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9. ABSTRACT The uncertainty of the Rhodesian situation makes it extremely difficult to project or make recommendations for irrigated agriculture. This paper discusses environmental conditions, African irrigation, European irrigation, regional development, and recommendations. The African irrigation projects are rooted in the earliest decades of white occupation, have been there a long time, and have not expanded much. They are firmly embedded in the landscape and the regional economy and will probably survive. New investment in small holder irrigation projects must consider carefully the long term viability of such projects, their ability to repay investment capital, and their contribution to the national economy and development. Their potential role of stimulating the regional economy in remote areas should be considered in formal assessment. The greatest opportunities for African agricultural settlement exist in the underutilized European farms of the high rainfall areas, not in irrigation development areas. The future operation of the irrigated estates has several options: continuation in the hands of the private companies of government takeover as state farms or cooperative management by the work force. The regional economy and the population dependent on it demand that lowveld development be maintained at its present level. Additional investments demand careful analysis before capital resources are committed. Irrigation investment is not the most profitable use of scarce capital resources, nor will it show great social benefits. The high rainfall areas of the Rhodesian highland ought to provide ample scope for the future of Zimbabwe.

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FINAL REPORT

WHITE AND BLACK IRRIGATION IN RHODESIA

by

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The University of Cincinnati

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ENVIRONMENTAL CONDITIONS

Precipitation Regions

The rainy season in Rhodesia lasts for five months from November to March when the intertropical convergence zone reaches its most southerly position. Moist air masses are drawn from the Atlantic into the northwestern part of the country and from the Indian Ocean into the eastern regions. Rainfall of the orographic type results when moving air masses rise above mountain and highland regions. Mean annual rainfall of more than 40 inches is received only in the restricted mountainous area marching along the eastern border with Mozambique, and a few other points of high elevation, notably the immediate vicinity of Salisburg (Appendix 1). Areas of mean annual rainfall between 32 and 40 inches are restricted to the highland backbone extending from Karoi through Salisbury to Umtali.

The southwestern corner of Rhodesia has the lowest rainfall averaging only about 20 inches. This region of low elevation is located in the rain shadow of the highland backbone of the country, so that moist air masses from the Atlantic rarely penetrate, and moist air entering from the Indian Ocean encounters no orographic obstacles capable of cooling the air sufficiently to result in coalescence of droplets and consequent precipitation. Much of the precipitation that is received arrives in the form of guti, that is fog, mist and drizzle, including some during the winter months without benefiting crops in this dry season.

Although the ultimate sources of moisture are the maritime air masses, much of the precipitation is recycled in the Rhodesian highland. Over much of the Rhodesian highveld rainfall is predominantly associated with local

convection, local thunderstorms often resulting in hail, rather than with the orographic or frontal effects of moving air masses (Soane and Miles, 1955, 1956). Re-precipitation through the operation of the local hydrologic cycle accounts for the low runoff yield amounting to no more than 7.7% of total precipitation characteristic of Rhodesia. Formation of local thunderstorms creates a high regional variability in precipitation, and contributes to great uncertainty of rainfall from year to year. Low and uncertain runoff yields are reflected in high variations in regimes of rivers having their catchment in the extensive highland regions. The few small rivers issuing from the eastern border mountains in contrast, provide both a higher yield per square mile and more reliable flows.

The variability of rainfall from year to year, and therefore uncertainty and risk to agriculture, increases consistently from northwest to southeast of the country (Appendix 1). In fact, a large area in the southeastern lowveld can be expected to receive as much as 24 inches of rainfall on the average only one year in five (Appendix 2).

The three maps of Appendices 1 and 2 clearly indicate that the region in which irrigation practices are obligatory for successful agriculture are found in the low elevation portions of the Sabi and Lundi River basins. This region has been assigned to the Sabi-Limpopo Authority for planning and development (Appendix 3). The present report will focus on this region.

This should not be interpreted as saying that irrigation practices are unnecessary in the remaining parts of the country. The vagaries of rainfall make supplementary irrigation beneficial in all parts of the country, and is, of course, indispensable for successful dry season cropping. This applies

particularly to orchard operation as trees otherwise enter a period of dormancy during the dry season. Only the eastern highlands are blessed with sufficient moisture to carry on tree plantation agriculture without supplementary irrigation (wattle, tea). Major irrigation operations are provided for the citrus estates of the Mazoe valley north of Salisbury and on citrus plantations in the vicinity of Umtali, both located in the high rainfall area. These will not be considered specifically in this report, but comments made about the plantation estates of the southeastern lowveld apply pari passu to their conditions and operations.

Moisture Needs

The Thornthwaite method for calculations the water balance of moisture in the soil between inflow from precipitation and outflow by evapotranspiration is capable of showing deficiencies and surplusses for plant growth, and thereby providing rough estimates of water needs for irrigation (Thornthwaite and Mather, 1955, 1957). Water balance calculations take into account the effect of temperature on potential evapotranspiration, the availability of moisture in the soil for an estimate of the actual amount of moisture evaporated and transpired by plants, and the capacity of the soil to hold and carry over moisture available to plant roots during dry spells. These calculations take into account the water holding capacities of differing soils within the root zone of crop land.

A graphic presentation of the progression of the water balance during the average year for four typical stations is provided in Appendix 4. These show water deficits which have to be supplied by irrigation for various seasons, and water surplus available for runoff during the late rainy season. Appendix

5 maps potential evapotranspiration and water availability for Rhodesia. Figure 3, (App. 5), indicates that average annual potential evapotranspiration is highest in the hot lowveld, where precipitation is least. Consequently (Fig. 4) surplus water for runoff is derived only from the highland areas. Moisture deficits (Fig. 5) are particularly a feature of the south-eastern lowveld, where water needed for irrigation ranges from 20 to 35 inches average per annum.

Agro-ecological Zones

The agricultural potential of the widely differing parts of the country as viewed by competent agricultural technicians is worth considering. An agro-ecological survey (Vincent and Thomas, 1961) has divided the country into five natural regions based on differences in temperature and rainfall (Appendix 6). Irrigation interest centers on regions 4 and 5, the regions of low effective rainfall. Both of these are recommended only for extensive livestock production by ranching the natural grasses of the veld. They differ in that region 4 is considered capable of supplementary production of drought resistant millet and sorghum crops for livestock feed at least during high rainfall years. All cropping in region 5 in contrast is entirely dependent on irrigation. (Fig. 1).

Under the Land Apportionment Act fully 70% of the African Tribal Trust Lands are located in regions 4 and 5 (App. 7). Note that despite this fact the vast majority of irrigation development and acreage is located in the European apportioned lands of regions 4 and 5.

Soils

Appropriate soil resources are not likely to prove a limiting factor to

the extension of Rhodesian irrigated agriculture. Adequate level land on suitable soils can be identified in sufficient quantities to the extent needed for utilization by the limited water resources available to the lowveld. Figures of 600,000 to 750,000 acres are commonly cited as capable of irrigation, but this may represent hope rather than reality. Contrast for instance locations of potentially irrigable lands in Appendices 3, 8, 22, and 23 for insight into the roughness of these estimates.

The most common soils of the southeastern lowveld have developed on paragneiss under mixed deciduous bushland and mopani woodland (Appendix 11). Their texture ranges from coarse grained loamy sands to quite massive porous hard clays. Although friable in the untouched veld or after they have baked in the sun for a long time, these soils are practically structureless and when saturated degenerate into oozey mud which puddles easily and badly. When thoroughly wetted they drain only slowly, and careful provision has to be made for surface or underground drainage (Converse, 1956).

In the lower Sabi Valley an extensive river terrace long proposed for irrigation development (Appendix 8, 11), has developed on granitic alluvium under mixed acacia-exphorbia bush cover. These soils are similar to the paragneissic soils, they can be practically structureless and suffer from problems of water management. Because of the flat topography of the terrace this area suffers from poor surface drainage and consequent tendencies to accumulate high levels of salt. (Fig. 2).

In the extreme southwestern part of the country a series of dark colored, heavy clay soils developed on basalt. These soils are very dark, extremely clayey, but intensely aggregated into large stable crumbs. Swelling and

shrinkage as they become alternately wet and dry is enormous, which complicates irrigation and indeed building structures on them. This soil is rather free draining, indeed so much so, that wet rice cultivation could not be maintained. Peanuts, wheat and beans appear to be best adapted to this type of soil (Cackett and Patterson, 1965).

Throughout the region, along water courses occur riverain soils, belts of recently deposited alluvium which are highly diverse. In some places these soils may be only a few inches thick, in others many feet deep. Normally they are well drained, fertile, have good water holding capacity and are easy to work. Converse (1956) considered such soil nearly ideal for irrigation.

In regard to the suitability of lowveld soils for irrigation use two things stand out. All of the soils are productive or can be made so with inputs of water and fertilizer. With the exception of the small areas of riverain soils, all the lowveld soils present problems of management. They suffer from excessive or inadequate drainage, tendencies towards salt accumulation, breakdown of structure, compaction, heaving, and selfworking. Management of these soils requires technical knowledge and a degree of sophistication from farmers for successful utilization.

Water Supply

The tropical wet and dry climate and the seven month long dry season insure that the regime of Rhodesian rivers is one of extreme fluctuation. Rivers tend to be in flood towards the end of the wet season and during the dry subside into trickles. Indeed, even large rivers issuing from the central highland tend to dry up completely during the winter months. The minimum

low water flow of the Sabi at Birchenough Bridge has been estimated at 25 cusec, that is low enough so the river can be forded by land rover.

The variability of rainfall and runoff necessitates river gauging records on the order of 40 years duration for reliable estimates of water supply availability. Although there are now some 470 hydrological recorder installations situated on the main rivers throughout the country, most of them have been in place for only about fifteen years (Loewenson, 1976). Data for the estimated potential yield of six zones of the country are provided in Appendix 9. The extreme variability of river regimes means that large storage capacities are necessary to provide adequate water supplies to carry an irrigation project through the long dry season. Because of long term storage requirements, and high rates of evaporation and seepage the yield from Rhodesian reservoirs tends to be only on the order of 50 percent of mean annual runoff.

Water quality of Rhodesian rivers is in general quite high. Salinity of the irrigation water affects the soil water solution, and may affect the soil structure as well, and both conditions may adversely affect plant growth. Rhodesian rivers have in general a dissolved salt content of about 100 PPM (Appendix 10), which places them into the first quality class by American irrigation water standards. Sodium salts which are the main culprit doing damage typically make up half or less of the total dissolved load.

Extremely friable, erodible, sandy soils covering the greater part of Rhodesia provide a considerable suspended load particularly in the form of silt to flowing water courses. Agricultural practices promoting soil erosion aggravate this condition. A high rate of sedimentation in reservoirs is one result. Silt loads may necessitate desilting works at the main canal intake

and may interfere with pumping works, and will at all times increase the maintenance work necessary on canals and laterals.

Physical Potential: Summary

The Rhodesian lowveld can be irrigated, and if crops are to be grown, must be irrigated. Neither soils nor water supplies present serious obstacles to irrigation activities. The quality of water supplies in fact is quite high, and adds only marginally to soil salinity problems. The soils, to be sure, are not "ideal", but neither do they present problems for which management techniques are unavailable.

The potential water supplies have not been nearly completely committed at the present stage of development, except in one river feeding one of the African projects (the Tanganda at Mutema). Consequently, the irrigation projects have not experienced water shortages during drought years. Overenthusiastic expansion of lowveld irrigation could change that, for irrigation does not so much solve the problems of uncertain rainfall, as transfer dependency from local precipitation to the uncertaincies of rainfall in the water supply source regions.

There is nothing about the lowveld situation to convince me that the physical potential is outstanding, that environmental resources provide opportunities of such superior quality that economic considerations might be of secondary importance. Just because the Rhodesian lowveld can be irrigated, does not mean it must be.

AFRICAN IRRIGATION

Early History

The ruins of the Inyanga complex bear witness that Africans mastered

the craft of terracing in past times. These ruins are located in the eastern province and stretch southward from Inyanga town almost to Umtali. They consist of walled terraces, water courses, fortifications and stone lined pits. The sites appear to have been occupied as late as the 18th century, when Africans already had access to firearms. Whether irrigation was practiced, however, is not clear. Nor is there any evidence that the aptitudes and skills of terracing and irrigation were carried over into the modern period. Perhaps these practices were lost during the Zulu incursions of the 19th century (Summers, 1958). The possibility of redevelopment along modern agricultural lines of this terrace area may be worth consideration.

At the time of the European occupation African farmers experience with dry season cultivation was limited to the making of matoro. These were gardens laid out in areas of a shallow water table, on alluvial bottom lands along streams and in swampy areas locally known as vleis. Such vleis are widespread in Rhodesia due to impediments in underground drainage, i.e., natural sub-surface dams provided by intrusive dike structures. Matoro were planted towards the end of the dry season when food supplies began to run low. Farmers raised sugar cane, rice, and early maize to ripen at the beginning of the rainy season before the regular crops were ready for sustenance. Matoro were continuously cultivated and not returned to fallow of shifting agriculture. Land of excessive wetness was drained where necessary by drawing shallow ditches.

Clearly, the practice of matoro was restricted by the availability of suitable land, yet it appears to have been an important part of the lowveld economy, where settlement in any case was restricted to the vicinity of permanent water courses. Lowveld settlement in any event has always been sparse,

and may have been limited by the quantity of fertile belts of alluvial soils and topography suitable for the making of matoro. The water management skills and cropping practices of matoro were carried over and provided the basis for the beginning of African irrigation.

Africans started drawing ditches and irrigating their land on a small scale soon after the occupation. Stimulated by the missionary example and occasional teaching, guided sometimes by Native Commissioners, individual irrigated gardens proliferated in the vicinity of Umtali, within access of an urban market for fruit and vegetables during the dry season. In some instances villages cooperated in digging an irrigation ditch to command a larger area of level land for irrigation. Three of the present government irrigation projects in the Sabi valley had their beginnings in such independent African efforts. Crops were taken over from matoro in the first instance, rice, maize, and finger millet for subsistance, but introduced vegetables and wheat were not slow in entering the cropping pattern. Small scale, free enterprise, labor intensive, and independent African irrigation could have had a prosperous future. Three developments served to bring it and matoro to an end.

In the first instance Africans have no tradition in the customary law regarding distribution and allocation of water resources. A peasant farmer thus had no recourse against upstream diversion from a stream or even from the ditch in which he had invested his labor. A strong chief might referee disputes, but in the absence of concepts regarding water as property there was nothing to prevent the chief from taking the lion's share for his own lands. The Rhodesian government might have provided a legal basis for African community operated irrigation projects, but did not do so.

The Water Act of 1927, based on the doctrine of prior appropriation, prohibited the abstraction of water from a public stream for tertiary uses without the possession of a court recorded right. Water rights are attached to land rather than to persons. Since Africans do not own the Tribal Trust Land they farm, they were in effect prevented from acquiring water rights either as individuals or in communities. The location of white settlement at higher elevations in any case assured upstream diversions to white farms. When the government finally did promote African irrigation projects in the 1930's, the European farms had already acquired priority rights on smaller and medium sized streams where seasonal shortages are likely to be common. Water rights issued in respect to African irrigation projects were vested in the Chief Native Commissioner not in individuals or specific projects.

A further limitation of African practices occurred through the passage of the Natural Resources Act of 1952. In order to promote conservation and prevent erosion of stream banks the law prohibits cultivation of annual crops or destruction of vegetation along stream banks. As public streams in the Act also include vleis the making of matoro is prohibited.

This history of early African irrigation efforts indicates that decline was the result of inadequate or lacking public policy guides, not the result of failure of African entrepeneurial initiative or the free market system. I would therefore anticipate some, perhaps considerable, scope for small scale private irrigation undertakings in the future. Provided, of course, that public institutions are structured to promote rather than curtail development of this nature.

The Government Projects

In view of the fact that the government African irrigation projects did not repay their capital costs (Appendix 12), did not even pay for their maintenance costs in the 1960's (Appendix 13), when the water charge was 25 sh., and probably do not do so even today when the water charge has been raised to R$14.00, it is necessary to ask why the government embarked on a policy of constructing African irrigation projects in the first place.

Government intervention in African irrigation started under the first Director of Native Agriculture, Emory D. Alvord. Alvord brought his experience of growing up on an irrigated farm in Idaho, agricultural education in the western United States, and energetic enthusiasm to bear on developing irrigated agriculture. Little capital was invested in the irrigation projects before World War II and Alvord justified the continuation of African initiated efforts as a means of famine relief. The provision of a locally grown supply of grain, he thought, would eliminate the recurring need for famine relief in the Sabi valley.

After World War II the authorities came to see the expansion of irrigation projects and the provision of boreholes as a means of opening up the lowveld for resettlement of Africans from lands designated as European under the Land Apportionment Act. The ideological nature of the objective undoubtedly contributed to the avoidance of careful economic analysis. Resettlement was effected both by gradual and spontaneous drifting-in of African farmers from white lands and overcrowded Reserves (Appendix 14), and by organized expulsions. To the extent that data could be recovered (Roder, 1965, page 118), about 40% of irrigation project farmers hail from white lands themselves, others come

from overcrowded reserves where African lands were lost, or descend from parents who left white farms.

Because irrigation farmers typically do not come from the immediate vicinity of the project, they owe little allegiance to the traditional chief or other land authority. Their orientation has rather been towards local representatives of the national government, and there has been a considerable tendency to be influenced by the representatives of African Nationalism. The irrigation farmers in short are innovation minded, and this has fostered adoptation of the necessary new farming skills and they have been able to build up a body of knowledge and expertise in agriculture unparalleled elsewhere in Rhodesia except perhaps in a few African Purchase Areas.

