ample supply of good quality seeds are made available.

F. Peas (Pisum sativum) are considered to be cool weather plants and are grown in the tropical countries at higher elevations. The average national yield is 900 kilograms per hectare, but research workers have obtained yields of 1.5 tons per hectare. Latest data available show 72,000 hectares devoted to this crop, ranking it fifth among the foodcrops in total cultivated area. Ministry of Agriculture sources report that 23% of the crop

is marketed or traded in one form or another, mostly by taking surplus production from high altitude regions into the urban areas.

Because of its cool climate requirement, this crop would not be suited for production in the proposed Nyabarongo valley project area, but is well adapted to the higher altitude regions of the Zaire-Nile Crest. Because of its importance in the staple diet of the population peas should be given increased emphasis in research programs.

G. Potatoes (Solanum tuberosum) grow well in the tropics when grown at medium and high altitudes. Average yields in Rwanda range from 4,760 kilograms per hectare at the low altitudes to 8,500 kilograms per hectare at the high elevations. I.S.A.R. experimental trials have produced excellent yields up to 25 tons per hectare. Although the average farmer may never attain similar yield levels, there remains considerable room for substantial gain in production if improved practices are applied.

The marketing system for potatoes is the oldest in the country, and about 36% of the estimated 54,000 tons produced is marketed or traded in some manner. In 1975, potatoes were grown on 23,000 hectares making the crop the eighth most important in terms of total planted area. The most important potato growing area in Rwanda is the Ruhengeri region which has an altitude above 1,900 meters.

Potatoes are more susceptible to disease in tropical areas, especially late blight which occurs at high humidity and temperatures below 60°F. Planting of resistant varieties is the most satisfactory control. Weekly sprayings of fungicides are fairly effective in the absence of frequent rainfall but is an expensive control measure. Although it may not presently merit top priority in research programs, potatoes should receive attention in future studies.

The Berger report on the Nyabarongo valley study indicated that yields of 8-9 tons per hectare are attainable in the proposed project area.

H. Rice (Orza sativa) is grown in the Nyabugogo valley a few kilometers north of Kigali (Kabuye) and at Gitarama. Information provided by the Ministry of Agriculture indicate that in 1977 an average yield of 2,644 kilograms per hectare was produced on 1,235 hectares. Total crop production amounted to 3,265,518 kilograms. Production data include the two crops grown during a one year period.

The Louis Berger study (5) reports rice yields of 2.5 tons per hectare (per harvest) could be produced in the Nyabarongo valley. Site observations support the statement that soils of the study area should be suitable for rice culture (discussed in water resources section) and should be considered among other crops for valley development projects. Because of its unique ability to germinate and grow successfully in water or submerged conditions, lands subject to occasional river overflows and temporary flooding, do not necessarily preclude the culture of rice.

Rice is one of the two most important cereals in the world, its total production comparing favorably with that of wheat. It's the principal foodcrop of nearly half of all the world's people. Rice is an annual grass, which tillers freely and grows to a height of from two to six feet. The color of unmilled rice varies with variety, but may be white, brown, amber, red or purple.

In general, rice is classified on the basis of length of grain, into short, medium or long grain types. The long-grain varieties have long, slender grains, vitreous in texture and usually commands the highest

price on the market. Short-grain varieties have short, blunt kernels with a starchy texture. Early maturing varieties require 120-130 days from seeding to maturity, whereas late varieties require about 140 days.

I. Sorghum (Sorghum vulgare) is planted on 133,000 hectares and ranks third in terms of total land devoted to its culture. Sorghum, which requires warm weather for optimum growth, is grown at all altitudes of Rwanda, but low-altitude plantings out-yield those of the higher elevations. Average yields range from 1,375 kilograms per hectare in low altitudes to 1,000 kilograms in high altitudes. However, experiment station plantings have produced yields of five tons per hectare using improved practices. Ministry of Agriculture data show that of the 47,600 tons of sorghum produced in 1975, about 33% was either marketed or traded. A substantial amount of the sorghum production is utilized for brewing beer.

Sorghums are short-day plants that can out-produce maize under dry, hot conditions because they remain dormant during drought but resume growth when favorable conditions reappear. The plants have a high resistance to dessication, a low transpiration ratio, a large number of fibrous roots, and the ability to produce a crop from the tillers and branches that develop after rains occur. The principal varieties require about 100-120 days to mature, although some early ones may be ripe 80 days after planting.

Yields of sorghum may fluctuate greatly from year to year, chiefly because of differences in rainfall. It grows well on nearly all types of soil that range from 5.5-8.5 pH and usually responds to the application of lime. In moist seasons, highest yields are obtained on heavy soils; in dry seasons, the crop does best on sandy soils.

The Louis Berger study (5) on the Nyabarongo valley reports that

yields of 1.5 tons per hectare were produced in the proposed project area. Sorghum should be adapted to the ecological conditions of the valley and included as one of the potential cultures.

J. Soybeans (Glycine max) are not of major importance in Rwanda but have attracted attention in recent years and may have a limited potential for selected areas. No data were available pertaining to the total planted area, but Ministry of Agriculture sources indicate average yields are approximately 830 kilograms per hectare for crops grown at low and medium altitudes.

Soybeans may be utilized for many purposes. Oil extracted from the seeds is used to make margarine, shortening, salad oil, paints, soap and for other industrial purposes. Soybean meal, a by-product of the oil extraction process, is a leading protein supplement for livestock feed. The beans can be eaten by humans in both the green or dry stages and grown for hay, silage and soil improvement purposes.

One of the difficulties associated with growing soybeans in the tropical zones has been the failure of pods to fill properly even when vegetative growth was satisfactory. Many varieties have unusual sensitivity to the day-night cycle, and most have critical day length periods at which blooming and seed development commences. In its flowering response, it is a classic example of a short-day plant, but varieties differ in the numerical length of their effective short days. When the soybean is planted in areas having a longer day length than its adapted zone, maturation is greatly prolonged. Under shorter day lengths, yields are generally reduced.

The Berger report on the Nyabarongo valley states that yields of

1,200 - 1,500 kilograms per hectare were produced within the study area, thus providing another possible option for future projects. Yields of three tons per hectare were obtained at the I.S.A.R. station at Rubona.

K. Sweet potatoes (Ipomoea batatas) ranked second among the foodcrops in total tonnage produced and fourth in total area planted, according to 1975 data released by the Ministry of Agriculture. The average yield in the low altitudes was 7,875 kilograms per hectare, compared to 7,900 at medium altitudes and 6,500 at high altitudes. There remains considerable scope for improvement since research trials have yielded up to 15 tons per hectare and may be attainable with improved practices. About 33% of the crop produced in Rwanda is reportedly marketed or traded.

Sweet potatoes, important in most tropical and sub-tropical countries, are grown from rooted adventitious shoots or sprouts (slips) produced at the proximal end of seed roots of the previous crop and from vine cuttings. Sweet potatoes can be grown in Rwanda during most seasons but are frequently planted in the low lands or river bottoms during the dry season where adequate moisture is available. The plant requires a warm season and will tolerate considerable drought. Sweet potatoes outrank most other carbohydrate foods as a source of nutritive elements such as carbohydrates, vitamins, and minerals, being particularly high in Vitamin A. They are used mainly as a human food but can be used to some extent for livestock feed.

Yields of eight tons per hectare were reported in the Berger report on the Nyabarongo valley, and sweet potatoes certainly should be included along with other crops possessing some potential for future projects.

L. Sugar cane (saccharum officinarum) provides over half of the world's total sugar production with the remainder provided by sugar beets. Sugar,

a commodity of great importance in world trade, is an essential food for people of all nations. Most of the present day leading varieties are complex hybrids synthesized by bringing together a diversity of genotypes from both cultivated and wild forms. Since the sugar cane plant is propagated vegetatively, once an improved hybrid seedling has been selected, it is a relatively simple task to increase it for commercial production. All varieties (clones) are homogeneous and will remain genetically pure when grown in close proximity, provided simple precautions are taken to prevent mechanical mixture. Sugar cane thrives best where annual rainfall is 115 or more centimeters.

Data provided by the Ministry of Agriculture show that 30,076 tons of sugar cane were produced in 1977 on 334 hectares for an average yield of 90 tons of cane per hectare and a total production of 2,229 tons of sugar. Commercial sugar cane production in the country is restricted to a land area consisting of 655 hectares located in the Nyabugogo valley a few kilometers north of Kigali and processed by one sugarmill in the area. The crop is harvested during the dry season, usually extending from June to September. Once a sugar cane crop is planted, it occupies the land for approximately four years and produces three crops. The first crop, following the actual planting of the cane stalks, is harvested in about 18 months. Two additional ratoon crops are usually harvested from the original planting.

All of the sugar produced is used for domestic consumption, but the supply is inadequate to satisfy Rwanda's total sugar requirements.

The Berger report (5) on the Nyabarongo valley mentions that cane yields of 60 tons per hectare were produced within the study area and projected 80 ton yields for the 1976 crop. However, actual production data

for the 1976 and 1977 crops were not available. Preliminary observations of the Nyabarongo valley support the contention that drainage and reclamation of the valley soils could make possible the production of sugar cane thus providing another land-use alternative for utilization of the proposed project area.

7. COMMERCIAL CROPS : (EXPORT)

A. Coffee (Coffea arabica) is indigenous to Africa but is also grown in other tropical areas where it grows under a fairly wide range of climatic conditions. Coffee thrives best in deep, well-drained soils of medium texture such as the volcanic loams of Rwanda. Of the many species of Coffea, only three have been found useful for coffee production, Coffea arabica, C. robusta and C. liberica. Of the three species, Coffea arabica is the most important. Most of the coffee grown in Rwanda is of the arabica type.

Coffee is by far Rwanda's most important export crop, accounting for over 50% of all exports. Ministry of Agriculture data, for 1975, show coffee occupying 28,800 hectares. Production for the same year was 24,385 tons. (Table 5). Rwanda's coffee production fluctuates considerably from year to year and is attributed mostly to the sensitivity of the plant to climatic variations and to poor maintenance. Of the estimated 48 million coffee trees in production, in 1975, approximately 50% were cultivated by some 425,000 farmers.

B. Tea (Thea sinensis) ranks second behind coffee in order of importance as a commercial export crop. Production of tea has grown rapidly in Rwanda, expanding from 830 tons in 1968 to 3,432 tons in 1975. This increase was attributed mostly to an expansion of the planted area achieved through the

TABLE V

PRINCIPAL COMMERCIAL EXPORT CROPS-1975*
(Area planted in 1000 hectares)

Coffee	28.8
Tea	3.5
Pyrethrum	3.9
Cinchona	0.4

PRODUCTION IN TONS

Coffee	24,385
Tea	3,995
Pyrethrum (dried flowers)	1,753
Cinchona (bark)	333

Source: Ministry of Agriculture

* Published in 1975 but not necessarily actual data for the year shown.

planting of recently drained marshes. Total planted area increased from 1950 hectares in 1968 to 5,500 in 1975. The Government's objective is to increase the area devoted to tea to about 10,000 hectares by 1980 principally through additional drainage and planting of marshlands located at higher elevations.

Tea, which is propagated by seeds, cuttings and buddings, is usually planted at elevations of 1,000 meters or higher in tropical areas. It thrives best in a deep, friable well drained soil with a pH range of 5 to 6.

C. Pyrethrum (Chrysanthemum cinerariaefolium) is cultivated on the volcanic soils of northern Rwanda at altitudes of 2,000 to 2,700 meters. Plantings of pyrethrum increased from 1,100 hectares in 1967 to 4,210 hectares by 1975. During the same period, the production of dried flowers expanded from 520 to 1,753 tons with most of the increase coming from the paysannats.

A pyrethrine extraction plant was constructed at Ruhengeri in 1972 which has a plant capacity for 3,000 tons of dried flowers or 150 - 180 tons of extract with 25% pyrethrine content. Installation of the plant has considerably improved Rwanda's position in the world market because of the volatile flower market. Pyrethrum is the source of pyrethrine, an important component for the production of natural insecticides.