In the early 1960's the lack of economic rationale for the projects brought a halt in further development. At that time 4,372 acres were irrigated in nine projects in the Sabi-Odzi valley. Double and sometimes triple cropping brought the cropped area to 7,000 acres. Another 300 acres were under irrigation on Nyamaropa project north of Inyanga in Manicaland (Fig. 3), plus 300 acres again on four small projects in Charter District. African irrigation in two projects in the Limpopo lowveld and on the lower Sabi at Chisumbanje remained still in the experimental stage.

Since UDI the government has reverted to its earlier policy of using irrigation development as part of its strategy for the resettlement of Africans on Tribal Trust Land. These are now expected to absorb even the unemployed surplus African population of the towns. By 1972, 14,000 acres were under irrigation in African areas (Nelson,1975, p. 306). In contrast

to earlier days these are expected to pay their own w.. or at least their maintenance costs. This objective is reflected in the progressive raising of the water rate to the current R&14.00 per year, and in increased demand for the cultivation of cash crops. Nevertheless the projects main function remains the provision of subsistence food supplies to cultivators.

Production History

Throughout their history the irrigation farmer have devoted their chief efforts to the growing of food crops primarily for their own consumption. From World War II until 1961 no year saw more than 13 percent of the production in commercial crops and the peak years occurred in the early part of that period. At Nyanyadzi, probably the most progressive of the projects, virtually the whole of the summer cropping season was devoted to maize. The highest proportion of acreage devoted to commercial crops was 32 percent achieved in 1958.

The production history of the irrigation projects can be summarized as a constant search for a commercial crop having a profitable and stable market. A succession of crops was tried with high hopes, successful cultivation by farmers, only to end in collapse of the market. Introduced in the late 1930's sunnhemp seed was for many years the only non-food crop raised on the projects. Production declined because insect damage turned highveld farmers from this green manure crop. Attempts to process sunnhemp for fiber did not give satisfactory return. Onions and peas had a brief vogue in 1954 but quickly saturated the urban market. The opening of a canning plant in Cashel in 1957 created a market for a variety of vegetables. An uneasy relationship existed for some years because the growers were unhappy with the perceived

spread in prices between what the cannery offered and the urban market for fresh vegetables. Closing of the Cashel factory in 1961 ended the contract relationship with the company, and left the growers searching for markets for their produce. Kenaf for seed and fiber was grown for two years, but production ceased when the Umtali processing plant closed. Sesame seed also lasted for two years but did not show a profit. Seed beans were grown at Nyanyadzi under contract to an international company, but this relationship ended presumably with UDI.

Irrigation is without doubt the most capital intensive method of farm production. It carries high risk, long lead times, and slow payout, and consequently high returns from commercial crops are necessary. Before UDI the African irrigation projects had failed to find markets for their undoubtedly high production potential which could come anywhere near providing the income necessary to recoup capital investments. There is no reason to believe that this situation has altered under the impact of economic sanctions. Cotton and wheat were introduced to the irrigation projects before UDI, they appear to have remained the chief commercial crops of the projects. Whether they show sufficient return to justify the investment in irrigation is doubtful.

Incomes from Irrigation

The economic position of irrigation farmers compares favorably with other African farmers in Rhodesia, and not badly with Africans in urban employment. A sample estimate in 1957 considered mean income per plot holder about £70 (Hunt, 1958). Median incomes at Nyanyadzi for 1961 gave estimates of £137. Incomes were proportional to the size of irrigated holdings; farmers with less than 3 acres had a median income of £101, those with more than 3 acres a median of £187 (Roder, 1965). These compare with net returns per family

from enterprises of African rural households, £26 for 1957, and £32 for 1961 (sample estimates by Johnson, 1964). A lower figure of gross income to a hard working successful irrigation farmer of £100 provided by Kay (1970) probably reflects the inclusion of newer, not yet fully established irrigation projects, rather than a decline in earnings.

Urban families in Umtali had a median income of £114 in 1959 (CSO, 1960). It is not known whether returns to irrigation farmers have kept pace with inflation or increases in wages paid to Africans in the money economy. In 1972 the two sectors employing the highest proportion of African wage labor, European agriculture paid an average of R$135, domestic service R$276 (Nelson, 1975, p. 325).

The comparative wealth of the irrigation farmers is easily visible in the field. The large number of well built brick houses, sometimes plastered, and often with corrugated roofs is immediately striking. Irrigation farmers own more capital equipment; two-wheel carts for transportation, plows, harrows, cultivators, seeders and bicycles than nearby farmers in the dry land. A very few were even able to acquire secondhand tractors or pickup trucks (Fig. 4). Most of their surplus however is apparently invested in livestock, particularly cattle but also sheep, goats and donkeys (Fig. 5).

The latter investment creates the problem of overgrazing, and the land adjacent to the perimeters of the irrigation projects tend to suffer from severe overgrazing and consequent soil erosion. It could be said, indeed, that irrigation development robs fertility from the range to transfer it in the form of manure to the irrigated land. (Fig. 6).

Management

Administration of each irrigation project since roughly the Second World War has been in the hands of a Land Development Officer. These filled a duel role of administrator enforcing government edicts handed down via District Commissioners, as well as providing agricultural advice and guidance. These twin roles of advisor and administrator were never clearly separated in the minds of cultivators, nor for that matter in the minds of the individual LDO's. The white officer always appeared to have enormous powers of enforcement at his command.

After UDI the white supervisory force on the irrigation projects was effectively doubled in that each LDO was paired with a project manager. This gave effect to a long standing recommendation to separate extension services from administration. There is good reason to believe, however, that this action was intended to reduce the isolation of white families among a politically aware African population. Attacks on isolated whites in the Reserves, including the burning down of the official residence of the LDO at Nyamaropa irrigation project, took place shortly before UDI. The staff increase also contributed to the Smith government's policy of maintaining the level of white employment.

There is some question how much free play the irrigation project situation allowed to the entrepeneurial spirit of African farmers. Irrigation, especially gravity irrigation on a compact project, requires a certain degree of discipline in respect of opening and closing weirs, irrigation times and water quantities. Schedules must be provided in some centrally planned rotation to all farmers. Beyond these needs, the advice of LDO's what and when

to plant were often interpreted as commands. The always ambiguous interaction between LDO and cultivator sharpened after UDI, administration became more compulsive as water rates were raised with a focus on paying at least recurrent maintenance costs (Appendix 13) and making the projects show returns on investment. In 1967 Control of Irrigation Schemes Regulations were promulgated giving the informal powers of irrigation managers the force of law. These must be seen to be believed (Appendix 15), as they permit control of every detail of the farming operation down to the spacing between trees and houses.

The growing Chisumbanje project, particularly, which is managed by the Sabi-Limpopo Authority followed a philosophy of close control over African agricultural activities. Management there does tell the farmers when, how much, and what to plant, insists on strict maintenance of irrigation times and quantities, application of fertilizer and pesticides is prescribed. Costs for these activities are borne by the farmer and collected by the Authority as a share of the crop at harvest time. There is some indication that this rigid regime has increased yields and incomes to farmers. The farmers however feel little proprietory interest in their holding, rather they see themselves as laborers on a company-owned estate, with the difference that they bear the risk of crop failure instead of receiving a fixed wage. In 1968, experts of the Sabi-Limpopo Authority wondered aloud to me why Chisumbanje had difficulty attracting African families willing to take up holdings.

Conclusion

The African irrigation projects in Rhodesia have created a body of about

4,000 cultivators and their families experienced in irrigation agriculture under the discipline of project conditions. These have developed a degree of expertise in irrigated crops, water application, and the management of small semi-commercial holdings. They have had no opportunity to gain experience in the management of irrigation projects either as individuals or through community boards. It is doubtful that they could provide a source of skills needed to take over the irrigated estates developed in the European land.

Nothing has been said about the African Supervisors and staffs of Agricultural Demonstrators, who work under the LDO's, and carry the responsibility of actually advising and teaching farmers in their fields and homes. The first of these were trained by Alvord personally, later generations were taught at Domboshawa Agricultural School, and about 1960 Chibero Agricultural College was set up for Africans. Many of them are experienced and competent practical extension specialists, and in a normal society would advance to officer level in due course. During the relatively liberal days of the Whitehead government, when CONEX (conservation and extension) services were separated from Native Administration (1962), a few were in fact appointed to LDO positions. Today many are bumping their heads against the color line that separates Supervisors from Officers.

The preparation and training of LDO's was of course also being progressively raised before UDI. Requirements for new entrants in the early 1960's was a B.Sc. in agriculture or its equivalent. Since then, the perceived need of the government to find employment for all whites, resulted in downgrading of positions involving work with Africans or in African areas. The disappearance of some of these officers would represent no loss to agriculture, CONEX, or the country.

It is my perception that adequate technical expertise exists among middle level African staffs that there need be no fear for continued operation of the irrigation projects, or indeed for African agricultural progress in the country generally. I see a large, qualified manpower pool eager to transcend the limitations imposed by the color line.

The foregoing does not guarantee that the new government will (or can) encourage good agricultural and conservation practices, or that public policy guides will be such as to allow staffs to bring the best technical expertise to bear on agricultural problems and development. Nor do I perceive among this group the management and scientific skills which would be needed to take over the corporate estates of the southeastern lowveld and elsewhere.

EUROPEAN IRRIGATION

Dams and Water Supplies

European irrigation in Rhodesia had its beginning with the coming of the first white settlers and missionaries. These had ditches dug to irrigate vegetable gardens for home consumption, often even before they built their houses (Moody, Jan. 1893). From these small beginnings developed the widespread practice of constructing farm ponds, small dams and boreholes for irrigation. Beginning during the depression and augmented considerably after World War II the government stimulated the provision of farm water supplies by providing loans on concessionary terms for this purpose. There must be only a very few of the approximately 7,000 European farms which do not have at least one small conservation dam (Appendix 16).

Since UDI private farmers in the African Purchase Areas have gained

access to these loan funds for farm dam construction, but probably only a small number have been able to take advantage of this opportunity. Most of the dams are undoubtedly used chiefly for watering livestock, rather than for small scale irrigation. The several hundred small dams constructed in the African Tribal Trust Land (Appendix 16) are used almost exclusively for watering stock and domestic water supplies.

Rhodesia has also constructed a sizeable number of large dams (Appendix 17). Not all of these were constructed by government, the Mazoe Dam was built by the British South Africa Company to irrigate their citrus plantations in the high rainfall area north of Salisbury. The Liebigs Corporation have constructed a dam on the Bubye River for their extensive livestock ranching operation in the lowveld and to irrigate supplementary feed crops. The majority of the large reservoirs in the highveld provide urban water supplies for the large cities, and until Kariba power came on stream were sources of hydro-electric power. Some, such as Sebakwe Dam near Gwelo have found new uses in the provision of irrigation water.

Irrigation Acreages

At present, approximately 130,000 acres of European farm land appear to be under irrigation in Rhodesia. 55 percent of this total, or 70,000 acres, are located in just one area, the Chiredzi District in the south-eastern lowveld. The remainder are widely dispersed throughout the European farming areas (Appendix 18), but especially in the well watered region of the eastern border and in the high rainfall area stretching from Umtali to Karoi in the north (Appendix 1). This development then concerns supplementary irrigation only, or double cropping in the dry season.

The quantity of irrigated land has increased rapidly since the end of Federation, and especially after UDI (Appendix 19). Irrigated acreage increased more rapidly in fact than cropland generally, and consequently so did the main irrigated crop acreages, sugar cane, cotton and wheat (Appendix 20).

The rapid increase in investment in irrigation is partly the result of policies followed by the Smith government. Since UDI development of the southeastern lowveld has been given high priority for government investment funds. These are said to have been made available by the repudiation of Rhodesia's foreign debts and loans received from the World Bank (Nelson, 1975, p. 215). Curtailment of remittances abroad by foreign exchange controls also had the effect of encouraging farmers and corporations to enlarge their investments including irrigation.

Economics of The Lowveld Frontier

That the vast bulk of the lowveld investment was placed in the European areas is easily explained by the ideological stance of the Smith government. That heavy agricultural investments were made in irrigation at all, may have to be ascribed to the romance somehow associated with irrigation, the dream of opening an inhospitable frontier, the seduction of making the desert bloom. That it is the most profitable investment possible in agriculture can be questioned. The high rainfall areas of the European highveld which do not require irrigation, or at best supplementary water, would likely show a greater return on investments. European farms in Rhodesia characteristically have less than 10 percent of their lands under crops, so ample scope for agricultural expansion exists. A reluctance to disturb private property relation-

ships in the European farming area and an ideological commitment to maintain free enterprise may have played a subconscious role in the minds of decision makers.

The World Bank some years ago worked out a model rule of thumb indicating that gross returns per acre to irrigation should approximate 25-33 percent of the costs of investment before irrigation projects could be considered economically viable (World Bank 1961). Investments in the early southeastern lowveld schemes have been estimated on the order of £150 to £200 per acre (Phillips, 1962, p. 322). Gross returns to sugar at 55 tons per acre may satisfy the World Bank model, cotton returns must be considered marginal, and wheat inadequate to meet repayment of the investment. The World Bank model also suggests that returns should be 20 to 30 percent greater with irrigation than could be achieved without in an alternate investment. I question if this is the case in the southeastern lowveld compared to alternate investment possibilities of the underutilized white farm lands of Rhodesia.

Lowveld Development History

The beginnings of southeastern lowveld irrigation are associated with the name of the pioneer farmer Murray MacDougall. Like Alvord on the African side, MacDougall brought agricultural experience in sugar cane growing with him from Guyana and Hawaii. MacDougall developed irrigation on his farm, Triangle Ranch, in the 1920's and 1930's, producing the first sugar in 1937. Shortages of the Second World War pursuaded the Rhodesian government to take over MacDougall's farm in 1941, to buy out his enterprise in 1945, and to enlarge his operation. By 1954 Triangle was again resold to

to a private corporation. This mixture of government and private enterprise activities of the early years has remained characteristic of southeastern lowveld development.

Serious investigations and long-term planning for the southeastern lowveld development began after World War II when a comprehensive report about irrigation possibilities appeared (Gibb, 1948). In that period, however, the expansion and intensification of agriculture in the highveld and the settlement of white immigrants on individual farms was seen as having priority. Only when the post-war stream of immigrants diminished and it became clear that the white lands would not attract large numbers of farming settlers, did interest again turn to the support of large scale corporate development.

Rapid large scale development started in 1958 with the construction of Kyle Dam on the Mtilikwe River, completed in 1960. In 1964 the Sabi-Limpopo Authority was created and charged with stimulating investment and development in the lowveld (Appendix 21). Comparison of Appendix 21 with Appendix 3 is interesting. The region given by Kay differs substantially from that the Authority assigned to itself, which does not even extend to the Limpopo River of its title. This is a reflection of the fact that we were dealing at that time not so much with an executive authority as with a promotional agency. Investment in lowveld development was initially intended to come from the private sector, while the Sabi-Limpopo Authority was charged with acting as a facilitator among the various government departments which retained the responsibility for providing the parts of infrastructure normally their responsibility. As private investment funds, both domestic

and foreign, became reluctant to enter agricultural enterprise in Rhodesia, the Authority increasingly undertook land development itself with government funds. Over the past ten years a complex integrated regional economy has come into being, complete with its own regional urban center.

The Corporate Plantations

The economic development in the southeastern lowveld and its future can be analyzed in two ways. In one sense we are dealing with three large corporate plantations which differ little from similar ventures elsewhere in the country, except for the spectacle of rotary irrigation sprayers creating rainbows in the brilliant sunlight. Controlled input of water is merely another factor of production, and does not make irrigation a fundamentally separate species of agricultural enterprise. The corporate plantations of the lowveld in this viewwould not require future treatment different from other private corporations in Rhodesia.

The lowveld situation can be looked at from another side, however. The massive investment in this small region since UDI has brought into existence a geographic complex of diverse economic activities in which irrigated agriculture is only the most important. The development also represents an intimate intertwining of public and private investments. Just how much funds have been sunk into the lowveld is not clear, one scholar estimates £40 million to 1967 alone (Kay, 1970, p. 128), presumably referring to public and private investments combined. Another gives R$29 million to the end of 1973 by the Sabi-Limpopo Authority alone, principally in irrigation works (Hunt, 1976,

p. 88). Regarding the lowveld as an example of integrated regional development, I would recommend that its future should remain under central direction.

Regional development of the southeastern lowveld has created an economic landscape of which irrigated plantations are the most conspicuous feature (Appendix 22). Irrigation depends on water storage in six major dams to carry supplies through the long season of low river flow. Rather than involving the Sabi and Limpopo Rivers of the Authority's title, the reservoirs store the waters of the Chiredzi, Mtilikwe and Tokwe Rivers, all tributaries of the Lundi (Appendix 3 and 23). Beneficiaries of these government developed water resources are three giant plantations. Triangle Ranch grew out of MacDougall's pioneer efforts; it is now owned by Hulett & Sons, Ltd., a predominantly South African company (Appendix 24). Hippo Valley Estates was organized by a consortium led by Ray Stockil, who at the same time also appeared as Vice-Chairman of the Sabi- Limpopo Authority, an example of the intertwining of government and business interests in the lowveld. Nandi the third estate was begun just prior to UDI, but the complications of that event led its international sponsors to withdraw. Unable to find private investors the authorities eventually decided to develop it itself through a subsidiary agency. It is now known as the Mkwasine Estate.