D. Cinchona (Cinchona spp.) ranks fourth in order of importance as a commercial export crop. Total area planted increased from 300 hectares in 1967 to 400 by 1975. The World Bank report indicates there are presently 868 hectares planted to cinchona. Of this total, 600 hectares of plantations are maintained by expatriate companies, 68 by state-owned plantations and 200 by small growers.

Ministry of Agriculture sources show an increase in production of

bark from 89 tons in 1967 to a total of 333 tons in 1975.

Cinchona trees are grown for the alkaloids, mostly quinine sulfate, which can be extracted from its dried bark and exported mainly to pharmaceutical companies in Europe.

8. PRODUCTION CONSTRAINTS :

A number of factors presenting the most formidable and pervasive constraints to the development of a viable and productive agriculture are identified and outlined. However, it is recognized that social, traditional and economic factors may present major impediments to the resolution of these problems.

A. Lack of appropriate technology and its application. Very few of the farmers use quality seeds, soil improvement and conservation measures. Improved cultural techniques including optimum planting dates, plant population densities and spacing distances are unknown. Many of the varieties in use are low yielding and plant protection techniques are not employed.

B. Acceleration of soil depletion and the low nutrient reserve status of many soils. Intensive cultivation, depletion of organic matter, shortening of the fallow period, absence of soil building practices, inadequacy of erosion control and cultivation on steep slopes have all contributed to soil depletion on many soils and will lead to further exhaution of the soil if these conditions remain unrectified. Excluding the soils of volcanic origin and the limited amount of alluvial soils, most other soils possess a low reserve of plant nutrients.

C. Lack of effective educational delivery system.

The present extension service has not been effective in diffusing

technological knowledge to growers. Once a base of innovative technology has been developed, the information must be properly disseminated to farmers who ultimately need to adopt these improved practices. Personal contacts and a close relationship between agents and producers are necessary to motivate the acceptance and adoption of the recommended agricultural technology. The extension organization needs to be strengthened with additional agents trained in extension methods, philosophy and the agricultural sciences. Greater logistical support will also be necessary and strong links between research and extension must be established.

D. Lack of infrastructure. The transportation and communication systems (roads, bridges, vehicles, etc.) are poor or non-existant in many areas. The farmer's access to production inputs and his ability to market his products are major deterrents to agricultural development.

E. Inadequate supplies of Quality Seed. Another pervasive constraint to agricultural development is the inadequate supply of genetically pure, high quality seed. There is no existing seed industry in the private sector, so the function of seed multiplication and distribution is a government responsibility. However, the scope and efficiency of this operation is limited and unable to adequately provide for the needs of Rwandan farmers.

F. Inadequate storage. Storage facilities for foodcrops are grossly inadequate and losses are estimated to be as high as 35% in some parts of the country due to moisture and insect damage. AID is attempting to alleviate the severity of this problem through financing of a CRS-administered local level storage project and, in the future, by supporting cooperative and communal level storage facilities.

9. AGRONOMIC RESEARCH RECOMMENDATIONS

It may be well to remember that important restraints on the transfer of farm technology from one part of the world to another are imposed by major differences in climate, soils, social and economic factors. Although the basic principles of pure and applied science may be universally valid, their application varies with specific environmental conditions. This complicates the role of research, because preconceptions and assumptions are frequently invalid. Adaptive research has to be geared to local conditions and technology developed for specific locales. Research programs designed to cope with the broad spectrum of plant breeding, soil management, and plant protection are massive undertakings that must be well supported by financial and personnel resources. Most of the research, adaptive to the specific needs of this country, should be conducted within the limits of its ecological zones.

For the immediate future, attention should focus on a comprehensive variety testing program including introductions from other countries of similar latitudes. The breeding program at the I.S.A.R. stations should be gradually expanded to include more crops. The cowpea (Vigna sinensis) should be tested for adaptability. Cowpeas are a short-day, warm weather crop adapted to a wide range of soils. It grows well on sandy as well as clay soils, and with some attention, has the ability to perform satisfactorily on infertile or acid soils. Other pulses, including many varieties of the common bean (Phaseolos vulgaris), the mung bean (P. Mungo) and lima beans (P. lunatus) should also be tested for adaptability.

The feasibility of using green manure crops on small farms should be investigated to determine their effects on soil productivity when interjected into the rotation cycle. There is very little evidence of previous work conducted with this practice in Rwanda. The efficiency of green manuring varies

considerably from region to region and depends to a great extent on the crop grown, soil and climatic factors. If proven feasible from a practical and economical standpoint, green manuring could significantly extend the duration of the rotational cycle and contribute to a more stable and productive type of agriculture.

Improvements in cultural techniques merit research priority, and efforts to determine optimum planting dates, row spacings, plant population densities, weed control and plant protection methods should be undertaken for all crops of significant importance.

The use of liming materials should be included in research efforts to determine response to higher levels of calcium and magnesium and their effects on the availability of phosphorous, both applied and native. The application of lime as a source of plant nutrients and for the attainment of optimal pH levels for specific crop requirements, offers promising possibilities for significant increases in crop production.

Despite negative attitudes on the part of many, a logical move for intensifying agricultural production would be to expand the use of commercial fertilizers and manure for all crops. Limited research conducted by I.S.A.R. indicates that soils of Rwanda respond to the use of chemical fertilizers, however, an intensive research program is needed to determine the economic feasibility, response and optimum rate of application of nitrogen, phosphorous and potassium for all major crops. Extensive soil testing will be required, and careful attention must be given to correlating soil analyses with actual field experiments, since plant response data will be the key to establishing optimum levels of input.

Economic, social and traditional factors will undoubtedly present major

impediments to the early acceptance and adoption of new recommended practices; nevertheless, a shift to innovative technology is imperative, if meaningful strides in agricultural development and productivity are to be attained.

10. PROJECT POSSIBLITIES

The agronomic research recommendations outline a number of areas providing project possibilities which could fit into the Government's policy of promoting rural communal development. Both the Nyabarongo valley and the Zaire-Nile Crest areas offer a potential for instituting viable projects.

Drainage and reclamation of the soils of the Nyabarongo valley would provide an opportunity for the resettlement of a substantial number of people and bring about 7,700 additional hectares of land into production. A soil capability classification will be required to determine the valley's potential and limitations for specific crops. (Crop possibilities for the Nyabarongo valley are discussed in the foodcrops section of this report). It is likely that many crops can be grown successfully in the proposed project without the installation of an irrigation system. Should this be the case, total cost for development of the valley would be significantly reduced.

Projects should be designed with the objective of retaining and improving soil fertility so as to arrest the present decline in yields and provide a sound basis for future yield increases. Such projects should include the use of green manure crops, erosion control practices, liming and chemical fertilizers.

A plant breeding program for the development of improved varieties of one or several of the major crops could make major contributions to increases in production.

A project to provide facilities for seed multiplication, processing,

storage and distribution could insure a supply of genetically pure, high quality seed and would establish a sound basis for appreciable yield increases

In determining priorities for agricultural development, decision makers will need the help of research to predict the consequences of alternative courses of action whether at the enterprise, community, regional or national level. Any program designed for selected target communities within either or both of the proposed project areas should include the collection of primary data on farming systems which is lacking. Such data would lay the basis for and facilitate research on soil and water management, optimum crop sequences and introduction of new or improved crops or cropping practices, which must be acceptable to the farmer before they can be integrated within existing farming patterns or be substituted for traditional systems.

Ideally, any development project to bolster agricultural production should follow an orderly sequence. First, it should emphasize the adoption of practices which would reverse the present trend of accelerating soil depletion and declining yields. Various techniques of soil conservation such as increased use of contour tillage, lister furrows, strip cropping, and, possibly, terracing should be given first priority. Second, soil building practices including the judicious use of green manure crops, animal manure, reforestation and other forms of vegetative cover should be an integral part of the program. Third, refinement of cultural practices that extend local varieties beyond their present capacity to respond in yield and quality-followed by plant breeding and adaptability trials for developing and selecting varieties for quality and yield. Fourth, methods must be developed to control pests and diseases, which attack and seriously damage crops. Lastly, in a production development project would come the implementation of post-harvest crop protection measures.

Project suggestions, among the cereal food crops, would include maize, sorghum and rice. Also, since little sustained work has been undertaken in Africa to improve the millets, these could be included among project possibilities. The grain legumes - cowpeas, peanuts and soybeans offer good project possibilities because of their potential role in improving the diets of the local population; the roots and tubers - cassava, potatoes and sweet potatoes - all important items in the Rwandese diet, possess immense scope for improvement.

XIII. ANTHROPOLOGIST'S ASSESSMENT OF PROJECTS

1. Rwanda's Needs and Priorities

Any assessment of the value of a particular project must naturally be made not only on the basis of its feasibility or inherent qualities, but in relation to the country's needs and their relative urgency.

The already extremely high rural population densities coupled with an estimated 3% annual growth rate constitute a terrible pressure on the land. This pressure has led to almost complete occupation of arable land (and much land that would not be considered arable elsewhere) and consequent deterioration of soils, through over-intensive use with the shortening or abandonment of fallow periods, and erosion on exposed steep slopes. It has led to widespread deforestation, not only because of the hunger for land, but because of a need for firewood, the only source of fuel for the rural population.

The topography of most of the country makes for very difficult communications, and the absence of adequate roads and bridges hinders both commercial exchanges and administrative contact with much of the population.

Commercial and industrial development of the country is severely constrained further by lack of adequate food storage facilities, insufficient mineral resources to serve as an industrial base, and the lack of financial resources to carry

out needed physical improvements or programs or to provide capital for commercial or industrial ventures.

No less serious is the lack of sufficient adequately qualified personnel to staff the Government services at all levels.

Of all these problems, obviously the most serious is that of overpopulation. Unfortunately, however, it is the one that appears to have no short-term solution. No birth control program could have any important impact before another generation had passed, the prospects for major industrial development that might absorb a significant proportion of the excess rural population are dim to say the least, and by all accounts the capacity and willingness of neighboring countries to accept large numbers of immigrants is not great, even assuming the willingness of Rwandans to leave.

It seems inevitable that Rwanda will have to live with increasing overpopulation for many years to come, and it is absolutely crucial that the arable soil which is the primary support for all its population be protected. If adequate measures are not taken in time, many of these soils will be eroded and degraded beyond recovery with disastrous results for the country as a whole.

2. <u>The Nyabarongo Valley Project</u>

In one of the two regions of the country that the team was

asked to reconnoitre the physical features of a project had already been outlined, namely the control of the lower reaches of the Nyabarongo river to allow drainage and possible irrigation of the extensive marshlands found there.

It has been estimated that it would be possible to reclaim, over a period of ten years, some 7,700 hectares of land through the measures proposed. Actually the amount would probably be somewhat less since on the one hand the figure does not take into account the land that would be lost by raising the level of water in the Akanyaru valley and upstream of the dam on the Nyabarongo just below the confluence of the two rivers, and on the other the fact that some of this land has already been drained and cultivated by farmers in the area. Nevertheless the present volume of water in the Nyabarongo and the uncertainty as to the time and height of its peaks make it impossible for much of this land to be reclaimed by the means available to them.

In spite of the attractiveness of being able to gain a sizeable amount of arable land, however, the project potentially has a number of important drawbacks.

In the first place, it would certainly cause a significant alteration of the environment, as pointed out in the hydrologist's report, the extent and nature of which is not known. Certainly, however, the adjacent hill slopes would be affected by the draining of the marshes, with which they are in contact by

capillary action. Furthermore, in the project region the papyrus swamps act as a filter for the waters of the Nyabarongo, which constitute the only source of water for most of the population. It would be foolhardy to proceed with a drastic alteration of the environment without first having assured the protection of existing resources in the area.