In keeping with Rhodesian ideology of promoting individual farm settlement, private farms have been offered at various times and under various conditions. Only about 50 farms of 500 acres each, of which 150 are irrigated, were taken up during the boom times before UDI. These are intimately associated with and dependent on the corporate estates.

The initial attraction to lowveld irrigation development was the production of sugar cane. In the years of the Federation domestic consumption rose to almost 100 thousand tons per year most all of which was imported. Lowveld production satisfied domestic requirements within a few years after the start of large scale operations and imports of sugar ceased by 1963 (Fair, 1964). Since, both irrigated acreage and sugar production continued to increase rapidly (Appendix 19 and 20), sugar became an export commodity subject to sanctions after UDI. Collapse of the world sugar price at that time did nothing to aid the situation. Triangle and Hippo Valley Estates were forced to reduce their sugar output and face heavy financial losses.

Diversification of production thus became a necessity after UDI, but the corporations have always pursued some subsidiary interests. MacDougall's pioneer efforts included experiments in growing citrus fruit and bananas. Citrus fruit, oranges, grapefruits and lemons are now produced in large quantities especially by Hippo Valley. Cotton has taken the place of sugar cane on a large portion of the irrigated acreage. Rice is grown on a large scale, and so is wheat especially during the winter season of the irrigation cycle. These crops do well under lowveld conditions, cotton yields are on the order of 3,000-5,000 pounds, wheat 7,000-8,000 pounds per acre (Hunt, 1976). But it is doubtful that alternative production patterns can justify the costs and investment in irrigation. It appears rather that the Rhodesian government has pushed for domestic supplies of these crops as a substitution for imports which are costly to obtain under sanctions, and to conserve foreign exchange reserves.

A development of importance are large scale cattle feeding operations. Cattle are obtained from the surrounding ranching areas, a move which integrates the extensive utilization of the natural grassland with the intensive agriculture of the estates. This economic activity was especially effective during the recent drought years when the irrigation projects remained unaffected by the shortfalls in precipitation. Livestock feeding operations are based in part on crop by-products, e.g., the tops of sugar cane, citrus pulp, cotton seed, and wheat straw. Some crops, such as maize, sorghum, beans and peanuts, are grown specifically to feed cattle and the African labor force. (The juxtaposition is deliberate.)

Conclusion

White Rhodesian society has a tendency to see itself in a mythical light as a pioneer society opening up an uncivilized frontier, omnicompetent men proceeding by trial and error to tame the wilderness of darkest central Africa. In this view Rhodesia appears as the last outpost of the rugged, independent individual, in the free swinging private enterprise tradition. The Sabi-Limpopo lowveld development shares in this mythology and in turn promotes it. Perhaps the myth had more to do with the decision to proceed with lowveld enterprise than all economic analyses put together.

The reality is of course more prosaic. Legends abound about Alvord and MacDougall, but both men are good examples of the experience and expertise they brought with them to Rhodesia. The, by African comparison, highly complex and sophisticated economy of Rhodesia has been the beneficiary of an enormous amount of imported technical expertise. In this

irrigation is no exception, in that the lowveld development would scarcely have been possible without the role of the corporations. There is good reason to believe that Rhodesia, which has received so much technical assistance already, will continue to need more even under the best conditions of the future.

The private enterprise mythology is difficult to apply to irrigation development. The European farming community of Rhodesia is as dependent on government protection and subsidy, research and organization as in any of the industrially developed countries. The lowveld development provides many examples of government intervention in the economic process. If a future African government wishes to take over the lowveld plantations it has numerous precedents as guides. It need look no further than the wartime intervention in MacDougall's enterprise, or the development of Mkwasine.

REGIONAL DEVELOPMENT

The Spread Effect

Intensive agricultural development of the lowveld has been accompanied by ancillary economic activities in the region. Factories have sprung up to process agricultural products. Triangle and Hippo each have their sugar mill (Fig. 7), and alcohol is distilled from by-products. A cotton gin has been constructed at Triangle, and a rice mill set up in Chiredzi. Hippo has a cannery for citrus fruit, juices, the preparation of concentrates and the extraction of oils.

All this economic activity in the lowveld is served by a new minor

regional urban center, the town of Chiredzi. This new town is essentially a market center serving the wholesale and retail needs of the surrounding population. It provides central social and cultural facilities, hotels, churches, bars, etc. Chiredzi has the only hospital in the area, and is served by an airport with regular flights to Fort Victoria and Bulawayo. The region is served by an electric power supply grid.

Population

Chiredzi has a white population of approximately 300. Another 300 are headquartered on the irrigation estates, and another 1,000 whites appear dispersed on outlying parts of the irrigation development and on surrounding ranches in the lowveld.

The African population is more difficult to assess (Appendix 25). The pre-conquest African population of this harsh environment was probably never very great. Nevertheless the concentration of people in the surrounding Tribal Trust Lands is striking. The estates are estimated to employ 10,000 permanent workers, mostly on contract. How many of these are Rhodesian and how many foreigners, mostly from Mozambique is difficult to say. The national percentage of foreign labor in agriculture was 50 percent at the time of the 1969 census. I would assume the percentage of foreign labor in the lowveld to be higher. In addition a fluctuating number of casual seasonal workers from nearby African areas tends to be employed.

Transport Network

Economic activity would be impossible without accessibility to national and world markets. The lowveld region is served by the international rail

line from near Gwelo to Maputo, closed this year as a sanctions measure. A branch line has been extended through Hippo, Triangle and Chiredzi to Mkwasine. It is intended eventually to be carried across the Sabi at least as far as Chipinga in the eastern highland. Recently (1975) a railway connection has been constructed between Rutenga on the mainline and the South African rail system at Beit Bridge. The decision to choose this route may have been influenced by the transport needs of the bulky exports of the lowveld, although the alternative connection to West Nicholson meets a railroad whose tight turning radii are clearly not up to modern standards. The Rutenga-Beit Bridge Line incidentally was built as an emergency measure and lacks a proper roadbed.

The years since UDI have seen the construction of a network of paved roads serving the lowveld. They have an unfortunate tendency to parallel and duplicate the rails (Appendix 25). Nevertheless roads provide the most direct access to Fort Victoria, the nearest major town. Another important road carries eastward from Chiredzi across the lower Sabi into the extreme southeastern corner of Rhodesia. The old Sabi causeway (Fig. 8) has recently been replaced by a high level bridge, which provides connections to the eastern highland and the city of Umtali.

Research

That lowveld settlement has long ceased being a pioneer frontier undertaking is perhaps best demonstrated by the heavy emphasis on research related to agriculture. The first lowveld irrigation research station was established in 1950 following the Gibb report south of Birchenough Bridge. This was followed by the Chisumbanje experimental plots, and the Chiredzi

research station in 1967. The three stations are intended to operate as a closely knit unit (Appendix 11). Sugar research is carried on at a lowveld experiment station established in 1966 and controlled by the Rhodesian Sugar Association rather than by government (James, 1976). It may share responsibility that cane yields have risen from 55 tons per acre in 1964 to 80 to 100 tons recently.

Sophisticated research on schistosomiasis, the specific scourge of irrigation projects, is pursued at several centers. Provision of cooking, drinking and washing water, as well as latrines has proven inadequate to curtail infection, until children, but especially boys, can be disuaded from bathing in canals or the canals are made snail free (Clarke, 1972).

Even research into cloud seeding has been carried on in Rhodesia (Stevens, 1974). Results indicate that increasing runoff to replenish a large reservoir encounters difficulties, and that utilization of aircraft because of their needed wide dispersion will be low and costly.

Summary

Questions have been raised regarding economic returns to investment from irrigation in Rhodesia. These are difficult to assess at all times, impossible under economic sanctions in the absence of export data, and not easily forecast for an uncertain future. Irrigation projects once created are difficult to abandon, not merely because of the investment physically sunk into the landscape, but especially because a large population has resettled itself, cast its lot with this economic activity and would be left stranded without water supplies.

Irrigation projects stimulate a profound transformation of the regional

economy. They are the most urban form of agricultural activity in that they require close settlement, and thus create central places. (Central place is a generic term for all nucleated settlements, i.e., towns and villages of all sizes, emphasizing the marketing and service functions to a surrounding hinterland). As foci of intensive development irrigation projects stimulate ancillary economic activities in surrounding areas, and the integrated use of many resources that otherwise could not be tapped in the isolation of the lowveld, e.g., ranching and mining (Appendix 23).

The Role of the African Projects

The regional aspect of integrated development has already been emphasized in regard to the white lowveld. (Appendix 3 and 25). It applies equally to the African irrigation projects, eight of which have become the sites of central places (Appendix 26). One of them, Nyanyadzi, in fact is the largest population concentration in the area, outranking the white country towns of the eastern uplands. The existence of a central place opens opportunities for making public and private central services available not possible to dispersed subsistence farmers of the bundu (remote countryside). Central services of a private nature at Nyanyadzi (Appendix 27) include general and specialized stores, service station, hotel, and various buildings and construction operations (Fig. 9). Public central services are exemplified by a clinic, police post, schools, and post office. (Fig. 10).

Central places are intimately associated with the transportation and communication infrastructure. Pioneer beginnings in both the African and European lowveld were served by poor earth roads. As the projects grew, they contributed an initially small but later growing incentive for im-

provements in the infrastructure. Highways, railroads and air services were developed along with radio and telephone communication. With better roads came passenger bus lines and truck services. These in turn stimulated increased private enterprise activities, and the entire regional economy developed. Assessment of the benefits of the totality of regional growth would be extremely difficult, but surely requires not merely economic but also political and social analysis.

CONCLUSIONS AND RECOMMENDATIONS

The uncertainty of the Rhodesian situation makes it extremely difficult to project or make recommendations for irrigated agriculture. A few issues are of outstanding importance.

African Projects

The African irrigation projects are rooted in the earliest decades of white occupation, have been in existence for a long time, and have not seen much expansion since UDI. They are firmly embedded in the landscape and the regional economy, and their investment may be considered fully depreciated. They will survive.

Future African irrigation projects certainly will not be planned to enforce segregation and the Land Apportionment Act. New investment in small holder irrigation projects must consider carefully the long-term viability of such projects, their ability to repay investment capital, and their contribution to the national economy and development. Their potential role of stimulating the regional economy in remote areas should be considered in formal assessment. But without any doubt the greatest

opportunities for African agricultural settlement exist in the under-utilized European farms of the high rainfall areas, not in irrigation development.

Corporate Estates

The white irrigation development, in the lowveld as well as elsewhere, does not represent individual farm holdings. The bulk of irrigation farming in Rhodesia is in the hands of a few private corporations owned at least in part by foreign nationals, and operates intimately entertwined with government agencies. Most of the investments in irrigation since UDI appear to have been public rather than private. The irrigated estates are highly sophisticated operations, depending on considerable inputs of scientific and technical manpower and knowledge. Irrigation in the lowveld has created a complex regional economy complete with infrastructure, urban center and way of life. The future of the corporate estate should not be assessed as comparable to private white farms, but rather looked upon in the same mode as other foreign corporations, e.g., mine holdings or manufacturing plants.

The future operation of the irrigated estates has several options. One, continuation in the hands of the private companies; two, government takeover as state farms; or three, cooperative management by the work force. Alternately, the estates could be broken up and distributed among smallholders, as either private property, for cash rent, or on the basis of share cropping. Whatever the future holds, will be intimately associated with the decisions of the labor force to stay or leave after a free government takes office. Affected will be not only the high level white manpower, but

also the large proportion of the labor force recruited from Mozambique, and the Rhodesian workers from other parts of the country or from nearby Tribal Trust Land.

Initially at least I would expect the private corporations to remain in control of management. The lifting of economic sanctions would reopen international markets at profitable prices and renew the vitality of lowveld irrigation without necessarily decreasing the diversity forced by economic sanctions. To the extent that technical manpower chooses to leave Rhodesia, the national and international connections of corporate management will enable the companies to recruit replacements.

If the low level work force chooses to go home or foreigners are expelled, replacements may be difficult to find. Agricultural wages under an African government, whether beholden to an electorate or not, are likely to rise. Rhodesian Africans are certain to search for farms of their own when the European high rainfall areas are thrown open to resettlement. Renewed foreign recruitment of contract labor, especially from Mozambique or Malawi may become a necessity.

Over the longer run the government will want to take over ownership and management of the irrigated plantations. The lowveld economy although labeled private enterprise is already heavily dependent on and intertwined with public authorities and investments. Water supplies and infrastructure were paid out of the public purse. It is to be expected that a new government will divorce itself from the incestuous relationship with the corporations, and expect a greater return on its investment. It will scarcely be satisfied to take this return merely in increased taxes, water charges, and royalties. Whether a new management in the lowveld becomes initially labelled a worker's

cooperative scarcely matters, in effect, the estates will become state farms managed and operated by one or more statutory corporations.

I would consider the breakup of the irrigated estates into smallholdings a disaster. The very layout and design of the irrigation enterprise, the size of irrigated blocks of land, the use of overhead spray equipment, the central headquarters, maintenance and repair shops, are predicated on integrated management (Appendix 24). Operating the corporate estate as a small holder irrigation project would require effective central direction with considerable enforcement powers. It would also require a great deal of discipline and expertise from the small holder farmers themselves. Small holders would come to regard themselves as creatures at the whim and call of management, not as free yeoman farmers. Experience at Chisumbanje and elsewhere has shown that this is an unacceptable way of life, and volunteers to take up smallholdings may well not be forthcoming.

The always great uncertainties of markets for commercial non-food crops make African farmers reluctant to risk a large share of their agricultural activity on these. The first priority of the smallholder must be a harvest of subsistence food crops, lest his family starve. Smallholders on irrigation projects in the lowveld would and do feel bound to grow maize and sorghum for their own consumption rather than sugar cane and cotton. The effects on profitability of the projects for the national economy can be imagined, since these food crops can be equally effectively grown without irrigation.

The regional economy and the population dependent on it demand that lowveld development be maintained at its present level. Whether additional investments are justified demands careful analysis before capital resources

are committed. Basically the Smith government's push into the lowveld was ideological, spectacular construction of prestige projects, the aura of pioneering a settlement frontier, and a reluctance to disturb white farming in the highland combined with maintaining the fiction of the private enterprise ideology. It stands to reason that irrigation investment is not the most profitable use of scarce capital resources, nor will it show great social benefits. The high rainfall areas of the Rhodesian highland ought to provide ample scope for the future of Zimbabwe.

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APPENDIX I

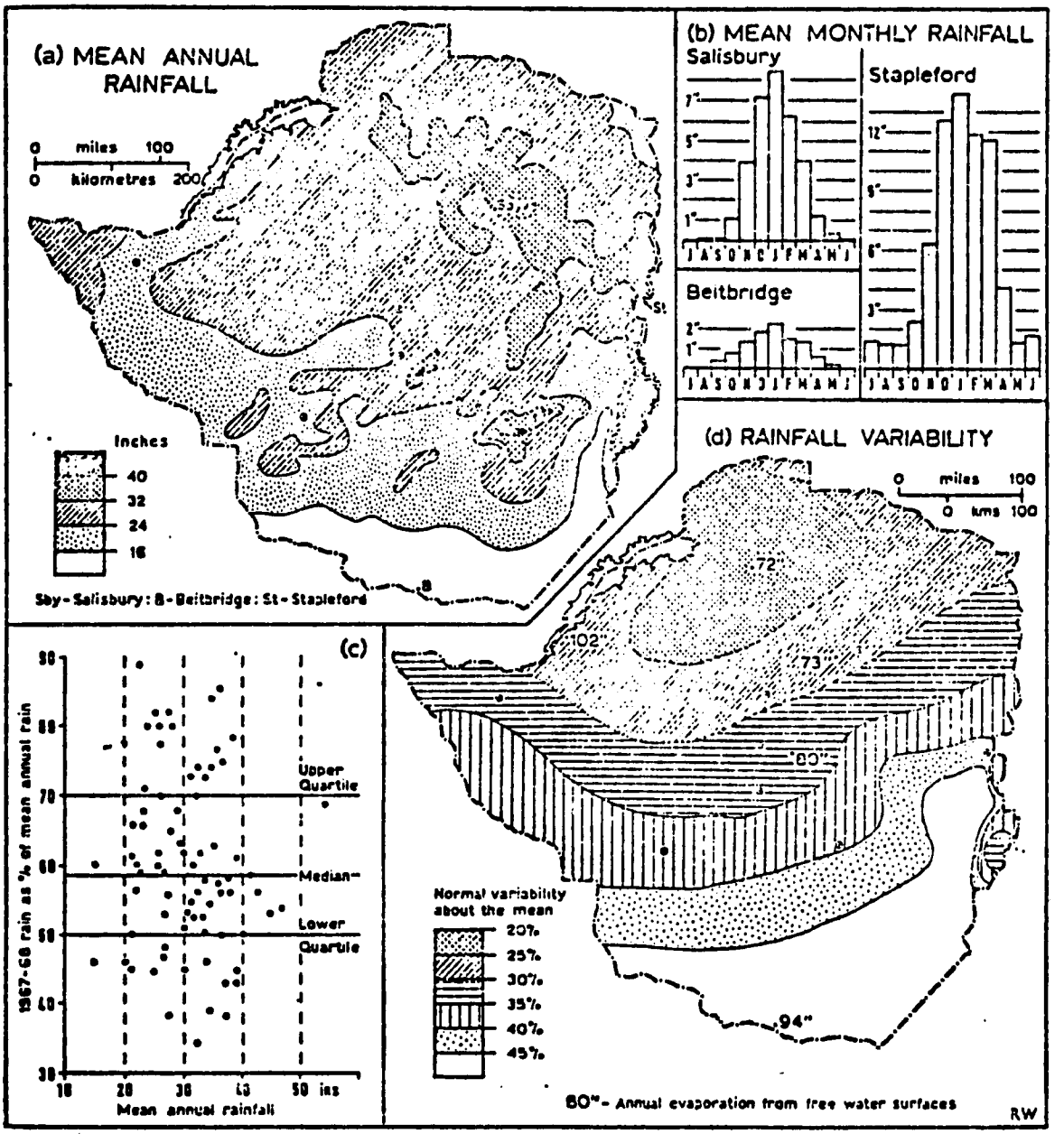
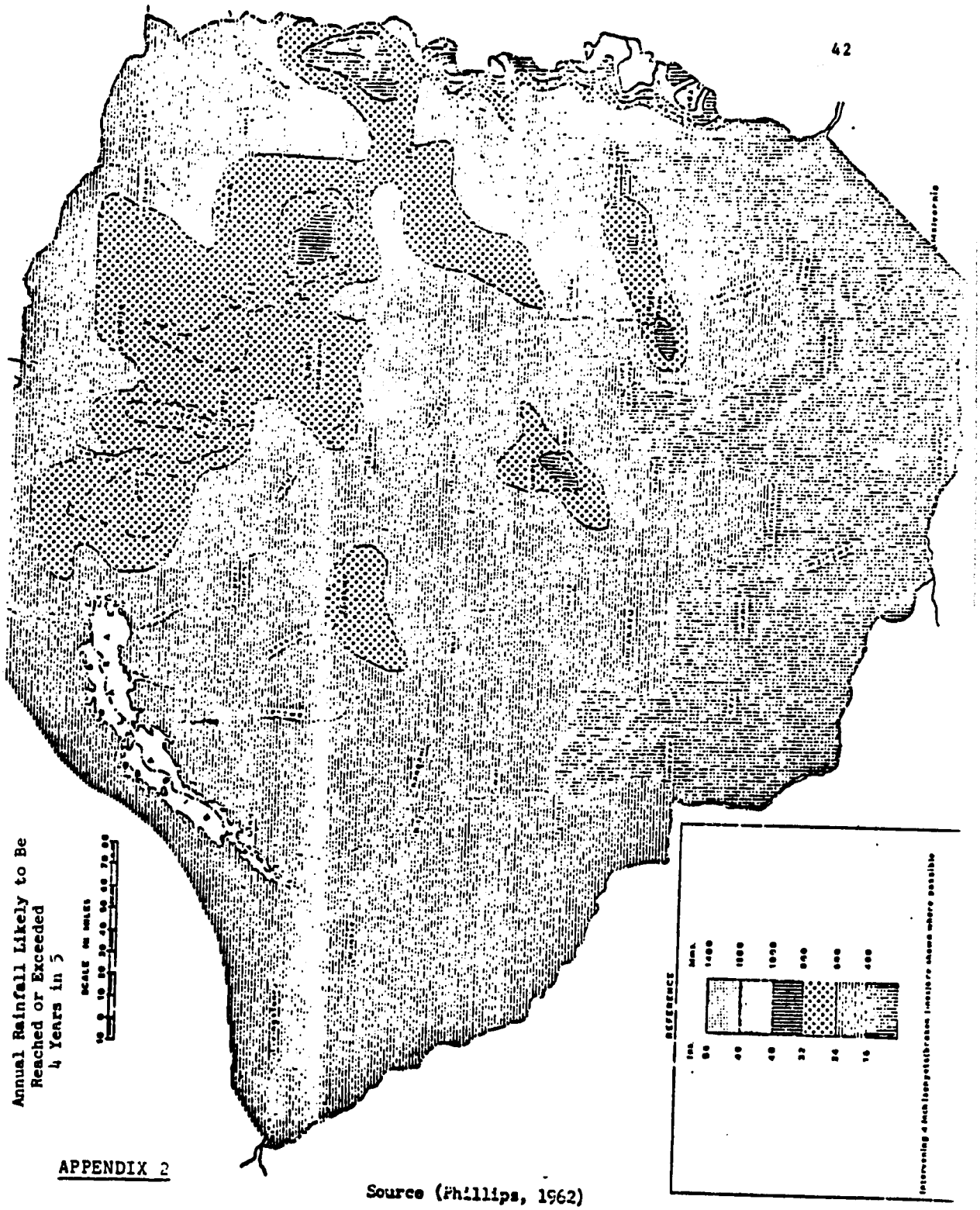


FIG. 3. Some characteristics of rainfall. (a) Mean annual rainfall; (b) Mean monthly rainfall at selected stations; (c) 1967–8 rainfall as percentage of mean annual rainfall at selected stations; (d) rainfall variability.

(Source: Kay 1970)



APPENDIX 2

Source (Phillips, 1962)

APPENDIX 3

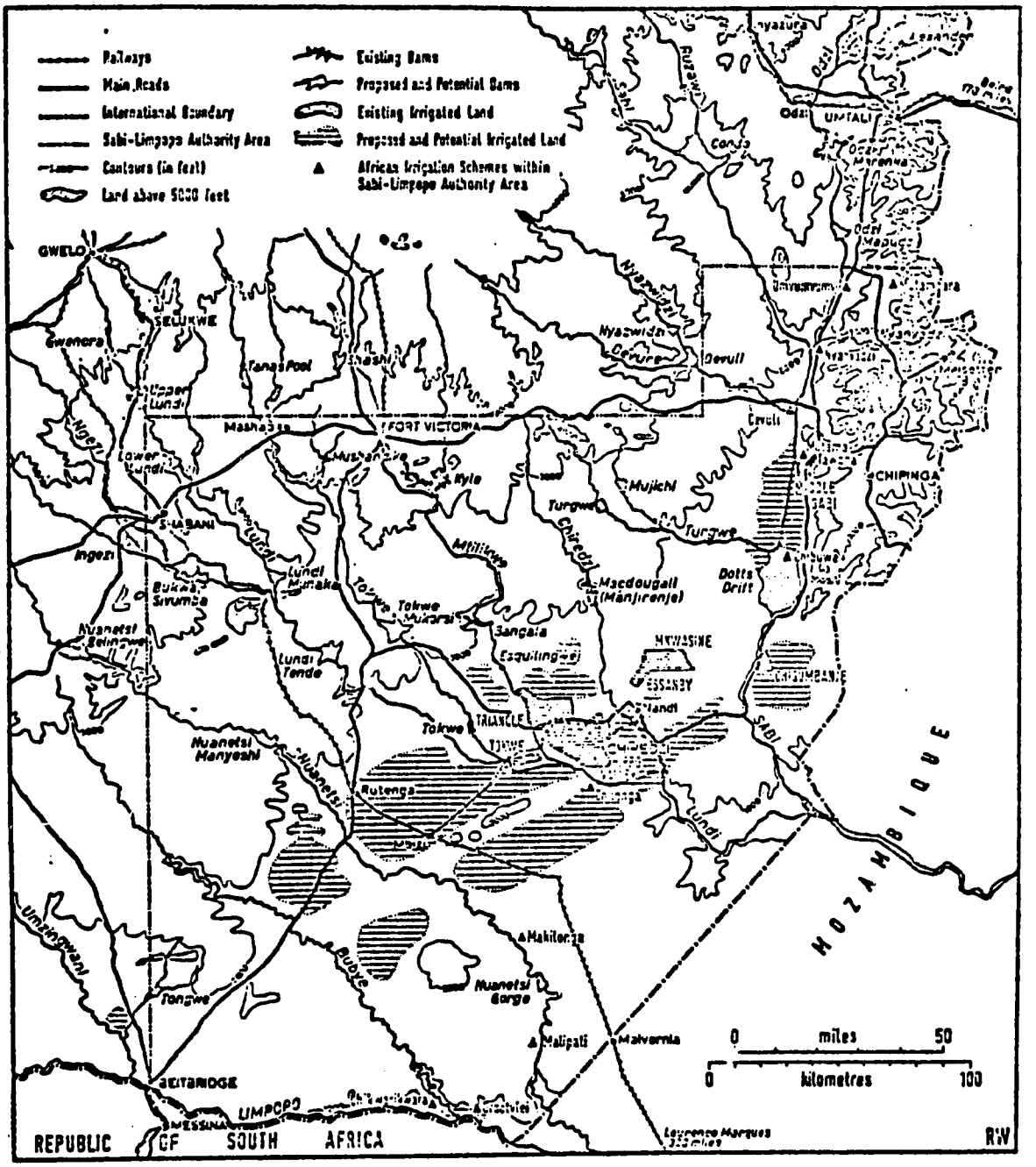


FIG. 33. Aspects of development and possibilities in the Sabi–Limpopo Authority's Area.

Source: (Kay, 1970)

APPENDIX 4

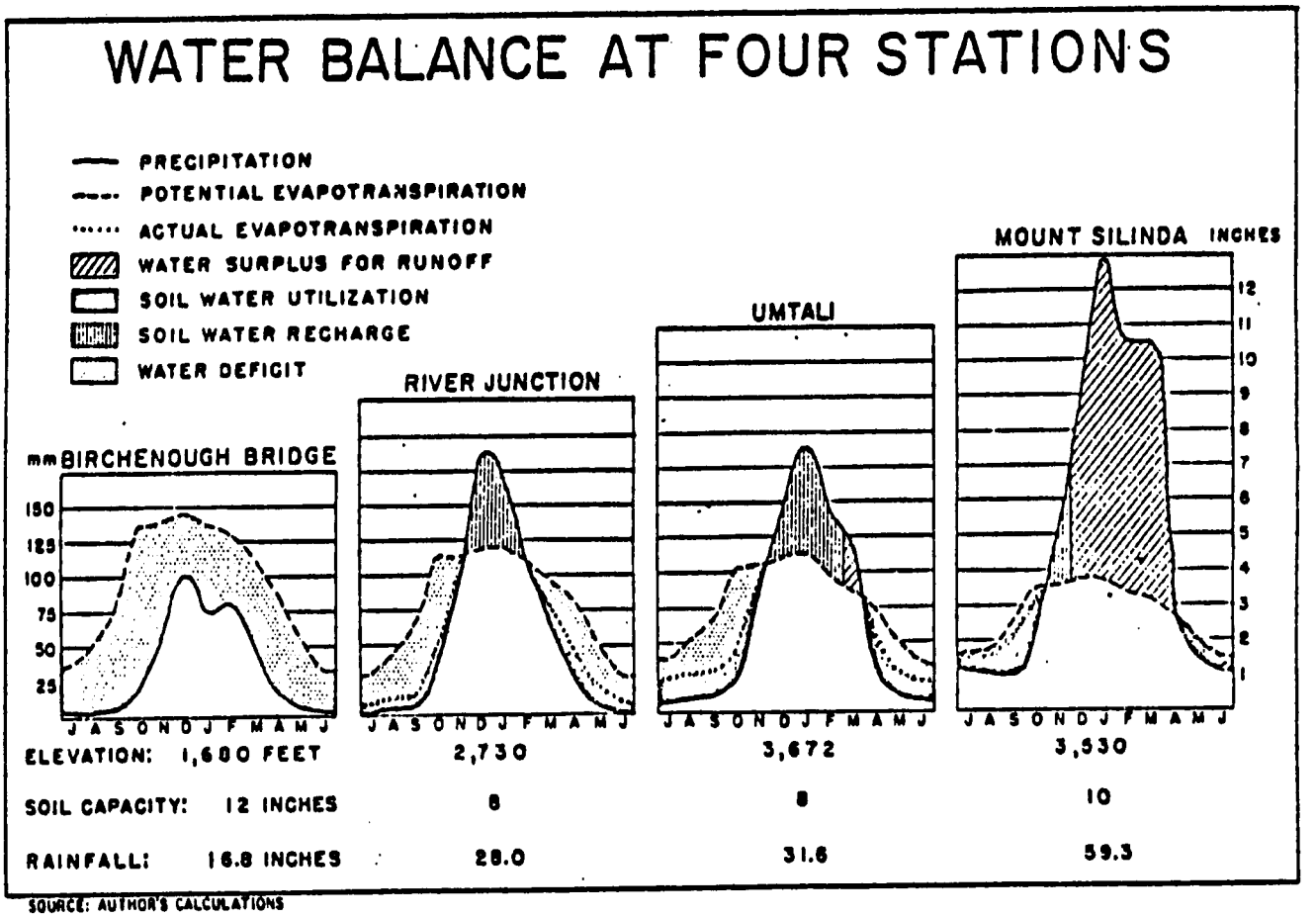


Fig. 6

Source: (Roder, 1965)

APPENDIX 5

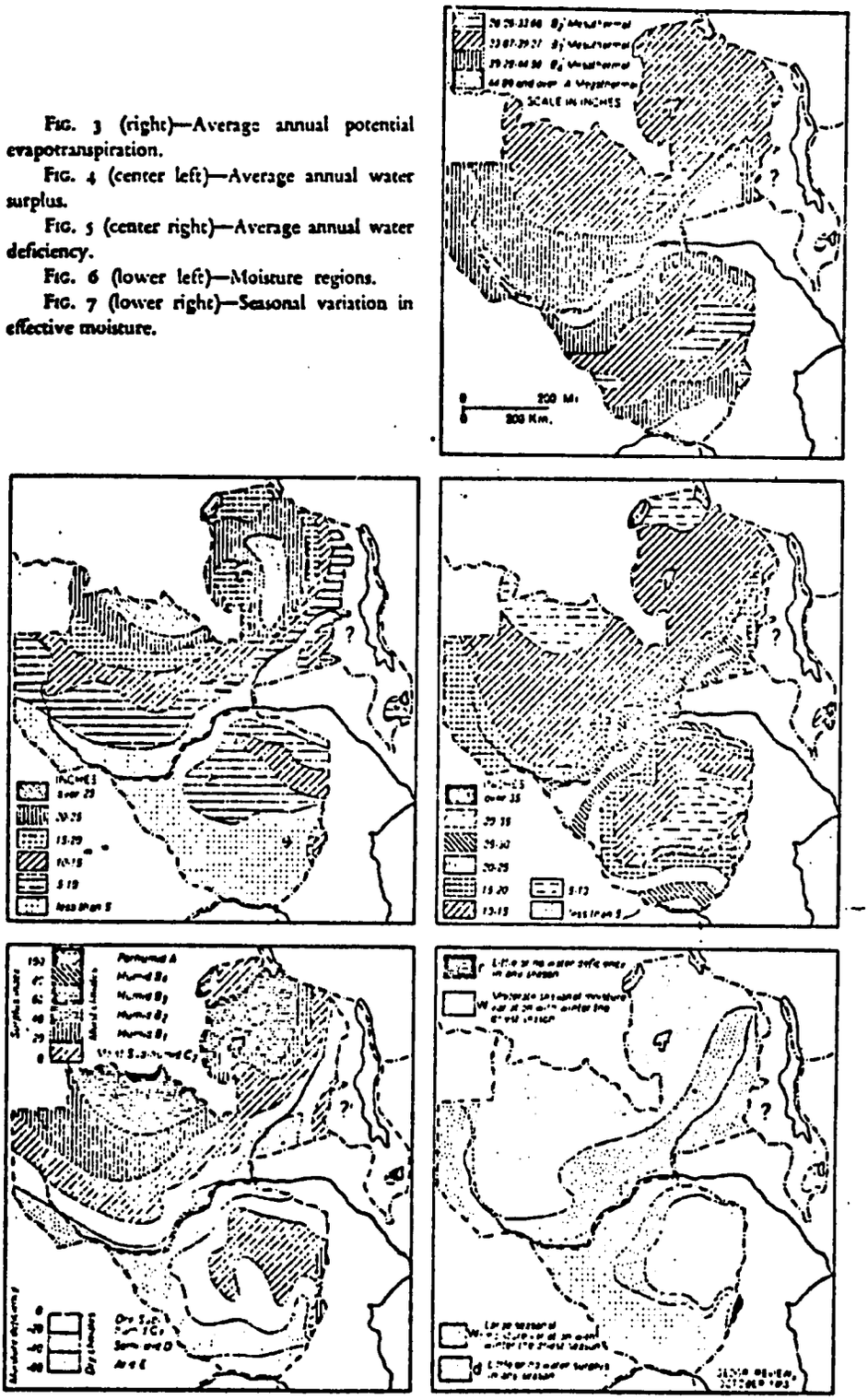
FIG. 3 (right)—Average annual potential evapotranspiration.

FIG. 4 (center left)—Average annual water surplus.

FIG. 5 (center right)—Average annual water deficiency.

FIG. 6 (lower left)—Moisture regions.

FIG. 7 (lower right)—Seasonal variation in effective moisture.