Secondly, the high cost of the project, even if extensive irrigation were not involved, would not only be uneconomical in relation to farmers' income and any possible future returns, it could also have the unfortunate effect, in the third place, of encouraging the production of commercial crops to help recover some of the expense. This could lead to the exploitation of individual farmers through forced cultivation of particular crops at arbitrarily low prices, as seems to have happened in the cases of cotton and tea production elsewhere in the country. There is also ample reason, fourthly, to assume that any capital intensive project would be a prime source of graft.

In the fifth place, it should be noted that the 7,000 odd hectares of land that the project could recover would add very little to the more than 800,000 hectares now under cultivation and that only gradually over a ten year period.

In short, for technical, economic, social, and national priority reasons the project seems ill-advised at this time.

3. Alternative Treatment of the Nyabarongo

If the above project is currently unadvisable, other activities in the Nyabarongo valley are possible and more in line with national priorities.

An immediate need is for reforestation of the summits of the surrounding hills throughout the entire basin. If properly done with an appropriate mixture of trees, it would provide a number of important benefits - it would help to stop erosion at its most dangerous point, it would act as a reservoir of water serving the lower slopes, it would provide an urgently needed source of wood for fuel, construction, and furniture, and it would tend to level out the flood peaks of the river and reduce its sediment load.

This program of reforestation should be carried out in conjunction with an agro-pastoral extension project such as that being run by Cooperation Technique Allemande at Nyabisindu. This aims at the control of erosion by the establishment of living barriers of leguminous grasses and trees and both the maintenance and improvement of soil fertility through appropriate rotations of crops under permanent soil cover with the addition of manure obtained from stabled animals.

While these measures are being carried out, an ecological study of the river basin should be made and changes in the regime

of the river, involving not only rates of flow, but sediment load, quality, and changes in course should be continuously monitored.

Once the physical condition of the basin has been more or less stabilized as a result of the program recommended above and the suggested studies have been made, it would be appropriate to re-examine the desirability of controlling the river in some such manner as suggested in the hydrologist's report.

All of this is easier said than done, of course. In some places the summits are occupied and cultivated. Generally speaking, land on hills is private land(except where abandoned) as opposed to communal. Wealthy farmers and absentee owners of lands could be expected to resist such measures, which would further reduce grazing lands. The difficulties of reaching, convincing, and controlling the many thousands of farmers involved would be enormous.

However, there are circumstances that would facilitate such a program. In the first place, judging by the response to the Swiss reforestation program, that of C.T.A. at Nyabisindu, and the national reforestation program organized through umuganda, the great majority of the farmers are well aware of the need for trees and have relatively little need for pasture. They are beginning to accept the need to keep their animals in stables in spite of the break with tradition that this involves and the extra work entailed in growing fodder and caring for the animals.

Even assuming good will and a recognition of self interest on the part of the majority of the farmers, however, much will depend on the understanding, competence, and energy of local officials in the communes, sectors and hills, and here there is wide variation.

4. Zaire-Nile Watershed Region

This region, the second which the team was asked to investigate, is of critical importance. The continued destruction of forests here in extremely rugged terrain threatens the climate, the loss of their regulative effect on the waters of the rivers that spring from the watershed, and the increasing transport of sterile sediments from eroding slopes. It contains, furthermore, in the Nyungwe, one of the last remaining high altitude natural forests in Africa. Not only is the study of its flora and fauna of great scientific and potentially practical value, it is also the habitat of the pygmoid Twa people.

The region as a whole is densely populated, and the need for cultivable land for foodcrops, pasture for animals, and firewood, together with governmental pressure to grow commercial crops such as tea in an area of steep slopes and heavy rainfall make the need for erosion control and reforestation particularly urgent. It is unlikely that reforestation will be feasible, however, unless it is linked to a program that through modification of cultivation practices and control of land use will succeed first in arresting the erosion and decline in fertility of soils and then in increasing yields so as to alleviate in some measure

the increasing population pressure.

Unfortunately, there are a number of factors present in the region, some of which, of course, are general to the country as a whole, which will inhibit the achievement of these goals. A major difficulty, affecting the ability of extension programs to reach farmers, the communication of ideas, and the distribution of goods, is the lack of adequate roads and bridges. The free exchange of foodcrops is further restricted by inadequate storage facilities and by the existence of strong local food quality preferences. The presence of absentee-owned herds of cattle makes it difficult to control overgrazing and the destruction of forests. As elsewhere in the country, weak governmental infrastructure and the increasing alienation of youth from agricultural pursuits are additional serious impediments.

On the other hand, the excellent potential for small-scale hydro-electric plants, favorable rainfall and the presence of numerous water sources, the existence of rich soils in volcanic zones and alluvial deposits, an experienced agricultural population, the presence of cooperative organizations, and in some areas a spirit of inter-family cooperation beyond the national norm, are all positive factors. The existence of as yet undetermined quantities of mineral resources, such as tin, wolfram and gold, are potentially favorable, but uncontrolled

exploitation could lead to serious destructive effects on the environment.

Among possible projects in the watershed region high priority should be given to the preservation of the Nyungwe natural forest, the necessity for which could be justified on its scientific value alone, apart from its hydrological value and function as habitat for the Twa people. The forest has not yet been turned into a national park, as urgently recommended by Budowski (16) in 1976, and the Swiss forestry program is not on a scale capable of preserving more than a small part of it. Any project directed toward this end should, of course, involve close cooperation with related programs of other donors. The Swiss efforts include experimental reforestation on the fringes of the forest, forestry training, and an agro-pastoral program in Kibuye. The C.T.A. Nyabisindu project also has a tree planting program covering the prefectures of Butare, Gikongoro, and Gitarama, while FAO is directing a program in Butare and Gikongoro involving reforestation and pastures.

Successful protection of the forest would, of course, require modification of present land use patterns surrounding it to achieve a balanced exploitation of renewable resources along the lines suggested above in connection with the Nyabarongo valley. An intensive extension program would be essential. Needless to say, a project along these lines would be appropriate and urgent

throughout the watershed region.

As indicated above, a program providing for the improvement or construction of roads and bridges that would provide access to the more remote already inhabited areas would facilitate the operation of any extension program and provide economic incentives to the population.

The development of small-scale hydro-electric power sources could be particularly helpful in supplying regional marketing centers by increasing the services they could offer the surrounding populations. The provision of electricity for individual homesteads would seem less urgent.

5. General Comments

The foregoing analysis of Rwanda's needs and priorities and its conclusion that the most urgent problem is the preservation of the agricultural resources of the country, suggest the need for a series of projects all directed toward that end. One should not see the Nyabarongo valley project as an alternative to any that might be developed in the watershed region. Indeed the two are linked by the river itself. What is done in the watershed will affect the river, and nothing should be done to the lower reaches of the river without treating its sources.

With 95% of the population engaged in agriculture, the mandate is obvious to deal with the mass of the population and to avoid large-scale commercial developments which would benefit

the few and leave unchecked the progressive destruction of most of the arable land.

This will require the development and staffing of extension programs that will reach effectively not only the farmers themselves, but the local communal and sector officials charged by the national government with the responsibility for development. Frequently the most effective way to reach many farmers will be through communally organized agricultural projects using the free labor provided by the system of umuganda. The success of such ventures will depend inevitably on the attitudes, energies and abilities of the local officials.

The acceptance by the population of different cultivation and conservation techniques is unlikely, furthermore, unless they build on an intimate understanding of traditional techniques and their advantages as well as disadvantages. Colonial rule has on the one hand introduced procedures which were adopted only under pressure and have since been abandoned on emotional grounds by many, and on the other, through a school system too faithfully based on European education, introduced theoretical ideas about agriculture among the educated which are inappropriate to conditions here. A further obstacle to acceptance of new ideas lies in the fact that the vast majority of farmers have no reserve of resources with which to experiment. They must be certain that any new procedures they try will work and be worthwhile, and it

is in the nature of the problems faced and the kinds of solutions that are appropriate that the benefits will not soon be obvious.

It follows that any extension program must be flexible and attuned to the differing needs and personalities of particular populations, and its participants must be imbued with the idea that they are looking for the best solutions to a whole series of related problems rather than attempting to enforce the acceptance of a rigid preconceived program.

It should also be kept in mind that it is women who do most of the agricultural work and consider themselves the experts, so it would be wise to make an effort to include female extension agents in the program, if they can be found. It might also be worthwhile engaging youth groups where possible in cultivation or animal husbandry projects, given their present under-employment in these areas.

The ultimate effectiveness of such extension work will depend, however, not only on explaining rational techniques to rational people, but in coping with the myriad social problems that may stand in the way of their being carried out. This calls for social anthropological analysis of the people in the project area, not only to understand present motivations and constraints, but to be able to follow changes as they take place. Only in this way will any extension program be able to achieve the degree of adaptability necessary to make it truly effective.

It is recommended that an expatriate social anthropologist and a Rwandan counterpart with similar training be engaged for the first two years of the project. This should provide sufficient knowledge of the population concerned to serve as a basis for its proper sociological orientation and to cope with initial problems. After that briefer field trips could update and supplement the original findings at periodic intervals. It goes without saying, that the expatriate anthropologist would have to be fluent in French, and it would be highly desirable if he or she had made at least an initial study of Kinyrwanda before arriving. Every effort should be made to acquire reasonable fluency in it while in the field.

XIV. RECOMMENDATIONS FOR STUDIES AND PROJECTS

Because of the close relationship or linkage between proposed studies and projects for the Zaire-Nile crest region and the Nyabarongo valley basin, no attempt is made to limit them geographically for obvious reasons.

1. Watershed Protection

By far the most important long-term need of Rwanda is the adequate protection of its watersheds from the extensive wide-spread erosion that is presently causing a gradually accelerating general degradation of the soils as the protective forests and other vegetative cover is removed. If allowed to continue unchecked, agricultural production will decline to the point where the soils will become unproductive or will be unable to produce the amount of food required to feed a rapidly expanding population. Population pressures are already causing serious problems in some regions.

Even the introduction and general acceptance by the rural population of a coordinated agricultural development program embodying the latest improved cultural techniques, high-yielding adapted varieties, soil-building legumes, green manure crops, stable manure, chemical fertilizers and disease and pest control, will be able only to provide temporary relief if soil erosion is not effectively controlled.

The problem is particularly acute in the Nile-Crest region and the upper basin of the Nyabarongo river, although erosion does occur throughout the valley. This region represents approximately half the area of Rwanda and contains most of its best soils and favorable rainfall distribution.

It is strongly recommended that AID explore with the Government of Rwanda and the various other international aid organizations, in particular those already engaged in various aspects of reforestation and soil conservation, ways and means through which it could make a positive contribution toward the development of an effective and coordinated national program of reforestation and soil conservation, beginning with the areas determined to be the most seriously affected.

An immediate need is for reforestation of the summits of the surrounding hills throughout the entire basin. If properly done with an appropriate mixture of trees, it would provide a number of important benefits: it would help to stop erosion at its most dangerous point, it would act as a reservoir of water serving the lower slopes, it would provide an urgently needed source of wood for fuel, construction and furniture, and it would tend to level out the flood peaks of the river and reduce its sediment load.

A close look should be taken at the soil conservation

and soil building practices presently being introduced with considerable apparent success by the German agro-pastoral project at Nyabisindu, to determine to what extent they might be appropriate in other regions having different soils, rainfall and altitude.

2. Ecological and Environmental Impact Study

Prior to the initiation of a development project in the lower Nyabarongo valley an ecological and environmental impact study should be undertaken in view of its possible impact on the project and the quality of life throughout the basin.

Related to the overall soil conservation program should be an examination of the serious problem of pollution in the Nyabarongo caused by the uncontrolled dumping of water carrying a heavy sediment load resulting from the washing of tin ores at various mines in the valley. Perhaps settling ponds or diversion of the silt-laden water into swampy areas to build the soils might be an acceptable solution. The deposition of heavy sediment loads in downstream reservoirs and flood control structures will shorten substantially their useful life. Thus, reduction of the sediment load carried by the Nyabarongo is both highly desirable and necessary.