Source: (Howe, 1953)

APPENDIX 6

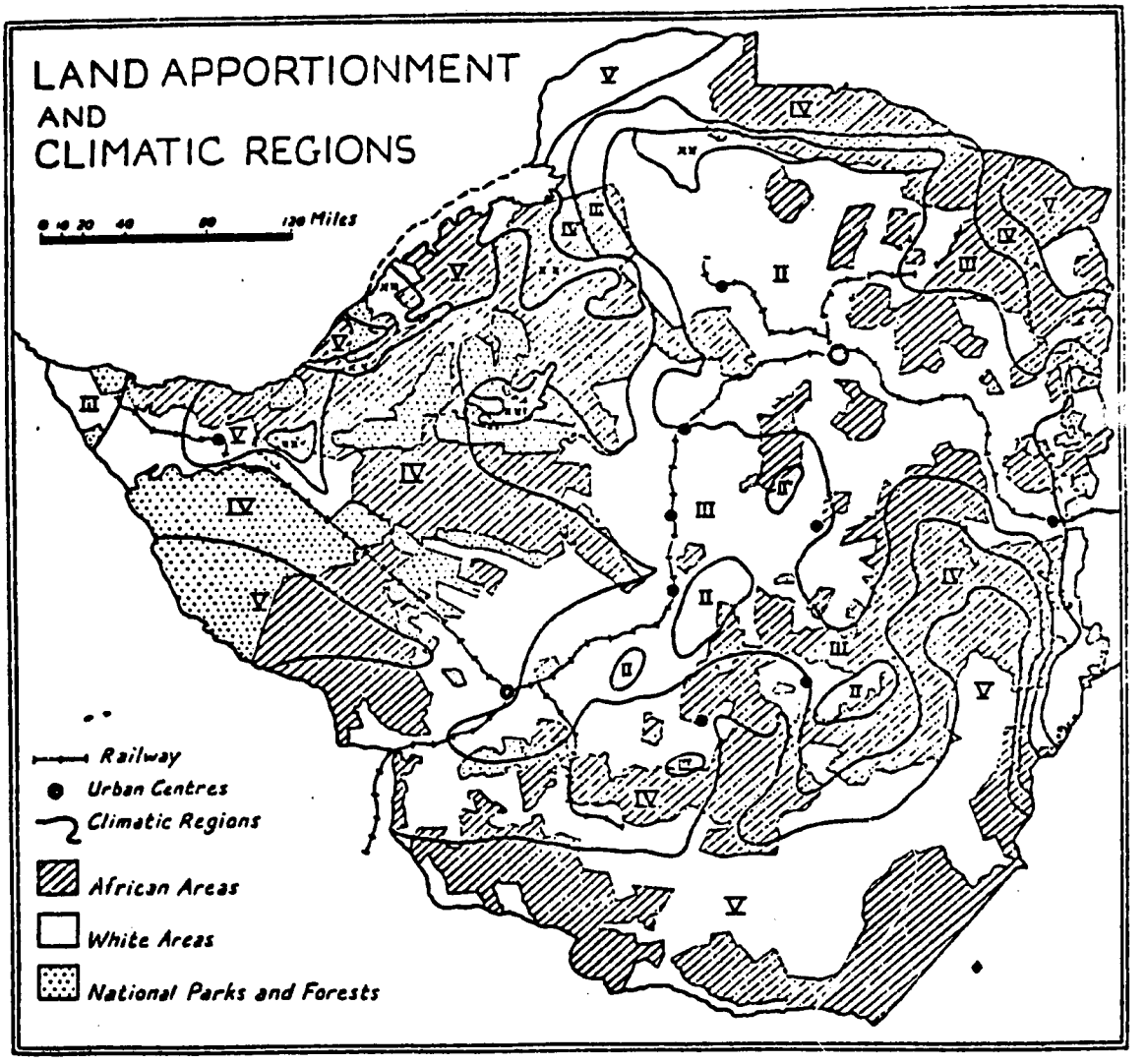


FIGURE 1.

Source: (Roder, 1964)

APPENDIX 7

TABLE 3.—ACREAGE OF NATURAL REGIONS IN WHITE AND AFRICAN AREAS IN THOUSANDS OF ACRES

Natural region	White, including national and undetermined			African			Southern Rhodesia	
	Acres	Per cent of white	Per cent of S.R.	Acres	Per cent of African	Per cent of S.R.	Acres	Per cent
I	1,235	2.2	1.3	280	0.7	0.3	1,515	1.6
II	13,957	25.4	14.4	4,157	10.0	4.3	18,145	18.7
III	10,790	19.5	11.1	6,148	14.7	6.3	16,939	17.4
IV	16,775	30.3	17.2	15,327	36.5	15.8	32,148	33.0
V	11,417	20.7	11.7	14,006	33.4	14.5	24,423	26.2
XX	1,030	1.9	1.1	1,985	4.7	2.0	3,015	3.1
Total	55,234	100.0	56.8	41,950	100.0	43.2	97,184	100.0

Source: *Agro-Ecological Survey*, p. 104 (discrepancies in totals due to rounding).

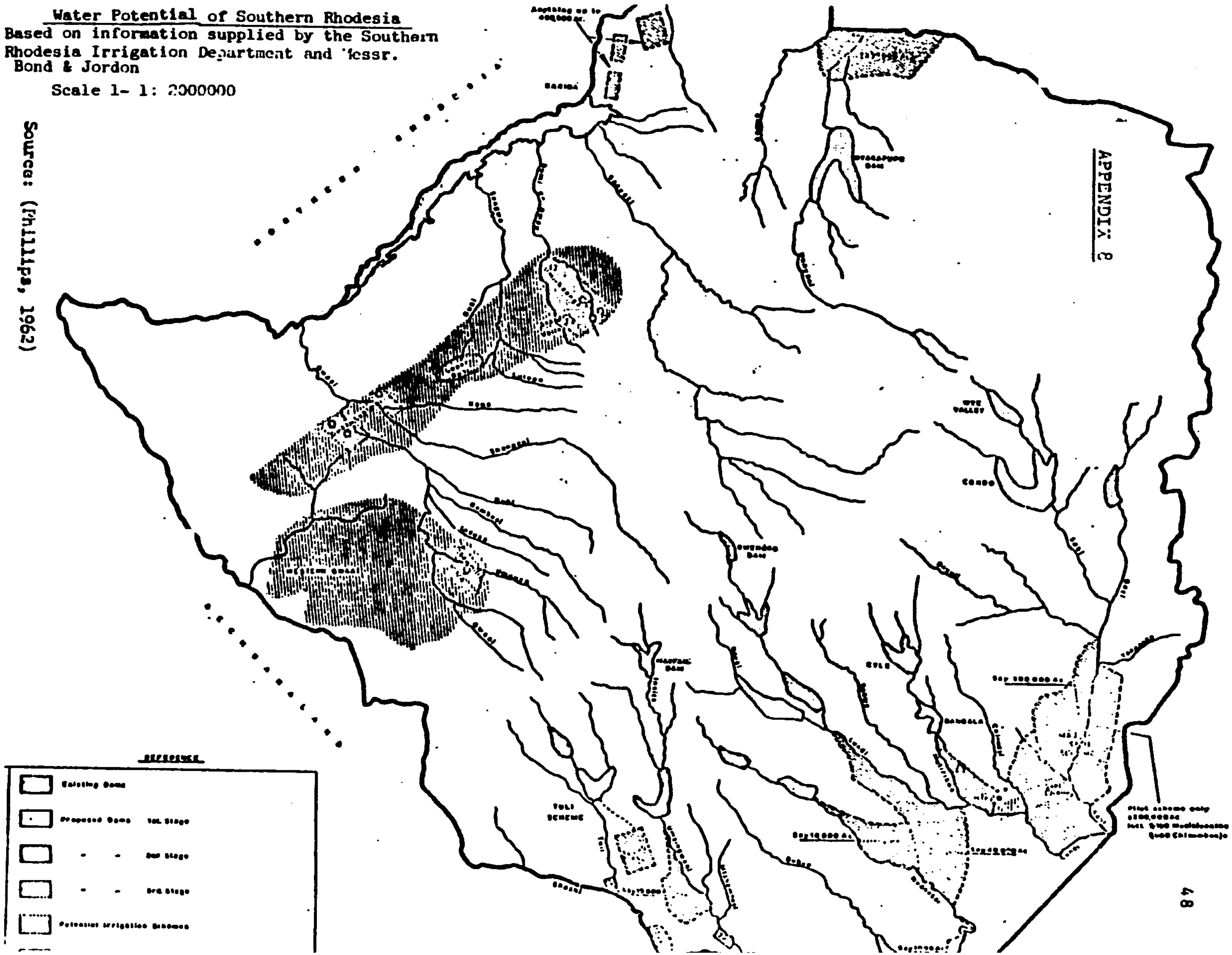
Source: (Roder, 1964)

APPENDIX 8

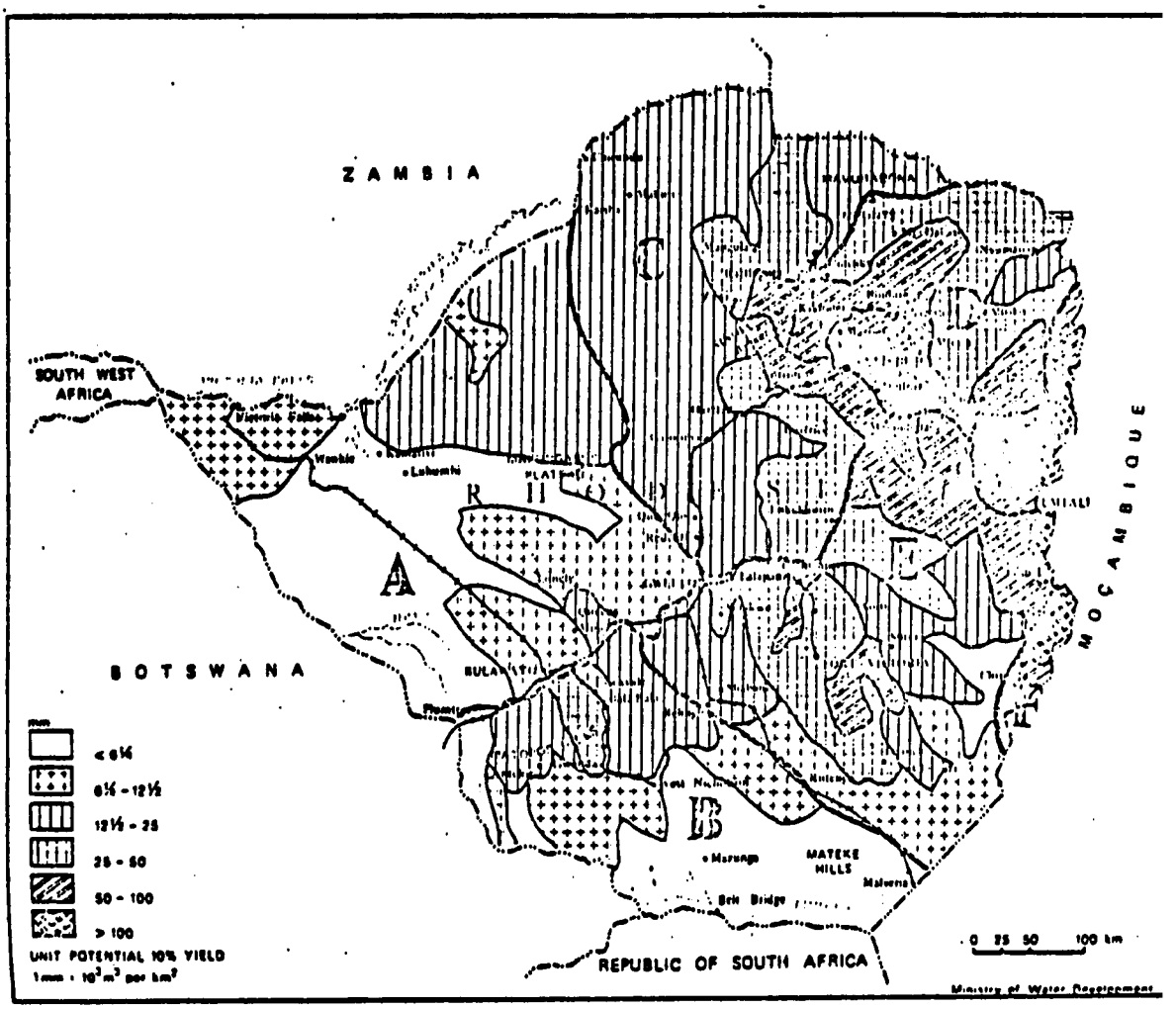
Water Potential of Southern Rhodesia
Based on information supplied by the Southern Rhodesia Irrigation Department and Messr. Bond & Jordon

Scale 1- 1: 2000000

Source: (Phillips, 1962)



APPENDIX 9



Source: (Lockenson, 1976)

9A

Hydro zone	Area		Mean annual run-off (MAR)	Optimum storage	Potential yield
	km^2	mm	10^3m^3	10^3m^3	10% risk 10^3m^3
A	102 980	21	2 208 800	5 340 700	878 900
B	62 060	24	1 467 540	3 246 600	624 900
C	89 980	58	5 390 500	9 372 400	2 688 900
D	37 660	98	3 694 300	4 954 500	2 097 400
E	85 050	71	5 799 200	8 696 700	3 140 400
F	7 080	212	1 504 500	1 175 400	1 047 400
Totals	381 810	52	20 064 840	32 786 300	10 477 500

Source: (Loewenson, 1976)

APPENDIX 10

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TABLE 5

STANDARDS FOR IRRIGATION WATERS

Quality Class	Conductivity (EC x 10^5 at 25^o C)	Salt Content ppm	Sodium Percentage
1	0 - 100	0 - 700	under 60
2	100 - 300	700 - 2,000	60 - 75
3	over 300	over 2,000	over 75

Note: EC x 10^5 = micromho x 10.

Source: Orson W. Israelson, Irrigation Principles and Practices (New York: John Wiley and Sons, 1950), p. 263.

TABLE 6

ANALYSIS OF SELECTED IRRIGATION WATERS

		Umvumvumvu	Nyanyadzi	Tanganda	Sabi
Electric Conductivity EC x 10^5 at 25^o C		20	20	15	13
Total Salt Content ppm		140	140	105	90
Cations	Ca	1.25	1.20	.82	.48
	Mg	.90	.75	.48	.32
	Na	.54	.43	.39	.66
Anions	HCO_3	2.55	2.24	1.53	1.22
	SO_4	--	--	--	--
	Cl	.11	.14	.17	.31
Sodium Percentage		20	18	23	45

Note: Samples taken August, 1960.

Source: Department of Native Agriculture.

Source: (Rodier, 1965)

APPENDIX 11

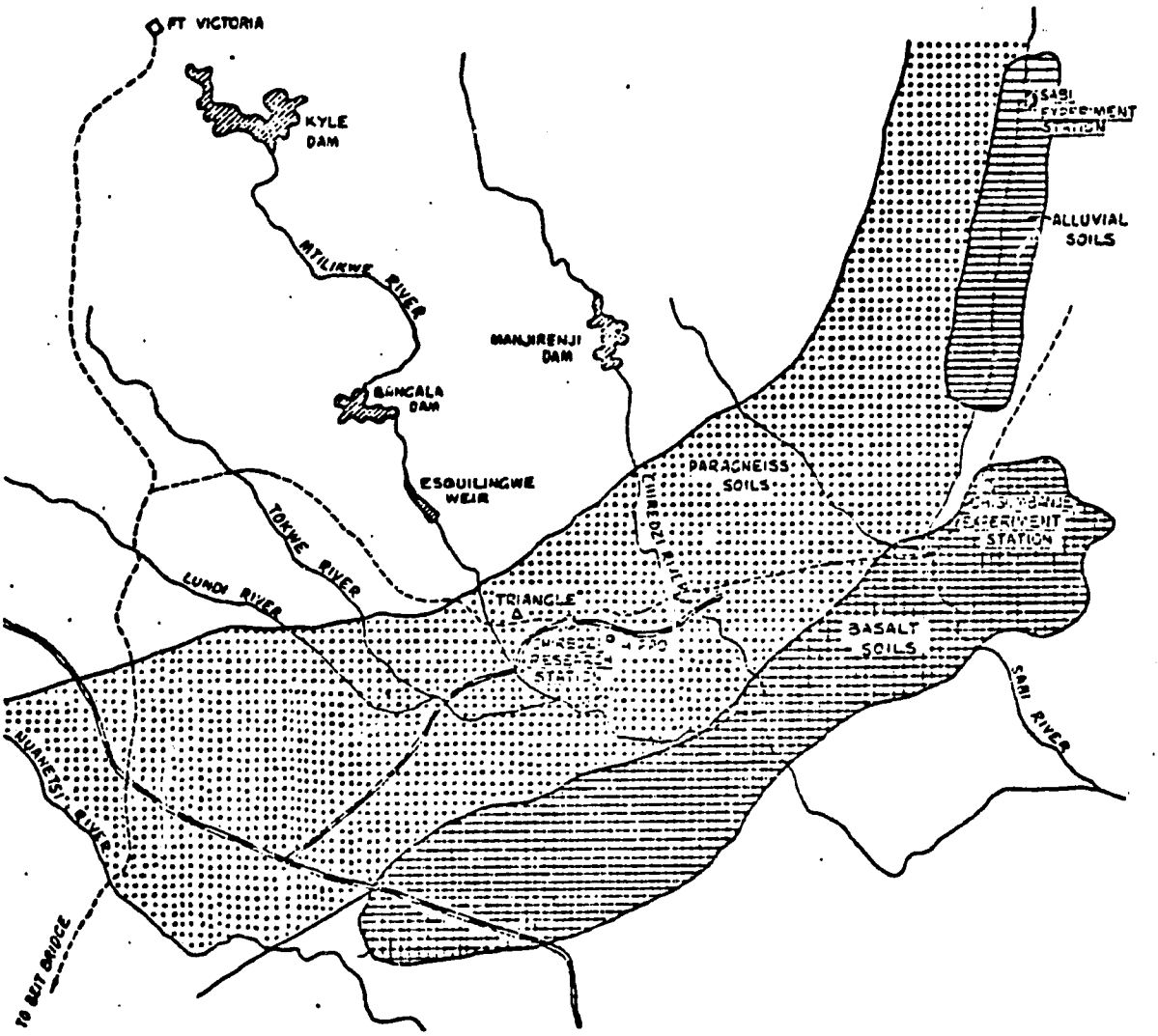

Fig. 3. Sketch map to show the location of the new Chiredzi Research Station and its satelite Experiment Stations, Sabi Valley and Chisumbanje, in relation to the main soil types in the Lowveld which are being developed for large scale irrigation.

Source: The Rhodesia Science News, vol. 2 (No. 4, April 1968) p. 49

APPENDIX 12

TABLE 114

SUMMARY OF COSTINGS FOR IRRIGATION SCHEMES IN THE AFRICAN AREAS

Scheme and Type†	Capital Estimated Total Costs: £'s‡	Estimated Cost per acre§
	£	£
Nyanyadzi .. .. G	16,000	21·2
Tawona .. .. P	5,500	14·2
Mutema .. .. G—P	6,600	9·2
Chibuwe .. .. I—IV, P	19,400	21·1
Umvumvumvu .. .. G	3,000	12·7
Mutambara .. .. G	4,000	13·2
Devuli .. .. G	16,000	30·8
Maranke .. .. G	20,000 (721 acres)	27·7
Nyachowa .. .. G	2,000	18·0
Nyamaropa .. .. G	77,000 (1,500 acres)	51·2
Chilonga .. .. P and G; no S	—	—
Murambinda .. .. G/S	—	—
Sachipiri .. .. G/S	—	—
Nyakoni .. .. G/S	—	—
Mwerihari .. .. G	—	—

* As already explained, the current water charge is a uniform 25s. per acre per annum. This compares with average maintenance costs now running at more than £4 per acre. If schemes were to be fully economic, the charges to be met would include not only maintenance charges, but also amortisation of capital and interest charges on capital.

† G: gravity; G/P: gravity and pumping; G/S: gravity with storage; P: pumping.

‡ Most of these costs are estimated minimum costs. Full costs are unobtainable.

§ None of these schemes has either storage works or very long lined canals, hence their comparatively low cost.

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Source: (Phillips, 1962)

APPENDIX 13

TABLE 120

MAINTENANCE COSTS ON AFRICAN IRRIGATION SCHEMES IN MANICALAND, 1959 to 1961

Scheme	Estimated costs to 1959*		Actual costs 1960		Actual costs 1961		Acreage
	£ *Total*	£ *Per acre*	£ *Total*	£ *Per acre*	£ *Total*	£ *Per acre*	
Nyanyadzi	2,500	3·3	3,544	4·7	3,014	4·0	756
Umvumvumvu	800	3·4	1,146	4·9	1,022	4·3	236
Mutambara	1,200	4·0	1,779	5·9	1,343	4·4	302
Devuli	1,500	2·9	3,871	7·4	2,013	3·9	520
Tawona..	2,000*	5·2*	2,286	5·8	2,842	7·3	388
Mutema	1,500	2·1	1,876	2·6	2,470	3·4	717
Chibuwe I to IV	4,500*	4·9*	4,964	5·4	5,639	6·1	918
Maranke	1,000	1·4	569	0·8	410	0·6	721
Nyachowa	400	3·6	311	2·8	410	3·7	111
Totals	15,400		20,296		19,163		4,669
Mean		3·3		4·3		4·1	

Note: On these schemes the sum of 2 3s. OD. per annum is included toward the pumping costs per acre: fuel lubricant, wages. This does not include depreciation and maintenance of machinery.

Source: (Phillips, 1962)

APPENDIX 14

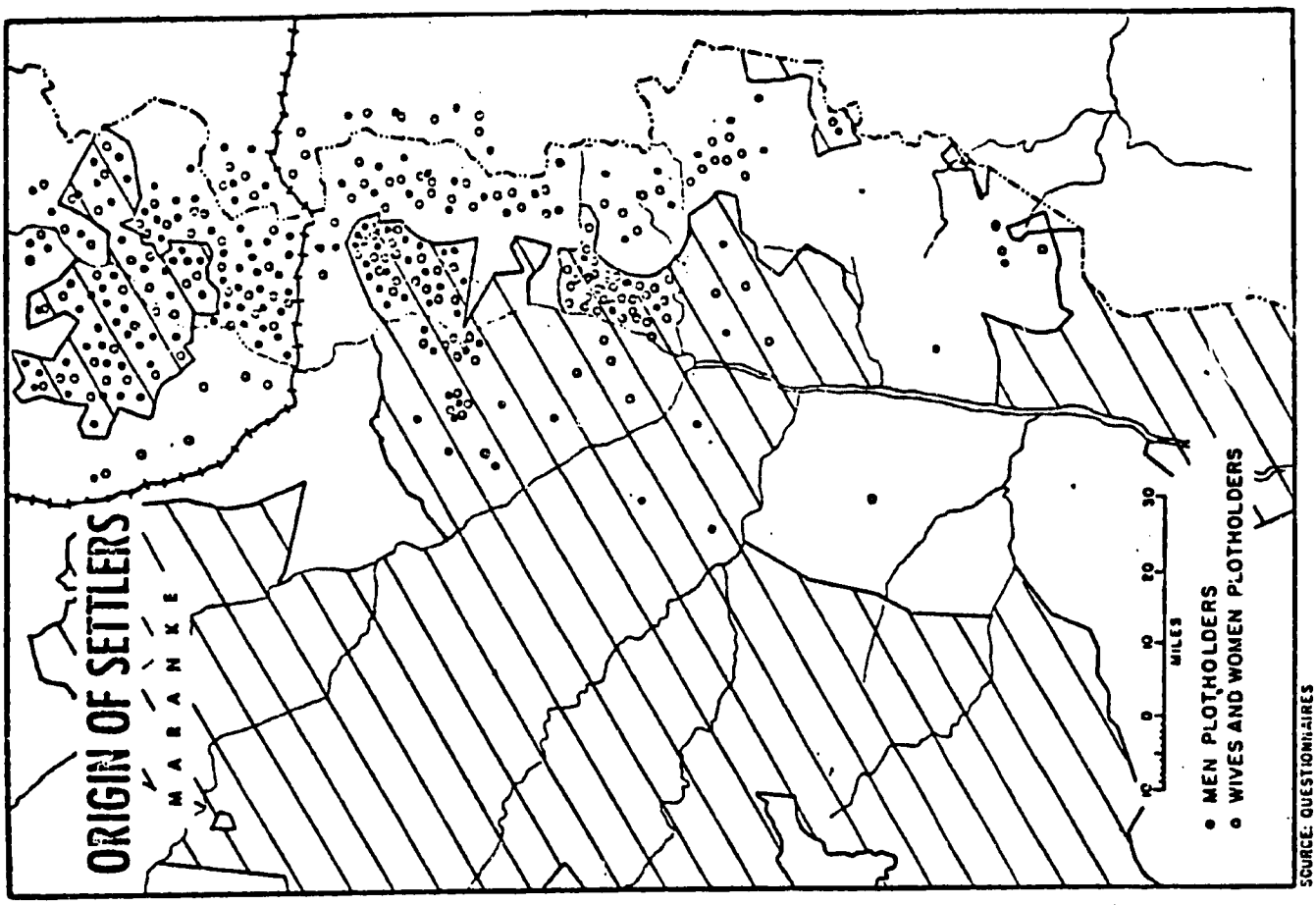


Fig. 16

Source: (Roder, 1965)

Maranke project has a similar high proportion of people from white areas and, as the dot map shows, the remainder hail from the crowded reserves of Mutasa and Zimunya; only a few come from Maranke Reserve itself. An explanation of this phenomenon must be sought in the fact that Chief Maranke's land was left largely untouched by land apportionment, while the lands of Mutasa and Zimunya were severely reduced. The latter reserves in consequence are severely overcrowded, this appears to have been the cause of an exodus to Maranke project.

Powers of district commissioner or irrigation manager in regard to proper farming of irrigation allotments

9. (1) The district commissioner, the irrigation manager or any person acting under the written authority of the district com-

1737

missioner may, in regard to irrigation allotments, give orders to lessees relating to—

(a) the manner and extent of land preparation, cultivation, manuring, fertilization and irrigation;

(b) the types of crops that may or may not be grown on the whole or any portion of the irrigation allotment;

(c) the type and timing of rotation to be practised in respect of crops;

(d) the general farming system to be applied;

(e) the control and eradication of noxious weeds and other undesirable plants, pests, vermin and animal diseases;

(f) the types of shrubs or trees which may or may not be planted on an irrigation allotment or on any part thereof and the distance to be allowed between any such trees or shrubs and any permanent structures;

(g) the grazing of stock;

(h) the times and manner of applying water and the quantity of water to be applied;

(i) the times, periods and number of diversion points at which water may be diverted;

(j) the manner in which water may be diverted on to an irrigation allotment and the prohibition of any practices which may be damaging to land surface and soil structures;

(k) the prevention of the wasteful use of water;

(l) the dates on which any kinds of crops or fodder should be planted, treated, fertilized, sprayed and harvested;

(m) the construction and maintenance of roadways, drains or any permanent furrows or structures;

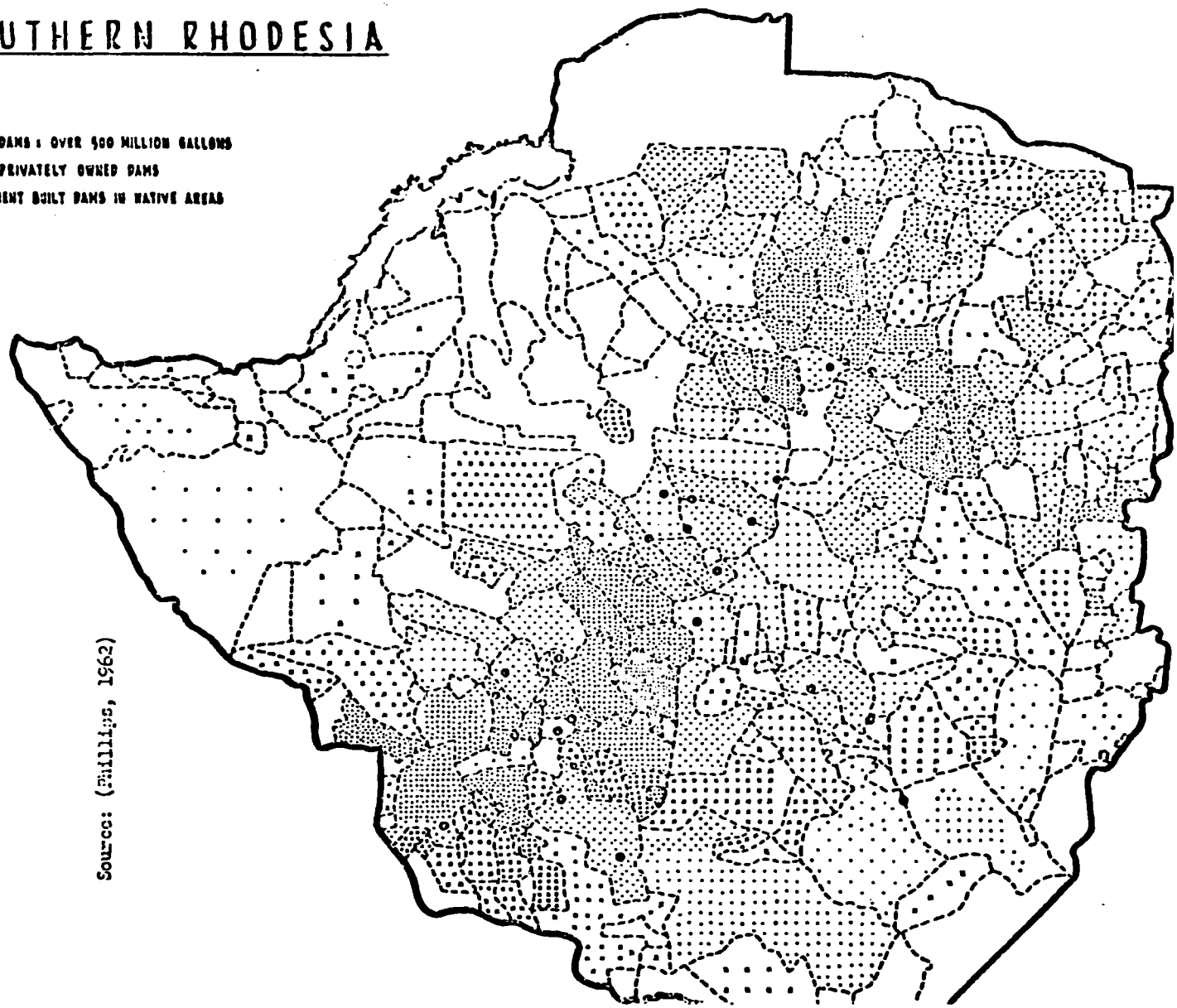
(n) the construction and maintenance of sanitation or health measures and the disposal of rubbish.

(2) Every lessee shall comply with any order issued in terms of subsection (1).

1738

Source: ACT 9/67 - Tribal Trust Land (Control of Irrigation Schemes) Regulations, 1967.

SOUTHERN RHODESIA

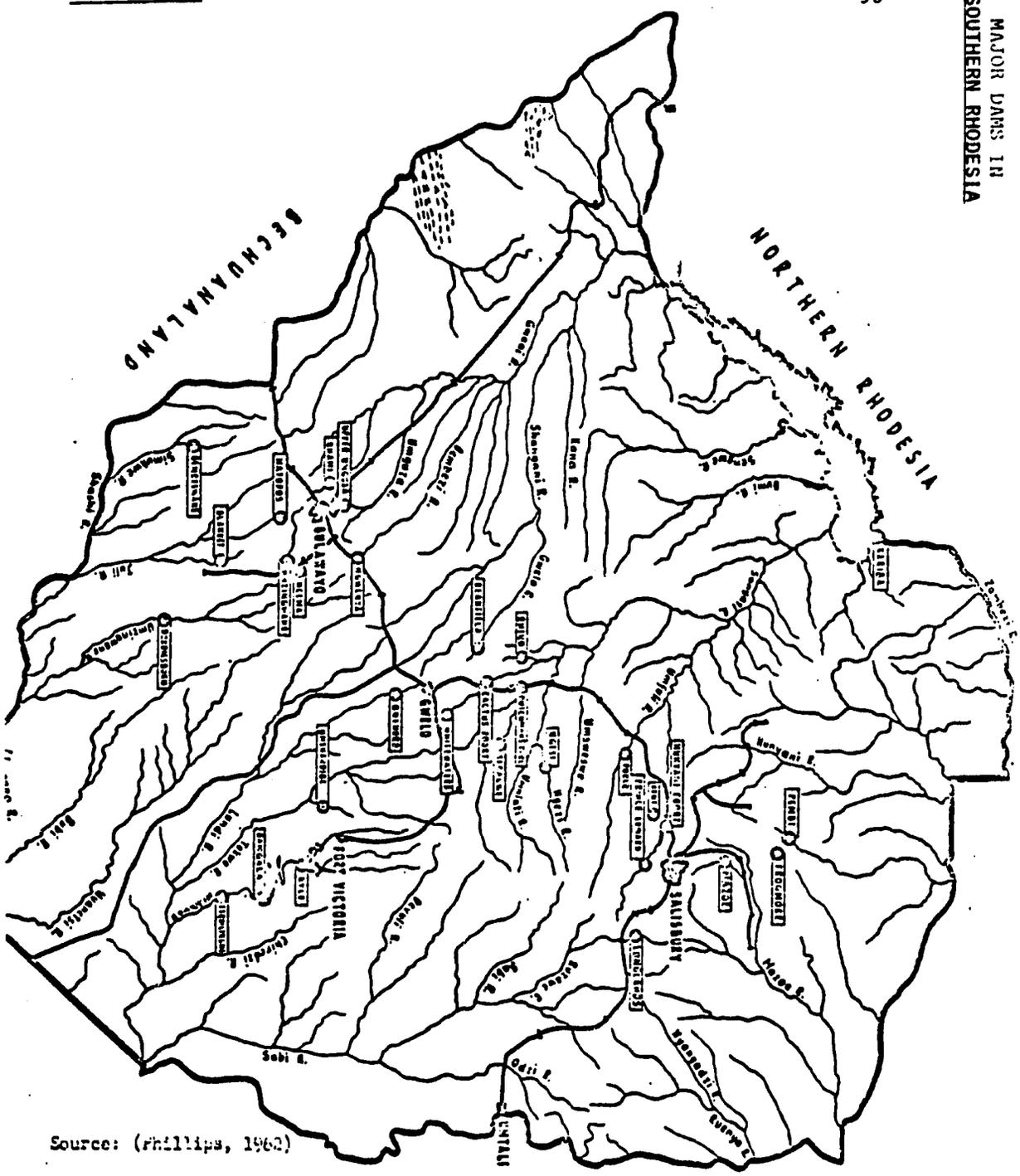


Source: (Phillips, 1962)