Should water storage reservoirs and flood control structures be constructed in the proposed project area, they, combined with the drainage of swamps for reclamation of lands for

agriculture, will have a major effect on the ecology of the affected areas. Also, drainage of the papyrus swamps will destroy or displace much of the plant and animal life and affect the water supply of the surrounding population. The swamps are the habitat of a rich variety of bird and animal life, some of which might be endangered as a result of the proposed project.

It is estimated that a minimum team of three specialists: an ecologist, a biologist, and a trained environmentalist, would require 5-6 months for basic data collection and analysis. The cost of the study would be approximately US$ 115,000.

3. Lower Nyabarongo River Valley Area

On the basis of investigations previously carried out, and the conclusions reached during the present survey, reclamation and development of the proposed project area below the confluence of the Nyabarongo and the Akanyaru rivers, is entirely feasible. However, while sufficient physical information is available to evaluate the possible alternatives, it is not sufficient to determine the optimum plan or combination of plans.

Before any large investments are made in project planning, the optimum combination needs to be identified in feasibility

studies for which more physical facts will be needed. Two major pre-feasibility studies are recommended.

A. A Study of River Stability and Morphology

This study is needed to assemble and analyze sediment load and transport capacity information. Foremost among the unanswered questions is that concerning morphological changes that may be expected in the river due to alteration in its natural regime. Both the Nyabarongo and the Akanyaru will be changed substantially. The Nyabarongo through the project area will have a reduced discharge much of the year and will no longer carry the former flood peaks. Sediment load and sediment carrying capacity will both be changed. Its erosive capacity will be altered substantially during much of the year. Whether or not its new character will lead to accelerated downcutting o. the channel bottom, erosion of banks, or rapid changes in meander patterns remain to be analyzed. There is a strong possibility that one or all of the effects may be experienced. If so, appropriate counter-measures would have to be devised.

It is recommended that a qualified consultant be engaged to design a one-year plan of study specifying necessary field data collection and analytical methods to be used to forecast river changes. Data collection for the study could be undertaken by the Rwandan Genie Rural Service of the Ministry of Agriculture. The expert consultant would be responsible for

interpreting the data and analyses at the end of the study.

Estimated consultant cost US$ 33,000

Since it may be necessary to provide special instruments and equipment to the Genie Rural to enable the collection of complete and accurate data, it is suggested that US$ 7,000 be budgeted for this purpose.

Total study cost US$ 40,000

B. Soil Capability Classification(including irrigability)

Some of the alternative proposals for the development of the Nyabarongo valley project area involve extensive irrigation and drainage. Technical constraints are substantial in establishing a new irrigation project in an area not previously irrigated. Expanding an existing, successfully irrigated perimeter is usually a straightforward transfer of proven practices. On the other hand, opening up a new project challenges the most thoughtful applications of modern irrigation science and engineering. Water, the universal solvent, is to be combined with soil, an aggregation of complex chemically active constituents. What happens cannot be left to chance: success or disaster hinges on the reaction. Progress in soil science makes it possible to predict chemical and physical reactions. Long-term compatibility of water with soil can be established before an irrigation decision is made. However, this alone is not sufficient to insure success. Ground water must be under control otherwise the root zone may be too wet

for cropping. In some situations soluble salts accumulate in the soil, a residue from evapotranspiration. If natural drainage is not edequate artificial measures can be taken.

Drainage engineering is capable of assessing the capacity for drainage of project lands before the irrigation project decision is made. What is necessary are field and laboratory measurements of appropriate parameters of soil and geology. The technologies described above constitute the tools for classifying land for irrigation and crop suitability. They enable a projection to be made of soil-water interaction over a long term. Clearly no irrigation project should be initiated without assurance that it can have an unlimited useful life.

This is not to say that the project decision rests solely on the physical irrigability of the land. Other questions such as economic costs and returns, national objectives for regional development, population redistribution, quality of life for rural poor, and the like, will be added. But without a competent classification of the land, a sound basis for a decision is missing. Therefore, it is strongly recommended that a team experienced in irrigability classification be employed to survey the proposed project lands and classify them as to suitability for irrigation and, moreover, for specific crops such as foodcrops, rice and sugarcane.

An estimated cost for this work is very difficult and

uncertain. It is estimated that about 8 months time will be required. The cost is calculated to be approx. US$ 382,500

A detailed breakdown of the study team is contained in section XI, 9, B of this report. Except for the three foreign experts, heavy reliance will be placed on the use of Rwandan middle and lower-level technical personnel and laborers.

C. General Comments

The present survey team is of the opinion that no justification exists for the development of a series of costly, elaborate irrigation perimeters, with their associated drainage systems. Apart from development cost considerations it is reasonable to expect that a variety of crops, except possibly rice, can be grown successfully on many of the soils in the project area without irrigation, providing there is adequate drainage and a controlled flow of water through the area. Furthermore, there is no assurance that the installation of an elaborate irrigation system would result in yield increases of such a magnitude to justify the added cost of the system. This would appear to indicate the choice of one of the lower cost development alternatives or combinations, as reported elsewhere in this report.

The successful development, operation and maintenance of an elaborate irrigation and drainage system requires a sophisticated level of technical competence for satisfactory

results. On the agricultural side, the choice of and development of irrigated crops is quite complicated. Each crop has specific water requirements during the growing season and application of water must be controlled to meet those requirements and prevent excessive wetness or dryness. Rwanda does not have the technical personnel capable of operating and maintaining an irrigation system once it is placed in service. Furthermore, the farmers of this country are not familiar with irrigated agriculture and would require extensive training and guidance for an extended period. At present the Extension Service lacks qualified personnel at all levels and has no technical staff capable of advising the farmers concerning approved irrigation practices, and of supplying the continuing necessary support services.

Irrigation may be required in some of the reclaimed valley lands having light sandy surface soils which would tend to dry during the dry season, and which might not be supplied by groundwater. This is why a land capability classification is essential prior to preliminary project design so that the irrigation needs can be identified. If irrigation is needed, the most simple water distribution system should be designed. It should be operated and maintained by a farmers cooperative association for which substantial technical advisory services will be needed.

The team is of the opinion that the major emphasis in

the project area should be on small plots for individual subsistence farmers for raising foodcrops on the approximately 7,700 hectares to be reclaimed, rather than on the allocation of large areas for the production of commercial crops. The latter could lead to the exploitation of individual farmers through forced cultivation of particular crops at arbitrary low prices as seems to have happened in the cases of cotton and tea production elsewhere in the country. The project could provide land for new farmers in addition to those presently living on and farming the hillsides along the marshy valley bottoms. As many as 50,000 people might be directly affected by the project and many more would benefit indirectly.

4. Roads and Bridges

The topography of most of the country makes for very difficult communications, and the absence of adequate roads and bridges hinders both commercial exchanges and administrative contact with much of the population. It also inhibits the ability of extension programs to reach farmers, the communication of ideas, and the distribution of goods.

A program for the improvement or construction of secondary roads and bridges would provide access to the more remote already inhabited areas and provide economic incentives to the population.

Apart from the need for secondary roads, high priority should be given to the improvement of the main road between

Kigali, Gitarama and Kibuye.

It is recommended that AID finance a survey by a civil engineer to determine the most likely area for developing a road network, taking into account the density of the population to be served, the agricultural production of the region and the mineral and other resources available. The active interest of the people in supporting such a project by supplying necessary labor, should be taken into account.

It is estimated that 6 weeks services of an engineer experienced in the construction of secondary rural roads, and of bridges, in underdeveloped countries would be required.

Estimated cost $ 12,000

Assuming a favorable report by the engineering consultant AID might wish to consider a rural road program to be supervised by an engineer and a surveyor to trace the roads with the assistance of Peace Corps Volunteers and personnel from the Ministry of Public Works.

AID would provide the necessary instruments, tools, culvert materials, cement, etc. Labor would be provided from communal sources, including umuganda. Perhaps some form of a cash/food for work program might be desirable to meet any additional labor requirements, although it is realized that such programs are difficult to supervise and have not always been successful.

5. Agricultural Cooperatives and Credit

The agricultural cooperative movement in Rwanda is relatively weak and needs substantial support. Agricultural credit is limited for the small farmer although in some areas there are Banques Populaires which try to meet the need for credit. This lack of adequate credit, even though the credit needs of a subsistence farmer are usually not large, acts as a brake on development in the agricultural sector.

It is recommended AID finance a study of the cooperative movement as well as an analysis of the requirements in the country for an expansion of agricultural credit facilities on a regional or national basis.

A team of two men, a cooperative specialist and an agricultural credit specialist, both with experience in African cooperative and credit institutions, would be required for one month each. In addition to evaluating the present status of cooperatives and credit, they would select an area where the interest and needs of the rural population indicated a basis existed for a pilot project on the assumption that proper training and guidance would be provided over a reasonable period.

Estimated cost of the survey US$ 16,000

6. Foundation Seed Project

It is recommended that AID consider the possibility of providing facilities, technical supervisory services and the training of personnel for the multiplication, processing, storage and distribution of genetically pure, high-quality seed. One of the major impediments of agricultural development in Rwanda has been the inadequate supply of good quality seed. Farmers are frequently forced to plant seeds of low quality simply because better quality seeds are not generally available.

There is no existing seed industry in the private sector, so the function of seed multiplication and distribution is a government responsibility. There is presently a Belgian Technical Assistance Project concerned with seed selection. However, the scope of this operation is limited and unable to adequately provide for needs of Rwandan farmers.

A desirable site should be selected in either the Zaire-Nile Crest or Nyabarongo valley proposed project areas for construction of three buildings: an office, a structure to house the seed cleaning and grading equipment, and a storage warehouse. Land would be needed for growing and multiplying foundation seed which is the basic source of seed for multiplication and distribution to farmers. In fact, the establishment of an effective foundation seed program is the first step necessary for an overall seed development program.

The seed project center may involve an area of approximately 25 hectares, depending on the size of the project area selected, and the capacity of the facilities required would be governed by the size of the geographic area delected, the number of farmers to be served and the crop or crops chosen for emphasis. The project should be staffed with the following professionals:

One experienced agronomist(seed specialist) PhD level

One agronomist(crops) B.S. level

One agronomist(soils) B.S. level

A minimum of two Rwandan agronomists(A-2) would be assigned to the project for on-the-job training to prepare them for eventual management and operational responsibilities for the Center. Also, provision should be made to send the Rwandan agronomists to Mississippi State Univ., or a similar institution, to receive up to two months intensive training in all aspects of commercial seed production, processing and distribution.

It is essential that the foundation seed project be closely associated with the I.S.A.R. stations in order to benefit from the results of their research. A seed center designed to provide an adequate and dependable source of pure, high-quality seed for all farmers within the project area, could develop into a national program with the potential to make significant contributions to the agricultural production

of Rwanda.

A rough estimate of the costs of establishing and operating a foundation seed project over a 5-year period is given below. It is not known what the Rwandan Government's contribution to the project might be.

Technical Supervisory Staff	
Senior agronomist(seed specialist), 5 years	US$540,000
Agronomist(crops), 3 years	288,000
Agronomist(soils), 3 years	288,000
Rwandan Technical Staff	
Two Agronomists(A-2)	26,000
Rwandan Junior Staff	
Secretary/typist	9,792
Bookkeeper	11,750
Truck driver	9,792
Two drivers	13,786
Mechanic	11,750
Two skilled laborers	7,833
Watchman	1,305
Field laborers(as required)	10,000
Training	8,000
Buildings	
Office, 64 m^2 @ $300/$m^2$	19,200
Processing facility, 75 m^2	22,500
Warehouse, 75 m^2	22,500

<u>Seed Processing Equipment</u>	$ 30,000
<u>Vehicles</u>	
Large truck (U.S.)	16,000
3 Pickups (U.S.)	30,000
1 Tractor, wheeled, approx. 85hp, with implements and spare parts	20,000
<u>Miscellaneous</u>	
Tools, small implements, sprayers, dusters, pesticides, fertilizers, etc.	25,000
Estimated cost US$	1,411,208

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