APPENDIX 16

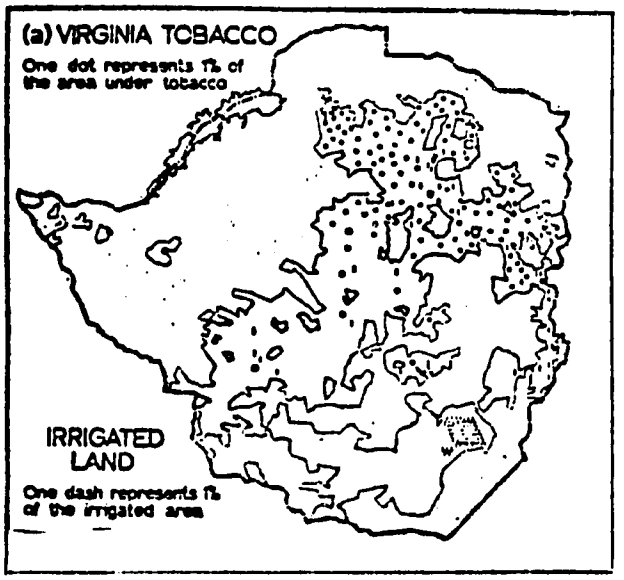
APPENDIX 17

MAJOR DAMS IN
SOUTHERN RHODESIA



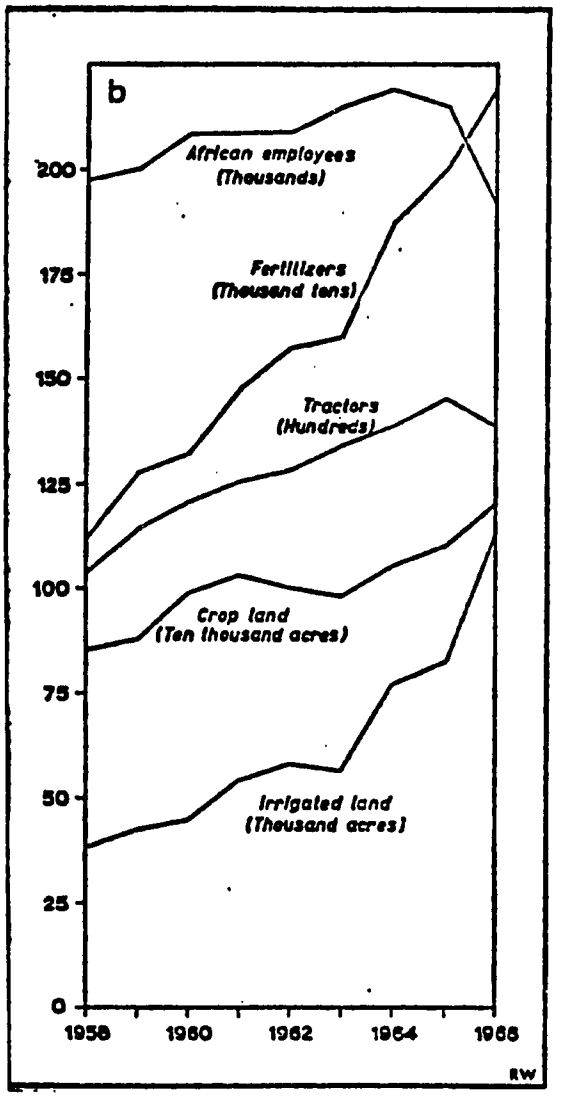
Source: (Phillips, 1962)

APPENDIX 18



Source: (Kay, 1970, p. 107)

APPENDIX 19



Source: (Kay, 1970)

APPENDIX 20

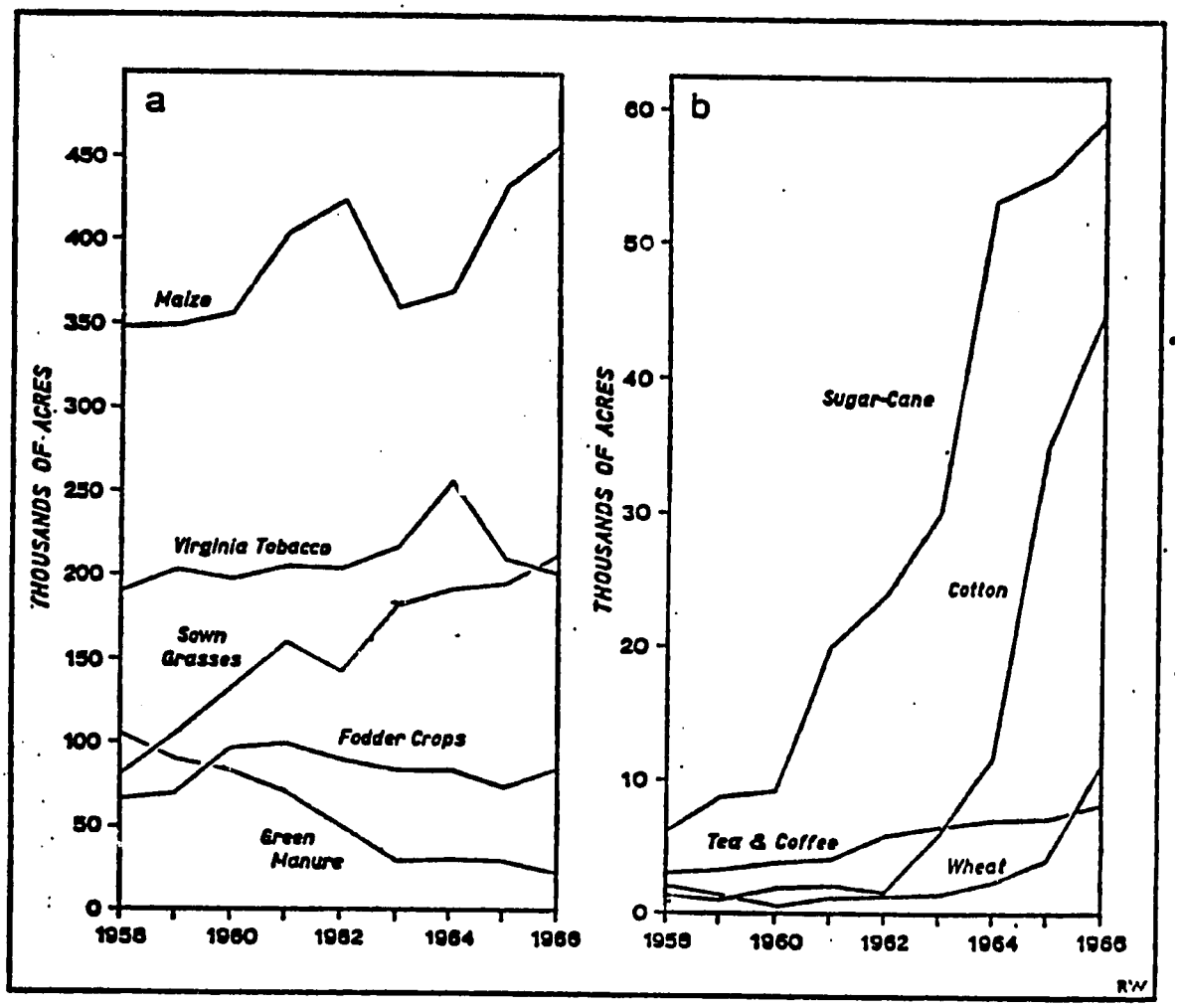
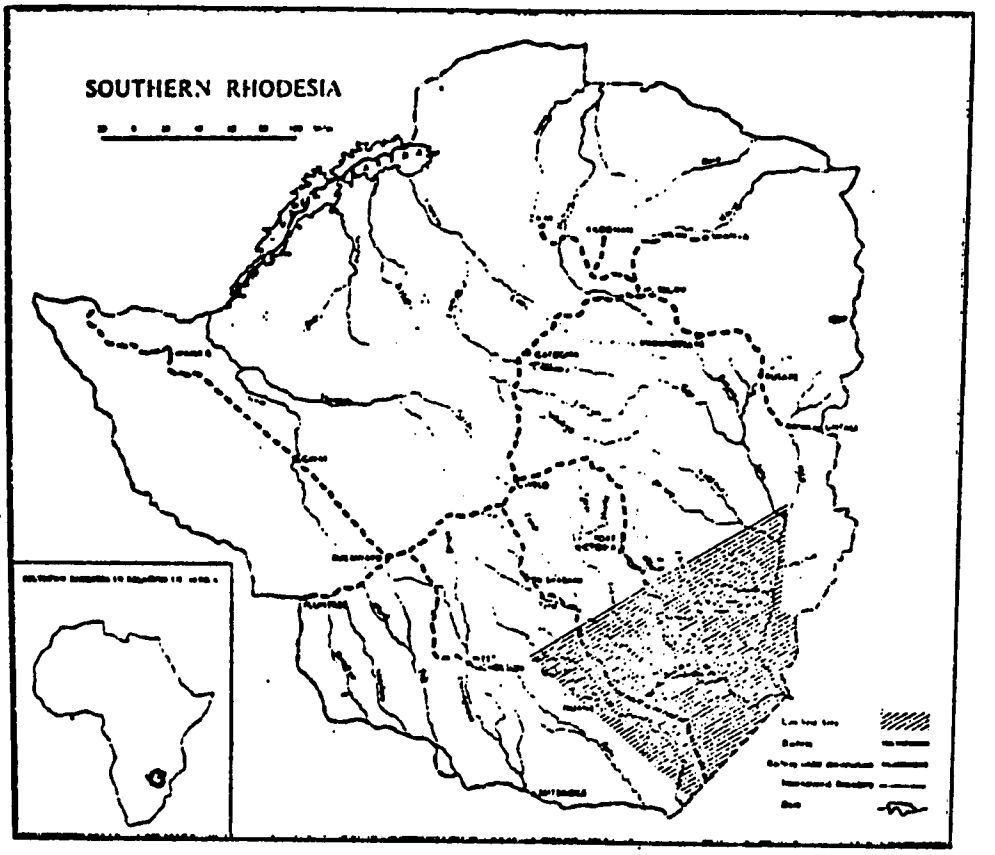


FIG. 27. Recent trends in European production of selected crops.

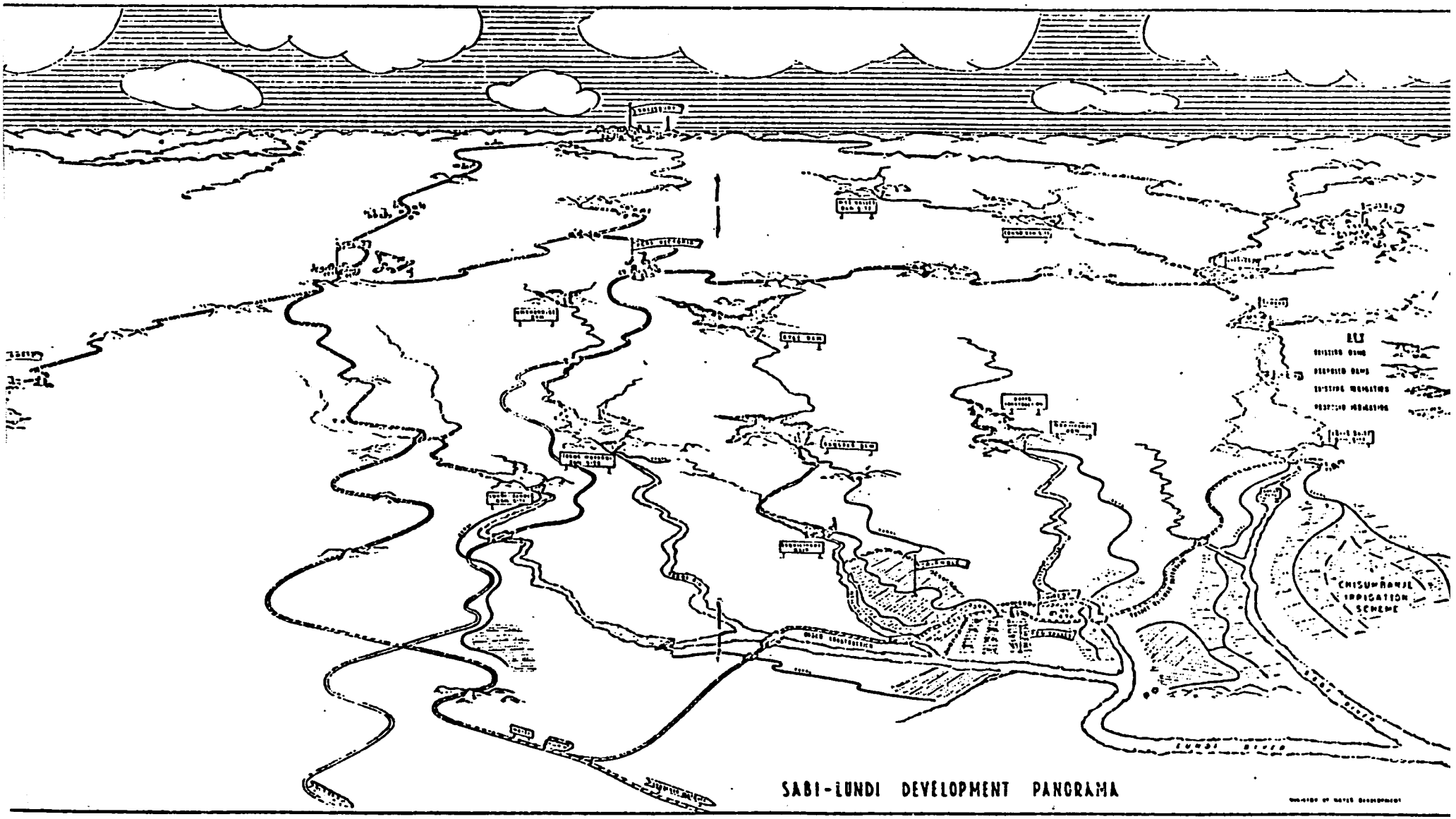
Source: (Kay, 1970)

APPENDIX 21



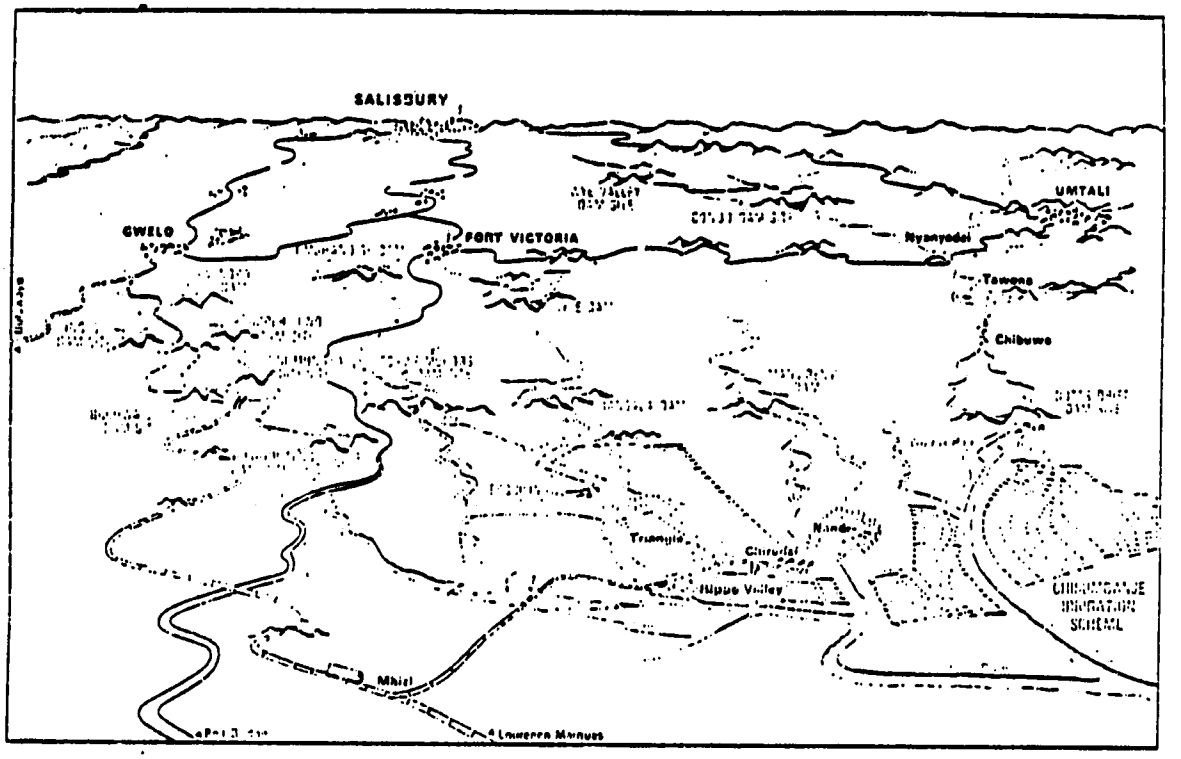
Source: (Sabi-Limpopo Authority, 1965)

APPENDIX 22



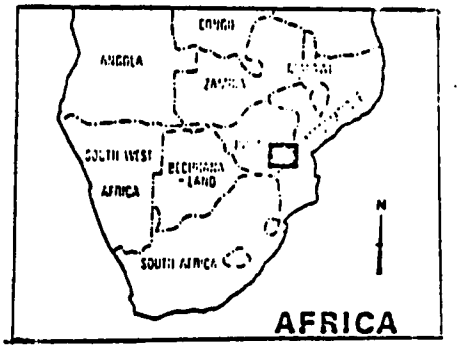
SABI-LUNDI DEVELOPMENT PANORAMA

22



SABI-LIMPOPO DEVELOPMENT PLAN

Source: (Fair, 1964, p. 192-193



Irrigated areas

Potential irrigable areas

Dams

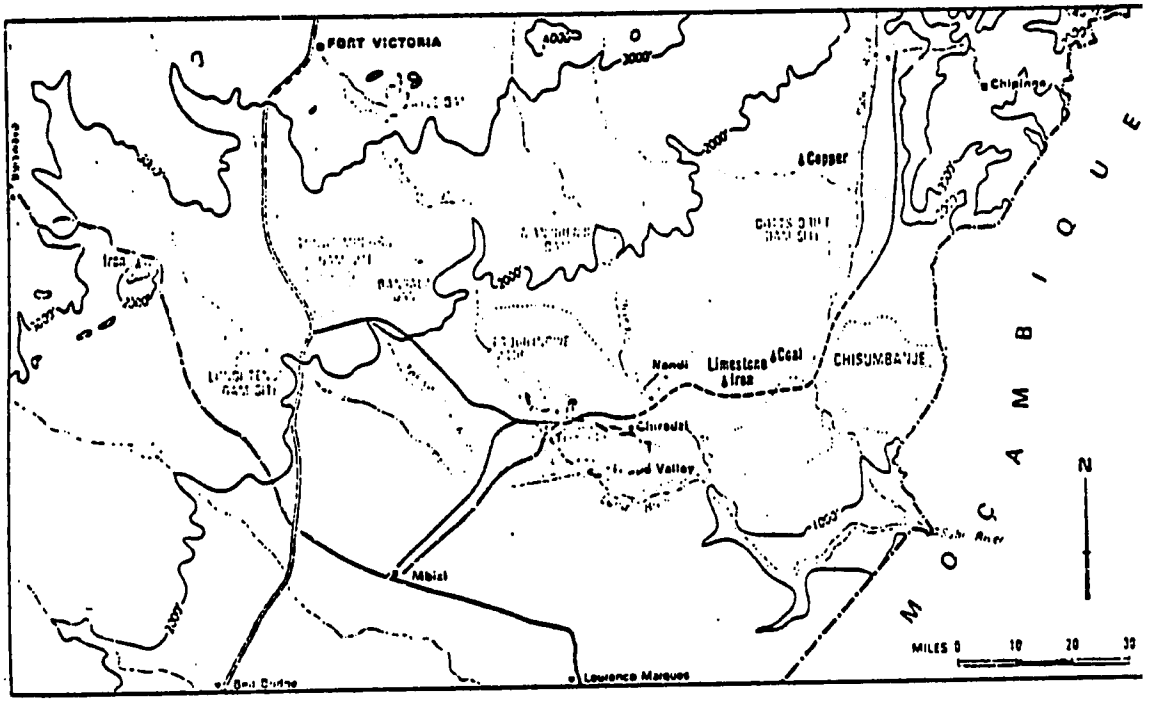
Canals

Railways (existing and planned

Roads

APPENDIX 23

SABI-LIMPOPO DEVELOPMENT PLAN



Source: (Fair, 1964, p. 192-193)

LEGEND

- Existing dams
- Proposed dam sites
- Irrigated areas
- Potential irrigable areas
- Towns
- Existing railways
- Proposed railways
- Roads (existing and planned)
- Contours at 1000' intervals
- Mineral occurrences
- International boundaries

APPENDIX 24

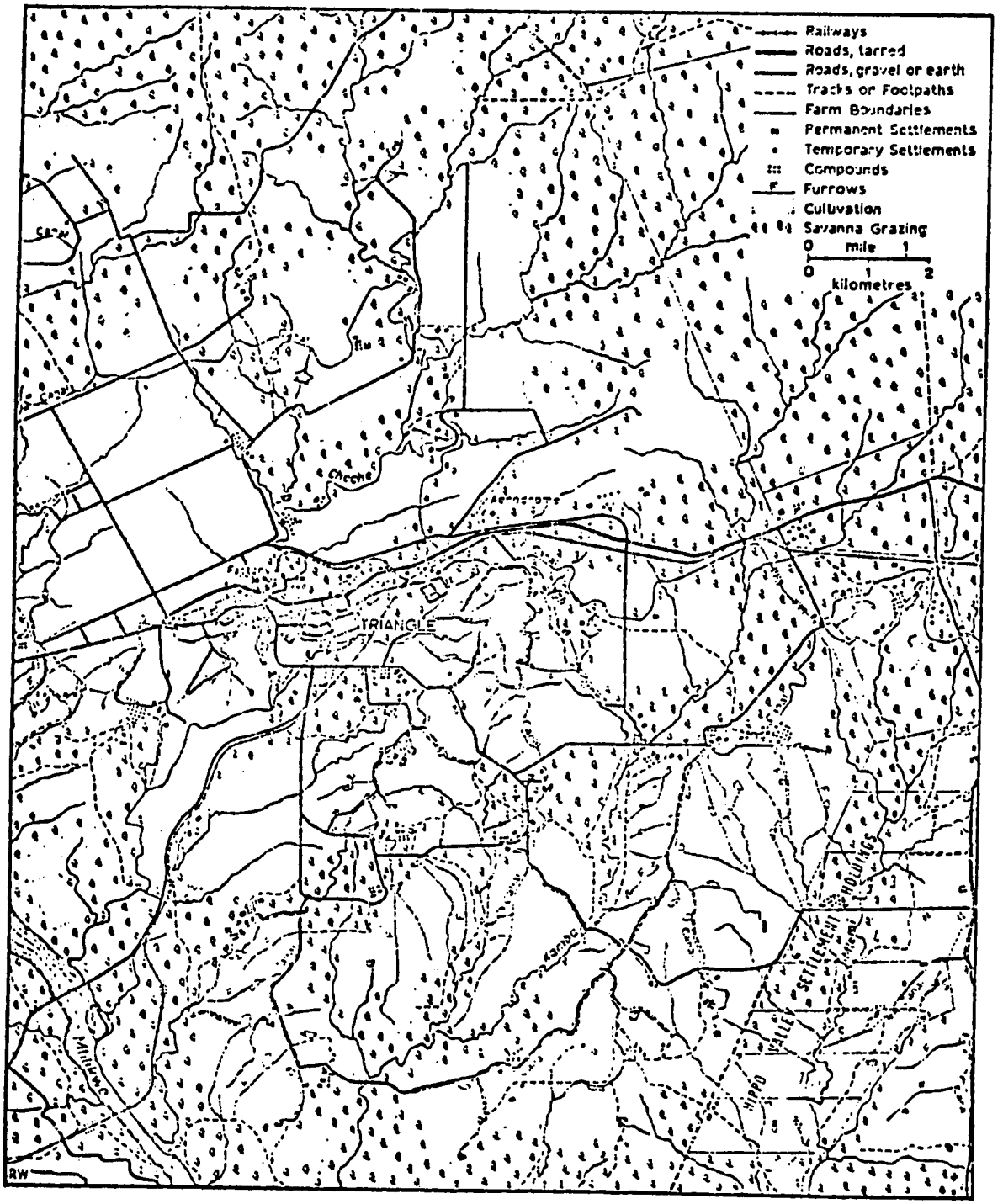


FIG. 32. Irrigated farmland – part of Triangle estate and Hippo Valley settlement holdings. Based on Sheets 2031 C4, 2031 D3, 2131 A2 and 2131 B1 of the 1:50 000 topographical series published by the Surveyor-General.

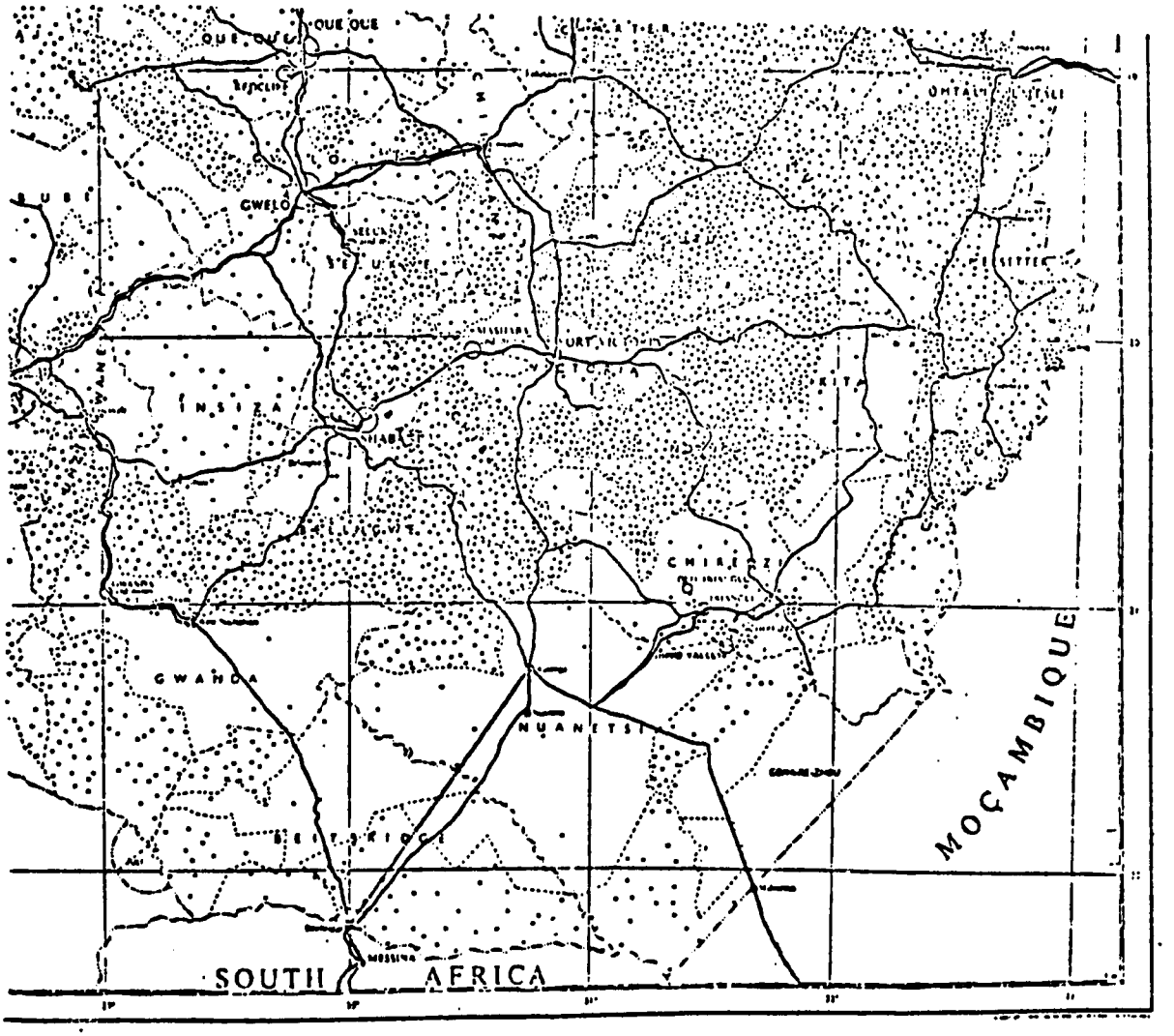
Source: (Kay, 1970)

APPENDIX 25

AFRICAN POPULATION DISTRIBUTION

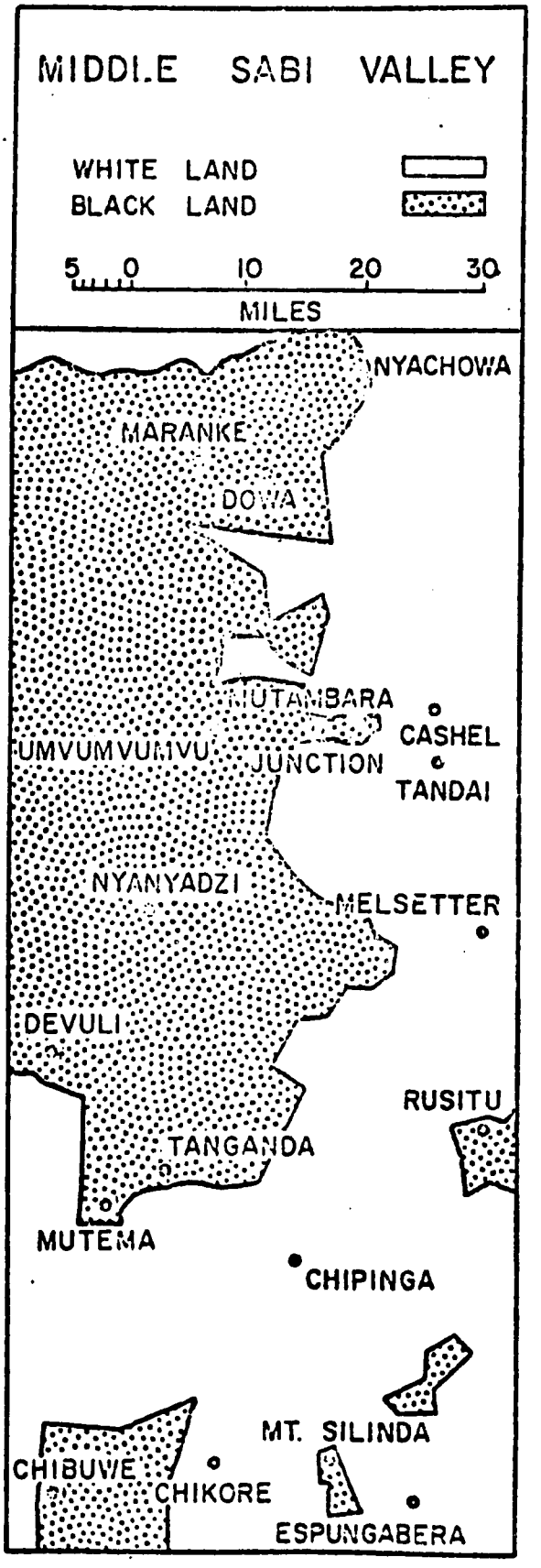
AS AT APRIL–MAY 1969

Source: (Kay, 1972)



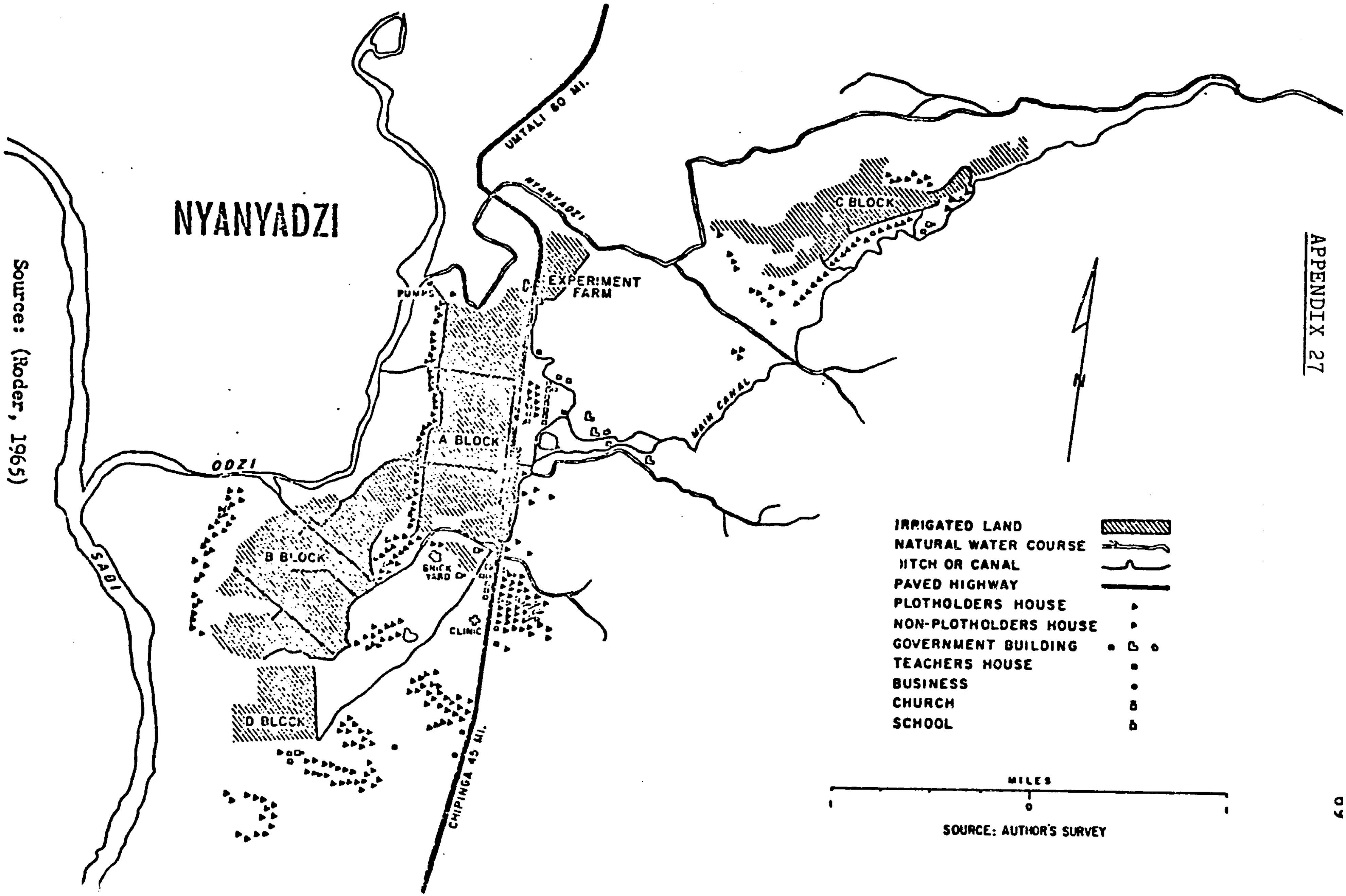
APPENDIX 26

CENTRAL PLACES IN THE MIDDLE SABI-ODZI VALLEY: those associated with irrigation projectsemphasized



Source: (Roder, 1973)

APPENDIX 27



Source: (Roder, 1965)